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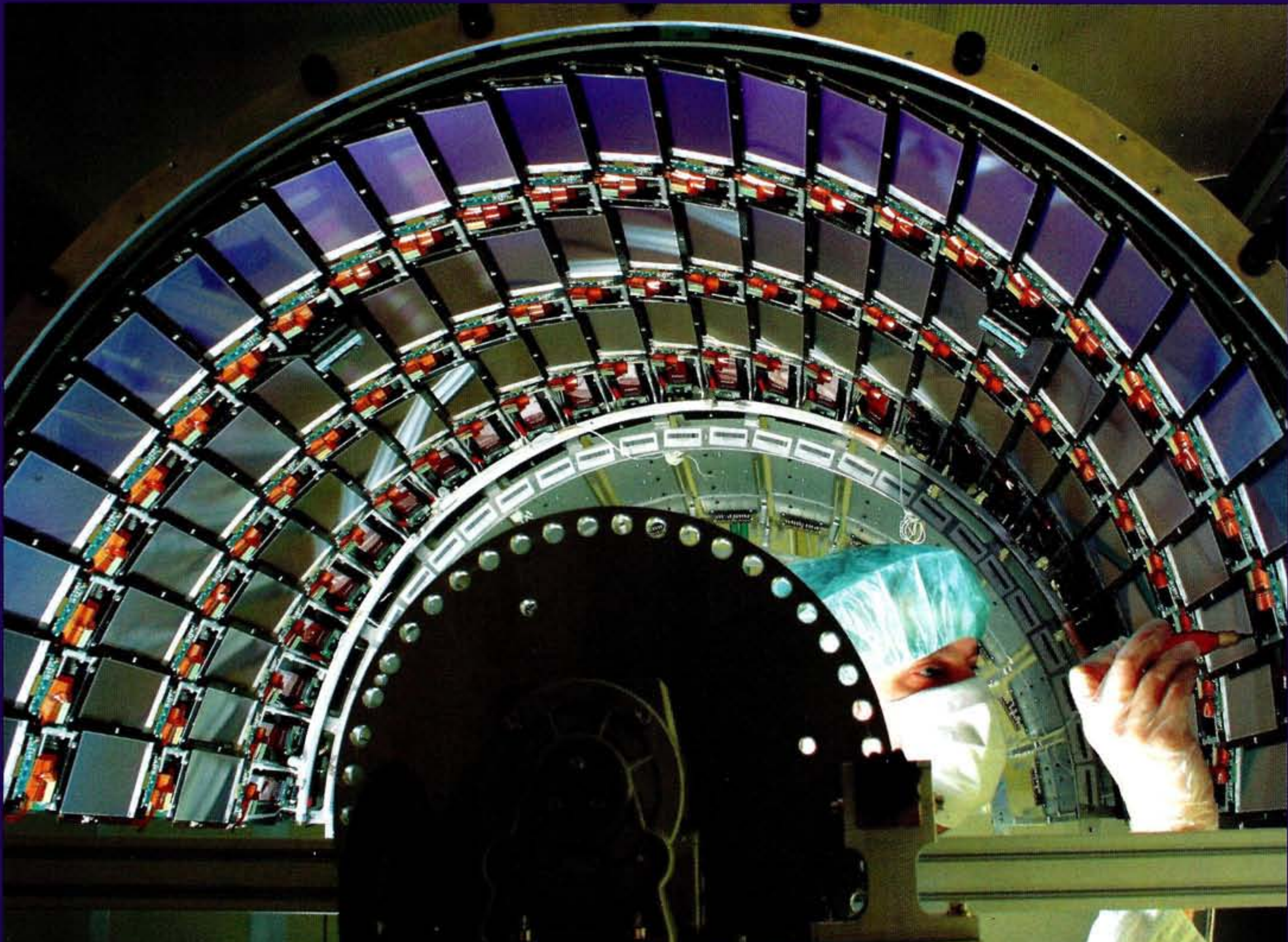

Silicon makes tracks for CMS

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

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Wormser takes over at LAL p43

Cover: *The final screw is adjusted on a module of Layer 4 of one half of the silicon tracker for the CMS experiment, which has been assembled in Pisa using modules constructed by many CMS collaborators in labs throughout Europe and the US (p6). (Courtesy INFN Pisa.)*

ADVERTISING FEATURE

SAES® Getters' Ultra-High Vacuum Pumps Support the Upgrade of the Beijing Electron Positron Collider

Over 200 SAES® CapaciTorr® non-evaporable getter pumps will be used to preserve ultra-high vacuum conditions in the new double-circumference storage ring of the Beijing Electron Positron Collider currently under upgrade from the Institute of High Energy Physics of Beijing, China.

