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50 years 1959–2009

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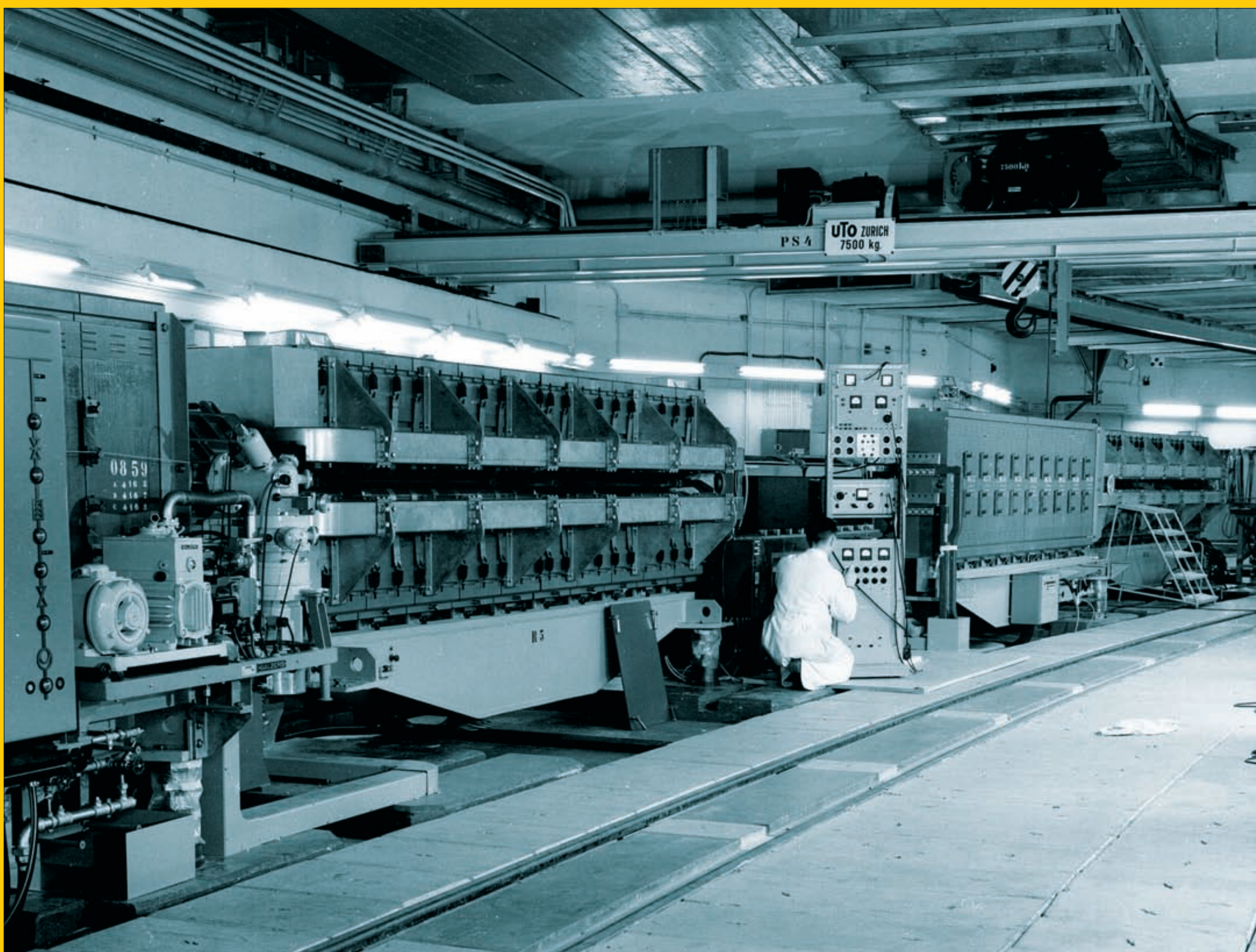

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Covering current developments in high-energy physics and related fields worldwide

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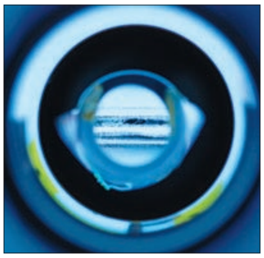
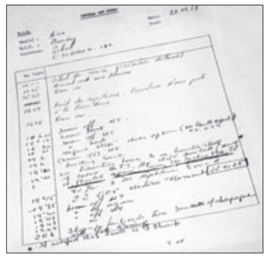


Taking gradients to new limits p5



A night in November p19

Herwig Schopper at 85 p36

Cover: The Proton Synchrotron (PS) started up 50 years ago on 24 November 1959 (p19). Built as CERN's first big accelerator, for protons, it went on to become a key link in the accelerator complex that acted as injector to the Large Electron–Positron (LEP) collider. LEP saw its first collisions in August 1989 (p23) and was inaugurated in November that same year (p28).

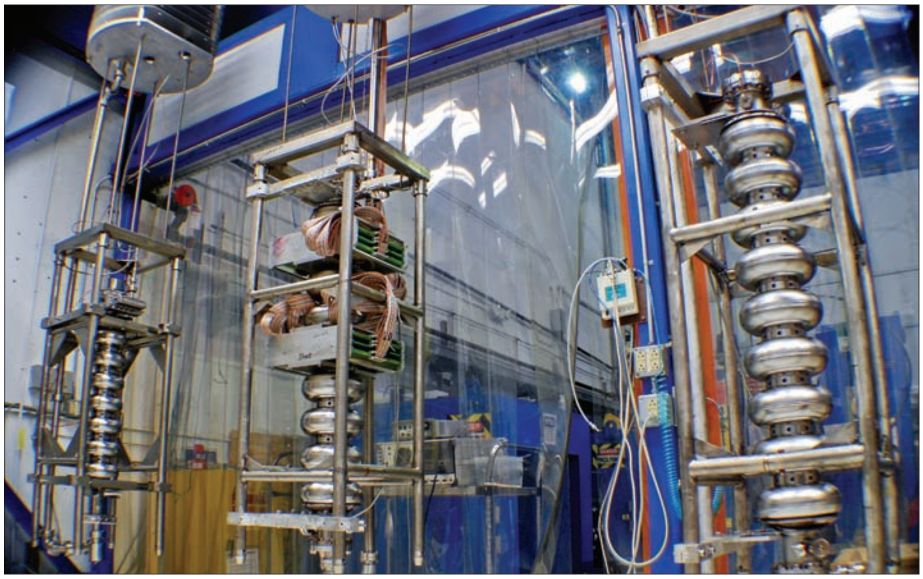
NEWS

JEFFERSON LAB

US industry-built ILC cavity reaches 41 MV/m

For the first time, an industry-made superconducting radiofrequency (SRF) cavity has reached and exceeded the accelerating gradient required for the envisioned International Linear Collider (ILC). The US-built cavity achieved 41 MV/m at the ILC's superconducting operating temperature of 2 K, far exceeding the specification of the ILC Global Design Effort (GDE) of 35 MV/m. The ILC would require 16 000 such cavities.

Advanced Energy Systems Inc (AES) in Medford, New York, built the hollow niobium accelerating structure. A team at the Jefferson Lab processed it by electropolishing and then tested it as part of R&D funded by the US Department of Energy. In addition, they tested seven more AES cavities, one of which reached 34 MV/m, close to the specification. Several other North American companies are also attempting to manufacture ILC test cavities.

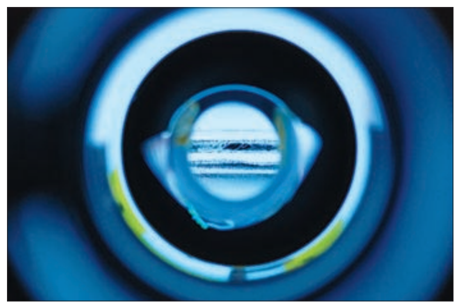


Three electropolished cavities await cryogenic testing at Jefferson Lab: an AES cavity (right); a large-crystal niobium cavity, built in-house, with T-mapping system mounted (middle); and a prototype cavity for the facility's CEBAF upgrade (left) processed using the "ILC recipe". (Courtesy Jefferson Lab.)

Jefferson Lab's Rongli Geng, leader of the GDE Cavity Group, characterizes the 41 MV/m result as "remarkable". He believes that it may be attributable to improvements in cavity treatment specific to AES cavities, which are aimed at optimizing the properties of the materials. Such optimization provides opportunities to attack the performance limitations of SRF cavities and improve the production yield in a realm other than processing and fabrication.

One such opportunity may have appeared during Jefferson Lab's testing of AES cavities in conjunction with the heat treatment that removes hydrogen from cavity surfaces. Both the successful cavity and the one that was nearly successful underwent quicker, hotter heat treatment than had previously been standard: 2 hours at 800 °C instead of 10 hours at 600 °C. Because the AES-built cavities appeared to be stiffer, the revised treatment temperature primarily targeted the optimization of mechanical properties. However, because other improvements in material properties might also have occurred, the team at Jefferson Lab is conducting further investigations.

New temperature-mapping and optical-inspection tools adopted about a year ago under the guidance of ILC GDE project managers may also help to overcome the performance limitations of SRF cavities and improve the mass-production yield. "T-mapping" of cavity outer surfaces involves strategically placing thermal sensors to provide vital information about excessive heating in defective regions up to the point of local breakdown of superconductivity that causes a cavity to quench. This diagnostic procedure works in conjunction with the optical inspection of the surfaces within a cavity, which involves a mirror and a long-distance (around 1 m) microscope that together afford detailed mirror-reflected views of defective regions magnified at scales of about 0.1–1 mm.



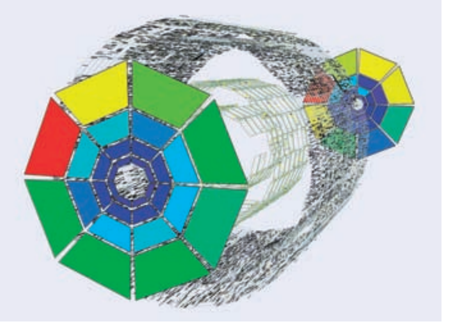
A mirror-reflected image of an interior weld on the equator of an ILC prototype cavity. A long-distance microscope aligned to magnify this kind of image can allow optical inspection of features a few micrometres in scale. (Courtesy Jefferson Lab.)

Sommaire

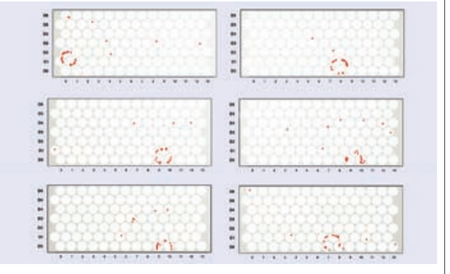
LHC NEWS

First ions for ALICE and rings for LHCb

Injection tests on 25–29 September delivered heavy ions for the first time to the threshold of the LHC. Particles were extracted from the Super Proton Synchrotron (SPS) and transported along the TI2 and TI8 transfer lines towards the LHC, before being dumped on beam stoppers. These crucial tests not only showed that the whole injection chain performs well but they were also interesting for the ALICE collaboration because they included bunches of lead ions. By using a dedicated "beam injection" trigger, the ALICE detector registered bursts of particles emerging from the beam stopper at the end of the TI2 transfer line, some 300 m upstream of the detector, shedding light on the timing of the trigger.



Hits in the ALICE detector recorded as lead ions strike a beam-stop 300 m upstream.



The first Cherenkov rings from the RICH1 detector of the LHCb detector. The small and large rings are from the same particle passing through the two different radiators in RICH1.

While the LHC has undergone repairs and consolidation work since the incident that brought commissioning to an abrupt end in September 2008, the ALICE collaboration has been busy with important installation work, which has included the first modules of the electromagnetic calorimeter (*CERN Courier* May 2009 p7). This allowed the start in August of a full detector run with cosmic rays, which was scheduled to last until the end of October. In addition to trigger information from the silicon pixel and ACORDE detectors (the latter built specially for triggering on cosmic muons) ALICE is now making extensive use of the trigger provided by its time-of-flight array (TOF). The high granularity and the low noise (0.1 Hz/cm^2) of the multigap resistive-plate chambers of the TOF, combined with the large coverage (around 150 m^2), offers a range of trigger combinations.

More than 100 million cosmic events had been accumulated in the central detectors by early October, both with and without magnetic field. Even the forward muon system – oriented parallel to the LHC beam – has collected several tens of thousands of the very rare quasi-horizontal cosmic rays, which traverse the full length of the spectrometer at a rate of one particle every couple of minutes.

Near-horizontal cosmic rays are also valuable for checking out the LHCb detector, which is aligned along the LHC beam line, and they recently allowed observation of the first rings from the one of the two ring-imaging Cherenkov detectors, RICH1 (*CERN Courier* July-August 207 p30). There are two types of radiating material in RICH1: aerogel for lowest momentum particles (around a few GeV/c) and perfluoro-n-butane (C_4F_{10}) to cover momenta from 10 GeV/*c* to around 65 GeV/c. This is the first time that the RICH detector has seen a particle as it will once the LHC re-starts.

The shutdown of the LHC has also provided the opportunity for the LHCb collaboration to finish the detector completely, with the installation of the fifth and final plane of muon chambers. Other improvements include modifications to reduce noise in the electromagnetic calorimeter to a negligible level and network upgrades. During a recent commissioning week, in preparation for the LHC re-start, the LHCb team managed to read out the full detector at a rate of almost 1 MHz. Data packets were sent at 100 kHz through to the LHCb computer farm and each sub-detector was tested to ensure that the system could handle data at this rate.

AWARDS

Nobel for optical fibres and CCDs

Charles Kao, who worked at Standard Telecommunication Laboratories, Harlow, UK, and was vice-chancellor of the Chinese University of Hong Kong, recieves the 2009 Nobel Prize in Physics for "groundbreaking achievements concerning the transmission of light in fibres for optical communication". Kao's studies indicated in 1966 that low-loss fibres should be possible using high-purity glass, which he proposed could form waveguides with high information capacity.

Willard Boyle and George Smith, who worked at Bell Laboratories, Murray Hill, New Jersey, share the other half of the prize "for the invention of an imaging semiconductor circuit – the CCD sensor". They sketched out the structure of the CCD in 1969, their aim being better electronic memory – but they went on to revolutionize photography.

ATLAS and CMS collect cosmic-event data…

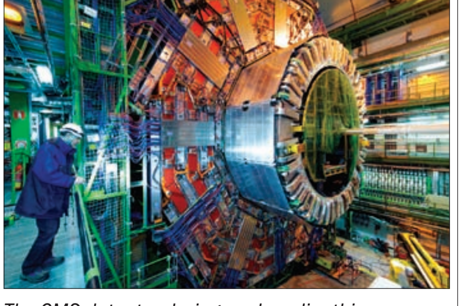
The ATLAS collaboration has made the most of the long shutdown of the LHC by undertaking a variety of maintenance, consolidation and repair work on the detector. as well as major test runs with cosmic rays. The crucial repairs included work on the cooling system for the inner detector, where vibrations of the compressor caused structural problems. The extended shutdown also allowed some schedules to be brought forward. For instance, the very forward muon chambers have been partially installed, even though this was planned for the 2009/10 shutdown. The collaboration has also undertaken several upgrades to prepare for higher luminosity, such as the replacement of optical fibres on the muon systems in preparation for higher radiation levels.

The ATLAS detector is now ready and waiting for the first collisions.

In parallel, the analysis of cosmic data collected last year has allowed the collaboration to perform detailed alignment and calibration studies, achieving a level of precision far beyond expectations for this stage of the experiment. This work is set to continue, in particular from 12 October, when the ATLAS Control Room is to be staffed round the clock. The experiment will collect cosmic data continuously until first beam appears in the LHC. During this time, the teams will study the alignment, calibration, timing and performance of the detector.

CMS has also been making the most of testing with cosmic rays. During a five-week data-taking exercise starting on 22 July, the experiment recorded more than 300 million cosmic events with the magnetic field on. This large data-set is being used to improve further the alignment, calibration and performance of the various sub-detectors in the run up to proton–proton collisions.

As with the other experiments, the shutdown period provided the opportunity for consolidation work on the detector. One of the most important items in CMS was the complete refurbishment of the cooling system for the tracker. The shutdown also gave the collaboration a chance to install the final sub-detector, the pre-shower, which consists of a lead–silicon "sandwich" with silicon-strip sensors only 2 mm wide. The pre-shower, which sits in front of the endcap calorimeters, can pinpoint the position of photons more accurately than the larger crystal detectors in the endcaps. This will allow a distinction to be made between two low-energy photons and one high-energy photon – crucial for trying to spot certain kinds of Higgs-boson decay.



The CMS detector during work earlier this year.

…while the LHC gets colder and colder

The cool-down and commissioning of the LHC continues to progress well. Six of the eight sectors were at a nominal temperature of 1.9 K by the end of the first week of October, and the final two sectors, 3-4 and 6-7, were on course to be fully cold two weeks later. Teams are starting to power the magnets as each sector reaches 1.9 K, so the machine should be fully powered soon after the cool-down is completed.

The new layer of the quench detection system (QDS), installed in four sectors, is functioning well. In particular, the new software and hardware QDS components allowed teams to measure the resistance of all of the splices in sector 1-2 quickly and with unprecedented accuracy. All of the measured resistances showed small values and most are significantly below the original specifications. Teams were also able to test the new energy-extraction system that dumps the stored magnetic energy twice as quickly as previously. This provides better protection for the whole machine.

Preparations are thus continuing towards the planned restart, with the injection of the first bunches of protons into the machine scheduled for mid-November. The procedure will be to establish stable beam initially in each direction, clockwise and anticlockwise, just as with LEP 20 years ago (p23). This will be followed by a short period of collisions at the injection energy of 450 GeV per beam. Commissioning will then begin on ramping the energy to 3.5 TeV, again working first with each beam in turn. After this, LHC physics will finally begin with collisions at this energy.

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

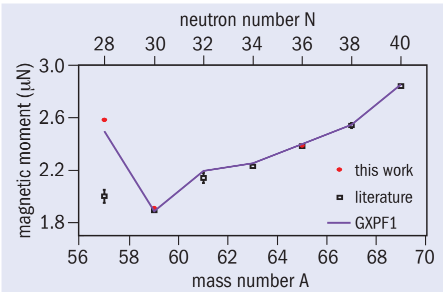
NUCLEAR PHYSICS

LISOL takes dipole moments that are close to magic

The nuclear shell model remains an essential tool in describing the structure of nuclei heavier than carbon, with shells corresponding to the "magic" numbers of protons (Z) or neutrons (N) associated with particular stability. A good way to probe the shell model is through the study of the magnetic dipole moment of a nucleus. Indeed, the model should describe particularly well the magnetic dipole moment of an isotope with a single particle outside a closed shell, as in this case the moment should be solely determined by this last nucleon. Copper isotopes (Z = 29), with one proton outside the closed shell of nickel (Z = 28), provide an example of such a system, which has been systematically studied at CERN's ISOLDE facility with the Resonance Ionization Laser Ion Source (RILIS). The COLlinear LAser SPectroscopy (COLLAPS) collaboration uses collinear laser spectroscopy on fast beams and the NICOLE facility employs nuclear magnetic resonance on oriented nuclei.

Unfortunately, the tendency for chemical compounds to form in the thick target of the ISOLDE facility, does not permit the efficient release of the short-lived isotope ^{57}Cu ($T_{1/2}$ = 199 ms), This isotope is of particular interest as it can simply be described as the doubly-magic ^{56}Ni plus one proton, but a recent measurement of its magnetic moment strongly disagreed with this picture (Minamisono *et al.* 2006).

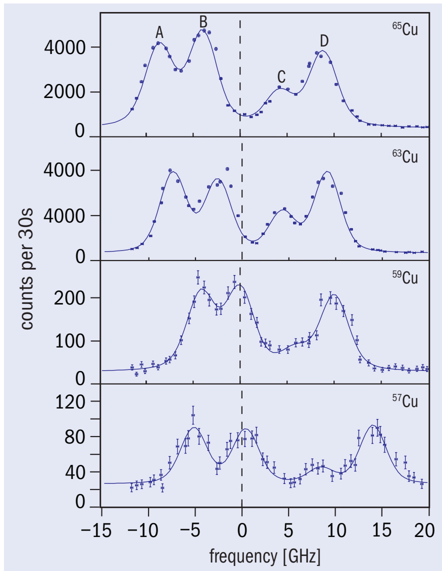
The Leuven Isotope Separator On-Line (LISOL), a gas-cell-based laser ionization facility at the Cyclotron Research Centre in Louvain-La-Neuve in Belgium, is perfectly suited for ^{57}Cu. Beams of protons at 30 MeV and of ^{3}He at 25 MeV impinge on a thin target of natural nickel. The radioactive copper isotopes produced recoil directly out of the target and are thermalized and neutralized in the argon buffer gas. The flow of the buffer gas then transports the isotopes to a second chamber where two laser beams, tuned on atomic transitions specific to the element of interest, give rise to resonance ionization of the atoms.



Ground state nuclear magnetic dipole moments of the odd-A copper isotopes from LISOL (red dots) and previous experiments (squares). Theoretical calculations using the GXPF1 interaction, a ^{40}Ca core, and the full fp-shell valence space is shown with a solid line.

Resonance ionization has provided very pure beams of radioactive isotopes for more than a decade. It also enables in-source resonance ionization laser spectroscopy, as at ISOLDE's RILIS. The new feature recently developed at LISOL is the implementation of laser spectroscopy in a gas-cell ion source (Sonoda *et al.* 2009). Its first on-line application has been the measurement of the magnetic dipole moment of the interesting copper isotopes ^{57,59}Cu.

A team at LISOL observed the hyperfine structure spectra of several isotopes of copper, namely ^{57,59,63,65}Cu, and extracted the hyperfine parameters, which yield the magnetic dipole moments. They were able to perform the measurement of ^{57}Cu with yields as low as 6 ions a second, showing the high sensitivity of the technique (Cocolios *et al.* 2009). The accuracy is demonstrated by the very good agreement with known hyperfine parameters for ^{63,65}Cu and with the measured magnetic dipole moments for the stable isotope ^{65}Cu and for the radioactive isotope ^{59}Cu, studied previously at ISOLDE. This meant that the team at LISOL was able to disprove with confidence the previous measurement of the magnetic dipole moment of ^{57}Cu. Moreover, the new value is in agreement with several nuclear shell model calculations based on the N = Z = 20 ^{40}Ca core and the N = Z = 28 ^{56}Ni core, thereby confirming understanding of nuclear structure in this region.



Typical examples of the single hyperfine spectra of ^{57,59,63,65}Cu. Each point is sampled for 30 s. ^{57}Cu and ^{63}Cu are measured simultaneously, as are ^{59}Cu and ^{65}Cu.

This new technique opens the door for the study of short-lived refractory elements, which are not accessible at ISOLDE, to be probed in new radioactive ion beam facilities, such as at the accelerator laboratory at the university of Jyväskylä (JYFL), GANIL in Caen, RIKEN in Tokyo and the National Superconducting Cyclotron Laboratory at Michigan State University.

Further reading

T E Cocolios *et al.* 2009 *PRL* **103** 102501.
K Minamisono *et al.* 2006 *PRL* **96** 102501.
T Sonoda *et al.* 2009 *Nucl. Instr. and Meth. B* **267** 2918.

SCIENCEWATCH

Compiled by John Swain, Northeastern University

An eye for quantum detection

The human eye is a remarkable photodetector, with a detection efficiency near unity for numbers of incident photons above a certain small threshold, while being blind to those below this level. This leads to the interesting possibility of doing quantum optics using the human eye as a detector. This would need to be based on a suitable quantum system, however, one with interesting quantum entanglement present but with several photons in whatever states were to be detected.

Pavel Sekatski and colleagues at the University of Geneva have shown that by using stimulated emission to amplify photons from correlated pairs it is possible to create multiphoton states that can robustly show violations of Bell's inequality, even with high losses. The multiphoton states essentially act as witnesses to the entangled states that they came from. While the actual experiment with a human eye might be a little tricky, this work does suggest interesting possibilities in quantum information technology that are far from obvious.

Could the human eye act as a detector in a quantum experiment? (Courtesy Lavinia Daniela Trifan pop/Dreamstime.com.)

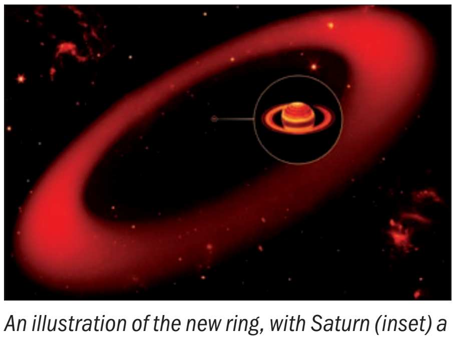
Further reading

P Sekatski *et al.* 2009 *Phys. Rev. Lett.* **103** 113601.

That's one giant ring

Saturn's spectacular system of rings is well known but it now turns out to be far bigger than ever imagined. The largest ring previously known lies at 3 to 8 times the radius of the planet. This is dwarfed by the new find, which stretches from 128 to 207 times the radius of Saturn, and is 40 times as thick.

The ring's low density kept it from being discovered until Anne Verbiscer of the University of Virginia and colleagues used data from the Spitzer space telescope's multiband imaging photometer to make out the ring by its thermal emissions in response to being heated by sunlight. A bonus from this discovery is understanding why Iapetus – one of Saturn's moons – is mysteriously dark on one side. It seems this darkening is from material falling from the newly discovered ring.



An illustration of the new ring, with Saturn (inset) a mere dot. (Courtesy NASA/JPL-Caltech/Keck.)

Further reading

A J Verbiscer *et al.* 2009 *Nature*, advance online publication, doi:10.1038/nature08515.

Nanotube friction

New research by Marcel Lucas of the Georgia Institute of Technology in Atlanta and colleagues shows dramatic variations in the friction of carbon nanotubes depending on whether they are stroked along or perpendicular to their axes. The transverse coefficient of friction turns out to be higher.

The researchers explain this frictional asymmetry by a "hindered rolling" effect, which they also find is reduced in chiral nanotubes. As well as helping to sort nanotubes, this could lead to anisotropic adhesives with far-reaching applications.

Further reading

M Lucas *et al.* 2009 *Nature Materials*. Published online doi:10.1038/nmat2529.