Pioneering the development of the getter technology, the SAES Getters Group is the world leader in a variety of scientific and industrial applications where stringent vacuum conditions or ultra-high pure gases are required. For 60 years its getter solutions have been supporting innovation in the information display and lamp industries, in technologies spanning from large vacuum power tubes to miniaturized silicon-based micromechanical devices, as well as in vacuum thermal insulation. SAES Getters is also a key-player in the manufacturing and marketing of advanced solutions for ultra-high vacuum applications, including particle accelerators. Dozens of machines around the world, encompassing electron and positron storage rings, synchrotrons, ion colliders and nuclear radiation facilities, already employ SAES' NEG technology for primary pumping of their vacuum chambers and systems.

Ranked among the eight largest high-energy accelerator centers in the world, the Beijing Electron-Positron Collider – BEPC II (www.ihep.ac.cn) – is being reformed with funds of the Chinese central government: estimated to be completed by the end of 2007, the ambitious project will allow the collider to improve its performance to one hundred times the present level. Following the world's most advanced collider patterns, the old storage ring will be replaced by a new double ring, with a circumference of 240 meters, which will enable electrons and positrons to move in their own rings and to collide with each other at defined interaction points.

SAES' CapaciTorr NEG pumps help preserve ultra-high vacuum conditions in high energy machines

SAES' CapaciTorr NEG pumps will support the ultra-high vacuum system of the storage ring by maintaining the vacuum level in the 3×10^{-10} torr region, as required for the correct operation of the system.

CapaciTorr pumps have been selected due to the proven chemical sorption action for all active gases resulting in high pumping speed, as well as for their capability to operate in the presence of high magnetic fields.

SAES' proprietary high porosity getter material configurations improve these pumps' performance over traditional NEG pumps, particularly providing higher sorption capacities that result in a longer lifetime per activation and in an extended number of venting-reactivation cycles.

A great emphasis has been made by the BEPC II management staff on the overall quality of this technological upgrade, which is regarded as one of the most important scientific projects that China has undertaken in recent years. The decision to adopt a western technology on such an extensive basis is the result of a full commitment to quality: SAES' CapaciTorr product line is the most advanced and high-performing high-vacuum pumping technology for this application field.

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NEWS

CERN

LHC project passes several milestones

Progress on the construction of the Large Hadron Collider (LHC) at CERN has passed several important milestones in recent weeks. In mid-September the first 600 m of the cryogenic distribution line that will supply superfluid helium to the superconducting magnets passed initial testing at room and cryogenic temperatures. At the same time, the number of magnets installed in the tunnel passed the 100 mark, and several major contracts related to their construction have been successfully completed.

The tests of the cryogenic line, which were the first to be implemented at close to the eventual operating conditions in the LHC tunnel, took place in sector 7-8. This is where technical problems were discovered during the initial installation in summer 2004, so that the system had to be redesigned, repaired and reinstalled (*CERN Courier* January/February 2005 p5).

After several days of testing and cleaning at room temperature, the cool-down itself took 15 hours. This is a two-stage process using a 4.5 K helium refrigerator and a nitrogen pre-cooler. After the initial 10 hours of cool-down, the system reached the first temperature plateau of 80 K. Then, by the evening of 14 September, the cryogenic line had been brought down to around 5 K, about 3 K above the eventual operating temperature. The complete cold-commissioning process takes about five weeks. Once the thermal design has been validated, the magnets can then be connected to the cryogenic line.

Meanwhile, by the end of September, 102 of the LHC's 1232 superconducting dipoles had been put in position in the tunnel. At the same time one of the most important contracts for the LHC had successfully concluded, with the supply of all 7000 km of the superconducting cable that forms the heart of the machine's magnets. This cable has been provided by four companies in Europe – Alstom-MSA (France), EAS (Germany), Outokumpo (Finland/Italy) – Furukawa in Japan and OKAS in the US.

This is not an artist's impression! A long line of superconducting magnets is beginning to wend its way along the 27 km tunnel of the Large Hadron Collider.

Staff from CERN join in celebrating the shipping of the last collared coil by BNN.

This was the latest in a series of contracts for the LHC that have recently come to completion. At the end of May, Belgian firm Cockerill Sambre of the Arcelor Group cast the last batch of steel sheets for the superconducting magnet yokes, which constitute around 50% of the accelerator's weight. This was the first major contract to be concluded for the LHC; worth 60 million Swiss francs, it was signed just after CERN Council approved the LHC project in December 1996.

October saw the completion of the 60 km of vacuum pipes for the LHC beams by a single firm, DMV of Bergamo, Italy. These 16 m long pipes, made from austenitic steel, had to be continuously extruded and had to contain not a single weld in order to ensure perfect leak tightness between the vacuum inside and the superfluid helium outside. In the first week of September, the last rolls of austenitic steel for the collars of the dipole magnets arrived at CERN from NSSC (Nippon Steel) in Japan. The collars are designed to contain most of the magnetic forces created in the eight layers of superconducting coil that provide the magnetic field.

The production of the collared coils is also well on track. On 8 August Babcock Noell Nuclear (BNN) delivered their last collared coil, completing their contract for one-third of the dipole magnet coils. The contracts with the two other suppliers will also come to an end during the autumn of 2006.

Sommaire

LHC EXPERIMENTS

Silicon trackers begin to take shape for CMS and ATLAS

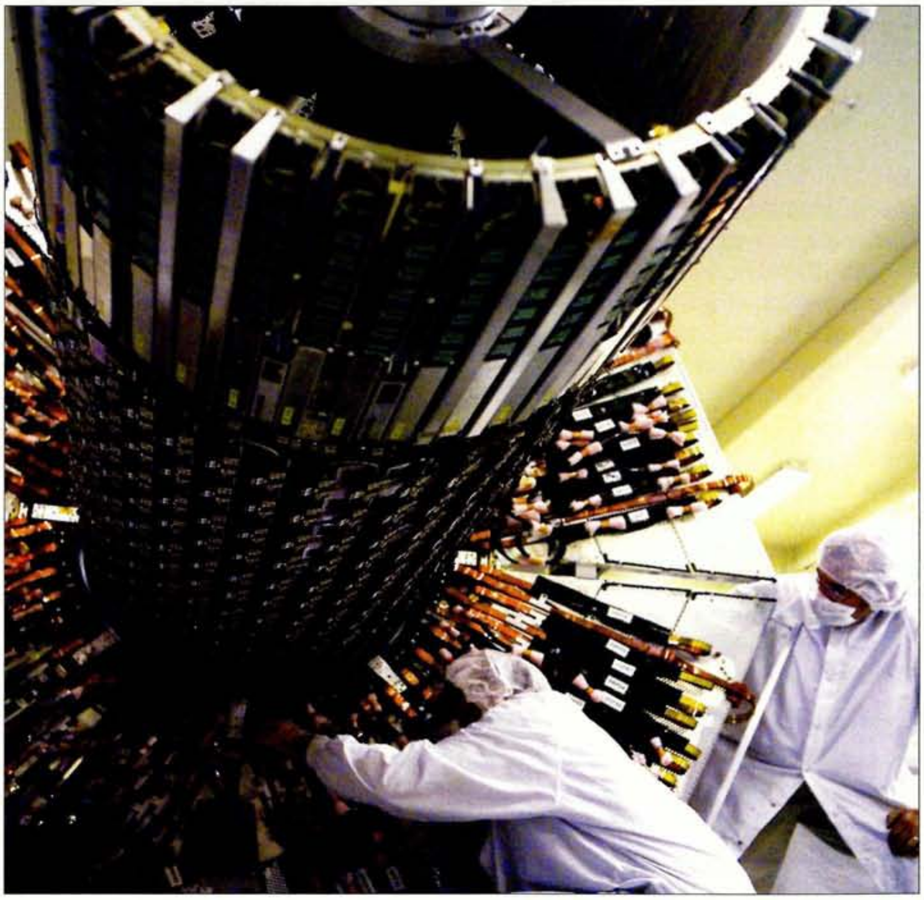
Over the past few months the silicon microstrip tracker of the CMS experiment has been making steady, and rapid, progress towards meeting its next major target – installation of the complete detector in its site at intersection point 5 on the Large Hadron Collider in November 2006.