Black holes are big in the entropy of the universe

It often seems as though every few years one astrophysical quantity or another turns out to have a value quite different from what was thought. Now, the entropy of the universe as a whole has joined this list. Chas Egan and Charles Lineweaver of the Australian National University in Canberra have used measurements of the supermassive black hole function to show that these black holes are by far the largest contributors to the entropy of the universe. They find that the monsters supply at least an order of magnitude more than previously estimated. They have also made a first calculation of the entropy associated with dark matter within the universe.

Further reading

Chas A Egan and Charles H Lineweaver 2009 http://arxiv.org/abs/0909.3983.

Optical lattice gives boost to atomtronics

Atomtronics – an extension of electronics in which the things that move around are entire ultracold atoms in an optical lattice instead of electrons in a crystalline lattice – has just had a large boost. Ronald Pepino and colleagues at the JILA at the University of Colorado have shown that by setting up potential wells of varying depths in an optical lattice it may be possible to construct the equivalents of diodes and transistors, with the analogue of voltage being played by quantities of atoms held in reservoirs.

It is not yet clear whether such devices could give much competition for conventional electronic devices. However, they could provide models for many-body systems with superb control of parameters and complete freedom from lattice imperfections.

Further reading

R A Pepino *et al.* 2009 *Phys. Rev. Lett.* **103** 140405.

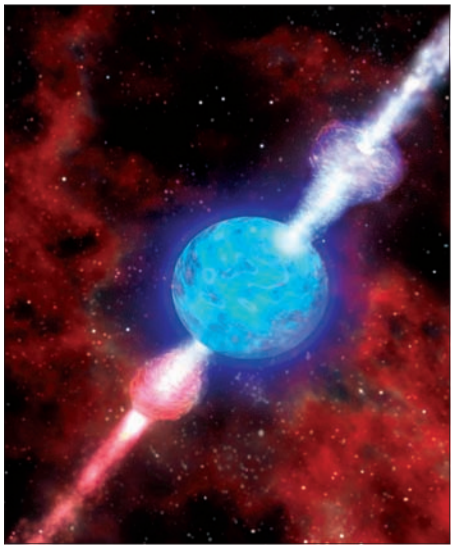
Compiled by Marc Türler, ISDC and Observatory of Geneva University

Can invading black holes explain GRBs?

X-ray observations of gamma-ray bursts (GRBs) by the Swift satellite suggest that the central engine can be active for up to a few hours. A new theoretical study shows that this is difficult to explain in the standard scenario of jet formation and instead proposes a different mechanism that would work not only for collapsing stars but also for stars invaded by a black hole companion in a binary system.

The collection of hundreds of GRB afterglows by NASA's Swift satellite since its launch in November 2004 is an observational breakthrough in the characterization of these powerful stellar explosions. The typical X-ray-afterglow emission is characterized by a rapid fading in the first minutes followed by a shallow decay lasting up to a few hours and a somewhat steeper decay afterwards. In addition, many GRB afterglows show X-ray flares superimposed on this general trend (*CERN Courier* October 2005 p11). While those features are consistent with the cannonball model, they were unexpected in the frame of the standard fireball model (*CERN Courier* December 2005 p20). Despite these difficulties, the latter remains the favoured model for long GRBs.

In this context, the intermediate shallow decay and the presence of X-ray flares are interpreted as evidence of ongoing activity of the central engine for several hours after the prompt GRB. This is a problem for models in which the ultra-relativistic jet at the origin of the GRB phenomenon is powered by the annihilation of neutrinos in a disc of matter that forms around a nascent black hole at the heart of a collapsing star. Indeed, the neutrino-heating mechanism requires a high mass-accretion rate onto a rapidly spinning black hole – a process that cannot be sustained for more than a few minutes.



Rendering of a black hole powering a relativistic jet from within a star resulting in a gamma-ray burst. (Courtesy Dana Berry, SkyWorks Digital/NASA.)

A new theoretical study by Maxim V Barkov and Serguei S Komissarov from the Department of Applied Mathematics at the University of Leeds proposes an alternative to the prolonged neutrino-heating problem in the standard "collapsar" model. They demonstrate that jets of long GRBs can also be powered via a magnetic process, such as the Blandford–Znajek mechanism. This mechanism, proposed in 1977, uses the rotational energy of the spinning black hole to power the jet. Compared with the neutrino-driven GRB model it has the advantage that it can account for the prolonged jet activity with a somewhat lower constraint on the spin of the black hole; but on the other hand, it requires a strong magnetic field at the black-hole horizon. One way to reduce the magnetic constraint is to start with a neutrino-driven supernova explosion that opens jet channels for the subsequent magnetically driven GRB.

A particularly interesting possibility discussed by Barkov and Komissarov is the case of a close binary system composed of a Wolf-Rayet star – a massive, dense star that has blown away its outer layer of hydrogen – and a black hole. The black hole could lose momentum in the wind of the companion star and ultimately spiral into the star's centre, devouring it from the inside. In the Milky Way, there is luckily only one such binary system, Cyg X-3, which has an orbital period of about 5 hours. The black hole might eventually parasite on the Wolf-Rayet star, disrupt it and produce a GRB to be observed in billions of years' time in a remote galaxy.

Further reading

M V Barkov and S S Komissarov 2009. Submitted to *MNRAS*. http://arxiv.org/abs/0908.0695.

Picture of the month

The 19-year-old Hubble Space Telescope has undergone a refound youth. This image by the Wide Field Camera 3 is one example that shows the power of the observatory after the fourth servicing mission in May 2009. The group of five galaxies is known as Stephan's Quintet. The name is a bit of a misnomer because the bottom-left galaxy actually lies seven times closer to Earth than the rest of the group. Three galaxies have elongated spiral arms and long, gaseous tidal tails that contain new-born star clusters – proof of the galaxies' close encounters. The broad coverage of the new camera from visible to near-infrared light results in unprecedented colours that depict the various ages of the stars. Star-forming regions are blue or pink, while older stars trace the shape of the galaxies with an orange haze. (Courtesy NASA, ESA and the Hubble SM4 ERO Team.)

CERN COURIER ARCHIVE: 1966

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

CERN

The next neutrino experiments

In 1931, Pauli postulated the existence of neutral, very light and very feebly interacting particles [to resolve the energy crisis in nuclear beta-decay]. Now called electron anti-neutrinos ($\bar{\nu}_e$), they are produced, with an electron, e.g:

$$n \rightarrow p + e^- + \bar{\nu}_e$$

The most prolific sources of $\bar{\nu}_e$ are nuclear reactors; each of us is bombarded by thousands per second from the world's reactors. Cowan and Reines detected "neutrino" interactions for the first time in 1955 at the Savannah River reactor, USA, winning a wager made by Pauli that they would never be observed.

The Sun is our most powerful source of electron neutrinos (ν_e), bathing the Earth in more than 10^{10}/cm^2/second. They are produced, with a positron, in the fusion of hydrogen to produce heavier elements, e.g. deuterium:

$$p + p \rightarrow d + e^+ + \nu_e$$

To study solar neutrinos, very large detectors have been installed deep in the earth to escape confusing background [e.g. in the Homestake Mine, USA]. Will the solar neutrino flux be measured at last and lead to a more precise understanding of how the Sun transforms mass into energy?

'Laboratory' neutrinos

The ν_μ and $\bar{\nu}_\mu$, generated from pions or kaons, are especially suitable for experiments at high-energy accelerators [see later].

$$\pi^+ \text{ or } k^+ \rightarrow \mu^+ + \nu_\mu, \quad \pi^- \text{ or } k^- \rightarrow \mu^- + \bar{\nu}_\mu$$

In 1963–64, about 1000 interactions of ν_μ were detected in the CERN heavy-liquid bubble chamber (HLBC) at the Proton Synchrotron (PS). The previous Brookhaven results, which demonstrated the existence of the two neutrinos, ν_e and ν_μ, were confirmed, with increased evidence that ν_μ interacts to produce muons and never electrons. No evidence was found that ν_μ from kaons differ from those from pions, nor that the type of particle called "strange" is often produced in $\bar{\nu}_\mu$ interactions.

Perhaps most interesting was the lack of evidence for the intermediate boson, W, postulated to be the carrier of the weak force. If the W exists at all, its mass must be greater than 2 GeV/c^2, much higher than first thought.

Plans for the next step

The principal information from the first experiments came from "elastic" interactions:

$$\nu_\mu + n \rightarrow \mu^- + p$$

where both the muon and the proton had a high probability of escaping from the target nucleus.

Inelastic interactions are much more difficult to investigate, the simplest being:

$$\nu_\mu + p \rightarrow \mu^- + \pi^+ + p$$

where the pion is likely to be absorbed in the target nucleus, so the kinematic analysis will be less accurate.

This problem would not occur for interactions with "free" protons. Therefore an obvious next step was to replace freon, CF_3Br, in the HLBC by a fluid like propane, C_3H_8. To obtain the same event rate in propane as in freon requires a ten-fold increase in neutrino flux.

The HLBC volume has been increased from 500 to 1180 litres to give more than a three-fold increase in event rate. When "Gargamelle" is available, its effective volume should be some seven times more than the present HLBC.

The new neutrino beam

To produce a neutrino beam, the accelerated proton beam is brought out of the PS and directed onto a target to produce secondary particles that include neutrino "parents", pions and kaons, which decay after a short time.

In the first experiments, the neutrino parents were focused into a parallel beam and directed towards the detector by a magnetic horn, invented by S van der Meer at CERN. In the new system, the parents will be partially focused by a new horn, designed by D H Perkins of the University of Oxford and W Venus, after which two magnetic correcting elements, reflectors, developed by A Asner and Ch Iselin, will converge them towards the detector, significantly improving the neutrino flux. To filter out all particles except the feebly interacting neutrinos, shielding has been rebuilt from 6000 tonnes of steel ingots generously lent by the Swiss authorities. The new horn, reflectors and steel block will produce, for each proton incident on the target, a neutrino flux about six times greater than before.

Behind the shielding, the HLBC will operate with propane for the first time. A few neutrino events on "free" protons are expected per day, with about five times as many events on carbon nuclei. A magnetic field of 27 kG will select candidate interactions so that less than 10% will be on carbon. The "carbon" events, being in propane, can be measured with much greater precision than in the first experiment, allowing an invaluable re-examination of previous conclusions.

Spark chambers will be associated with the HLBC to test the law that a ν_μ always transforms to a μ^-, and a $\bar{\nu}_\mu$ to a μ^+. The chamber array will be able to detect a violation as small as one μ^+ per thousand muons produced by ν_μ.

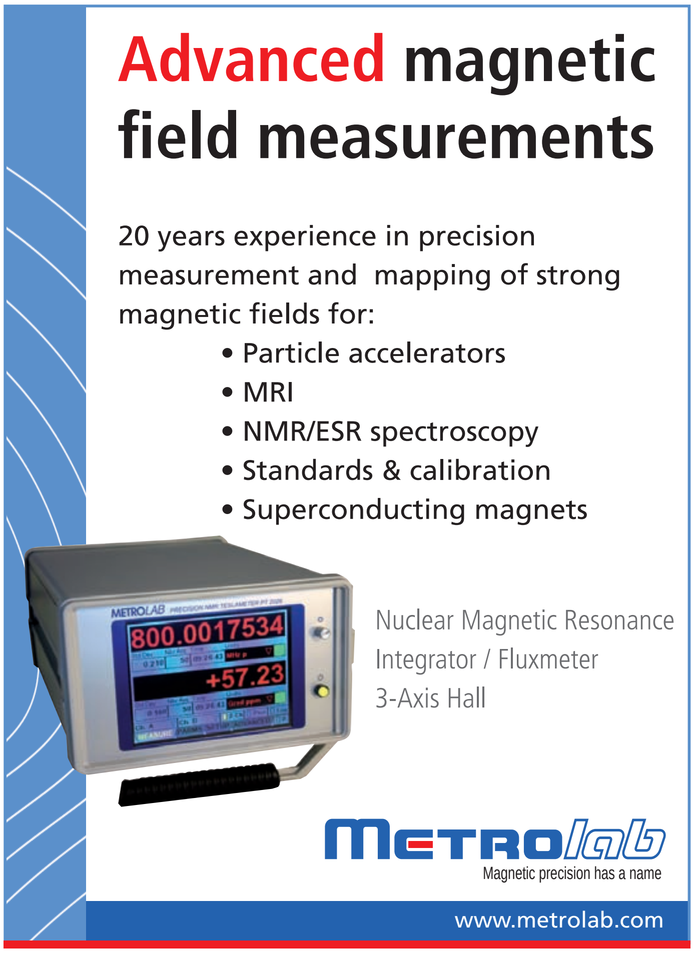
Neutrinos carry a significant fraction of the total energy of the universe. What is the cosmological role of these tantalizing, all-permeating particles? It may be interesting to review later, what has been the outcome of this programme and to assess what contributions have been made to increase our understanding of the nature of neutrino interactions.

● Compiled from the article by C A Ramm pp211–217.

COMPILER'S NOTE

In the Homestake Mine the measured solar ν_e flux was only a third of that predicted. This "problem" was eventually solved as being due to neutrino identity-changing flavour oscillations: quantum mixing that requires neutrinos to have non-zero mass, currently estimated to have an upper limit in the 1 eV region.

Using ν_μ at the PS, neutral currents were observed in Gargamelle in 1973, providing the first clear evidence for a neutral weak force carrier, the Z^0. This gave a strong boost to electroweak theory, which by then predicted much higher masses for both the Z^0 and the charged W than was first thought. Discovered at CERN in 1983, the W (80.4 GeV/c^2) and Z^0 (91.2 GeV/c^2) are almost as heavy as the silver nucleus.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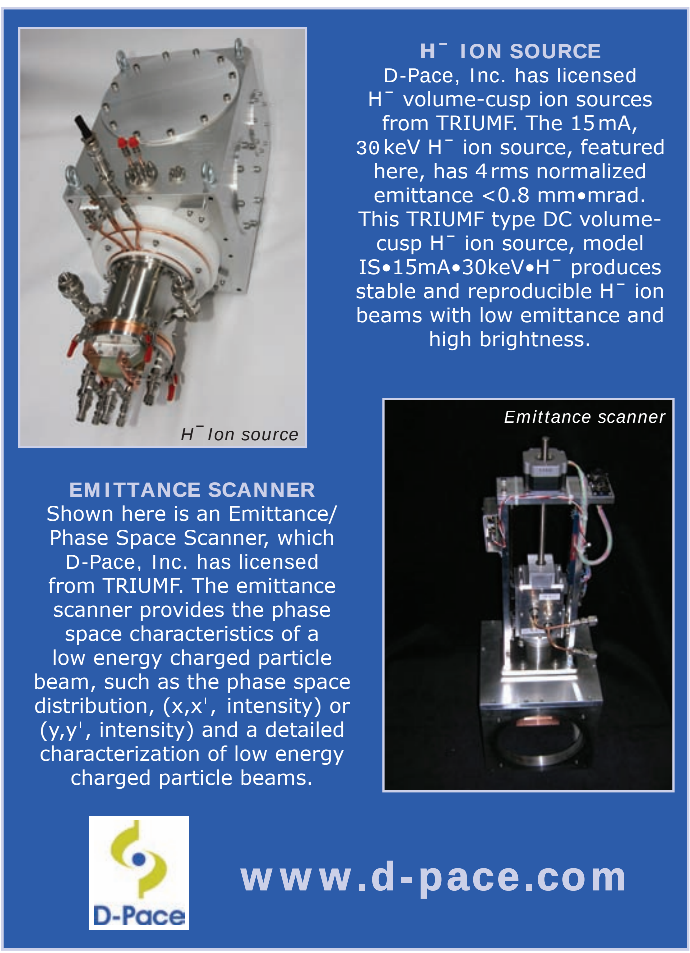
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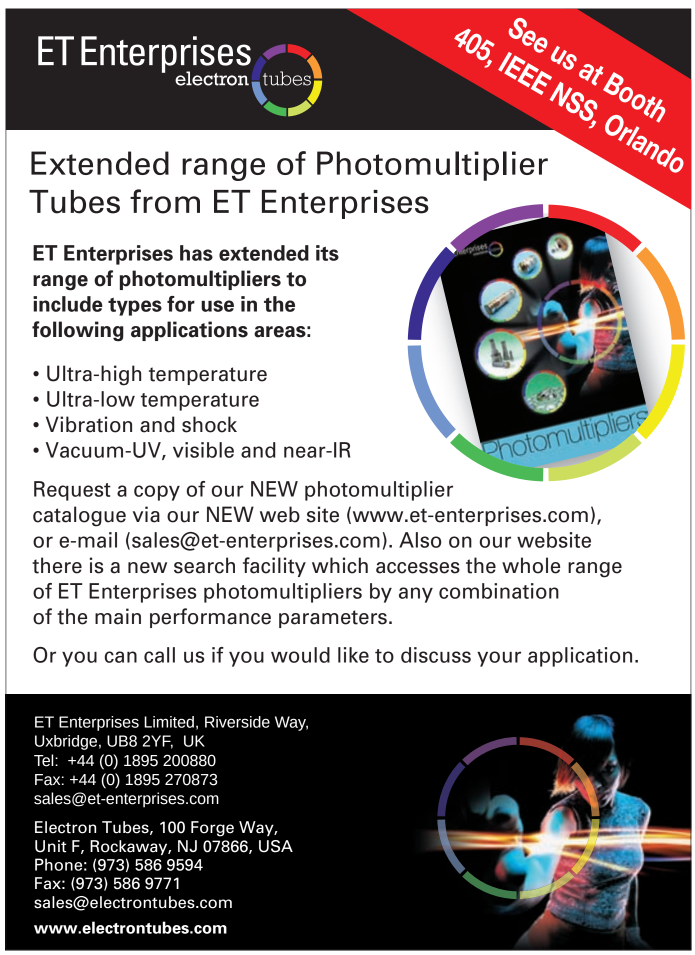
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The EIC's route to a new frontier in QCD

A worldwide effort to determine the best way to explore the frontier in understanding precisely how quarks and gluons form hadrons and nuclear matter in the context of QCD has determined that the ideal future facility would be a high-luminosity, high-energy polarized electron–ion collider. **Abhay Deshpande**, **Rolf Ent** and **Richard Milner** report.

Understanding the fundamental structure of matter requires determining how the quarks and gluons of QCD are assembled to form hadrons – the family of strongly interacting particles that includes protons and neutrons, which in turn form atomic nuclei and hence all luminous matter in the universe. Leptons have proved to be an incisive probe of hadron structure because their electroweak interaction with the hadronic constituents is well understood. Experiments to probe the quarks and gluons within the hadrons require high-intensity, high-energy lepton beams incident on nucleons; and if the leptons and nucleons are polarized, then measurements of spin-dependent observables are possible, so casting light on the spin structure of the hadrons.

Current experiments with polarized leptons focus predominantly on the valence quarks. To learn more about the sea quarks and gluons, physicists who study hadron structure have identified a high-luminosity, polarized electron–ion collider (EIC) as the next-generation experimental facility for exploring the fundamental structure of matter. The proposed EIC would be unique in that it would be the first to collide highly energetic electrons and nuclei, and be the first to collide high-energy beams of polarized electrons on beams of polarized protons and, possibly, a few other polarized light nuclei. It would be designed to achieve at least 100 times the integrated luminosity of the world's first electron–proton collider, HERA, over a comparable operating period.

The EIC would offer unprecedented opportunities to study, with precision, the role of gluons in the fundamental structure of matter. Without gluons, matter as we know it would not exist. Gluons collectively provide a binding force that acts on a quark's colour charge but – unlike the photons of QED – they also possess a colour charge, so can self-interact. These self-interactions mean that gluons are the dominant constituents of matter, making QCD equations extremely difficult to solve analytically. Recent theoretical breakthroughs indicate that analytic solutions may be possible for systems in which gluons collectively behave like a very strong classical field – the so-called "colour glass condensate (CGC)". This state has weak colour coupling despite the high gluon density and

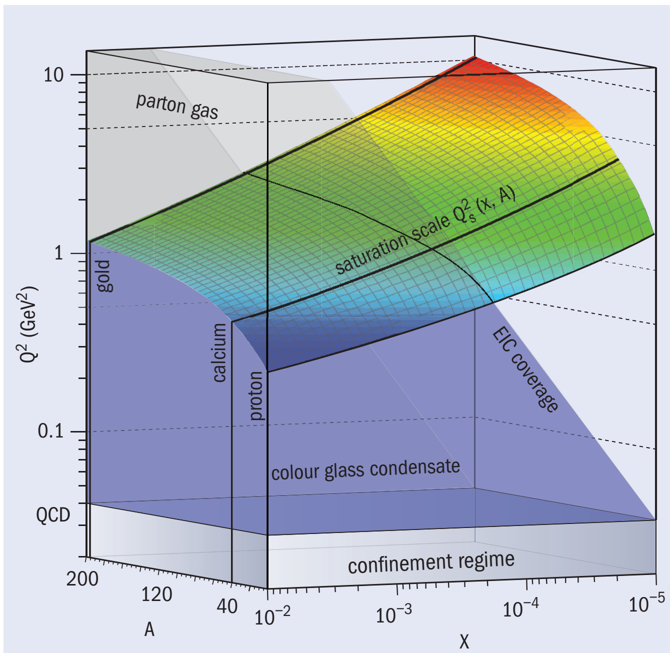


Fig. 1. Regimes of hadronic matter in QCD, shown as a function of the momentum transfer of the electron, Q^2, the relative momentum fraction of the gluon in the nucleus, x, and the atomic number A of the probed nucleus. The multicoloured surface indicates the saturation scale Q_s^2 as a function of x and A. The saturation regime ($Q^2 < Q_s^2$) that is kinematically accessible by the EIC is depicted in blue.

is characterized by a "saturation" momentum scale, Q_s, which is related to the gluon density. QCD also predicts a universal saturation scale where all nuclei, baryons and mesons have a component of their wave function with identical behaviour, implying that they all evolve into a unique form of hadronic matter.

The discovery of CGC would represent a major breakthrough in the understanding of the role of gluons in QCD under extreme conditions. To probe the CGC optimally requires collisions of ▷

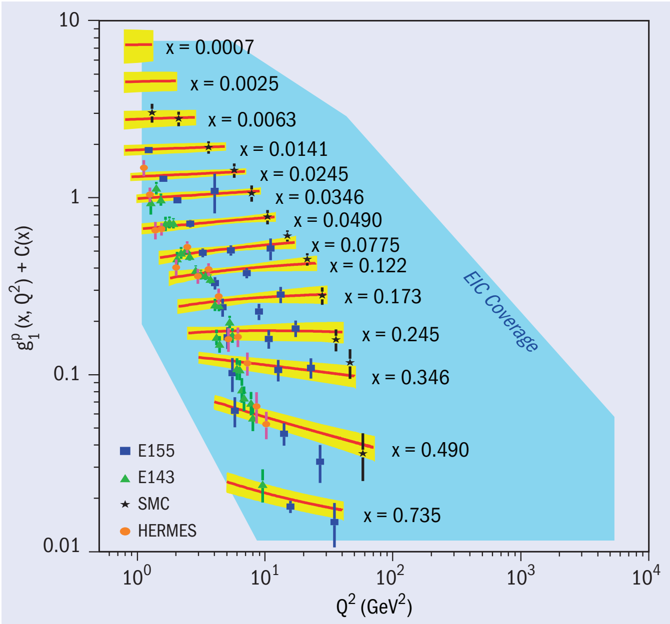


Fig. 2. The world's data on polarized deep-inelastic scattering results for the proton, from SLAC experiments E143 and E155, SMC at CERN and HERMES at DESY. The curves (and error bands) are from a global QCD fit by Helmut Boettcher and Johannes Bluemlein. The area shaded in blue represents the enlarged (x,Q^2) area accessible by an EIC.

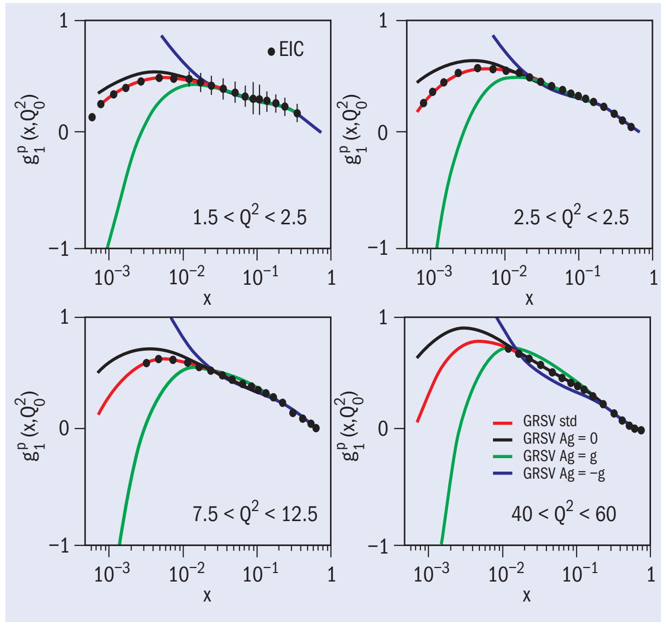


Fig. 3. Projected EIC data for the polarized proton structure function $g_1(x,Q^2)$ as a function of Bjorken-x in four Q^2 bins, measured at a centre-of-mass energy of 65 GeV, for 5 fb^{-1} integrated luminosity. Error bars are statistical. The curves show theoretical predictions based on different sets of spin-dependent gluonic contributions.

high-energy electrons and heavy ions (with large atomic number, A) resulting in large centre-of-mass energy (i.e. small gluon momentum fraction, x). The EIC would allow exploration of this novel regime of QCD because the use of heavy nuclei in experiments amplifies the gluon densities significantly over electron–proton collisions at comparable energies. Figure 1 shows the dependence of the saturation scale Q_s^2 on x and A and indicates the region that would be accessible to the EIC.

The ability to collide spin-polarized proton and light-ion beams with polarized electrons (and possibly also positrons) would give the EIC unprecedented access to the spatial and spin structure of protons and neutrons in the gluon-dominated region, complementary to the existing polarized-proton collider, RHIC, at Brookhaven National Laboratory (BNL). Figure 2 illustrates how the EIC would extend greatly the kinematic reach and precision of polarized deep-inelastic measurements compared with present (and past) polarized fixed-target experiments at SLAC, CERN, DESY and Jefferson Lab.

The polarizations measured so far for the sea quarks and gluons are consistent with zero, albeit with large uncertainties. Given that the quarks contribute only about 30% to the spin of the proton, this is surprising. The EIC is ideally suited to resolve this puzzle: it would measure with precision the contribution of the quarks and gluons to the nucleon's spin deep in the non-valence region (figure 3) and also study their transverse position and momentum distributions, which are thought to be associated with the partonic orbital angular momentum. This could provide tomographic images of the nucleon's internal landscape beyond the valence-quark region, which will be probed with the 11 GeV electron beam at Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF). Both measurements are essential to understand the constitution of nucleon spin.

Excited by these prospects, physicists came together in 2006 to form the Electron–Ion Collider Collaboration (EICC) to promote the consideration of such a machine in the US. They have developed the scientific case for an EIC with a centre-of-mass energy in the 30–100 GeV range and luminosity of about 10^{33} cm^{-2}s^{-1}. The flagship US nuclear-physics laboratories BNL and Jefferson Lab have developed preliminary conceptual designs based on their existing facilities, namely RHIC and CEBAF, respectively. These early concepts have since evolved into significantly more advanced designs (figure 4). Options include the possibilities of realizing electron–nucleus and polarized electron–proton collisions at lower energies and at lower initial costs. Considerable effort is underway to achieve the highest luminosities – up to 10^{35} cm^{-2}s^{-1} – which would maximize the access to the physics and help in make the strongest possible case for the EIC.

Future prospects

The scientific argument for the EIC has been discussed in the US nuclear-physics community since its first formal presentation at the Nuclear Science Advisory Committee's (NSAC) 2002 long-range planning exercise and most recently in a similar exercise held in 2007. The result is that the EIC has been embraced as embodying the vision for reaching the next QCD frontier. The community recognizes that the EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and would be complementary to those planned for the next generation of accelerators in Europe and Asia. NSAC has recommended that resources be allocated to develop the necessary accelerator and detector technology for the EIC.

Two separate proposals for EICs are being considered in Europe. In the LHeC the existing LHC hadron beam would collide with a 70–140 GeV electron beam (*CERN Courier* April 2009 p22). The

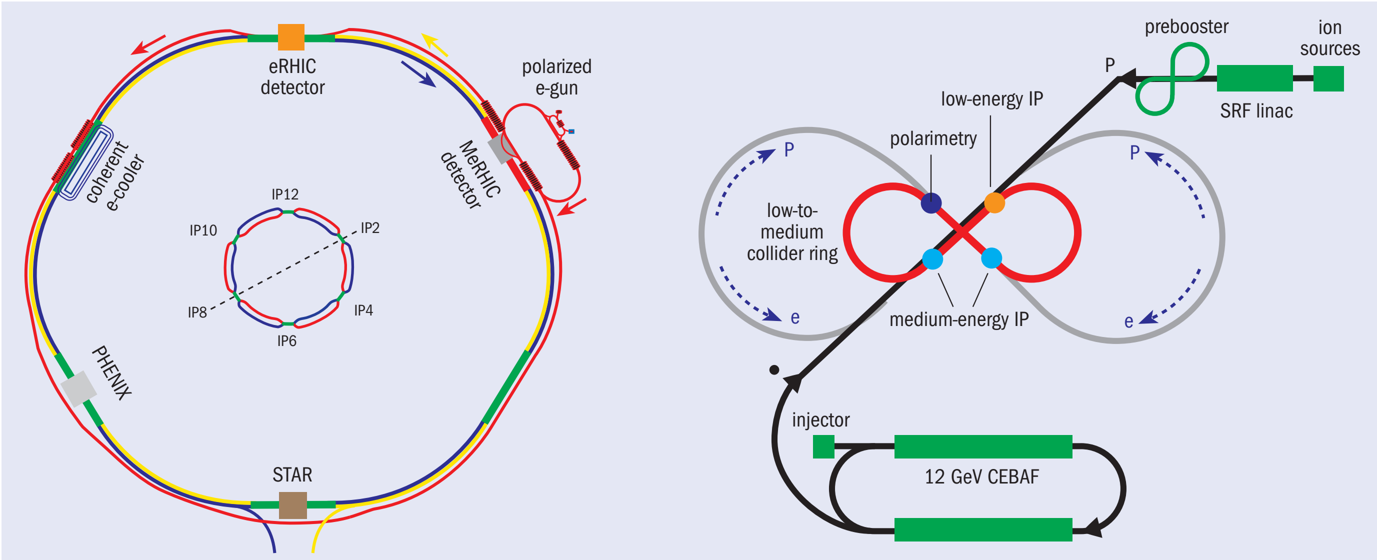


Fig. 4. On the left, the conceptual design of eRHIC at BNL using the existing RHIC facility; Medium-Energy eRHIC (MeRHIC) would be the first stage of the eRHIC, with a race-track accelerator to collide electron beams (up to 4 GeV/c) with the existing RHIC beams (50–250 GeV polarized protons, and 12–100 GeV/A ion beams) shown in red near the MeRHIC detector. The extension of MeRHIC into the eRHIC would include placing an electron accelerator in the existing RHIC tunnel (shown in red), with up to 20 GeV polarized (30 GeV unpolarized) electrons colliding with the RHIC beams at the location of the eRHIC detector. On the right, the EIC at Jefferson Lab based on the about-to-be-upgraded CEBAF accelerator. The initial stage of this concept is shown in green (the injector complex) and red (the collider), with three possible interaction points for up to 60 GeV polarized-proton beams and ion beams of corresponding rigidity. The upgraded hadron beam facility (shown in grey) is expected to reach 250 GeV with polarized protons.

resulting collisions with the 7 TeV proton beam would allow a centre-of-mass energy of about 1.4 TeV. Such a high energy would enable the study of gluons and their collective behaviour at their highest possible densities (lowest possible x). It would also allow exploration of possible physics beyond the Standard Model with a lepton probe at very high Q^2. The other European EIC proposal is motivated by the spin structure of the nucleon. The European Nucleon Collider (ENC) would make use of the High-Energy Storage Ring (HESR) and the PANDA detector at the proposed Facility for Antiproton and Ion Research (FAIR) at GSI. The centre-of-mass energy proposed for this facility is around 14 GeV, which lies between the fixed-target experiments HERMES at DESY and COMPASS at CERN. The primary goal of ENC is to explore the 3D structure of the nucleons, including the transverse-momentum distributions and generalized parton distributions for the quarks.

Since 2007 the EICC has met approximately every six months at Stony Brook University in New York, Hampton University in Virginia, Lawrence Berkeley National Laboratory and, most recently, at GSI. The next meeting is scheduled to take place at Stony Brook University in January 2010. The directors of BNL and Jefferson Lab have formed an EIC International Advisory Committee (EICAC) to help prepare the case for the project in the US. The EICAC met for the first time in Washington DC in February 2009 and will meet again in November at Jefferson Lab. The EICC is working towards the consideration of the EIC by NSAC as a priority for new construction in its next long-range plan anticipated in 2012 or 2013.

● Detailed information on EICC and EICAC meetings is available at http://web.mit.edu/eicc.

Résumé
Le projet EIC : aux frontières de la QCD

Pour mieux comprendre comment quarks et gluons forment les hadrons et la matière nucléaire, les physiciens travaillant sur la structure du hadron ont conclu qu'un collisionneur électron-ion polarisé de grande luminosité serait l'installation idéale. Cette machine serait la première à produire des collisions entre des faisceaux d'électrons de haute énergie et des faisceaux de noyaux. La collaboration EIC préconise une machine ayant une énergie dans le centre de masse de l'ordre de 30–100 GeV et une luminosité d'environ 10^{33} $cm^{-2}s^{-1}$ et met en avant l'intérêt d'une telle machine, qui pourrait être construite aux États-Unis.

Abhay Deshpande, *Stony Brook University,* **Rolf Ent**, *Jefferson Laboratory, and* **Richard Milner**, *Massachusetts Institute of Technology.*

Accelerator R&D gets a collaborative boost

The EU Commission and partners from universities, research centres and industries throughout Europe have launched EuCARD, a new four-year project centred on accelerator R&D for high-energy physics, nuclear physics and light sources, co-ordinated by CERN.

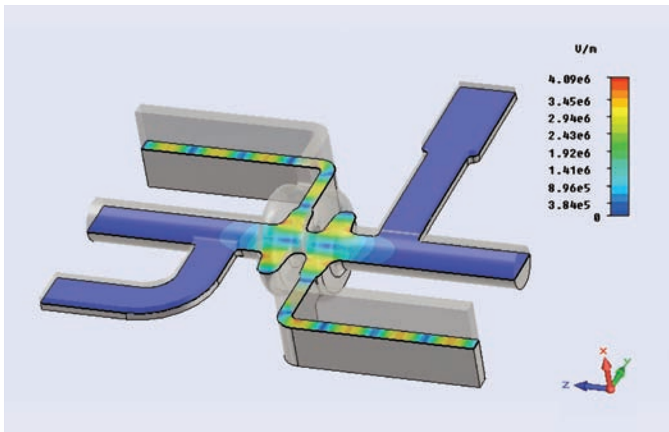
A sustained effort to develop the potential and performance of particle accelerators is a key ingredient of experimental particle physics. It is also true for nuclear physics, light sources and myriad other applications of accelerators in research and industry. These different fields often share ambitious R&D challenges – hence the idea of a common venture that brings together different partners in Europe and beyond and that focuses on top-priority accelerator R&D issues.

The Co-ordinated Accelerator Research in Europe (CARE) project, which was overseen by the European Steering Group for Accelerator R&D (ESGARD), pioneered collaborative work in accelerator R&D on a European scale. The five-year project grouped together 22 partners and more than 60 associated institutes and was co-funded by the EU's Framework Programme 6. Combining networking and R&D, CARE had three main goals: to optimize the use of existing infrastructures: collaborate on new state-of-the-art technologies; and develop links between accelerator physicists and particle physicists.

CARE's networking activities enhanced European knowledge to investigate efficient and cost-effective methods to produce intense and high-energy electron, proton, muon and neutrino beams. These are the Electron Linear Accelerator Network (ELAN) and the networks for High-Energy High-Intensity Hadron Beams (HHH) and Beams for European Neutrino Experiments (BENE). R&D activities within CARE included:

- Superconducting Radio Frequency (SRF) to investigate superconducting cavity technology with a gradient exceeding 35 MV/m
- PHIN, an activity for photoinjector technology for two-beam acceleration concepts, new-generation light sources and novel acceleration techniques
- High Intensity Pulsed Proton Injectors (HIPPI) to study normal and superconducting structures for the acceleration of high-intensity proton beams, as well as challenging beam-chopping magnets and beam dynamics
- Next European Dipole (NED) for research into cable technology for reaching high magnetic fields (>15 T) using high current densities (>1500 A/mm^2)

When CARE came to an end on 31 December 2008, the co-ordinator, Roy Aleksan from the Commissariat à l'énergie atomique (CEA), announced that 129 deliverables and more than 700 scientific publications had been achieved, including 18 PhD theses.



The EuCARD proposed design of a compact crab cavity for the LHC luminosity upgrade showing the magnetic field in the cavity (centre) and vacuum chamber. (Courtesy Cockcroft Institute/Lancaster U.)

From CARE to EuCARD

Beyond the scientific outcome, CARE created a favourable environment for future European projects in accelerator R&D. ESGARD triggered the preparation of a new European project, taking into account the new priorities in accelerator R&D. The result is the European Co-ordination for Accelerator Research & Development (EuCARD), a four-year project co-funded by the EU's Framework Programme 7 (FP7), which involves 37 partners from 45 European accelerator laboratories, universities, research centres and industries. In response to the EC's request, this project's mandate includes a contribution to the emergence of lasting structures in the accelerator field, beyond the duration of European projects.

The EuCARD project started on 1 April 2009 and is co-ordinated by CERN, with Jean-Pierre Koutchouk as project co-ordinator, Ralph Assmann as deputy and Svetlomir Stavrev as administrative manager. Its management bodies are the Governing Board and the

EuCARD partners

European Organization for Nuclear Research (INO), Austrian Institute of Technology (AT), Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (DE), Budker Institute of Nuclear Physics (RU), Commissariat à l'Énergie Atomique (FR), Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (ES), Centre National de la Recherche Scientifique (FR), Columbus Superconductors SpA (IT), Instituto de Fisica Corpuscular (Consejo Superior de Investigaciones Cientificas – Universitat de València) (ES), Deutsches Elektronen-Synchrotron (DE), Bruker HTS GmbH (DE), Ecole Polytechnique Fédérale de Lausanne (CH), Forschungszentrum Dresden-Rossendorf e.V. (DE), Forschungszentrum Karlsruhe GmbH (DE), Gesellschaft für Schwerionenforschung GmbH (DE), Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences (PL), Istituto Nazionale di Fisica Nucleare (IT), Andrzej Soltan Institute for Nuclear Studies in Swierk (PL), Politecnico di Torino (IT), Paul Scherrer Institut Villigen (CH), Politechnika Wrocławska (PL), Royal Holloway University of London (UK), Russian Research Center "Kurchatov Institute" (RU), University of Southampton (UK), Science and Technology Facilities Council (UK), Technical University of Lodz (PL), Tampere University of Technology (FI), Helsingin Yliopisto (University of Helsinki) (FI), Université Joseph Fourier Grenoble (FR), University of Lancaster – Cockcroft Institute (UK), University of Malta (MT), Université de Genève (CH), University of Manchester – Cockcroft Institute (UK), University of Oxford (UK), Universität Rostock (DE), Uppsala Universitet (SE), Politechnika Warszawska (PL).

Steering Committee. The Governing Board represents the project partners and has elected Tord Ekelof, of the University of Uppsala, as chair. The Steering Committee represents the project's activities, with all work-package co-ordinators and deputies as members. A co-ordination office at CERN offers central support to the community, benefitting from the active involvement of the CERN's EU Office.

The collaborative R&D programme includes 21 "tasks" grouped under five themes (work packages), described in more detail below. Most studies are deeply rooted in the work plans and funding of the collaborating laboratories, thereby providing a robust environment. The EuCARD contribution brings the added value of collaborative work between accelerator laboratories, universities, specialized institutes and private companies.

Five themes

The theme "High-field magnets", led by Gijs de Rijk of CERN and François Kircher of the CEA, involves 13 partners. The primary goal is a new jump in achievable magnetic fields, rated as the top priority by the EC project review. This includes the study, design and construction of a model 13 T niobium–tin (Nb_3Sn) accelerator dipole. The study and construction of a very ambitious inner coil "booster" to be added to this dipole aims to reach significantly higher fields, possibly 20 T. Potential applications are test stations for superconducting cables (e.g. FRESCA at CERN); phase II of the LHC upgrade; wigglers and undulators; and all accelerators requiring more compactness. Two associated studies will investigate the use of high-temperature superconductors for superconducting links and of Nb_3Sn for short-period helical undulators for the International Linear Collider (ILC) positron source.

The theme "Collimation and materials", led by Ralph Assmann of CERN and Jens Stadlmann of GSI, involves nine partners. Robust and efficient collimation is a necessity and a challenge for both the LHC and the future Facility for Antiproton and Ion Research (FAIR) at GSI. This theme is recent in accelerator sciences and includes the successive steps necessary to allow collimator implementation: beam modelling; energy deposition calculations; behaviour of materials, especially under shock waves (accidental beam loss); radiation damage; and implementation and testing of warm and cold collimators.

The theme "Linear colliders", led by Grahame Blair of Royal Holloway, University of London, and Erik Jensen of CERN, involves 11 partners. It has two aspects: technologies for the Compact Linear Collider Study (CLIC), with two-beam acceleration; and the stabilization and beam delivery issues that are common to CLIC and the ILC. The studies include: the design and construction of improved power extraction and transfer structures for CLIC Test Facility 3; the demonstration of higher-order mode (HOM) damping in the presence of alignment errors; breakdown simulations and diagnostics instrumentation; and precise synchronization devices with 20 fs resolution. Stabilization will be investigated for the linac and final focus, using purposely built mock-ups, with targets of 1 nm and 0.1 nm respectively. Beam delivery methods and instrumentation for emittance preservation will be investigated on the Accelerator Test Facility 2 in Japan and on PETRA III at DESY.

The theme "Superconducting radio frequency technologies" is led by Olivier Napoly of the CEA and Olivier Brunner of CERN and it involves 15 partners. This is the largest work package of EuCARD and covers various aspects of the superconducting technology applied to the production of RF fields and related topics. It will study new technologies being investigated for superconducting thin-film deposition. Using bulk material, accelerating cavities will be developed for hadron linacs and investigations carried out on couplers, mostly with a view to reliable and industrial cleaning. New, advanced telecommunication computing-architecture technology will be applied to low-level RF, with an application at the free-electron laser facility, FLASH, at DESY. On the same machine, investigations will be done on the HOM signals used as beam-diagnostic devices. An improvement programme for the superconducting RF gun at the Electron Linac for beams with high Brilliance and low Emittance (ELBE), Forschungszentrum Dresden-Rossendorf, covers beam characterization and the preparation and characterization of photo-cathodes. ▷

The fifth theme, "Innovative accelerator concepts", is led by Marica Biagini of INFN and Rob Edgecock of the UK's Rutherford Appleton Laboratory (RAL) and involves five partners. It provides support for exciting innovative concepts developed in several laboratories, such as the crab-waist crossing-scheme, non-scaling, fixed-field, alternating-gradient accelerators and plasma-wave acceleration. The EuCARD contributions range from feasibility studies to beam diagnostics for a better evaluation and understanding of their upcoming implementations.

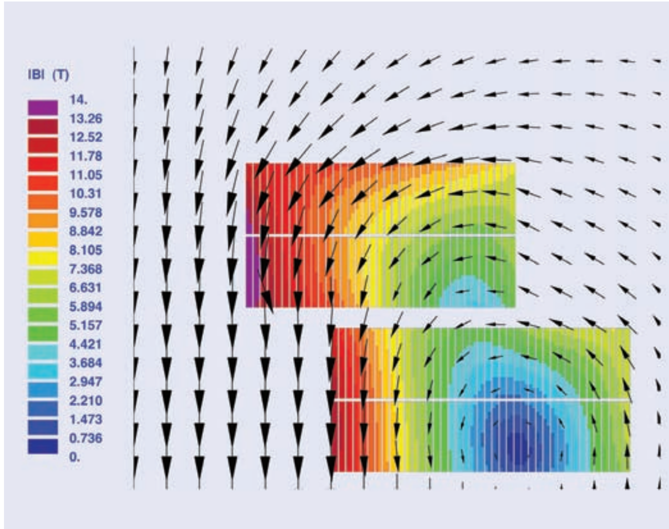
A large community

EuCARD also involves networks, which are grouped under three headings. The network for neutrino facilities (NEu2012), led by Vittorio Palladino of INFN and Silvia Pascoli of the Institute for Particle Physics Phenomenology, Durham University, aims to structure the European neutrino community for a coherent approach to the upgrade of existing infrastructures and/or a road map to new ones. The network is in liaison with EUROnu, the FP7 Design Study for A High Intensity Neutrino Oscillation Facility in Europe, and worldwide studies. The network is already active in participating or contributing to the organization of all major neutrino physics events.

The accelerator science networks (AccNet), which are led by Frank Zimmermann of CERN and Alessandro Variola of CNRS-LAL, divide into two specialized networks, though some topics such as crab cavities span them both. The accelerator-performance (EuroLumi) network continues and extends the activity of CARE-HHH on the LHC, FAIR and other accelerator upgrades, interfacing with the US LHC Accelerator Research Program. It bridges the gap between accelerator physics, accelerator technology and experimental physics, with the goal of defining optimized upgrades. The RF technologies (RFTech) network, which covers both normal and superconducting RF, encompasses all aspects of RF technology, such as klystron development, RF power distribution, cavity design, low-level RF and costing tools.

Finally, the network for scientific communication and outreach is led by Ryszard Romaniuk of Warsaw University of Technology and Kate Kahle of CERN. An important aspect of European projects and motivation for EU funding is communication, dissemination and outreach, so as to strengthen the European research area and facilitate future collaborative ventures. This network is already active, creating a website, publication portal and database, and a project newsletter. It is looking into the possibility of publishing a series of booklets on accelerator sciences and the co-ordinators welcome contact from potential authors.

Research accelerators are by nature open to a large community of users. To stimulate and support wide use of accelerator-related R&D facilities, EuCARD operates two schemes under EU rules for "Transnational Access": the Muon Ionization Cooling Experiment (MICE), with a muon beam of around 200 MeV/c and ionization-cooling facility under development at RAL; and the High Radiation Material test facility (HiRadMat), a pulsed irradiation facility under development at CERN. In both cases more details for potential users can be found at http://cern.ch/EuCARD/activities/access.



The magnetic field in the block-coil of a quadrant of the 14 T model dipole.

As soon as the project started in April, the EuCARD activities entered an active phase, achieving the planned early milestones. Several articles have already been published, thanks to the anticipation of several partners. The co-ordinator and Steering Committee look forward to the collaborative work ahead.

● For more about EuCARD and its scientific events, visit http://cern.ch/eucard.

Résumé

R&D sur les accélérateurs : collaboration renforcée

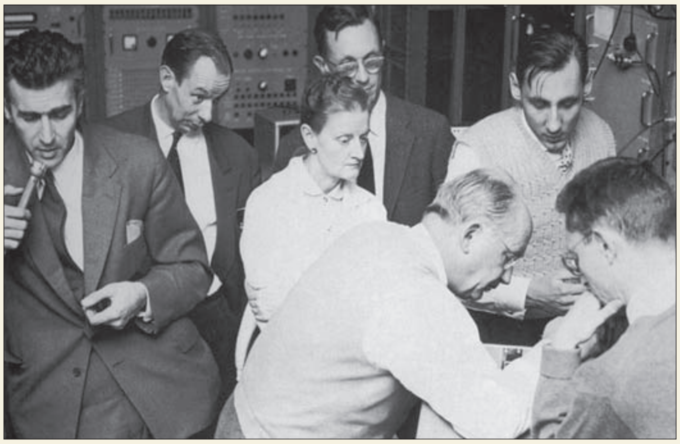
Sous l'impulsion du Comité ESGARD, un nouveau programme européen de R&D en sciences des accélérateurs a vu le jour le 1er avril 2009, pour une durée de quatre ans, succédant au projet CARE. Il est doté d'un budget de 31 MEuros, dont un tiers est assuré par la Commission européenne, et d'un fort soutien de la communauté des accélérateurs, représentée par 37 participants, soit plus de 45 laboratoires, universités ou enterprises de 12 pays, ainsi que du CERN. Plus de 45 autres laboratoires non européens sont associés informellement, assurant ainsi l'ouverture nécessaire dans des domaines où le développement se fait au niveau mondial.

Jean-Pierre Koutchouk, *CERN and EuCARD co-ordinator;* **Roy Aleksan**, *CEA and CARE co-ordinator;* **Kate Kahle**, *CERN and EuCARD deputy co-ordinator of communication.*

A night to remember

In this article written for *CERN Courier* in 1969, **Hildred Blewett** gives a personal account of the events leading to the start-up of CERN's Proton Synchrotron on 24 November 1959, on the very evening before was she was scheduled to return to the US.

Remember the night of 24 November 1959? Of course I do. I was sitting in the canteen eating supper with John Adams, as we had done many times that fall. There was not a wide choice of food in those days – spaghetti or ravioli or, occasionally, fried eggs – but our thoughts were not on the meal. We had hardly spoken, our spirits were low, then John lit his pipe and said, "Well, now that we've finished eating, we might as well walk over and see if anything is happening." As we went in the direction of the PS buildings, I asked him, "Shall we go to the Main Control Room or over to the Central Building? Chris Schmelzer said that Wolfgang Schnell has that radial phase-control thing working." John pulled on his pipe, "Probably doesn't matter, it may not do much good." Our hopes had been dashed fairly often. Then, after a few more steps, he added, "Let's go to the Central Building and see what they're up to." It was about quarter to seven.



Expressions still worried as some of the commissioning team cluster around an oscilloscope. Left to right: John Adams (with pipe clutched in his left hand), Hans Geibel, Hildred Blewett, Lloyd Smith, Chris Schmelzer, Wolfgang Schnell and Pierre Germain. (Courtesy B Sagnell.)

Trudging along, I thought back over the past weeks, back to 16 September when, during the Accelerator Conference at CERN, Adams had made the electrifying announcement that protons injected into the PS had gone one turn round the magnet ring. Since that time, attempts to put the PS into operation had brought a few triumphant moments but most of the time we had been discouraged, puzzled by the beam's behaviour, frustrated by faulty equipment or, after quick trials of this remedy or that, in despair over the lack of success. The protons just didn't want to be accelerated.

I had to go back soon to help on the AGS. Pressure for high-energy protons in the United States was mounting even higher with the imminent production of European ones, so I had already booked passage to sail home. For some time I had been saying to everyone that we must get the protons through "transition" before I left. Now it was 24 November, I must leave Geneva the following day, but the prospects were bleak. Would this beam-night be any different?

Although the PS had been ready to accept protons from the linac in September, a great deal of final testing had not been completed and installation and cabling was going on in the ring and the Main Control Room. Consequently, for the first few weeks, beam tests could be scheduled only for Tuesdays and Thursdays from six to ten in the evening; during the final weeks of my stay there was also some time on Friday evenings. During these sessions, our spirits ranged from high to low as the beam behaved somewhat as expected or baffled us completely.

Early in October, the programmed part of the r.f. system was ready for trial. Schmelzer and Hans Geibel were in the Central Building and Pierre Germain was peering at scopes in the Main Control Room. Linac said beam was ready and inflector working. Hine was in the MCR, looking at the injected beam, adjusting quadrupoles, changing inflector voltage, rushing from one scope to another. The beam isn't spiralling properly... wait... all right, go ahead r.f.... Central Building says it's on, programme on. Yes, beam is being captured... it's accelerated... but lost after a few milliseconds. Changes in the r.f. programming... is the beam better... yes, now it goes for 10 milliseconds... no, it's 15... now it's gone again. But we went home satisfied – some beam had been captured, there had been some acceleration.

More evenings with trials of the r.f. programme followed. The r.f. system had been designed to run with a frequency programme to a few GeV, then to switch over to an automatic system with a phase-lock and with errors in the beam's radial position fed back to the r.f. amplitude for correction. When this automatic system was ready, it was tried with switching-in much earlier than planned and this did succeed in accelerating the beam somewhat longer. But then it was lost, usually in a series of steps and all gone after a few tens of milliseconds. I don't remember if we reached 2 or 3 GeV on an occasional pulse, but certainly no more. The behaviour of the beam remained erratic and unstable. What was wrong?