This has been especially encouraging to the CMS collaboration as the past year has seen significant problems with relatively small details in a few key components, delaying the assembly of modules and their subsequent integration into the mechanical superstructure. However, these problems have now been overcome and the subsequent assembly speed of several inner layers of the tracker has demonstrated the readiness of the teams of engineers and physicists, who had used some of the time during the pauses to refine their procedures.

The CMS tracker will be the largest silicon system ever built, with more than 200 m^2 of silicon microstrips surrounding three layers of pixel detectors in a cylindrical barrel-like layout, with end-caps completing the tracking in the forward and backward regions. The construction involves teams from all over Europe and the US, who have developed components and pioneered automated techniques to manufacture modules that must withstand the stringent conditions at the heart of the CMS.

The inner barrel (see cover picture) is the responsibility of an Italian consortium. The delivery of the first half to CERN is expected this month, followed by the second half in January 2006. While tests begin on the inner barrel in a brand new integration facility, which is currently being erected at CERN, it will be joined by, and later inserted inside, the outer barrel system. This is largely the responsibility of CERN, and consists of modules arranged in rods that are being manufactured in the US by teams who have experience from Fermilab experiments. The two end-caps will complete the assembly in mid-2006; one will be built by a French ▷

One of the CMS silicon tracker end-cap petals under test in a close-to-final environment in Lyon. (Courtesy IN2P3-CNRS Lyon.)



The insertion of a completed barrel of the ATLAS inner detector into its support structure.

team in the facility at CERN, the other by a German team in Aachen.

The remaining off-detector electronics and cooling systems are also beginning to arrive at CERN. These will allow the completed tracker to be studied for several months before it is moved to its final underground location at the centre of the CMS. Once in operation it will provide precise radiation-hard tracking for many years.

Meanwhile, September saw an important milestone for the ATLAS inner detector project with the delivery of the fourth and final Semiconductor Tracker (SCT) barrel to CERN. A few days after delivery, on 20 September, the barrel was integrated into the final configuration of the full barrel assembly.

The SCT has a silicon surface area of 61 m^2 with about six million channels and is part of the ATLAS inner detector, where charged tracks will be measured with high precision. More than 30 institutes from around the world have contributed to building the component parts and structure of the SCT.

Moving outwards from the interaction region, the ATLAS inner detector comprises the pixel detector (consisting of three pixel layers), the SCT (four silicon strip layers) and the transition radiation tracker, or TRT (consisting of about 52 000 straw tubes).

During 2004 a team of physicists, engineers and technicians from several SCT institutes set up one of the largest silicon quality-assurance systems ever built (corresponding to about 15% of the final ATLAS readout system), which was capable of analysing the performance of one million sensor elements on nearly 10 m^2 of silicon detectors simultaneously. Using this system to test barrels prior to their integration, the team found that more than 99.6% of the SCT channels were fully functional, an exceptionally good performance that exceeded specifications. The work is taking place in the SR1 facility at CERN, which was purpose-built by the ATLAS inner detector collaboration and houses a 700 m^2 cleanroom.

This month the ATLAS inner detector teams will integrate the silicon tracker with the barrel TRT and test their combined operation in SR1. At the end of this year the SCT end-caps will arrive at CERN, and then be inserted into the TRT end-caps during spring 2006. In March 2006 the inner detector team will then place the barrel inner tracker in a steel frame and transport it to the ATLAS underground cavern. The entire integration process is scheduled to be finished at the end of 2006, when the all-important pixel detector will be inserted in the tracker.