Measurements of the beam's position on the radial pickup ▷

electrodes were hastily plotted by Adams to show that the closed orbit was off in some places, but only by a few centimetres, surely not enough to prevent some beam from going to transition. The rate of rise of the magnetic field was varied to look for eddy-current troubles. Colin Ramm and the Magnet Group rushed round the ring in the daytime, searching for stray fields or remanence effects. Jean Gervaise scanned the survey data for possible errors in magnet positions while Jack Freeman hunted for signs of beam disappearances with radiation monitors. More trials of the r.f., with and without phase-lock, more diagnostic equipment hurriedly inserted, more measurements. But the protons made no progress.

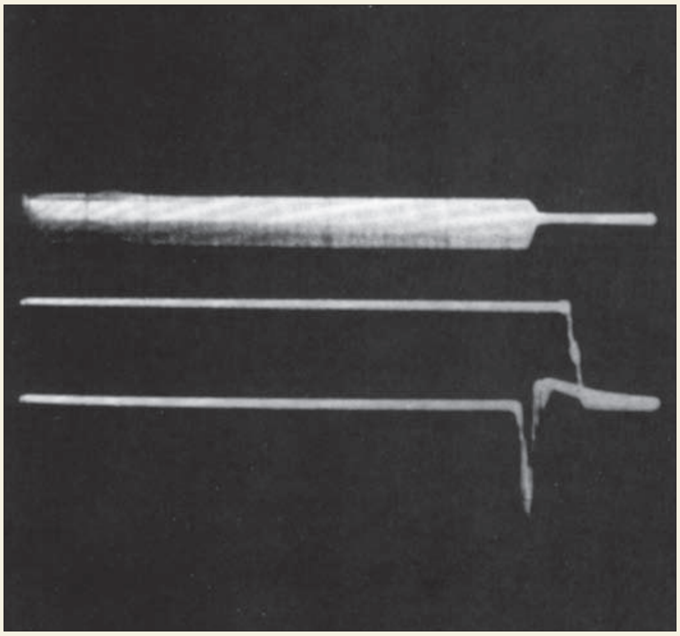
A broad green trace

During those Tuesday and Thursday evenings in October and early November, many of the PS builders gathered round the tables in the centre of the Main Control Room. At one stage, to save (or prevent?) people from going home to eat and being late for the scheduled 6 p.m. start-up, Hine arranged cold meats, cheese and bread to be sent to the MCR. As I recall this was not a rousing success. There were periods of frantic activity. But there were also long periods of waiting. We sat at the tables and waited and waited. One night, just as beam came on, all of the lights went out – trouble at the CERN main power house – and we groped our way out in darkness, Adams striking matches all the way.

I had a desk in Mervyn Hine's office where, in the mornings, particularly after beam-nights, one after another would come in – Johnsen, Hereward, Schoch, Schmelzer, sometimes Adams, many others – and the talk would start. Are the closed-orbit deviations causing serious trouble? Is the linac emittance all right? What about the missing bunches, caused by the poor performance of the inflector? Every Monday morning, in the PS Conference Room, there was a meeting of the "Running-in Committee", starting at 9 a.m. sharp and lasting until well after 1 p.m., or even 2 p.m. Discussions and arguments – on and on.

Occasionally, on a Sunday, I would go along the lake to visit my good friends, Kjell and Aase Johnsen, and we would recall the days in 1953 when the first designs for the PS were being worked out by groups in various places (Harwell, Paris, Heidelberg, Bergen etc.) all under the leadership of Odd Dahl in Bergen. John Blewett and I had spent some months in Bergen in the summer of 1953 and, during that time, Johnsen had been working on the behaviour of the beam at transition energy (where there is no phase stability). His calculations had given us the first confidence that beam could be accelerated through this dangerous region.

Many of these things were in my thoughts as Adams and I approached the Central Building. I was depressed about having to leave the next day, with the protons still balking. I had wanted so much to see this machine operate successfully before I left. All through the years, I had been so involved with CERN and its PS that I had felt a glow of pride with each milestone passed during construction. More than ever, over these past weeks, I had felt that it was partly my machine too. John interrupted my thoughts with, "Well, Hildred, we haven't done much during your stay. It's hardly been worthwhile, you haven't learnt...". I broke in, "Wolfgang thinks this radial phase-control will really work, he's very optimistic, and maybe...". But I knew that no-one else had great hopes for any improvement. Even Schmelzer had thought it was hardly worth the



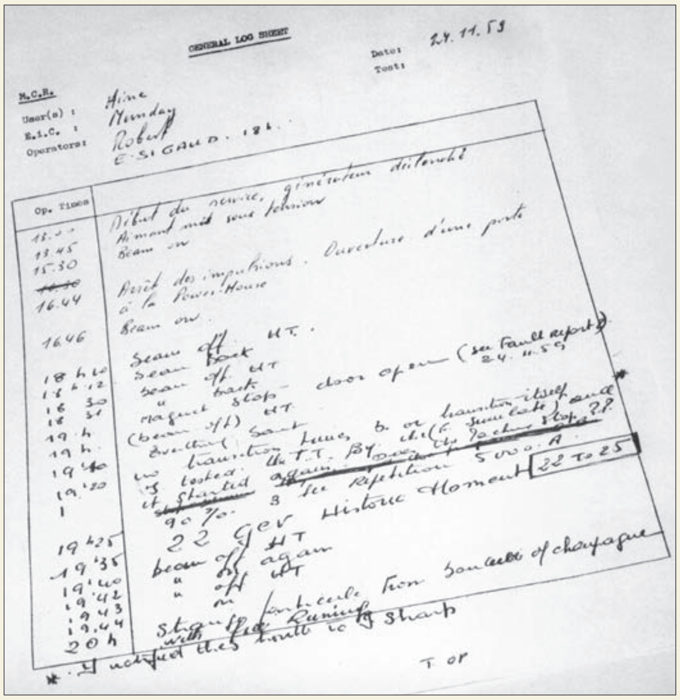
Oscilloscope traces indicating that the PS had accelerated protons to an energy of 25 GeV. The top trace corresponds to beam circulating without energy loss, the middle trace shows the magnet voltage, and the bottom trace gives a signal at the end of the acceleration cycle, when beam is lost.

effort, but Schnell had gone ahead over the last couple of weeks wiring it up for a quick test. Just a few days before, I had been down in the basement lab, listening to his enthusiasm. The idea was to use the radial-position signal from the beam to control the r.f. phase instead of the amplitude. With this system, the sign of the phase had to be reversed at transition and, in his haste, Schnell had built this part into a Nescafe tin, the only thing of the right size.

Adams opened the door to the Central Building. For a moment the lights blinded us, then we saw Schmelzer, Geibel and Rosset – they were smiling. Schnell walked towards us and, without a word, pulled us over to the scope. We looked... there was a broad green trace... What's the timing... why, why the beam is out to transition energy? I said it out loud – "TRANSITION!"

Just then a voice came from the Main Control Room. It was Hine, sounding a bit sharp (he was running himself ragged, as usual, and more frustrated than anyone), "Have you people some programme for tonight, what are you planning to do? I want to...". Schnell interrupted, "Have you looked at the beam? Go and look at the scope." A long silence... then, very quietly, Hereward's voice, "Are you going to try to go through transition tonight?" But Schnell was already behind the racks with his Nescafe tin, Geibel was out in front checking that the wires went to the right places, not the usual wrong ones. Quickly, quickly, it was ready. But the timing had to be set right. Set it at the calculated value... look at the scope... yes, there's a little beam through... turn the timing knob (Schnell says that I yelled this at him, I don't remember)... timing changed, little by little ... the green band gets longer... no losses. Is it... look again... we're through... YES, WE'RE THROUGH TRANSITION!

How far? What's the energy? Something below 10 GeV because the magnet cycle is set for lower fields and a one-second repetition rate for testing. Hurried call to Georgijevic in the Power House. Change the magnet cycle to full field. Beam off while we wait. The



The PS log book, 24 November 1959. At 7.35 p.m., it reads "22 GeV Historic Moment". By 8 p.m. the entries had become rather incoherent.

long minutes drag by. Will the beam come on again? This is just the time for that dratted inflector to go off again, or the high-voltage set to arc over. Hurry up, Power House!

I remember Schnell murmuring, "I promised you we'd get through transition." But we were all rather awed by it. No one spoke – Schmelzer lit a cigar, Adams relit his pipe, we waited.

Finally, the call came through – magnet on again, pulsing to top field. Call the linac for beam. Beam on, it's injected, inflector holding, beam spiralling, r.f. on, all set as before, with the blessed phase-control and the Nescafe tin. Change timing on the scopes, watch them and hold your breath. One second (time for acceleration) is a long time. The green band of beam starts across the scope... steadily, no losses... to transition... through it... on, on how far will it go... on, on IT'S ALL THE WAY! Can it be? There it goes again, all the way as before... and again... and again. Beautiful, smooth, constant, no-loss green band... Look again at the timing... all the way... it must be 25 GeV! I'm told that I screamed, the first sound, but all I remember is laughing and crying and everyone there shouting at once, pumping each other's hands, clapping each other on the back while I was hugging them all. And the beam went on, pulse after pulse.

Did someone change the timing?

Slowly, we came back to Earth. John Adams was first. Looking very calm, he went to the phone to ring up the director-general, C J Bakker, to tell him the news but Bakker didn't seem to grasp it right away. (Could it be that John was just a little incoherent?) Schmelzer was beaming, for once even his cigar forgotten, cold on the ashtray. Schnell looked supremely happy, he was the hero of the hour. Gradually, I collected my wits enough to write out a telegram to Brookhaven that Geibel dashed off to send immediately. We went over to the Main Control Room and found Hine calling round to locate some sort of counter for checking the energy. Johnsen was saying, heatedly, "Did someone change the timing on this scope? I just turned away from it for a moment and here is the beam going out..." How could it be 25 GeV without poleface windings on? But all of the scopes showed the same smooth, green trace, one-second long – it really was 25 GeV. Even more unbelievable, the signal on the pickup electrodes gave an intensity of about 10^{10} protons a pulse. No, that can't possibly be right, we're lucky if it's 10^{9}. Check and recheck... look at the calibrations... yes, that number is right, 10^{10}.

The rest of that evening has been described many times. People came flooding in, I don't know who told them the news. Polaroid pictures of the scope traces were passed around for signatures on the back, cherished souvenirs. Bottles appeared, by magic, including the famous bottle of vodka given to Adams by Nikitin (p25). Bakker arrived with a bottle of gin under his arm. Bernardini bounded in, hugged Adams and Hine, launched into a description of what he wanted to do as a first experiment, then lapsed into pure Italian. Miss Steel and the secretaries were there, smiling happily – they had had to put up with our complaints and bad humours. I remember Colin Ramm muttering, "Where do we go from here? What about two or three hundred GeV?" (He was ahead of the times.) I left shortly before midnight to pack my suitcases.

Early next morning (at 2 a.m. New York time) I had a phone call from John Blewett offering congratulations from Brookhaven and asking questions. My telegram had come as a bombshell and the word had spread rapidly across the United States. What had brought success? I told him about the phase-control system and, since it was similar to the one being built for the AGS, it was a relief to know that this was just what the protons liked.

Then out to the Lab for final goodbyes, over to the auditorium to hear Adams tell the story to all of CERN, my PS friends grinning proudly but no one happier than I.

● Hildred Blewett (1911–2004) joined Brookhaven National Laboratory at its start in 1947 and in the early 1950s became one of the team who collaborated on the design of CERN's first high-energy accelerator, the Proton Synchrotron (PS), while also working on the similar machine proposed for Brookhaven, the Alternating Gradient Synchrotron (AGS). In the summer of 1959 she was invited to CERN to observe the commissioning and start-up of the PS, several months before the AGS would be ready.

Résumé

Ce soir-là ... le 24 novembre 1959

Hildred Blewett (1911–2004) a commencé à travailler au Laboratoire national de Brookhaven en 1947. Au début des années 50, elle a fait partie de l'équipe qui a participé à la conception du premier accélérateur de haute énergie du CERN, le synchrotron à protons (PS). Elle a aussi travaillé sur une machine similaire pour Brookhaven, le synchrotron à gradients alternés (AGS). À l'été 1959, elle a été invitée au CERN pour observer la mise en service et le démarrage du PS, quelques mois avant l'achèvement de l'AGS. Dans cet article, publié pour la première fois dans le Courier CERN *en 1969, elle rappelle le démarrage du PS, le soir même où elle devait repartir pour les États-Unis.*

Hildred Blewett, *extracted from* CERN Courier *November 1969, pp331–336.*

When LEP, CERN's first big collider, saw beam

CERN Courier delves into reports written by Steve Myers when LEP started up 20 years ago.

On 13 November 1989, heads of state, heads of government and ministers from the member states assembled at CERN together with more than a thousand invited guests for the inauguration of the Large Electron–Positron (LEP) collider (p28). Precisely one month earlier, on 13 October, large audiences had packed CERN's auditorium and also taken advantage of every available closed-circuit TV to see the presentation of the first results from the four LEP experiments, ALEPH, DELPHI, L3 and OPAL – results that more or less closed the door on the possibility that a fourth type of neutrino could join those that were already known. This milestone came only two months after the first collisions on 13 August and three months after beam had circulated around LEP for the first time.

The packed control room at the start-up of LEP on 14 July 1989. Carlo Rubbia, director-general of CERN at the time, is in the centre (with tie) and to his right Herwig Schopper, former director-general. Steve Myers is at the desk to the right.

Champagne corks had already popped the previous summer, soon after 23.55 p.m. on 12 July 1988, when four bunches of positrons made the first successful journey between Point 1, close to CERN's main site at Meyrin (Switzerland) and Point 2 in Sergy (France) – a distance of 2.5 km through much of the first of eight sectors of the 27-km LEP ring. It was a heady moment and the culmination of several weeks of final hardware commissioning. Elsewhere, the tunnel was still in various stages of completion, the last part of the difficult excavation under the Jura having been finished only five months earlier (*CERN Courier* October 2007 p42).

A year to do it all

Steve Myers led the first commissioning test and a week later he reported to the LEP Management Board, making the following conclusions: "It worked! We learnt a lot. It was an extremely useful (essential) exercise – exciting and fun to do. The octant behaved as predicted theoretically." This led to the observation that, "LEP will be more interesting for higher-energy physics than for accelerator physics!". However, he also warned, "We should not be smug or complacent because it worked so well! Crash testing took 4 months for about a tenth of LEP; at the same rate of testing the other nine tenths will require 36 months." Yet the full start-up was already pencilled in for July 1989, in only 12 months' time.

The following months saw a huge effort to install all of the equipment in the remaining 24 km of the tunnel – magnets, vacuum chambers, RF cavities, beam instrumentation, control systems, injection equipment, electrostatic separators, electrical cabling, water cooling, ventilation etc. This was followed by the individual testing of 800 power converters and connecting them to their corresponding magnets while carefully ensuring the correct polarity. In parallel, the vacuum chambers were baked out at high temperature and leak-tested. The RF units, which were located at interaction-regions 2 and 6, were commissioned and the cavities conditioned by powering them to the maximum of 16 MW. Much of this had to be co-ordinated carefully to avoid conflicts between testing and installation work in the final sector, sector 3-4. At the same time a great deal of effort – with limited manpower – went into preparing the software needed to operate the collider, in close collaboration with the accelerator physicists and the machine operators.

The goal for the first phase of LEP was to generate electron–positron collisions at a total energy of around 90 GeV, equivalent to the mass of the Z^0, the neutral carrier of the weak force. It was to be a veritable Z^0 factory, delivering Z^0s galore to make precision tests of the Standard Model of particle physics – which it went to do with ▷

outstanding success (*CERN Courier* May 2004 p24).

To "mass produce" the Z^0s required beams not only of high energy, but also of high intensity. To deliver such beams required four major steps. The first was the accumulation of the highest possible beam current at the injection energy of 20 GeV, from the injection chain. (This was itself a major operation involving the purpose-built LEP Injection Linac (LIL) and Electron–Positron Accumulator (EPA), the Proton Synchrotron (PS), the Super Proton Synchrotron (SPS) and, finally, transfer lines to inject electrons and positrons in opposite directions, which curved not only horizontally but also vertically as LEP and the SPS were at different heights). The second step was to ramp up the accumulated current to the energy of the Z^0, with minimal losses. Then, to improve the collision rate at the interaction regions the beam had to be "squeezed", by reducing the amplitude of the betatron oscillations (beam oscillations about the nominal orbit) to a minimum value. Finally the cross-section of the beam had to be reduced at the collision points.

The first turn

In June 1989 the LEP commissioning team began testing the accelerator components piece by piece, while the rest of CERN's accelerator complex continued as normal. Indeed, the small team found themselves running the largest accelerator ever built in what was basically a back room of the SPS Control Room at Prévessin.

The plan was to make two "cold check-outs" – without beam – on 7 and 14 July, with the target of 15 July for the first beam test. The cold check-out involved operating all of the accelerator components under the control of the available software, which proved important for debugging the complete system of hardware and software for energy ramping in particular. On 14 July, however, positrons were already available from the final link in injection chain – the SPS – and so the second series of tests turned into a "hot check-out". Over a period of 50 minutes, under the massed gaze of a packed control room, the commissioning team coaxed the first beam round a complete circuit of the machine – one day ahead of schedule.

In the days that followed, the team began to commission the RF, essential for eventual acceleration in LEP. The next month proved crucial but exciting as it saw the transition from a single turn round the machine to a collider with beams stored ready for physics.

By 18 July the first RF unit was in operation, with the RF timed in correctly to "capture" the beam for 100 turns round the machine. Two days later, the Beam Orbit Monitoring system was put into action, which allowed the team to measure and correct the beam's trajectory. Measurements showed that the revolution frequency was correct to around 100 Hz in 352 MHz, or equivalently, that LEP's 27 km circumference was good to around 8 mm. Work then continued on measuring and correcting the "tune" of the betatron oscillations, so that by 23 July a positron beam was able to circulate with a measured lifetime – derived from the observed decay of the beam current – of 25 minutes. Then, following a day of commissioning yet more RF units, the first electrons were successfully injected to travel the opposite way round the machine on 25 July.

Now it was time to try to accumulate more injected beam in the LEP bunches and to see how this affected the vacuum pressure in the beam pipe. By 1 August the team was observing good accumulation rates and measured a record current of 500 μA for one beam. This was the first critical step towards turning LEP into a useful collider. The next would be to ramp up the energy of the beam.

The late evening of 3 August saw the first ramp from the injection energy of 20 GeV, step by step up to 42.5 GeV, when two RF units tripped. On the third attempt – at 3.30 a.m. on 4 August – the beam reached 47.5 GeV with a measured lifetime of 1 hour. Three days later, both electrons and positrons had separately reached 45.5 GeV. Then 10 August saw the next important step towards a good luminosity in the machine – an energy ramp to 47.5 GeV followed by a squeeze of the betatron oscillations.

In business

On 12 August LEP finally accumulated both electrons and positrons. The next day the beams were ramped and squeezed to 32 cm, yielding stable beams of 270 μA per beam. It was time to turn off the electrostatic separators that allowed the two beams to coast without colliding. The minutes passed and then, just after 11 p.m., Aldo Michelini, the spokesperson of the OPAL experiment, reported seeing the first collision. LEP was in business for physics.

So began a five-day pilot-physics run that lasted until 18 August. During this time various technical problems arose and the four experiments collected physics data for a total of only 15 hours. Nevertheless, the maximum luminosity achieved of 5×10^{28} cm^{-2}s^{-1} was important for "debugging" the detector systems and allowed for the detection of around 20 Z^0 particles at each interaction region.

A period of machine studies followed, allowing big improvements to be made in the collider's performance and resulting in a maximum total beam current of 1.6 mA at 45.5 GeV with a squeeze to 20 cm. Then, on 20 September, the first physics run began, with LEP's total energy tuned for five days to the mass peak for the Z^0 and sufficient luminosity to generate a total of some 1400 Z^0s in each experiment. A second period followed, this time with the energy scanned through the width of the Z^0 at five different beam energies – at the peak and at ±1 GeV and ±2 GeV from the peak. This allowed the four experiments to measure the width of the Z^0 and so announce the first physics results, on 13 October, only three months after the final testing of the accelerator's components (*CERN Courier* July/August 2009 p28).

By the end of the year LEP had achieved a top luminosity of around 5×10^{30} cm^{-2}s^{-1} – about a third of the design value – and the four experiments had bagged more than 30 000 Z^0s each. The Z^0 factory was ready to gear up for much more to come.

● Based on several reports by Steve Myers, including his paper at the second EPAC meeting, in Nice on 12–16 June 1990.

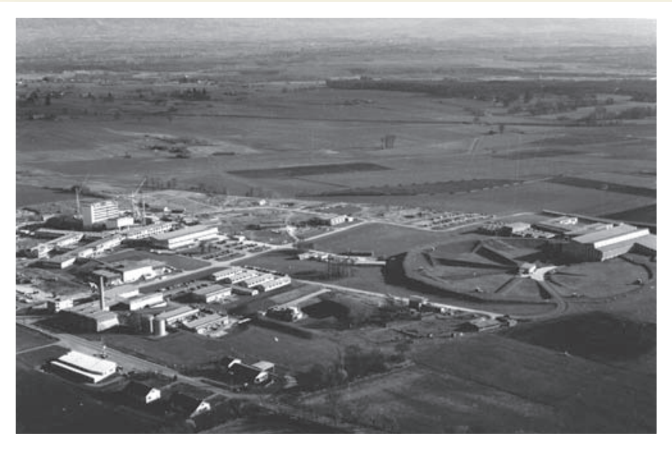
Résumé

Les premiers faisceaux du premier grand collisionneur du CERN

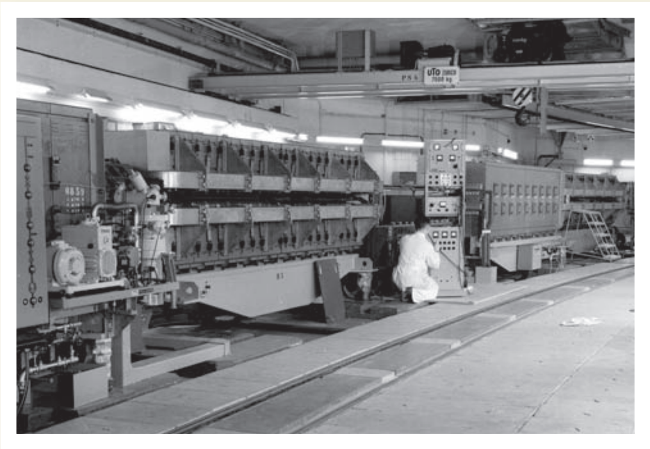
Le 14 juillet 1989, dans une salle de contrôle pleine à craquer, l'équipe de mise en service parvenait pour la première fois, un jour plus tôt que prévu, à faire faire un tour complet à un faisceau de positons, au grand collisionneur électron–positon (LEP). Un mois plus tard, le 13 août, se produisaient les premières collisions entre électrons et positons, ce qui devait mener rapidement à l'annonce des premiers résultats de physique le 13 octobre. L'article décrit les étapes successives de cette mise en service très réussie, d'après les comptes rendus de Steve Myers, chef de l'équipe de mise en service.

PS and LEP: a walk down memory lane

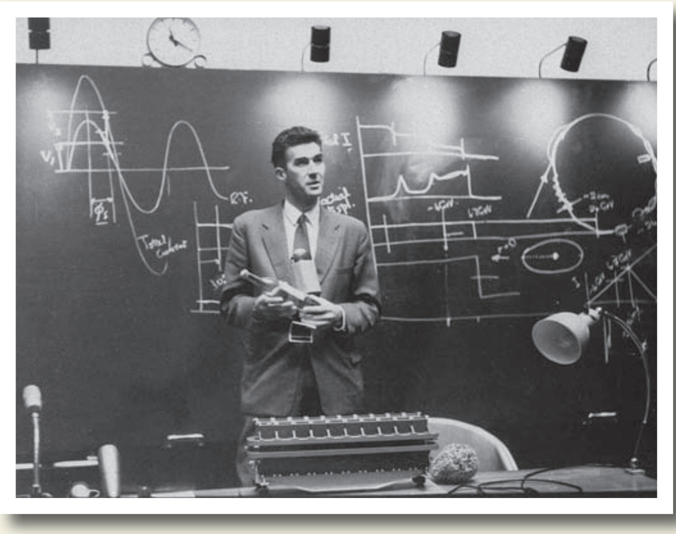
On the 50th anniversary of the start-up of the PS and the 20th anniversary of the LEP inauguration, CERN Courier takes a look at the family photo album of key events.



CERN in April 1959 with the Proton Synchrotron (PS) to the right.

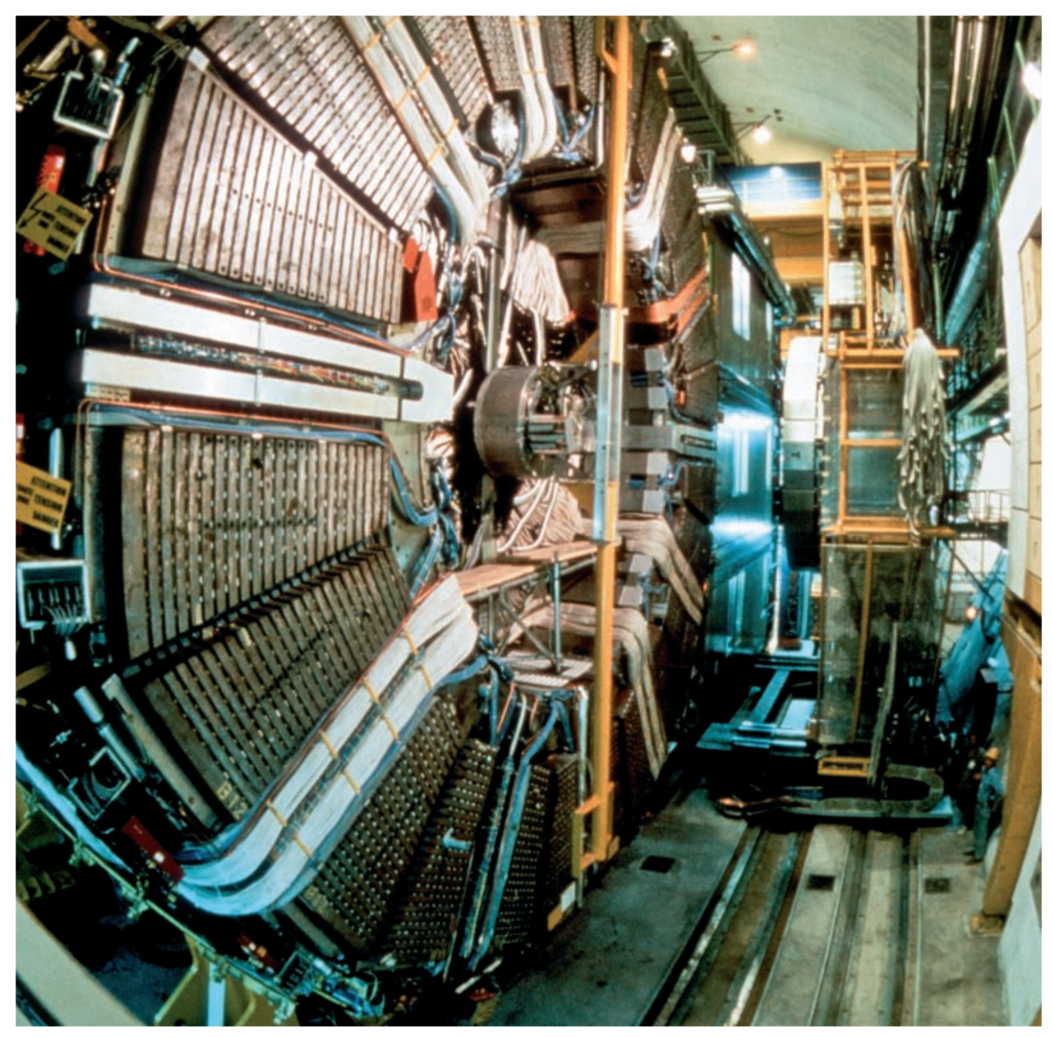


The first magnets installed in the PS some eight months before start-up.

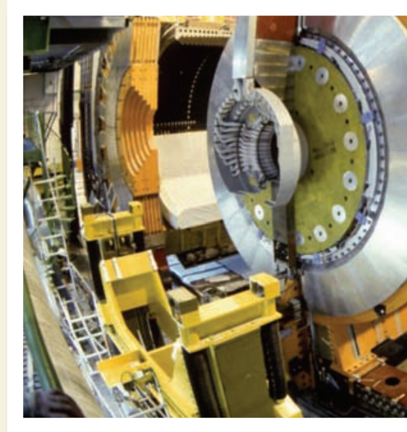


John Adams in the main auditorium on 25 November. In his hands is the vodka bottle that he had received from Dubna with the message that it was to be drunk when CERN passed the Synchrophasotron's world-record energy of 10 GeV. The bottle (empty!) was ready to be sent back to Dubna with a Polaroid photograph of the 25 GeV pulse.

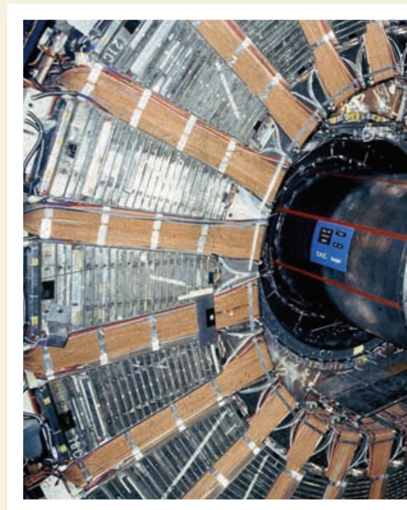
Brigitte Laurent pins up the messages of congratulations that CERN received from the whole world upon the successful operation of the PS.



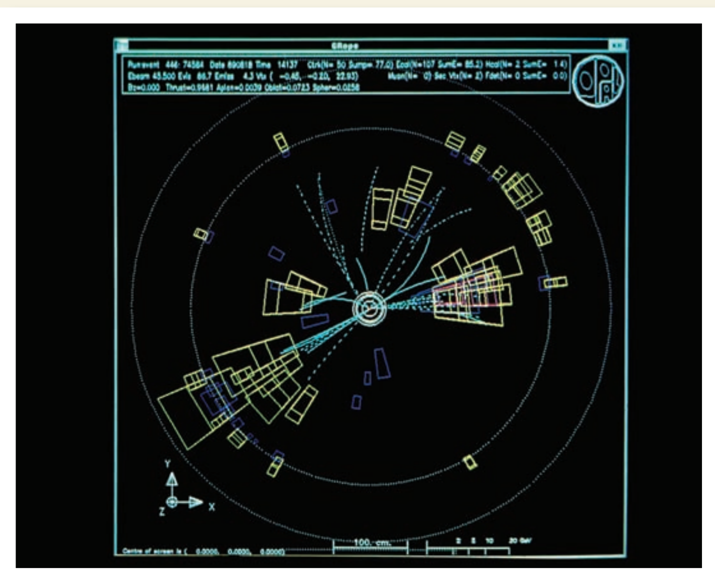
A view of the ALEPH detector in May 1989 with its massive segmented hadron calorimeter clearly visible.



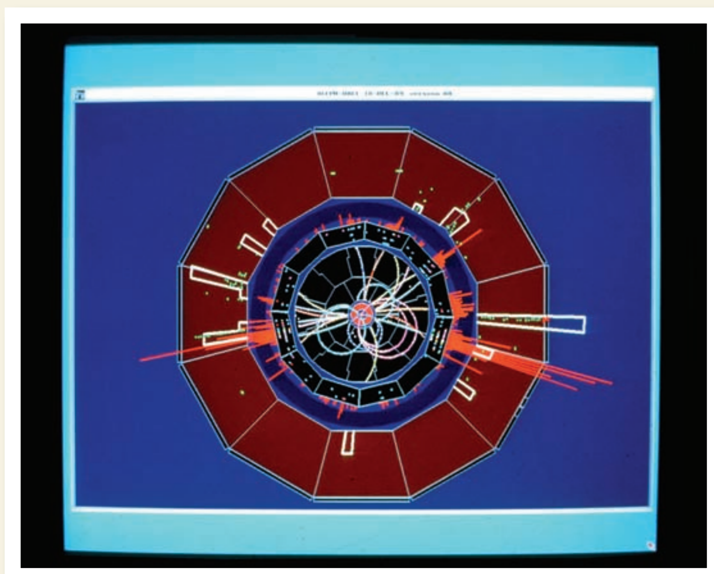
The barrel sections of the OPAL detector are



The time projection chamber is inserted into



One of LEP's first Z^0s, caught in the OPAL detector on 18 August 1989 during the pilot physics run. It decays to a quark–antiquark pair, creating two jets.



The decay of a Z^0 into a pair of hadron jets in the ALEPH detector, recorded in December 1989. By then each detector had amassed around 30 000 Z^0s.

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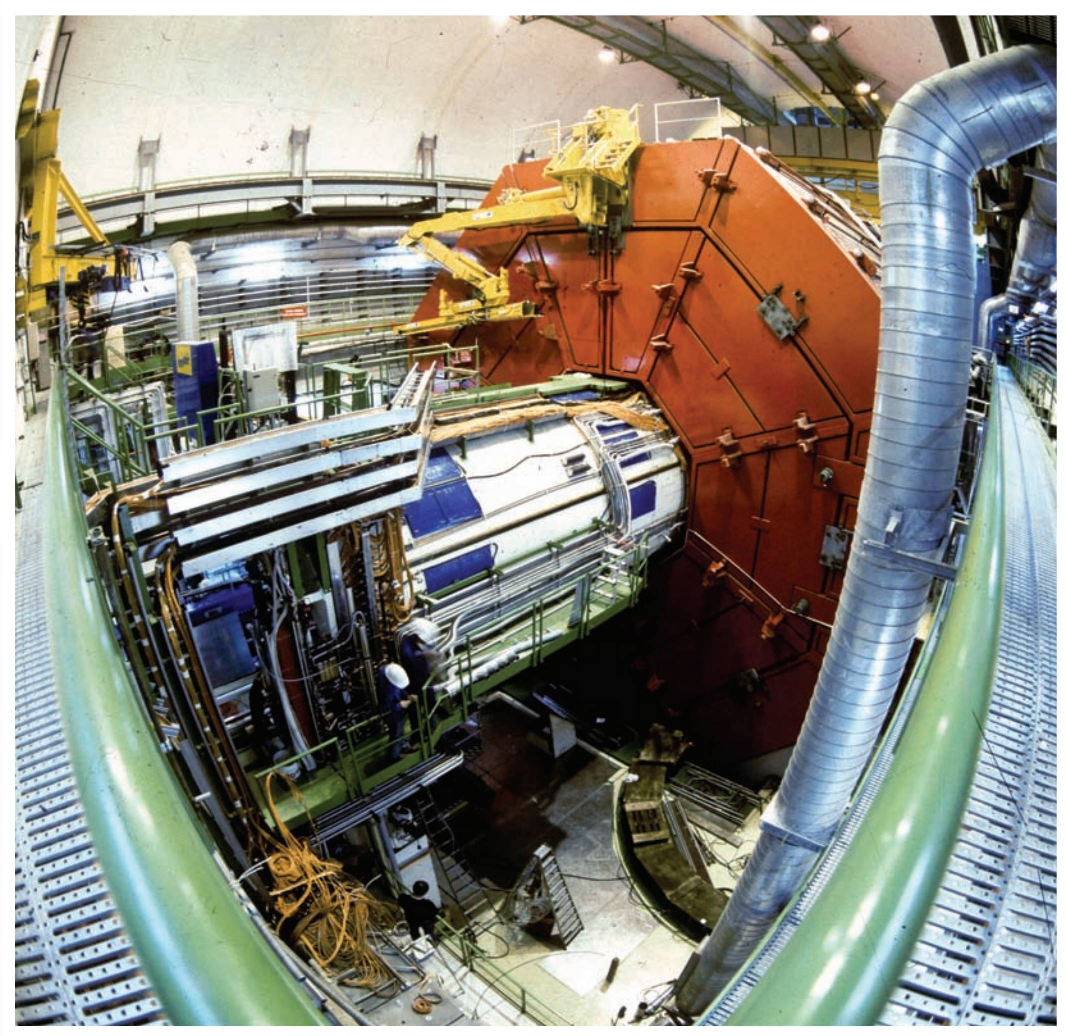
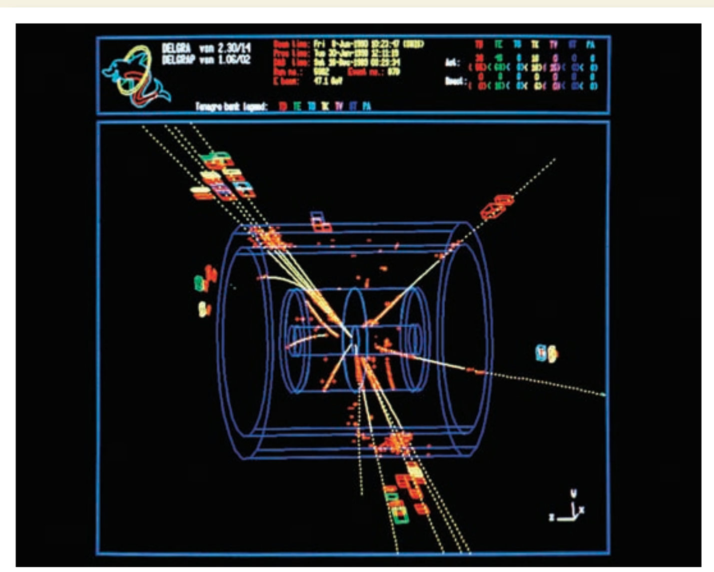
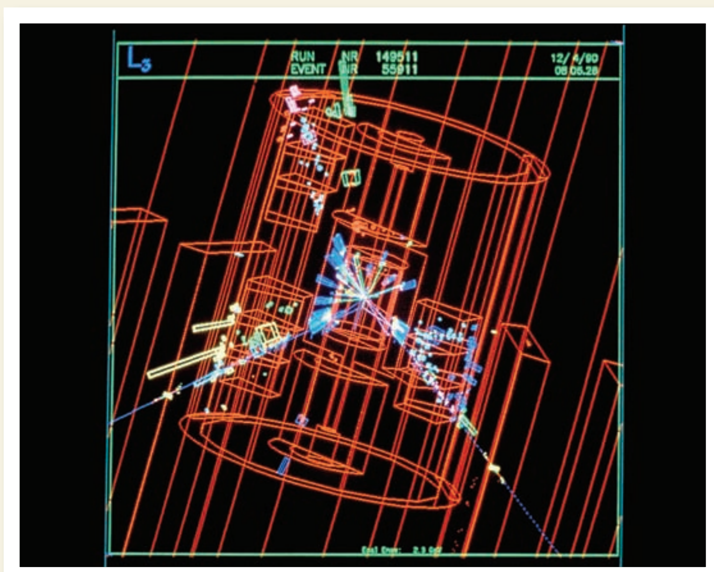
d into the DELPHI experiment in April 1989.



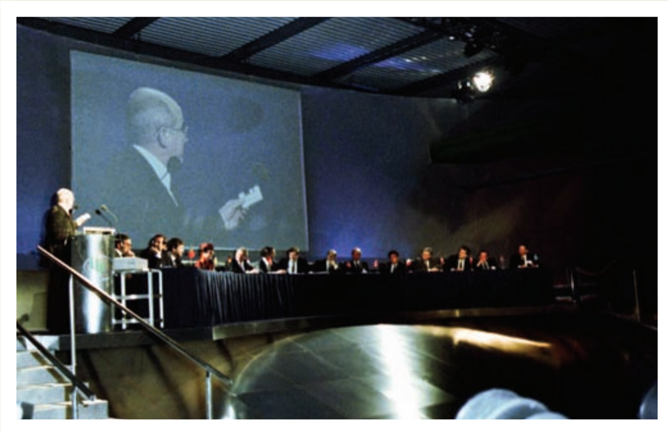
A feature of the L3 experiment was its huge magnet (red), with much of the detector located within its coils.



The DELPHI detector in December 1989 displays two hadron jets from the decay of a Z^0 to a quark-antiquark pair together with two isolated muons.



The decay of Z^0 to three jets in L3, in April 1990. In this case the Z^0 decays into a quark and antiquark, one of which emits a gluon, creating a third jet.



Emilio Picasso, LEP project leader, addresses the representatives from CERN's member states at the inauguration ceremony of LEP on 13 November 1989, three months after first collisions.

Six months to go: inside the LEP tunnel in January 1989. At this stage the other parts of the ring were still far from complete.

Heads of state at the inauguration. From the left, Princess Margriet of the Netherlands, King Carl Gustav of Sweden, CERN Council President Josef Rembser, President Francois Mitterand of France, President Jean-Pascal Delamuraz of Switzerland, Carlo Rubbia, director-general of CERN.

The signatures of the dignitaries who represented CERN's 14 member states at the time of the inauguration of LEP.

During the inauguration, Heinz Riesenhuber, minister of research and technology, Federal Republic of Germany, visits the LEP tunnel.

Setting the scene

The event on 13 November saw the culmination at CERN of weeks of intricate planning to put together a fitting formal inauguration of LEP, CERN's 27 km electron–positron collider.

The scene of the ceremony was the soccer-pitch size SM18 hall, built as an assembly shop for major LEP components, including its thousands of magnets, prior to their descent into the tunnel for final installation. For 13 November, SM18 had been decked out in full finery, hinting at the spectacle to come.

A fleet of buses ferried the guests, their CERN hosts and more than 200 press and media representatives from their assembly points to SM18 where, while waiting for the ceremony to begin, they could follow the arrival of the VIP contingents outside via wide-screen TV coverage, which was also beamed live across Switzerland and exported farther afield via Eurovision.

● January/February 1990 pp6–11 (extract).

Roy Glauber casts a light on particles

By applying optical theory to particle physics and quantum theory to optics, 2005 Nobel laureate Roy Glauber has developed intriguing links between the two fields, as he explained on a visit to CERN.

Roy Glauber talks of his work at a CERN colloquium on 6 August.

When Roy Glauber was a 12-year-old schoolboy he discovered the beauty of making optical instruments, from polarizers to telescopes. His mathematical skills stem from those early school days, when a teacher encouraged him to begin studying calculus on his own. When he progressed to Harvard in 1941 he was already a couple of years ahead and had absorbed a fair fraction of graduate-level studies by 1943, when he was recruited into the Manhattan Project at the age of 18. It was then that the erstwhile experimentalist began the transition to theoretician. Finding the experimental work rather less demanding than theory – "It seemed to depend on how to keep a good vacuum in a counter," he recalls, "and I didn't think I would do it any better" – he asked to join the Theory Division and was set to work on solving neutron-diffusion problems.

Following the war, Glauber gained his BSc and PhD from Harvard and after apprenticeships with Robert Oppenheimer in Princeton and Wolfgang Pauli in Zurich, he stood in for Richard Feynman for a year at Caltech and then settled back at Harvard in 1952. By this time, he says, "all of the interest was in nuclear physics studied through scattering experiments". With increasing energies becoming available at particle accelerators, the wavelength associated with the incident particles was decreasing to nuclear dimensions and below. Viki Weisskopf and colleagues had already developed the cloudy crystal-ball model of the nucleus, which successfully described averaged neutron cross-sections, and Glauber believed that the idea could be extended. "I had this conviction that it ought to be possible to represent the nucleus as a semi-translucent ball, from 20 MeV up," he recalls. However, what the optical models lacked, in Glauber's view, "was a proper quantitative derivation based on the scattering parameters of individual nucleons".

Inspired by work on electron diffraction by molecules that he had pursued at Caltech, Glauber began to think about how to apply optical Fraunhofer-diffraction theory to higher-energy nuclear collisions – in a sense, bringing about a fusion of two of his interests. At higher energies, he argued, individual collisions could be treated diffractively and allow nuclear calculations to be based on the familiar ground of optical-diffraction theory.

The result was a generalized nuclear diffraction theory, in which he introduced charges and internal co-ordinates that did not exist in the optical case, such as spin and isospin, and dealt with scattering from nuclei that contained many nucleons by treating arbitrary numbers of successive collisions. The key was to consider energy transfers that were small compared with the incident energy. This was a reasonable assumption at higher energies and it led to a useful approximation method that provided a mathematical development of the original optical model, and allowed treatment of the preponderance of inelastic transitions.

The theory turned out to work quite well for proton–deuteron and proton–helium collisions in experiments at the Cosmotron at Brookhaven. "You could see single and double scattering in the deuteron and helium," he explains, "and shadowing" – where target nucleons lie in the shadow of others. However, at the time there were no studies of heavier nuclei.

Glauber made the first of many visits to CERN in 1964 and arrived for a six-month sabbatical in February 1967. "It was a most dramatic time for me," he recalls. The group led by Giuseppe Cocconi had begun measurements of proton scattering from nuclear targets using the first extracted-proton beam from the PS (*CERN Courier* July/August 2009 p19). They made a series of measure- ▷

ments at 19.3 GeV/c but with the resolution of the spectrometer limited to 50 MeV, they could not separate elastic from inelastic scattering. Glauber realized that, extended to inelastic scattering, the theory would cover essentially all nuclear excitations in which there was no production of new particles. Together, the calculated elastic and inelastic cross-sections agreed exactly with what Cocconi's group was measuring. Glauber presented the results of his work with Giorgio Matthiae of Cocconi's group at a meeting in Rehovot in the spring of 1967. "We were doing quantitative high-energy physics for a change," he says.

The work at CERN with Cocconi's group left a big impression on Glauber: "It was something wonderful and inspiring." He became "hooked on CERN", returning many times for summers and sabbaticals, working on models for elastic scattering for experiments at the ISR and for UA4 on the SPS proton–antiproton collider. However, by the 1990s – the era of the Large Electron–Positron (LEP) collider – his visits became less frequent. "I found I had nothing new to say about LEP cross-sections," he admits.

Today there is renewed interest in Glauber's work, in particular among physicists involved with heavy-ion collisions (*CERN Courier* January/February 2006 p28). His early calculations of multiple diffraction laid the foundations for ideas that are central (in more ways than one) to studies in which nuclei collide at very high energies. The basic formalism of overlapping nucleons can be used to calculate the "centrality" of a collision – in other words, how head-on it is. However, other work in the field of optical theory also finds relevance in the unusual environment of heavy-ion collisions – in this case Glauber's work on a quantum theory of optical coherence, which led to his share of the Nobel prize in 2005 (*CERN Courier* November 2005 p8).

This work again dates back to the late 1950s and the discovery by Robert Hanbury-Brown and Richard Twiss of correlations in the intensities measured by two separated photon detectors observing the same light source. Their ultimate aim had been to extend their pioneering work on intensity interferometry at radio wavelengths to the optical region, so as to measure the angular sizes of stars – which they went on to do for Sirius and others. However, they first set up an experiment in the laboratory to reassure themselves that the technique would work at optical wavelengths. The result was surprising: light quanta have a significant tendency to arrive in pairs, with a coincidence rate that approaches twice that of the random background level. Extending the idea led to predictions that a laser source, with its narrow bandwidth, should show a large correlation effect. Glauber was sceptical, so he embarked on a proper quantum-theoretical treatment of the statistics of photon detection.

"Correlated pairs are characteristic of unco-ordinated chaotic emission from lots of sources," he explains, "where the statistics are Gaussian. This is not a characteristic of light from a laser where all of the atoms know quite well what the other atoms are doing." He realized correctly that this co-ordination means that there should be no Hanbury-Brown–Twiss correlation for a laser source and he went on to lay down the theoretical ground work for the field of quantum optics – the work that led to the Nobel prize.

There are similarities between the statistics in the detection of photons (bosons) and those of the detection of pions (also bosons) in heavy-ion collisions. The energetic collision should be like a thermal light source, with correlated pion emission akin to the Hanbury-Brown–Twiss correlations allowing the possibility of measuring the size of the source, as in the astronomical studies. Experiments do find such an effect but they do not see the full factor of two above the random background and the reason is yet to be properly understood. While the width of the measured peak may relate to the radius of the source, "we don't have a theory of the radiation process that explains fully the correlation", says Glauber, "no real quantitative explanation. Perhaps other things are upsetting the correlations."

Roy Glauber, right, with companion Atholie Rosett, centre, and CERN's director-general, Rolf Heuer.

The LHC will explore further the realm of heavy-ion collisions and push on with measurements of the proton–proton total cross-section, a focus of the TOTEM experiment (*CERN Courier* September 2009 p19). While these links remain between his work and CERN, Glauber observes that the laboratory has changed a great deal since his first visits, but he is still "very devoted to the place as an ideal". What then, does he hope in general for the LHC? "Pray to find a surprise," he says. "It may be difficult to design an experiment to detect what you least expect, but we really need some surprises."

● For Roy Glauber's colloquium at CERN on 6 August, see http://indico.cern.ch/conferenceDisplay.py?confId=62811.

Résumé

Roy Glauber : un peu plus de lumière sur les particules

En appliquant la théorie de l'optique à la physique des particules, ainsi que la théorie quantique à l'optique, Roy Glauber, le lauréat du prix Nobel 2005, a établi des liens étonnants entre les deux domaines, comme il l'a expliqué à l'occasion d'une récente visite au CERN. S'inspirant de travaux sur la diffraction des électrons par des molécules, Glauber s'est demandé dans les années 50 comment appliquer la théorie de la diffraction optique aux collisions nucléaires. C'est ainsi qu'est née une théorie novatrice sur la diffusion de particules de noyaux riches en nucléons, qui a été appliquée à des résultats d'expériences menées au CERN à la fin des années 60. Aujourd'hui, son travail intéresse les spécialistes des collisions d'ions lourds.

Christine Sutton, *CERN.*

NA60: in hot pursuit of thermal dileptons

Measurements by the NA60 experiment of excess muon pairs in nuclear collisions have not only clearly shown their thermal origin at SPS energies, but also answered long-standing questions on deconfinement into a quark-gluon plasma and chiral symmetry restoration.

Heavy-ion collisions at ultrarelativistic energies explore the transition from ordinary matter to a plasma of deconfined quarks and gluons – a state of matter that probably existed in the first few microseconds of the universe. Early experiments of this kind began 25 years ago at CERN, at the Super Proton Synchrotron (SPS), and at Brookhaven, at the Alternating Gradient Synchrotron followed by the Relativistic Heavy Ion Collider in 2000 – and now the LHC at CERN is preparing for heavy-ion collisions in 2010. Studies of the hadrons produced have given insight into numerous aspects of the medium formed in the collisions, including collective behaviour and thermalization. They have also indicated that the temperatures reached at beam energies above about 40A GeV may already exceed the critical temperature T_c for deconfinement into a quark-gluon plasma (*CERN Courier* September 2003 p30).

"...The very existence of a dilepton excess gave a strong boost to theory, leading to hundreds of publications, and provoked a number of open questions."

Electromagnetic probes such as photons and dileptons (l^+l^- pairs) have long held the promise of a more direct insight. Escaping without final-state interactions, they can reveal the entire space–time evolution of the produced medium, from the early partonic (quark–gluon) phase to the final freeze-out of hadrons, when all interactions cease. In the case of dileptons, experimental difficulties associated with low signal-to-background ratios (from high multiplicity densities), the superposition of nonthermal sources and a lack of sufficient luminosity have hindered clear insight in the past. Nevertheless, experiments at CERN observed an encouraging excess above known sources: CERES/NA45 in the mass region below 1 GeV, NA38/NA50 in the region above 1 GeV and HELIOS/NA34-3 in both mass regions. The very existence of an excess gave a strong boost to theory, leading to hundreds of publications, and provoked a number of open questions.

For masses below 1 GeV, thermal dilepton production is dominated by the hadronic phase and mediated mainly by the light vector meson ρ (770 MeV). With its strong coupling to $\pi^+\pi^-$ and a lifetime of only 1.3 fm – much shorter than that of the "fireball" produced – the ρ is the key test particle for "in-medium" changes of hadron properties such as mass and width close to the transition where chiral symmetry is restored, as Robert Pisarski first proposed. However, questions about how the ρ changes in the medium – does it shift in mass or broaden? – remained open. Above 1 GeV, thermal dileptons could be produced as "Planck-like" continuum radiation in both the early partonic and late hadronic phases, so offering access to the expected deconfinement transition, as first Edward Shuryak, and later Keijo Kajantie and many others, have pointed out. However, the origin of the dilepton-excess observed above 1 GeV was not clear. Does it arise from the enhanced production of open charm or from thermal radiation? Is it from partonic or hadronic sources? The status of thermal dilepton production in both mass regions at RHIC is even less clear.

Novel detectors

The NA60 experiment at CERN's SPS was built specifically to follow up on these open questions (*CERN Courier* March 2001 p6). By taking a big step forward in technology this third-generation experiment has achieved completely new standards of data quality in the field. Approved in 2000, it took data on indium–indium collisions at 158A GeV for just one running period, in 2003. Briefly, the apparatus complements the muon spectrometer (MS) previously used by NA10/NA38/NA50 with a novel radiation-hard, silicon-pixel vertex telescope (VT), placed inside a 2.5 T dipole magnet between the target region and the hadron absorber (Arnaldi *et al.* 2009a). The VT tracks all of the charged particles before they enter the absorber and determines their momenta independently of the MS, free from multiple-scattering effects and the energy-loss fluctuations that occur in the absorber. The associated read-out pixel chips were originally developed for the ALICE and LHCb experiments.

The matching of the muon tracks in the VT and the MS, in both coordinate and momentum space, greatly improves the dimuon mass resolution in the region of the vector mesons ρ, ω, and ϕ, reducing ▷

it from approximately 80 MeV to around 20 MeV. It also significantly reduces the combinatorial background from π and K decays and makes it possible to measure the muon offset with respect to the primary interaction vertex, thereby allowing the tagging of dimuons from simultaneous semileptonic decays of $D\bar{D}$ pairs – that is, open charm. The additional bend by the dipole field gives a much greater acceptance for opposite-sign dimuons at low mass and low transverse momentum than was possible in all previous dimuon experiments. Finally, the selective dimuon trigger and the radiation-hard vertex tracker, with its high read-out speed, allowed the experiment to run at high rates for extended periods, enabling a high luminosity.

Low mass to high mass

Starting with the low mass region, M <1 GeV, figure 1 shows the net dimuon mass spectrum from NA60, integrated over centrality, after subtraction of the two main background sources: combinatorial background and fake matches between the two spectrometers (Arnaldi *et al.* 2006 and 2008). The plot contains about 440 000 dimuons in this mass region and exceeds previous results by up to three orders of magnitude in effective statistics, depending on mass. The spectrum is dominated by the known sources: the electromagnetic two-body decays of the η, ω and φ resonances, which are completely resolved for the first time in nuclear collisions, and the Dalitz decays of the η, η' and ω. While the peripheral, "p–p like" data – the very glancing collisions – are quantitatively described by the sum of a "cocktail" of these contributions together with the ρ and open charm, this is not true for the more centrally weighted – more "head on" – total data shown in figure 1. This is because of the underlying dilepton excess observed previously.

Now, for the first time, the high data quality allows this excess to be isolated without any assumptions about its nature and without fits. The cocktail of decay sources is subtracted from the total data using local criteria that are based solely on the measured mass distribution itself; the ρ is not subtracted. Figure 2 shows the excess for one region in centrality (Arnaldi *et al.* 2006 and 2009b). The peaked structure seen here appears for all centralities, broadening strongly for the more central collisions, but remaining centred on the nominal pole position of the ρ. At the same time, the total yield relative to the cocktail ρ increases with centrality, becoming up to six times larger than for the most peripheral collisions.

All of this is consistent with an interpretation of the dilepton excess as arising predominantly from $\pi^+\pi^-$ annihilation via intermediate ρ mesons, which are continuously regenerated throughout the hadronic phase of the expanding fireball. (This is the "ρ-clock", which "ticks" at the rate of the ρ's lifetime and is presumably the most accurate way to measure the lifetime of the fireball). It is important to point out that the data as plotted, i.e. without any acceptance correction and p_T selection, can be directly interpreted as the space–time averaged spectral function of the ρ, owing to a fortuitous cancellation of the mass and p_T dependence of the acceptance filtering by the photon propagator and Bose factor associated with thermal dilepton emission (Damjanovic *et al.* 2007).

Figure 2 also shows the two main theoretical scenarios for the in-medium spectral properties of the ρ: dropping mass, suggested by Gerald Brown and Mannque Rho, and broadening as proposed by Ralf Rapp, Jochen Wambach and colleagues. The dropping-mass scenario, which ties hadron masses directly to the value of the chiral condensate (with vanishing values as chiral restoration is approached), leads to a shifted and broadened distribution that is clearly ruled out. The unmodified ρ, defined as the full amount of regenerated ρ mesons without any in-medium spectral changes ("vacuum ρ"), is also clearly ruled out. Only the broadening scenario, based on a hadronic many-body approach, describes the data well, up to about 0.9 GeV where processes other than 2π set in, as described below.

The results from NA60 thus end a decades-long controversy about the spectral properties of hadrons close to the QCD phase boundary. In general terms, chiral restoration should restore the degeneracy between chiral partners such as the vector ρ and the axialvector a_1, which are normally split by 0.5 GeV. Whether this happens by moving masses or by a complete "melting" with full overlap of the two partners has always been open to debate, but the question is now answered for the ρ – and with it probably for all light hadrons. Meanwhile, a more explicit connection between chiral-symmetry restoration and the hadron "melting" observed is under discussion by Rapp, Wambach and others.

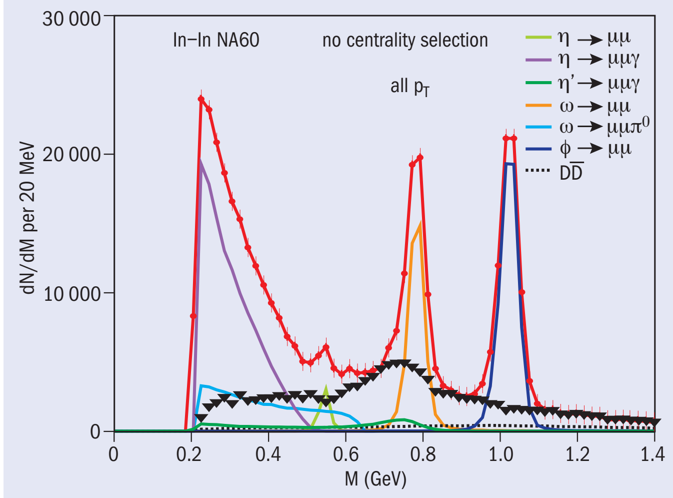


Fig. 1. Background-subtracted mass spectrum before (red dots) and after subtraction of known sources (triangles) with no acceptance correction.

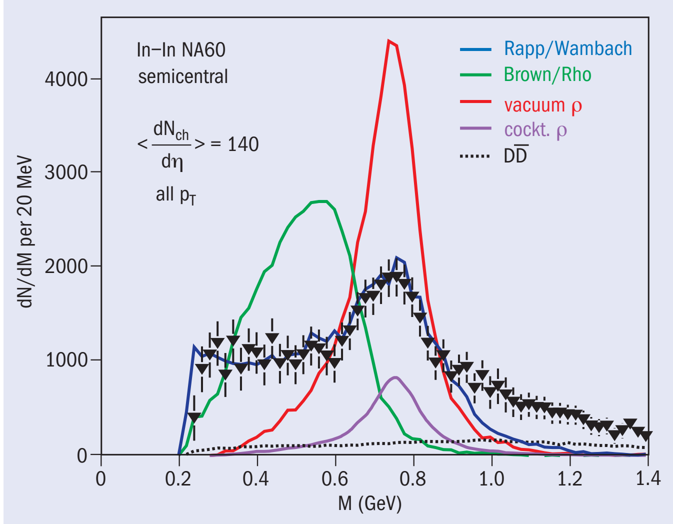


Fig. 2. Excess dimuons compared with theoretical predictions renormalized to the data for M <0.9 GeV with no acceptance correction.

Turning now to the mass region above 1 GeV, the use of the silicon VT has allowed NA60 to measure the offset between the muon track and the primary interaction vertex and thereby disentangle, for the first time in nuclear collisions, prompt dimuons from offset pairs from D-meson decays (Arnaldi *et al.* 2009a). The results are perfectly consistent with no enhancement of open charm relative to the level expected from scaling up the results from NA50 for masses above 1 GeV in proton–nucleus collisions. The dilepton excess, previously observed by NA34-3 and NA38/NA50, is therefore solely prompt, with an enhancement over Drell–Yan processes by a factor 2.3±0.08. This excess can be isolated, rather as for masses below 1 GeV, by subtracting the expected known sources, here Drell–Yan and open charm, from the total data. The resulting mass spectrum is quite similar to the shape of open charm and much steeper than that for Drell–Yan.

A true thermal spectrum

In the absence of resonances, the signature of any thermal source should be a Planck-like radiation spectrum. Now a 25-year-old dream has become reality with NA60's measurement of such a spectrum in high-energy nuclear collisions, isolated from all other sources. Figure 3 shows the mass spectrum of the excess dileptons for the complete range $0.2 < M < 2.6$ GeV, corrected for experimental acceptance and normalized absolutely to the charged-particle rapidity density (Arnaldi *et al.* 2009a). The shape is mainly a pure exponential, indicative of a flat spectral function as in the black-body case, except for the slight modulation around the nominal pole position of the ρ.

The figure also shows recent theoretical results from the three major groups working in this field. The general agreement between the data and these theoretical results, which are not normalized to the data, but are calculated absolutely, is remarkable, both for the spectral shapes and the absolute yields, and strongly supports the term "thermal". At the level of the detailed description of the dominant dilepton sources, all three groups agree on $\pi^+\pi^-$ annihilation for $M < 1$ GeV, one doing somewhat better than the others below 0.5 GeV through additional secondary sources and a larger contribution from ρ–baryon interactions. Above 1 GeV, 2π processes become negligible, and other hadronic processes such as 4π (including vector–axialvector mixing) and partonic processes such as quark–antiquark annihilation, $q\bar{q} \to l^+l^-$, take over.

All three models explicitly differentiate between the hadronic and partonic processes. But while the spectral shape and total yield for $M > 1$ GeV are described about equally well, the fraction of partonic processes relative to the total varies from 25% to more than 85% depending on the model. The large variations are from differences both in the underlying spectral functions and the fireball dynamics, which at least partially compensate each other in the total yields. However, the space–time trajectories are not the same for genuine partonic and hadronic processes, the former being "early" (i.e. from the initial temperature T_{init} to T_c) and the latter only "late" (i.e. from T_c to thermal freeze-out at temperature T_f). The question therefore arises whether these differences leave a measurable imprint on the dileptons that could reveal the dominant source.

The answer is "yes". Unlike real photons, lepton pairs are characterized by two variables: mass and transverse momentum p_T. Quite different from mass, p_T not only contains contributions from the spectral functions, but also encodes the key properties of the expanding fireball: temperature and transverse expansion ("radial flow"). The latter causes a blue-shift of p_T, which is well known from hadron production. However, in contrast to hadrons, which receive the full flow reached at the moment of decoupling, dileptons are continuously emitted during the evolution of the fireball and so reflect the space–time integrated temperature-flow history in their final p_T spectra. Because flow builds up monotonically during this evolution – being small in the early partonic phase (in particular at SPS energies, owing to the "soft point" in the equation-of-state) and increasingly larger in the late hadronic phase – the final p_T spectra keep a memory of the time ordering of the different dilepton sources, thereby offering a diagnostic tool for the emission region. ▷

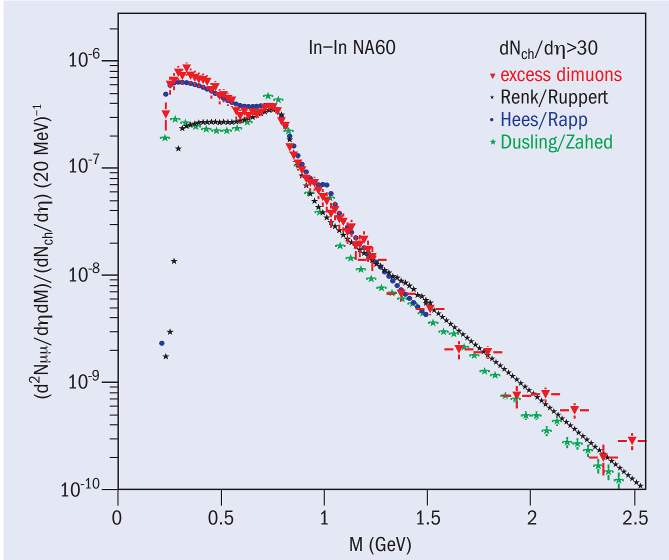


Fig. 3. Acceptance-corrected, inclusive mass spectrum of the excess dimuons in the combined mass region $0.2 < M < 2.6$ GeV, integrated over p_T, compared with three different sets of thermal-model results calculated absolutely, not normalized to the data.

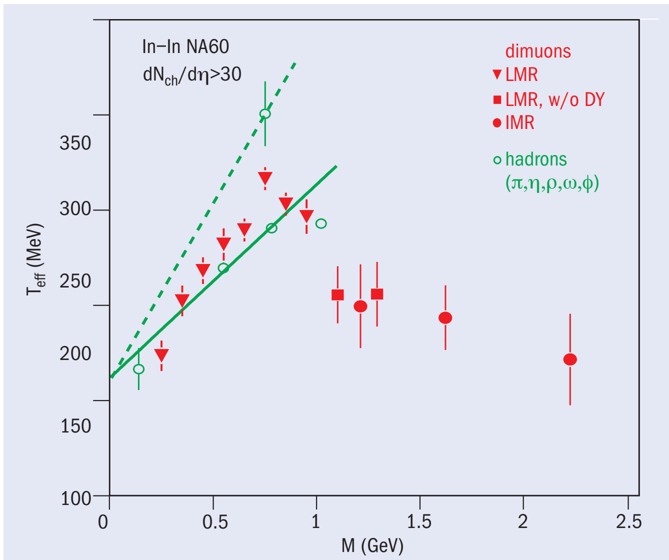


Fig. 4. Inverse slope parameters T_{eff} of the acceptance-corrected excess m_T-spectra v dimuon mass in the combined mass region $0.2 < M < 2.6$ GeV. Drell-Yan (DY) processes are consistently subtracted for $M > 1$ GeV. Hadron results are shown for comparison.

The variable commonly used here is $m_T = (p_T^2 + M^2)^{1/2}$ and all m_T spectra for the dilepton excess are found to be nearly exponential (Arnaldi *et al.* 2008, 2009a, 2009b). The full information can therefore be reduced to one parameter, the inverse slope T_{eff}, obtained by fitting the spectra with the expression: $1/m_T dN/dm_T \propto \exp(-m_T/T_{eff})$. Figure 4 (p33) shows the mass dependence of T_{eff} for the complete mass range $0.2 < M < 2.6$ GeV. It also includes the hadron data for π and for η, ω, ϕ obtained as a by-product of the cocktail-subtraction procedure. A separate value is added for the ρ peak visible in figure 2 (p32), which is generally interpreted as the "freeze-out ρ" without in-medium effects. It is obtained by disentangling the peak from the underlying continuum through a side-window method.

Taken together, the dilepton data and the hadron data suggest the following interpretation. The parameter T_{eff} is roughly described by a temperature part and a radial-flow part: $T_{eff} \approx T + Mv^2$, where v is the average flow velocity. The general rise of T_{eff} with mass up to about 1 GeV is therefore consistent with the expectations for radial flow. Maximal flow (about half of the speed of light) is reached for the ρ, owing to its maximal coupling to pions, while all other hadrons freeze out earlier. The dilepton values rise nearly linearly up to the pole position of the ρ, but always stay well below the ρ line (dotted). This is exactly what would be expected for radial flow of an in-medium, hadron-like source (here $\pi^+\pi^- \rightarrow \rho$) decaying continuously into dileptons. The average temperature associated with this region is 130–140 MeV.

For $M > 1$ GeV, i.e. beyond the 2π region, the dilepton values fall suddenly by about 50 MeV down to a level of 200 MeV – an effect that is even more abrupt for the pure in-medium continuum (Arnaldi *et al.* 2009b). The trend set by a hadron-like source in the low-mass region makes it extremely difficult to reconcile such a fast transition with emission sources that continue to be of predominantly hadronic origin above 1 GeV. A much more natural explanation is a transition to a mainly early, i.e. partonic source with processes such as $q\bar{q} \rightarrow l^+l^-$ for which flow has not yet built up. The observed slope parameter of T_{eff} around 200 MeV, which is essentially independent of M in this region, is then perfectly reasonable and reflects the average thermal values in the fireball evolution between a T_{init} of around 220–250 MeV and a T_c of about 170 MeV. All in all, these findings on T_{eff} may well represent a further breakthrough, pointing to a partonic origin of the observed thermal radiation for $M > 1$ GeV and thus, rather directly, to deconfinement at SPS energies.

One final point further underlines the thermal-radiation character of the observed excess dileptons. The study of the dimuon angular distributions in NA60 has yielded complementary information on the production mechanism and the distribution of the annihilating particles, again a first in the field of nuclear collisions (Arnaldi *et al.* 2009c). Because of the lack of sufficient statistics for higher masses the study is restricted to the region $M < 1$ GeV, but it finds that all coefficients describing the distributions (the "structure function parameters" λ, μ and ν, related to the spin-density matrix elements of the virtual photon) are zero and projected distributions in $|\cos\theta|$ and $|\phi|$ are uniform (figure 5). This is a non-trivial result: the annihilation of partons or pions along the beam direction would lead to $\lambda = +1$, $\mu = \nu = 0$ (the well known lowest-order Drell–Yan case) or $\lambda = -1$, $\mu = \nu = 0$, corresponding to transverse and longitudinal polarization of the virtual photon, respectively. The absence of any polarization is consistent with the interpretation of the excess dimuons as thermal radiation

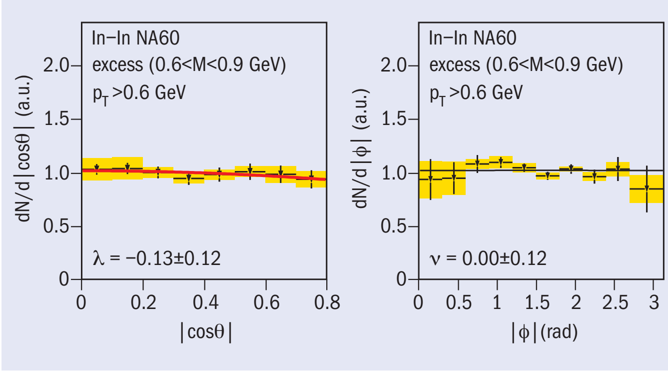


Fig. 5. Acceptance-corrected polar (left) and azimuthal (right) angular distributions of the excess dimuons in the mass window 0.6 <M<0.9 GeV. The specific reference frame used here is the Collins–Soper frame.

from a randomized system, as Paul Hoyer first suggested.

To summarize, the NA60 experiment, a latecomer at the SPS, has provided answers to all of the major questions left over by previous dilepton experiments: on the spectral function of the ρ in connection to the chiral transition; on the origin of the excess dileptons for $M > 1$ GeV in connection to the deconfinement transition; and on the thermal-radiation character of all excess dileptons. In addition, there has been major progress on charmonia. The answers are probably as clear as they could be at this stage of the field, but they will surely benefit from further progress in theory.

Further reading

All theoretical references mentioned in the text only by author names can be found in the NA60 references below.

R Arnaldi *et al.* 2006 *Phys. Rev. Lett.* **96** 162303.
R Arnaldi *et al.* 2008 *Phys. Rev. Lett.* **100** 022302.
R Arnaldi *et al.* 2009a *Eur. Phys. J.* **C59** 607.
R Arnaldi *et al.* 2009b *Eur. Phys. J.* **C61** 711.
R Arnaldi *et al.* 2009c *Phys. Rev. Lett.* **102** 222301.
S Damjanovic *et al.* 2007 *Eur. Phys. J.* **C49** 235.

Résumé

NA60 : à la recherche des dileptons thermiques

Les dileptons (paires l^+l^-) sont depuis longtemps considérés comme prometteurs pour l'exploration du milieu créé dans les collisions d'ions lourds. Par le passé, des expériences menées au CERN ont montré un excédent par rapport aux sources connues dans les régions de masse au-dessus et au-dessous de 1 GeV et ont suscité un certain nombre de questions. L'expérience NA60 auprès du SPS a été construite spécifiquement pour travailler sur ces questions. En faisant évoluer de façon considérable la technologie, elle a atteint de nouveaux standards de qualité de données dans ce domaine. Ses résultats démontrent l'origine thermique des paires de muons aux énergies du SPS et éclairent certains points concernant le déconfinement dans le plasma quarks-gluons et la restauration de la symétrie chirale.

Sanja Damjanovic, *CERN/University of Heidelberg*, **Ruben Shahoyan**, *CERN/IST Lisbon, and* **Hans J Specht**, *University of Heidelberg; NA60 Collaboration.*

CELEBRATION

CERN honours Schopper at 85

On 15 September CERN hosted a symposium to mark the 85th birthday of Herwig Schopper, who was director-general in the years 1981–1988. During the event colleagues recalled his long scientific career in nuclear and particle physics and looked back at other areas of science to which he has made decisive contributions and in which he continues to retain an ardent interest.

Schopper's role in world science is considerable and diverse: in frontier fields such as nuclear and particle physics as well as other areas of advanced scientific research; in the promotion of international scientific co-operation; and in the advancement of peace through scientific endeavour, to name just a few examples. He served as director of DESY, director-general of CERN and president of the SESAME Council. His leadership resulted in remarkable contributions towards the many achievements of these laboratories, most notably characterized by the successful construction of the Large Electron–Positron (LEP) collider at CERN (p23).

Samuel Ting, recipient of the 1976 Nobel Prize in Physics and spokesperson of the Alpha Magnetic Spectrometer (AMS) collaboration, opened the symposium with an overview of Schopper's contributions to nuclear and particle physics. He reminded the audience of experiments from the 1950s through to the 1970s, including important contributions to the study of the structure of the proton and neutron through electron-scattering experiments. Schopper's part in the development of innovative detector technologies, which continue to remain in use in high-energy physics experiments, includes the development of the hadron-calorimetry technique to measure energy in neutron–proton and neutron–nuclei scattering experiments. Ting also recalled Schopper's significant role in the approval and construction of LEP – two major milestones in the history of CERN – as well as his important role on the AMS experiment, serving as senior adviser and proposing new detector techniques.

Herwig Schopper speaks at the symposium held in his honour at CERN.

Cecilia Jarlskog of Lund University took a trip back in time to recall the pioneering work in the 1950s on parity violation. Schopper's contributions were highlighted by his work on the circular polarization of gamma rays as further evidence of parity violation. He continued these studies unabatedly, working on circular polarization of external and internal bremsstrahlung as well as on electron and positron emitters throughout the 1960s.

Moving beyond CERN, Albrecht Wagner, former director of DESY, recalled Schopper's time at DESY in the 1970s and also looked to the future. Schopper oversaw the construction of the electron–positron collider PETRA in the period 1976–1978. PETRA turned DESY into a truly international high-energy physics laboratory and experiments there went on to do seminal work in particle physics with the discovery and study of the gluon. Schopper's initiative also led to the construction of the ARGUS experiment at DORIS. By establishing HASYLAB at DORIS, DESY branched out into synchrotron science to satisfy the needs of its growing user community. With such strong foundations, DESY now has highly attractive opportunities for future research in photon science, particle physics and astrophysics.

Mariano Gago, minister for science, technology and higher education of Portugal (and himself a particle physicist), and Juan Antonio Rubio, director-general of CIEMAT in Spain, evoked memories of Schopper's essential part in the development of particle physics on the Iberian Peninsula and elsewhere in Europe. Schopper's vision paved the way for Portugal to become CERN's fourteenth member state in 1986. His pivotal role in Spain's re-accession to CERN in 1983 is also much acknowledged. Thanks to CERN in general, and Schopper in particular, both Portugal and Spain now have a highly developed scientific and technical level in particle physics and contribute significantly to CERN's physics programmes. Their involvement with CERN and particle physics has also benefited these countries in areas that reach beyond particle physics.

Costas Papanicolas of the Cyprus Institute and Khalid Toukan of SESAME both spoke about an issue that Schopper has dedicated himself to in recent years – the establishment of research centres in the eastern-Mediterranean region and the Middle East. Schopper has left his signature on the Cyprus Institute – whose activities include research on the environment, energy and water – by being one of the organization's founding fathers, and he continues to show much interest in the advancement of science in Cyprus. He is also a committed leader and supporter of the international SESAME centre, which will produce X-rays that can be used in a range of experiments from condensed matter to biology; he was president of the Council of SESAME from 1999 to 2008. The success of the SESAME project would not have been possible without his dedication to it. His efforts have been a guiding force in bringing nations together through science in these regions of the world.

The symposium was also dedicated to Schopper's wife Ingeborg, who passed away on 14 September. CERN's director-general, Rolf Heuer, led the audience in a moment of silence in her honour.

● The presentations and a recording of the symposium are available at http://indico.cern.ch/conferenceDisplay.py?confId=66622.

APPOINTMENT

Cambridge particle physicist is to be next director of ICTP

Fernando Quevedo of Cambridge University has been appointed as the new director of the Abdus Salam International Centre for Theoretical Physics (ICTP). He will succeed Katepalli Sreenivasan, who has led the institute since 2003 and will now be returning to the US to pursue his interests in research and teaching.

Quevedo is a well known theoretical particle physicist with wide-ranging research interests in string-theory phenomenology and cosmology. He was awarded the 1998 ICTP prize in recognition of his important contributions to superstring theory.

Born in Costa Rica, Quevedo received his early education in Guatemala. He obtained his PhD from the University of Texas at Austin in 1986 under the supervision of Steven Weinberg. Following research appointments at CERN, McGill University in Canada, the Institut de Physique in Neuchatel and the Los Alamos National Laboratory, as well as a brief term as professor of physics at the Mexican National Autonomous University (UNAM), he joined the department of applied mathematics and theoretical physics at the University of Cambridge in 1998.

A Guatemalan national, Quevedo has received honorary doctorates from the Universidad del Valle de Guatemala and the Universidad de San Carlos de Guatemala and is the founder and co-ordinator of the International Network of Guatemalan Scientists.

The choice of Quevedo as the next director is in keeping with the spirit of ICTP – founded in 1964 by Nobel Laureate Abdus Salam – which is to do first-rate research while acting as the anchor for scientific capacity building in developing countries.

Fernando Quevedo is to take the helm as the new director at the ICTP in Trieste. (Courtesy ICTP.)

CERN USERS

The Users' Office: 20 years and going strong

Twenty years ago, the same issue of *CERN Courier* that reported on the first collisions in the Large Electron–Positron (LEP) collider also contained a short article on another new venture at CERN (*CERN Courier* September 1989 p24): in July 1989 an office was created to assist the growing number of "users" – the visiting physicists, engineers, technicians and students who come to CERN to work on the broad range of projects and collaborations. With the start-up of LEP, the expansive trend was clearly set to continue.

Since then the LHC experiments in particular have brought still further additions to the family of users, the total rising from 4500 to nearly 10 000 during the past 20 years. What's more, these users now come from a broader range of countries, with large representations from Russia and the US in particular. The office must help all of these users with any difficulties on a site that spans two countries, such as with their individual requirements for visas. As the CERN community has changed, so too have the surrounding nations, with the expansion of the EU and the introduction of the Schengen agreement on border controls. Before the inception of the Users' Office, it was common for users to spend a day or more wandering round CERN in search of the necessary documentation and information to make their stay official.

Chris Onions (right), the current head of the Users' Office, with Bryan Pattison, who was the first manager back in 1989, outside the office in its current location in building 61.

While the office has undergone various changes throughout its lifetime it has persisted in being a welcoming bridge to help settle the thousands of visitors from all around the world. It currently employs six multilingual staff to handle day-to-day operations – no more, in fact, than when it started in 1989. Users' registrations are limited to a maximum of two years, so with 10 000 users the team handles approximately 100 renewals and new registrations every week, as well as many requests for information and help from users and the experiment's secretariats. During peak periods such as July, when many students coming to CERN on the Summer Student Programme are registered as users, it is not uncommon to see long queues stretching out from the office.

In September, the office celebrated its 20-year anniversary with a drink offered to its various representatives of the user community, CERN management and staff members from the services with which the office is involved. These days, the office could not handle the needs of the many users without liaising with other services to provide a professional "welcoming" process at CERN.

● CERN users can find all that they need to know before coming to CERN at the Users' Office website: http://ph-dep-usersoffice.web.cern.ch/ph-dep-UsersOffice/.

Construction starts on new office space

With the LHC about to re-start, the new collider is continuing to attract more and more researchers, most of whom will come to CERN for some period. To ensure that the laboratory can cope with this influx, work has begun on a new block of offices. Building 42 will provide 300 additional workstations for researchers analysing LHC data, in addition to the 800 already available in the adjoining Building 40. With this building, CERN has gone "green". It will be more environmentally friendly than the older buildings, equipped with features such as a grass roof, enhanced insulation and automatic sun blinds.

The foundation stone was laid for the new building in a ceremony on 9 September in the presence of officials representing the Geneva State Council and the local Swiss community of Meyrin. At the ceremony, CERN director-general, Rolf Heuer, warmly thanked the Swiss Confederation, the Geneva State Council and the Fondation des immeubles pour les organisations internationales (FIPOI). The Swiss Confederation supported CERN's loan application to finance the construction of Building 42 via (FIPOI) and the Canton of Geneva provided the land.

An illustration of Building 42 – with its grass roof – with the larger, existing Building 40 behind.

Ceremony for the laying of the foundation stone of Building 42. From left to right: architect Jacques Perret, CERN's director-general Rolf Heuer, Geneva state councillor in charge of the Institutions Department, Laurent Moutinot, Swiss state secretary for education and research, Mauro Dell'Ambrogio, and mayor of Meyrin, Roland Sansonnen.

LHC OUTREACH

Institutes in Kolkata put on an LHC carnival

The start-up of the LHC in September 2008, preceded by media hype about the impending disaster of black holes "gobbling up" everything, made the LHC a glamorous and exciting phenomenon in contemporary science. It fuelled the curiosity of people from all sections of society, in India, as in many other parts of the world.

Triggered by this explosion of popular interest, the Variable Energy Cyclotron Centre (VECC) and the neighbouring Saha Institute of Nuclear Physics (SINP) organized an LHC outreach programme earlier this year. On "Science day", about a thousand excited and enthusiastic young students from high schools and graduate-degree courses from all over the state of West Bengal came to participate in "Understanding the universe through the Large Hadron Collider". The main hall of the auditorium could not accommodate all of the young visitors, so a video telecast was arranged outside the hall.

Enthusiastic students at the exhibition hall at the LHC outreach event. (Courtesy Tapan Nayak.)

Premomoy Ghosh started the programme with an introduction, followed by a simple pedagogical presentation by Bikash Sinha, who explained the magic of little bangs and the big bang. Pijushpani Bhattacharjee and Jan-e Alam then elaborated on the astrophysics and cosmology of quark-gluon plasma. Tapan Nayak gave a lively video presentation that explained the experiments at LHC. To conclude the event, Abhee Kanti Dutta-Majumdar anchored a question-and-answer session, which was a huge success, and a vote of thanks was given by Dinesh Srivastava. The outreach programme also included an exhibition featuring scale models and posters.

The visiting students said that they felt as though they had been physically transported to CERN, and the excitement was obvious on their faces. It had been an overwhelmingly successful science carnival.

COMMEMORATION

Milan dedicates square to Giuseppe Occhialini

Giuseppe Occhialini, known as "Beppo" to his friends and to the older generation of physicists, spent more than half of his life as a scientist living in Milan. To honour and remember his presence, the physicists of the physics department of the Università Statale di Milano took the initiative to ask the town authorities to give Beppo's name to a square located in the Città degli Studi. The proposal was promptly seconded by the physics department of the Università Statale Della Bicocca, the Milanese university established 10 years ago, where the physics department is named after Occhialini.

A view of the square now named after Occhialini, together with the nameplate. (Courtesy Guido Vegni.)

The approval from the mayor of Milan, Letizia Moratti, came during the symposium on "Highlights in today's physics", which was held in Milan in 2007 to celebrate the centenary of Occhialini's birth.

The official inauguration of the square finally took place on 22 June 2009, in the presence of the rector of the Università Statale, Enrico Decleva, together with authorities from the university and the town. Also present were many of Beppo's friends, physicists and non-physicists, and his daughter, Etra.

The square is located 100 m from the old Physics Institute where, in the basement, Occhialini had established his Nuclear Emulsion Laboratory when he arrived in Milan in 1952. It is also within walking distance of the new physics department where he worked up to his retirement in 1983.

● For more about Occhialini's life and work, see *The Scientific Legacy of Beppo Occhialini*, P Redondi *et al.* (eds) Springer 2007 (*CERN Courier* May 2007 p49).

VISITS

Ömer Dinçer, Turkish minister of labour and social security, right, was welcomed to CERN on 9 June by director-general, Rolf Heuer (seen here demonstrating a gift of CERN's special temperature-sensitive coffee mug that illustrates the history of the universe). The minister also toured the ATLAS underground experimental area and spoke to Turkish scientists at CERN in the ATLAS 3D visitor centre.

Prince Albert II of Monaco came to CERN on 2 September and visited the CMS experiment. Although it was closed for testing at the time, the prince was able to see the scale of the detector and learn about the electromagnetic calorimeter. He also toured the CERN Control Centre.

On 4 September, **Danilo Türk**, president of the Republic of Slovenia, left, visited CERN. He toured the ATLAS experiment with Rolf Heuer, centre, and Fabiola Gianotti, ATLAS spokesperson. He also saw the ATLAS visitor centre and met Slovenian scientists at CERN.

ANNIVERSARY

Russian Federation sets off celebrations of the centenary of Nikolai Bogoliubov's birth

The 2009 International Bogoliubov Conference on Problems of Theoretical and Mathematical Physics was one of the major events in the Russian Federation (RF) to celebrate the centenary of the birth of the Russian physicist Nikolai Nikolaevich Bogoliubov (1909–1992). The conference, which takes place every five years, was held this year on 21–27 August at the Russian Academy of Sciences (RAS) in Moscow and at JINR in Dubna and organized by the RAS, JINR and the Moscow Lomonosov State University (MSU). It was also sponsored by the Russian Foundation for Basic Research, the RF's Federal Agency for Science and Innovation, the Dynasty Foundation and the JINR joint scientific programmes Heisenberg–Landau, Votruba–Blokhintsev and Bogoliubov–Infeld.

Special attractions included a large photo exhibition in both Moscow and Dubna, showing different periods of Bogoliubov's life and scientific career; a presentation of the 12-volume collection of Bogoliubov's scientific works from 2005 to 2009 published by the RAS/Nauka; and a new series of brochures in which well known physicists share their recollections about "Bogoliubov the teacher". An exhibition of his papers and books by and about him was also organized at the JINR library.

Around 300 physicists and mathematicians from leading scientific centres in 30 countries attended the conference. They included scientists of the older generation who were pupils and colleagues of Bogoliubov, as well as young people who have only recently started their careers in mathematics and physics. More than 160 reports were presented, dealing with modern problems in mathematics, nonlinear mechanics, quantum-field theory, elementary particle theory, statistical physics and kinetics.

The conference opened on 21 August – the exact centenary of Bogoliubov's birth – in the presidential hall of the RAS, where Valery Kozlov, vice president of the RAS, welcomed the participants. The first day included plenary talks on non-equilibrium statistical mechanics, new approaches in complex analysis, searches for new physics at the LHC, problems in modern cosmology and form factors in pion physics. During the day, participants paid tribute at Bogoliubov's tomb in Moscow's Novodevichy cemetery and placed flowers. The day ended with the screening of a new documentary about Bogoliubov. The second day followed with more plenary talks, covering aspects of string theory, mathematical modelling of reactor processes, charged-particle dynamics, the Bogoliubov hierarchy, Navier-Stokes systems and N=4 supersymmetry.

The bronze Bogoliubov memorial plaque unveiled at the JINR Laboratory of Theoretical Physics. From left to right: Dmitri Shirkov, Mikhail Bogoliubov and Alexei Sissakian. (Courtesy JINR.)

The conference continued in Dubna on 24–27 August at the Bogoliubov Laboratory of Theoretical Physics. The Dubna session began with a talk by JINR's Director, Alexei Sissakian, titled, "Bogoliubov – Teacher and Master." Afterwards, a plaque dedicated to the great scientist's memory was unveiled on the laboratory wall. Plenary sessions then commenced with the awarding of the N N Bogoliubov Prize for 2006–2008 to Dmitri Shirkov, one of his closest co-workers, and Boris Paton, president of the National Academy of Sciences of Ukraine (*CERN Courier* September 2009 p31).

Plenary talks by speakers from several countries covered a range of topics in particle and nuclear physics including: new trends in quantum-field theory; physics at the LHC; neutrino physics and astrophysics; duality and non-perturbative physics in quantum chromodynamics; and the Nuclotron-based Ion Collider Facility and prospects for research with heavy-ion collisions at JINR. Parallel sessions were held on the topics to which Bogoliubov made decisive contributions, and which continue to form the basis of modern fundamental mathematics, mechanics and theoretical physics: mathematics and nonlinear mechanics; quantum-field theory and elementary particle theory; statistical mechanics, kinetics and quantum theory of condensed state of matter; and nuclear physics.

The conference concluded in Dubna on 27 August with the awarding of the prize for the best reports in mathematics and physics among the young scientists (up to age 35). The winners in physics were V Katkov of JINR, for the report "Peculiarities of field emission for carbon nanosheets", and A Bagrov of the RAS Institute of Mathematics, for the report "Critical formation of covered surfaces in collisions of nonextending shock gravitational waves in the de Sitter space". In mathematics the prize was awarded to A Pechen of Princeton University for the report "Dynamics and control of open quantum systems". The awarding of the Bogoliubov Prize 2006–2008 for young scientists (up to age 33) also took place; the winner was I Ivanov of the RAS Institute of Mathematics, for the cycle of papers "A new approach in the general two-doublet Higgs model".

The centenary celebrations continued in Kiev with a conference at the Bogoliubov Institute of Theoretical Physics of the National Academy of Sciences (NAS) of Ukraine on 15–18 September. A general meeting of the NAS, which was dedicated to the centenary, followed on 21 September. Festive events are also to be held in Nizhny Novgorod and Sarov, at the All-Russian Scientific Research Institute of Experimental Physics, and a Joint Festive Meeting of the RAS Presidium, the JINR Scientific Council and the MSU Scientific Council will be held in October.

IPAC

Accelerator conferences go international

In 2007 the European Particle Accelerator Conference (EPAC) and its older sister the North American Particle Accelerator Conference (PAC), both on a two-year cycle, agreed to join the Asian Particle Accelerator Conference (APAC), on a three-year cycle (*CERN Courier* November 2007 p29). The International Particle Accelerator Conference series (IPAC) will in future move between Asia, Europe and North America, intermeshed with a North American PAC in odd years.

Preparations for the first conference in the new series are now in full swing. IPAC '10 will take place in Kyoto, Japan, on 23–28 May 2011. It will be followed by IPAC '11 in San Sebastian, Spain, on 5–9 September 2011, and IPAC '12 in New Orleans, US, on 20–26 May 2012.

While the scientific programme of IPAC '10 will resemble earlier APAC and EPAC events – with three half-day plenary sessions, a maximum of two sessions in parallel the rest of the time, and poster sessions completely de-coupled from the oral sessions – the organization is taking on a far more international flavour. The

organizing committee of IPAC '10 and also that of IPAC '11, which has just started work, are composed 50% from the region and 50% from the rest of the world. Particular care is being taken to ensure that the scientific programme covers accelerator developments worldwide, catering for participants from all geographic and scientific horizons.

This move to a truly international event, as much in the style of organization as in the scientific programme, means the new series is eligible for sponsorship by the International Union of Pure and Applied Physics, an international governmental organization founded in 1922 to stimulate and facilitate international co-operation in physics and the worldwide development of science. The world is growing smaller and accelerator projects are increasingly more diversified and global. Cheaper international travel will most likely result in a larger proportion of international participants at future conferences and IPAC is gearing up to meet the challenge of making future events even more productive and exciting than the former regional ones.

● For more about IPAC '10, see www.ipac10.org, and for news on related events, see www.jacow.org/.

CELEBRATION

Alexei Onuchin reaches milestone 75th birthday

One of the pioneers of colliding-beam experiments, Alexei Onuchin, celebrated his 75th birthday on 3 October.

Onuchin has spent his scientific career at the Budker Institute of Nuclear Physics (BINP), which he joined in 1959. He was one of the leaders of the experiment at the VEPP-2 e^+e^- collider – working at an energy 1.18–1.34 GeV in 1970 – that discovered multihadron production (simultaneously with Frascati), one of the first indications of the existence of light quarks. He later became leader of the MD–1 experiment at the VEPP–4 e^+e^- collider operating in the γ resonance energy range in the years 1980–1985. One of its well known results is the measurement of the cutoff of large impact parameters in bremsstrahlung (the MD effect).

A founding father of the KEDR detector at the upgraded VEPP–4M collider, Onuchin

Alexei Onuchin. (Courtesy BINP.)

suggested, tested and constructed a 30 tonne liquid-krypton calorimeter, together with younger colleagues. His group also constructed a drift chamber using "cold" dimethyl-ether gas providing 100 μm resolution. Onuchin is also one of the leaders of the Novosibirsk group in the BaBar experiment at SLAC.

His long-standing love for Cherenkov counters is well known. Starting with pioneering water threshold counters in the experiment at VEPP–2, Onuchin later developed the MD–1 Cherenkov counters filled with ethylene pressurized to 25 bars and suggested the aerogel counters with wavelength shifters (ASHIPH) that are now operating in KEDR.

He is currently working on the development of a novel focusing aerogel-ring imaging Cherenkov detector. For his many years of work in this field, Onuchin received the Cherenkov prize of the Russian Academy of Sciences in 2008.

OBITUARIES

Hector Rubinstein 1933–2009

Hector Rubinstein, professor emeritus at Uppsala University, guest researcher and doctor *honoris causa* at Stockholm University, passed away on 8 August in his summer house in the Stockholm archipelago.

Hector Rubinstein was born in Argentina and left for the US in the 1950s to study physics. After gaining his PhD at Columbia University he moved to Paris for a post-doctoral position, later taking a faculty position at the Weizmann Institute in Israel.

In his early work, Hector studied the mathematical theory for strong interactions, SU(3), which had just been developed by Murray Gell-Mann, later to become known as the quark model. Later, during a stay at the Rutherford Laboratory in the UK at the beginning of the 1980s, he developed a set of new field-theoretical methods, i.e. sum rules that could be used to calculate particle masses and interactions in QCD, writing a highly cited review on this subject with LJ Reinders and S Yazaki in 1985.

While at the Weizmann Institute, Hector attracted a number of brilliant students, among them Gabriele Veneziano, Florian Scheck and Miguel Virasoro. The experimentally established correlations in strong interactions led to the Veneziano model (or dual-resonance model), which was later reinterpreted by Holger Bech-Nielsen and Yoichiro Nambu as a model for strings. In a sense, string theory was born in Hector's research group at Weizmann.


Hector Rubinstein. (Courtesy A Goobar.)

From the early 1970s Hector maintained scientific contacts in Scandinavia (his wife is Swedish), which led to his emigration to Sweden in 1984 and his appointment as professor at Uppsala University. Owing to his scientific reputation and his personal charisma, he became influential in the development of particle astrophysics and string theory in Sweden. Never shying away from controversy or pointing out incongruities, he also made important contributions to the public debate about the quality of physics research in Sweden.

In later years, Hector made a significant mark on the scientific publication process. After realizing early on that the internet would eventually revolutionize the way that physicists would publish their results, he played an important role in the foundation of the *Journal of High Energy Physics* in 1997, the first in a series of J-journals that earned excellent reputations under Hector's guidance. This is most recently illustrated by the publication of a complete scientific documentation of the LHC machine and detectors in the *Journal of Instrumentation*.

Apart from particle astrophysics, Hector's later work focused on cosmology, in particular the role of magnetic fields in the early universe. His last paper, written with Vittoria Demozzi and Slava Mukhanov only weeks before his death, addressed the question of whether primordial magnetic fields could be produced in inflation.

Hector remained active after his formal retirement in 2000. In addition to his research and journals work, he became a well respected mentor, always willing to give his advice to young researchers and graduate students. He had a great sense of humour and broad interests and, with his seemingly infinite stock of anecdotes, talking with him was not only worthwhile but also great fun.

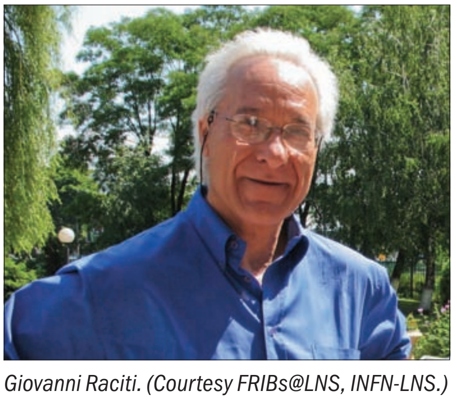
He is survived by his wife Helen and his three children and five grandchildren. He will be sorely missed.

L Bergström, J Conrad, A Goobar, P O Hulth, E Mörtsell, Stockholm University and U Danielsson, Uppsala University.

Giovanni Raciti 1949–2009

Giovanni Raciti, full professor of physics at the University of Catania, passed away on 19 August 2009 after almost a year of a strong and patient fight against his illness.

Giovanni was a passionate physicist: for him, physics meant fun to discover, enthusiasm to be shared and perfection to be achieved. He was a real nuclear physicist, having started with nuclear spectroscopy in transfer reactions at Saclay in the late 1970s before moving to higher energies with deep-inelastic and intermediate energy heavy-ion reactions at the Grand Accélérateur National d'Ions Lourds (GANIL) in Caen and at Saclay.


Giovanni Raciti. (Courtesy FRIBs@LNS, INFN-LNS.)

He was among the founders of the ALADiN experiment at the SIS synchrotron at GSI in 1987. The main aim was the systematic study of projectile fragmentation at relativistic energies. The experiment yielded pioneering results on the multifragmentation process and culminated in the determination of the nuclear caloric curve as a first signal of the long predicted liquid–gas phase transition in nuclear matter.

In 2000 Giovanni initiated a project at the

Laboatori Nationali del Sud in Catania to produce radioactive ion beams by projectile fragmentation followed by in-flight separation – the in-Flight Radioactive Ion Beams (FRIBs) project. The main goal of the project was to apply a tagging technique by identifying, on an event-by-event basis, each nucleus in the secondary beam "cocktail" before it impinges on the reaction target. He discovered the diproton radioactivity of ^{18}Ne only a few years ago, from the analysis of the first experiment conducted with these exotic species.

Giovanni was a member of several national and international evaluation committees, a referee of scientific journals and the spokesperson of numerous experiments and international projects. But most of all he was a teacher who inspired his students with his deep insight into physics and his enthusiasm for research. With his passing we have lost a passionate, deeply caring physicist, who always aimed for perfection. We will remember his warmheartedness, patience, honesty and humanity, and we will remember his smile to help us overcome our grief.

Titti Sfienti, University of Catania, and Uli Lynen, GSI.

NEW PRODUCTS

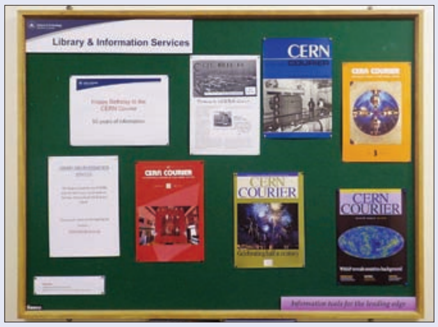
Future Technology Devices International Limited has announced the availability of multiport variants of its USB-powered USB-COM-PLUS family of communication modules. These are available in RS232 (EIA-232), RS422 (EIA-422), or RS485 (EIA-485) versions. The USB-COM232 modules provide dual or quad port options and the USB-COM422 and USB-COM485 modules provide dual port capability and differential and multipoint differential interfaces. For more information, contact Daniel McCaffrey, tel +44 141 429 2777; fax +44 141 429 2758; e-mail sales@ftdichip.com; or see www.ftdichip.com.

Highland Technology has introduced the Model P730 high-speed, multipurpose digital fan-out buffer. Housed in an anodized aluminium enclosure, the P730 features two input banks that are user-routable to two output banks, each consisting of four buffered electrical outputs. Input and output levels are independently adjustable enabling compatibility with CMOS, TTL, LVDS, NECL, PECL, NIM and sine wave systems. Fibre-optic inputs are optionally available. For further details, tel +1 415 551 1700; fax +1 415 551 5129; e-mail info@highlandtechnology.com; or visit www.highlandtechnology.com.

Keithley Instruments Inc has upgraded its RF Vector Signal Generator line with new capabilities that reduce signal generation times and enhance signal quality. The Model 2920A provides signal generation bandwidth options up to 80 MHz with a frequency range of either 10 MHz – 4 GHz or 10 MHz – 6 GHz. The Model 2920A is optimized for calibrating and testing components, such as amplifiers, filters and wireless receivers thoroughly over their full range of performance at exceptional speed. For more information, tel +49 89 84 93 07 40; e-mail info@keithley.de; or see www.keithley.com.

Unitemp has manufactured the LC500, a new low-cost, high-quality temperature chamber for testing and monitoring semiconductors, with a low power consumption of 13 A. It has a temperature range of −20 °C – 80 °C with an accuracy of ±1 degree with heat dissipation of 350 W continuous. Constructed from stainless steel grade 430, the cabinet measures 1350 × 553 × 650 cm internally and 2050 × 750 × 793 cm externally. An easily operated control panel is incorporated above the door at eye level. For further details, contact Paul Brown, tel +44 1628 850 611; or e-mail paul@unitemp.co.uk.

ZTEC Instruments has announced the new Extensible Display Manager (EDM) and Motif Editor and Display Manager (MEDM) control and display panels for their Experimental Physics and Industrial Control System (EPICS) digital oscilloscopes. These panels can be used to control all instrument functions and monitor acquired waveforms in real time. The instruments are accessed via LAN/Ethernet For more information, tel +1 866 342 0132; or visit www.ztecinstruments.com.



Spotted recently at the Rutherford Appleton Laboratory (RAL) in the UK: a noticeboard celebrating the 50th anniversary of the *CERN Courier*, with a selection of covers going back to the first edition (*CERN Courier* July/August 2009 p31). Many thanks to the library staff at RAL.

CORRECTIONS

The article on the discovery of weak neutral currents by the Gargamelle collaboration made an error in the number of authors who signed the electronic neutral-current paper but not the hadronic paper (*CERN Courier* September 2009 p27). There were five authors of the electronic paper (Charles Baltay, Helmut Faissner, Michel Jaffre, Jacques Lemonne and James Pinfold) who were not on the hadronic paper.

In the same issue, an unfortunate error was made in the name of the Polish president, Lech Kaczyński, in the caption to the photograph of his visit to CERN (p34). Apologies to all concerned.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel +44 (0)117 930 1264 Fax +44 (0)117 930 1178 E-mail sales@cerncourier.com
Please contact us for information about rates, colour options, publication dates and deadlines.

Tenure-Track Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of Virginia, located in Charlottesville, Virginia, invites applications for a tenure-track Assistant Professor position in experimental high energy physics. Under the terms of an agreement with the Fermi National Accelerator Laboratory in Batavia, Illinois (Fermilab) this position will carry teaching release time to enable the successful candidate to develop a strong research presence on new experiments that are planned for the intensity frontier. The appointment will begin August 25, 2010. Applicants must hold a doctorate in physics and be committed to student instruction at both the graduate and undergraduate levels. Prior experience in experimental particle physics is required. The University of Virginia experimental high energy group has a strong participation in the Mu2e and NOVA experiments at Fermilab. Candidates with interests in those experiments will receive special attention.

To apply, candidates must submit a candidate profile, cover letter, a curriculum vitae that includes your publication record, a statement of teaching philosophy, and a statement of research interest; both statements must be one page minimum or two pages maximum, through jobs@UVA (https://jobs.virginia.edu). The job posting for this position can be located under posting number 0604396.

Candidates are required to have four letters of reference sent directly to phys-hep-exp-pos@Virginia.EDU or Experimental HEP Search, Department of Physics, University of Virginia, McCormick Road, P.O. Box 400714, Charlottesville, VA 22904-4714.

Questions regarding the application process should be directed to Tammie Shifflett, tms4t@Virginia.EDU, 434-924-6565.

Applications received on or before December 31, 2009 will be given priority consideration; however, the position remains open until filled. For information on our department, please visit our website at http://www.physics.virginia.edu.

Women and members of underrepresented groups are encouraged to apply. The University of Virginia is an Equal Opportunity/Affirmative Action Employer and is strongly committed to building diversity within its community.

Divisional Fellow – Experimental Particle Physics

The **Physics Division at Lawrence Berkeley National Laboratory (LBNL)** is seeking a scientist with a record of accomplishment, creative ability and outstanding promise in the field of experimental particle physics. The **Divisional Fellow** position is a five year appointment with expectation of promotion to career Senior Scientist. The Divisional Fellow appointment is similar to a tenure track junior faculty position at a university. Appointment directly to Senior Scientist may be considered in exceptional circumstances.

The current program in experimental particle physics has two major thrust areas: ATLAS at the LHC and the study of neutrino oscillations using reactor neutrinos (Daya Bay). We are beginning programs on the physics of neutrinos and rare processes related to the planned high-intensity beams at Fermilab.

Candidates should have several years of experience in experimental particle physics beyond Ph.D. Experience in hadron collider physics or neutrino research desirable.

Interested individuals should apply online at: **jobs.lbl.gov**. Search for job **#23620**. Applicants must also email their CV, publication list, and statement of research experience and interests in pdf format and have at least five letters of recommendation (no more than one from an LBNL reference) sent to: **eppfellow09@lbl.gov.**

For full consideration, applications should be received by 18 December, 2009.

Berkeley Lab is an affirmative action/equal opportunity employer committed to the development of a diverse workforce.

BERKELEY LAB

THE CYPRUS INSTITUTE

Science and Technology Research Center (CaSToRC) - CaSToRC-09-04
We have two Computing Support Specialist positions available. These positions will provide computational expertise and technical support for the development of high performance computing facilities, data repositories and web and video collaboration services.

Required Education and Experience:
- BS degree (MS degree preferred) in a computer science, natural science, or engineering field required. Alternative degree fields will be considered if accompanied by equivalent experience (depending on nature and depth of experience as it relates to the current project).
- At least 2 years of experience with at least two of the above mentioned areas.

In addition, for a Systems Administrator role, successful candidates will need to have:
- At least 2 years of experience in Unix Systems Administration
- At least 2 years of experience in the hardware maintenance of computer systems
- Strong knowledge of computer systems and programming with at least 2 years of programming experience with one or more of the following: C, C++, Fortran.

Computational Scientist to work in atmospheric and climate modelling
Computation-based Science and Technology Research Center (CaSToRC) - CaSToRC-09-05
We are seeking an outstanding computational scientist to participate in the development of software and algorithms for atmospheric and climate modeling. The successful candidate will work with the research group of Prof. Jos Lelieveld that pioneers research in Climate Change. S/he will be engaged in projects involving challenging algorithmic problems and analysis techniques for large complex data sets.

Required Education and Experience:
- The candidate must have a Ph.D. in physics, computer science, or related scientific discipline. Experience with numerical methods, parallel algorithms, software development for High Performance
- Computer systems and strong programming skills are required. Experience in climate modeling is a plus but it is not required.

For further information, the full job descriptions and salary details please contact **castorc.info@cyi.ac.cy**.

For full consideration, interested applicants should send a CV, a sample of their work and the names of three contactable referees by e-mail to **HR@cyi.ac.cy** by the following dates:

CaSToRC-09-04 - 30th Nov 2009 **CaSToRC-09-05 - 30th Nov 2009** ***Recruitment will continue until the positions are filled.***

RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

The **Heidelberg Graduate School of Fundamental Physics (HGSFP)** at the Department of Physics and Astronomy at the University of Heidelberg, a school of the German Excellence Initiative, invites applications for

Doctoral Fellowships

in its core areas of modern fundamental physics: (a) Fundamental Interactions and Cosmology, (b) Astronomy and Cosmic Physics and (c) Quantum Dynamics and Complex Quantum Systems. Thesis research topics cover areas such as experimental and theoretical astrophysics, cosmology, accelerator based particle physics, precision measurements in physics, study of quantum systems – many body as well as small systems, low as well as high temperature physics, atomic, molecular and optical physics, mathematical physics and string theory. The HGSFP combines doctoral projects at the forefront of international research in the areas mentioned above with a rich and thorough teaching program. Further information can be found on the School's web site: **http://www.fundamental-physics.uni-hd.de**.

The branch Astronomy & Cosmic Physics is the International Max Planck Research School (IMPRS) for Astronomy and Cosmic Physics at the University of Heidelberg (**http://www.mpia.de/imprs-hd**). Students accepted into the Graduate School will automatically be members of the IMPRS-HD and conversely. Membership in the IMPRS for Quantum Dynamics in Physics, Chemistry and Biology (**http://www.mpi-hd.mpg.de/imprs-qd**) is envisaged if appropriate.

Highly qualified and motivated national and international students are invited to apply. Applicants should hold a Master of Science or equivalent degree in physics. At equal level of qualification, preference will be given to disabled candidates. Female students are particularly encouraged to apply.

Applications for fellowships should arrive by December 13, 2009. Applicants have to initiate their application registering via a web form available at **http://www.fundamental-physics.uni-hd.de/fellowships.**

ESRF
The European Light Source

European Synchrotron Radiation Facility

We Highlight Science

Physics and Chemistry, Life Sciences and Medicine, Earth and Environmental Sciences, Surface and Materials Sciences.

The European Synchrotron Radiation Facility (ESRF) is Europe's most powerful light source. The ESRF offers you an exciting opportunity to work with international teams using synchrotron light in Grenoble, in the heart of the French Alps.

Have a look at our vacancies at
www.esrf.eu/jobs
Contact us at **recruitment@esrf.eu**

Scientists - Post doctoral fellows - PhDstudents - Engineers - Technicians - Administrative staff

European Synchrotron Radiation Facility
ESRF, BP 220, F-38043 Grenoble Cedex 9, FRANCE,
Tel.+33 476 88 20 00 www.esrf.eu

University of Glasgow

Department of Physics & Astronomy

Lecturer

£31,513 - £35,469 / £38,757 - £44,930

You will pursue a world-class research programme relevant to theoretical elementary particle physics, with emphasis on collider phenomenology, broadening and strengthening the existing research portfolio in this area. Your work should enhance the linkages to the experimental programme (www.gla.ac.uk/physics/ppe/). There are also extensive opportunities to collaborate with other theorists and experimentalists in Scotland under the auspices of the Scottish Universities Physics Alliance (www.supa.ac.uk/). You should be able to teach undergraduate physics and possibly astronomy at all levels and postgraduate theoretical particle physics.

Informal enquiries relating to this post may be directed to Professor Christine Davies; email c.davies@physics.gla.ac.uk telephone + 44 (0)141 330 4710.

Further particulars and background information are also available from the PPT group web pages: www.physics.gla.ac.uk/ppt/

This post is available as either a grade 7 or grade 8 depending on qualifications and experience.

Apply online at www.glasgow.ac.uk/jobs

If you are unable to apply online please contact us on 0141 330 3898 for an application pack quoting Ref 00047-6.

Closing date 16 November 2009.

Interviews will be held over 7 and 8 January 2010.

The University is committed to equality of opportunity in employment.
The University of Glasgow is a registered Scottish charity, number SC004401.
www.glasgow.ac.uk

NATIONAL TAIWAN UNIVERSITY
Leung Center for Cosmology and Particle Astrophysics

Distinguished Junior Fellowship

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

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

These positions are available on August 1, 2010. Interested applicant should email his/her application with curriculum vitae, research statement, publication list and three letters of recommendation before December 31, 2009 to
Ms. Ting-Yi Wu tyw@phys.ntu.edu.tw
For more information about LeCosPA, please visit its website at
http://lecospa.ntu.edu.tw/
Three letters of recommendation should be addressed to
Prof. Pisin Chen, Director
Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

cerncourier.com

Foundation for Fundamental Research on Matter

The Foundation for Fundamental Research on Matter (FOM) promotes, co-ordinates and finances fundamental research of international standard/calibre in The Netherlands. It is an autonomous foundation responsible to the physics division of the national research council NWO. FOM employs about 900 people, primarily scientists (including PhD students) and technicians, who work at FOM research institutes and research groups at universities. FOM is chiefly financed by the NWO (Netherlands Organisation for Scientific Research) Governing Board and NWO Physics and can be considered as the Physics Division of NWO. In addition to the government funds of NWO, FOM acquires financial means from the European Union and through collaboration with the industry and universities. For additional information see www.fom.nl.

FOM

Nikhef is the national institute for subatomic physics in the Netherlands with about 240 employees: 145 physicists, 75 engineers / technicians and 20 employees for General support. Based in Amsterdam, it is a collaboration between four universities and the funding agency FOM. The institute coordinates and supports major Dutch activities in experimental subatomic physics, among them the ATLAS, LHCb and Alice experiments at the Large Hadron Collider at CERN and several astroparticle physics projects, such as the ANTARES neutrino telescope, the Auger cosmic-ray observatory and the Virgo gravitational wave interferometer. Nikhef has in addition a theory department.

Nikhef has an opening for a

staff scientist

with tenure in the heavy-ion physics programme.

Requirements

You have a PhD and an excellent research and publication record in high-energy physics, preferably in relativistic heavy-ion physics. You will join the activities of the heavy-ion group within the ALICE experiment. You are creative, competent in modern information technology, able to establish an active research line including supervision of PhD students and, able to communicate developments through seminars as well as public lectures. You have knowledge in data analysis and/or detector development in high energy physics.

Information

Further information can be obtained from the leader of the Alice group, prof. dr. Thomas Peitzmann (phone +31 30 2532512 or by email t.peitzmann@uu.nl) or from the chairman of the selection committee, dr. L.W. Wiggers, (phone +31 20 5925058 or by email p63@nikhef.nl). Job interviews are foreseen in week 4 and 5, 2010.

Applications

Candidates are invited to send their application, including curriculum vitae, list of publications as well as three letters of reference before December 15th, 2009 to Nikhef, att. Mr. T. van Egdom, P.O. Box 41882, NL-1009 DB Amsterdam, or by email to Teus.van.Egdom@nikhef.nl.

Please quote vacancy nr: 090892

All qualified individuals are encouraged to apply.

NIKHEF

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Postdoctoral or Research Associate (Photocathode Scientist)

The Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE) seeks a photocathode researcher to work on photocathode materials for high brightness photoemission electron sources. The successful candidate will play a key role in establishing the dedicated photocathode laboratory and will conduct research aimed at understanding the physics of high quantum efficiency photocathodes for production of bright electron beams, their design, characterization, and operation in a high performance accelerator environment. The position is either Postdoctoral or Research Associate, depending on the applicant's qualifications and experience. A Ph.D. in physics, material science, or chemistry is required. Applicants should have extensive experience with UHV systems and be well-versed with surface analysis techniques.

Refer to http://www.lepp.cornell.edu/JobsAtLEPP.html for full job description. Electronic submissions and inquiries may be addressed to search-CLASSE@cornell.edu.

Cornell University is an equal opportunity, affirmative action educator and employer.

Science & Technology
Facilities Council

The Science & Technology Facilities Council (STFC) is the UK's provider of large scale inter-disciplinary research infrastructures and their supporting technologies, which enable UK researchers to investigate the world we live in and understand the building blocks of the universe. Our Daresbury Science & Innovation Campus in Cheshire is home to world-leading science including nuclear physics, accelerator research, high performance computing and technology.

Laser Physicist/Engineer

3 year fixed term post-doctoral appointment

£26,610 - £29,566 plus a Recruitment & Retention Allowance of up to £3,000 plus Relocation package

Based in Cheshire

Ultrafast lasers are now being utilised in exciting experiments in conjunction with high performance charged particle beams. The Accelerator Science and Technology Centre (ASTeC) wishes to strengthen its core expertise in a variety of such areas. One example is in the development of unprecedented timing and synchronisation systems, capable of better than 10 femtosecond stability. Solutions based on mode-locked fibre lasers currently represent the leading technologies.

The Accelerator Science and Technology Centre (ASTeC) seeks to develop world leading optical timing systems and we are looking for someone who can take on responsibilities for applications on our ALICE Test Accelerator, utilising mode-locked fibre oscillators and stabilised links. There will also be wider opportunities for R&D studies on advanced optical techniques applied to diagnostics challenges and other particle beam interaction projects.

You will work closely with the ALICE research team and also in funded international programmes. Whilst postgraduate experience in optical systems is essential and their application to particle accelerators is desirable, training in the latter will be available.

For more detailed information about the roles and how to apply: please visit https://www.scitech.ac.uk telephone 01925 603954 or e-mail recruit@dl.ac.uk quoting reference number VND436/09.

Closing date for applications is 20 November 2009.

NO AGENCIES

STFC is an equal opportunity employer and promotes diversity in its workforce. We are particularly keen to consider applications from groups currently underrepresented in the workforce and we are positive about disability.

www.scitech.ac.uk

POSITIVE ABOUT DISABLED PEOPLE

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CERN
COURIER

ATTENTION RECRUITERS

CERN Courier now has a section on job opportunities in computing.

To promote your computing vacancies contact Sarah Vokins, e-mail **sarah.vokins@iop.org**; tel +44 (0)117 930 1196.

LEON M. LEDERMAN Postdoctoral FELLOWSHIP

The Fermi National Accelerator Laboratory (Fermilab) invites applications for the Lederman Postdoctoral Fellowship in experimental particle physics. The Lederman Fellow will have a choice of opportunity within the broad program of experimental research at Fermilab which includes research at the Tevatron and the LHC, neutrino physics, particle astrophysics, and experiments at the Intensity Frontier. In recognition of Leon Lederman's outstanding career in research and his commitment to the teaching of physics, we are looking for candidates who have demonstrated exceptional ability in research and who also wish to participate in physics outreach for a fraction of their time.

The Lederman Fellowship appointment is normally for three years with a possible extension. Candidates should either have obtained a Ph.D. in experimental particle physics, astrophysics, or a closely related field, after November 1, 2008, or should expect to obtain a Ph.D. in the same fields by June 2010.

Applications including a curriculum vitae, a description of prior research and research interests, and details of experience and interest in outreach, should be sent to LMLFAPP@fnal.gov. Applicants should also arrange for three or four references to be sent to the same address. Applications and their references should be received by November 23, 2009.

Fermilab

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

University of Bern
Faculty of Science

Applications are invited for an
open rank professorship in

Theoretical High-Energy Physics

b
UNIVERSITÄT
BERN

opening February 1, 2012, at the Albert Einstein Center for Fundamental Physics, Institute for Theoretical Physics, University of Bern, Switzerland. The position can be filled either at the Full Professor or at the tenure track Assistant Professor level. Candidates should have a strong research record in quantum field theory applied to particle physics, aiming at a detailed understanding of the strong interaction, the standard model, or its extensions, in particular using non-perturbative methods. The current research activities at the institute include effective field theories, non-perturbative quantum field theory, the standard model, flavor physics, supersymmetry, gravity, and string theory. The successful candidate is expected to build up a strong research group, to be experienced in acquiring external funding, and to actively participate in the teaching and supervision of Bachelor and Master students, as well as of Ph.D. students in the graduate school.

The University of Bern particularly encourages women to apply for this position.

Applications including a curriculum vitae, a publication list, copies of the most important publications, a brief outline of past and future research, and a summary of obtained external funding should be sent to **Prof. U. Feller, Dean of the Faculty of Science, University of Bern, Sidler-strasse 5, CH-3012 Bern, Switzerland**, by **November 15, 2009**.

For further information you may contact **Prof. U.-J. Wiese, Institute for Theoretical Physics, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland**, e-mail: **wiese@itp.unibe.ch, www.itp.unibe.ch**

RECRUITMENT COMPUTING JOBS

LemnaTec | The University of Adelaide Australia | University of South Australia | Australian Plant Phenomics Facility | ACPFG Australian Centre for Plant Functional Genomics

Three Postdoc Data Analysis Positions, Plant Accelerator, University of Adelaide, Australia

The Plant Accelerator at the Australian Plant Phenomic Facility at the University of Adelaide, South Australia — sometimes described as the CERN of biology — has 3 positions available for scientists to analyze the datasets measured with our LemnaTec conveyer system. All 3 scientists will initially be trained for 3 to 6 months at LemnaTec in Aachen, Germany, to become familiar with the hardware and software. (LemnaTec develops and produces image-processing hardware and software to take digital images of plants or other biological objects at different wavelengths, and then analyzes these images to measure visible parameters of the samples — e.g. colour, shape, size, architecture etc. — and correlate these data with experimental data such as genetic data.) This data will be utilized to accelerate pure and applied plant science research, for example biofuels and energy crops. For further information, see: http://www.plantaccelerator.org.au

After the initial training, two scientists will move to Adelaide, South Australia, and one will stay at LemnaTec in Aachen to perform further analysis.

The focus of these 3 postdoc positions is:

- ★ Administration of the LemnaTec system
- ★ Administration of the SQL database
- ★ Research and development of new image processing algorithms for analyzing the digital images

Most important is multidimensional correlation analysis of the measured image processing data with experimental and gene data.

Necessary skills:

- ★ Expertise in the analysis of large datasets and multidimensional correlation analysis
- ★ Expertise in the administration and programming of SQL databases
- ★ Microsoft and Linux C/C++/C#
- ★ English and German
- ★ Able to relocate to Aachen, Germany or Adelaide, South Australia

We are speaking about 3 full postdoc positions which are initially limited to 3 years but have a good chance of being extended after 3 years.

Salary is calculated according to the Australian University employment standard.
1 position HEO9 (ca. 120,000 AU$ gross per year)
and 2 positions HEO8 (ca. 100,000 AU$ gross per year)

The positions shall be staffed by January 2010.
Applicants should send their CV to Dr. Joerg Vandenhirtz - joerg.vandenhirtz@lemnatec.de.

The LemnaTec system used in research programs with BASF, Bayer CropScience, Pioneer/DuPont and Syngenta can be viewed at
http://www.lemnatec.com/filme/LemnaTec_GH_16-9.wmv

Creatis LRMN

French CNRS Creatis laboratory (based in Lyon) is looking for an engineer, a PhD student and 3 master students to work on highperformance and grid computing for medical imaging applications.

The **engineer position** is for 30 months, starting in January 2010. He/she will be in charge of the developments of a virtual imaging platform supporting compute-intensive medical image simulations in MRI, ultrasound, PET and CT. The target execution infrastructure is the EGEE grid, one of the largest distributed systems in the world. The engineer will interact with 4 other project partners in France and collaborate with some European research groups.

The **PhD subject** deals with the handling of heterogeneity for distributed applications. The candidate will propose models and algorithms to optimize applications running on highly heterogeneous platforms made of grids, clusters, supercomputers and GPUs. The thesis will be cosupervised with company Maat Gknowledge. Expected start date is January 2010.

Master subject 1 aims at developing and validating a realistic model for CT medical images. Model parameters will be tuned by comparison with experimental and clinical data to ensure realism of simulated images. Simulations will be conducted on local clusters.

Master subject 2 targets a parameter study for the segmentation of the left ventricle in 3D+t cardiac MRI. Based on large-scale experiments supported by the EGEE grid, the student will investigate the influence of 4 parameters on the quality of the segmentation and their dependencies.

Master subject 3 is related to our on-going effort to develop a high-level interface to perform GATE Monte-Carlo simulations on distributed platforms. The student will propose and implement load-balancing and data placement algorithms for GATE with the goal of speeding up intensity-modulated radiation therapy (IMRT) simulations.

Additional information about those vacancies is available at
http://www.creatis.insa-lyon.fr/site/en/node/39133

CSCS Swiss National Supercomputing Centre

System Engineer for Grid Computing and HPC Systems - Switzerland - Manno/Ticino

The HPC Co-Location Services (HCS) division of CSCS, the Swiss National Supercomputing Centre, provides highly specialized HPC services to external customers like the Swiss Federal Meteorological Survey "MeteoSwiss" or the Swiss Institute of Particle Physics (CHIPP). CSCS is therefore looking for a motivated System Engineer for Grid Computing and HPC Systems.
Together with CHIPP you will be part of one of the largest and most exciting experiments in a search for the origin of matter with the Large Hadron Collider LHC at CERN. CSCS offers you a dynamic, exciting field, the development of which you can profoundly influence. Considerable freedom of action, further training is encouraged. You will have the possibility to participate to international conferences and build your own network of professional contacts. In the midterm you will also have the chance to contribute to the other systems run by the HCS division, thus getting a broad overview of different HPC technologies.

Skills

You are ready to take responsibility for the cluster used by CHIPP and ready to cooperate with the international partners of the computing grid for the Large Hadron Collider experiment at CERN. Requisites are:

- Demonstrated experience in administering Linux clusters and servers
- Experience with cfengine or similar tools for cluster administration
- Experience with the scripting languages bash, Perl and Python
- Willingness to continuously learn and update with latest skills
- Problem solution oriented personality, capability to work under pressure
- Ability to work in teams and in international environments
- Fluency in English as working language

Highly desired is experience with the gLite Grid middleware, the dCache storage management system, the PBS batch system, the ARC Grid middleware as well with Nagios and maintaining Nagios configuration and plugins. Familiarity with UNIX systems programming in the C language ("strace" is your daily-use Swiss Army knife) would be a further advantage as well as knowledge of Systems administration of Solaris 10 and ZFS, familiarity with Tomcat and Java-based webservices and knowledge of Italian and/or German.

Notes

The position is open starting November 1, 2009 and is initially limited to a period of two years. Working place is Manno in the canton of Ticino, one of the most attractive places in Switzerland.
Please submit your letter of introduction and CV online at www.jobs.ethz.ch.
For additional information please contact Dr. Michele De Lorenzi, delorenzi@cscs.ch,
phone **+41 91 610 82 08**.

LEP – The Lord of the Collider Rings at CERN, 1980-2000: The Making, Operation and Legacy of the World's Largest Scientific Instrument by Herwig Schopper, Springer. Hardback ISBN 9783540893004 €39.95 (£36.99, $59.95). Online version ISBN 9783540893011.

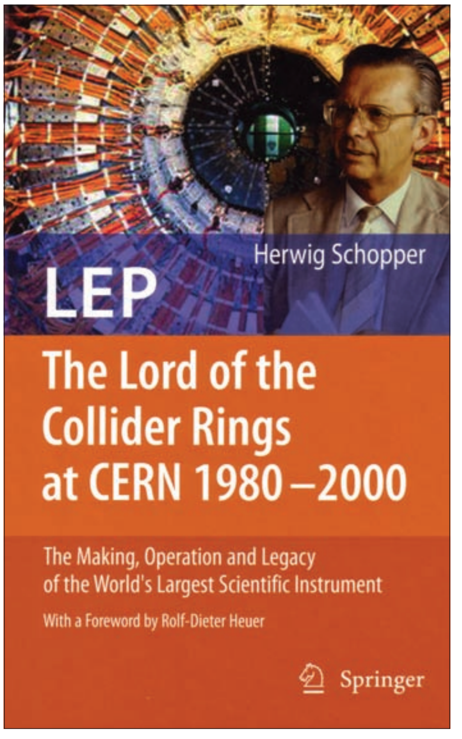
Herwig Schopper's energy and vitality remain undimmed, even though he turned 85 this year (p36). His book surveys the two decades of the Large Electron–Positron (LEP) collider, extending far beyond his own reign as CERN director-general in the years 1981–88.

From the outset, Schopper criticizes historians who have spurned his offer of first-hand but anecdotal input, preferring conventional archives and minutes. He contends that such lack of imagination can obscure the full picture. Thus the book is at its best when he relates how CERN's history was moulded rather than recorded. Nobody was taking minutes when Schopper had working breakfasts with influential council delegates. Another example is his nomination as CERN's director-general, where Italy was initially pushing for its own candidate. The sequel came later, when he carefully stage-managed an extension to his mandate to oversee the construction of LEP through to completion.

Fierce debate centred on the parameters of LEP: its circumference, tunnel diameter, precise footprint and the energy of its beams. Overseeing LEP called for a high level of scientific statesmanship. It was the largest civil-engineering project in Europe prior to the Channel Tunnel. As well as the technical challenge of building such a large underground ring at CERN, close to the Jura mountains, there was the diplomatic and demographic challenge of doing so beneath an international border, running close to and under suburbs and villages.

Closer to home was the thorny problem of catering for the physicists clamouring to use the new machine. How many detectors would be needed? Who would build and operate them? Who would lead the teams? With so much at stake, and so much enthusiasm, there was a lot of pushing and shoving to scramble aboard.

Schopper inherited the proton–antiproton collider in CERN's Super Proton Synchrotron ring and while LEP was being planned and built he presided over the laboratory during the historic discovery of the W and Z particles – the carriers of the electroweak force. He



recalls how this fast-moving research called for some skilful moves. In the middle of all this, the UK's prime minister Margaret Thatcher dropped in, accompanied by her husband – "an elder (*sic*) gentleman whom she treated with astonishing kindness," writes Schopper.

Experience had shown that LEP had to be presented from the outside as an integral part of CERN's basic programme. However, this meant that no new money would be available. CERN's research activities had to be pruned, a decision that did not go down well everywhere. Equally controversial were some deft moves on CERN's balance sheets, transferring money between columns earmarked for operations and investments.

While planning and construction of the machine was hectic, it was usually predictable, but in the middle of it all, CERN was caught unawares when the UK, one of its major contributors, suddenly menaced to pull out completely. To counter the threat, CERN had to undergo painful invasive examination by an external committee. Its final recommendations were difficult to swallow but left CERN leaner and sharper. Schopper's inside account of this period is most revealing.

Probably the biggest LEP controversy came right at the end. With its beam energy boosted to the limit in 2000, LEP was beginning to show tantalizing hints of the long-awaited Higgs particle. But the CERN juggernaut is irresistible. Before it had completed its act, LEP was kicked off the stage by the LHC proton collider for which the tunnel had been presciently designed right from the start. Schopper describes the resulting criticism and points out that it would indeed be ironic if the LHC found the Higgs inside the energy range that was still being explored by LEP.

Making decisions is not easy: long-term advantages can demand short-term sacrifices. Political popularity is another luxury, but highly visible VIP visits do seem to boost an organization's self-esteem. Most titillating is when Schopper puts LEP aside and reveals what went on behind the scenes to get the Pope, the Dalai Lama and other VIPs to visit CERN. The initial machinations and detailed planning for the visits of French presidents and prime ministers had to be abandoned when their last-minute changes called for frantic improvisation.

The cumbersomely titled *The Lord of the Collider Rings* is a valuable addition to particle-physics literature but it is mainly written for insiders. The names of people, machines and physics measurements tumble onto the page with little introduction. Schopper acknowledges that some of the illustrations are not optimal. This makes the book look as though it were hastily assembled and gives the CERN reader a sense of *déjà vu*, which is underlined by a statutory presentation of the Standard Model.

There are a few minor errors. Schopper naturally prefers the Germanic Wilhelm von Ockham to William of Occam, of eponymous razor fame, who was English (but died in Bavaria). *Physics World* is published by the UK Institute of Physics, not the "British Physical Society". Furthermore, there is little mention of the Stanford Linear Collider, which briefly trod on LEP's toes in 1989.

Schopper's anecdotes and insider views are certainly better entertainment – and possibly more incisive – than a dry formal history. After his LEP revelations, one now looks forward to what his successors at CERN will say about the groundwork for the LHC (historians, please take note).

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