The whole assembly of the inner detector will sit in the 2 T magnetic field of the central superconducting solenoid, which has a diameter of about 2.5 m. This will deflect the tracks of charged particles passing through the inner detector. The much larger air toroid magnet system (cover picture *CERN Courier* September 2005) is to deflect the tracks of muons, which penetrate to the outer reaches of the huge ATLAS detector.

NOBEL PRIZES

Rewards for optics in theory and practice

The 2005 Nobel prize in physics has been awarded to three physicists working in the field of optics, in recognition of past advances in the understanding of light as well as the present-day potential of laser-based precision spectroscopy. Roy Glauber of Harvard University receives half the prize for "his contribution to the quantum theory of optical coherence", while John Hall of the University of Colorado and Theodor Hänsch of the Max-Planck-Institut für Quantenoptik in Garching share the other half for "their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique".

The recognition of Glauber's work comes appropriately enough in 2005, the centenary of Albert Einstein's work on the photoelectric effect, in which he described radiation in terms of quanta, later termed photons. Glauber's aim in his seminal paper of 1963 was to move from a semi-classical description of the photon field in a light beam towards a full quantum theoretical description, in particular to describe correlation effects. In Glauber's words, "There is ultimately no substitute for the quantum theory in describing quanta."

Roy Glauber (second from left) at the Quark Matter conference in August. Glauber has received the Nobel prize for his work in the field of optics, but his expertise has for many years extended also to particle physics.

Glauber's name is also familiar in particle physics, however, where he is widely known for his "Glauber model", which nowadays has a range of applications in understanding heavy-ion interactions. In August 2005 he gave an opening talk at the Quark Matter 2005 conference in Budapest, 50 years after his original paper using diffraction theory to develop a formalism for calculating cross-sections in nuclear collisions. Glauber himself has regularly spent time as a visiting researcher in CERN's theory division, from 1967 until the mid-1980s.

The work of Hall and Hänsch is by contrast a *tour de force* in experimentation. In developing a measurement technique known as the optical frequency comb, they have made it possible to measure light frequencies to within an accuracy of 15 digits. The "comb" exploits the interference of lasers of different frequencies, which produces sharp, femto-second pulses of light at extremely precise and regular intervals. This allows precise measurements to be made of light of all frequencies and has many applications in both fundamental and applied fields.

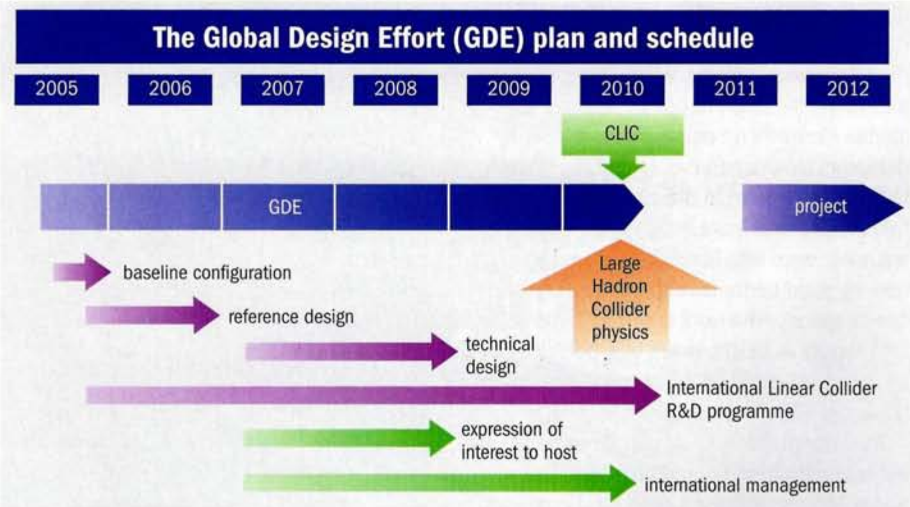
In particular, in particle physics the technique is allowing precise measurements of asymmetries between matter and antimatter, and possible drifts in the fundamental constants. Hänsch himself is a member of the ATRAP collaboration, which has successfully made antihydrogen at CERN's Antiproton Decelerator (AD) (*CERN Courier* December 2001 p5). Moreover, the frequency comb technique is being used in the ASACUSA experiment at the AD, which studies the spectroscopic properties of anti-protonic helium (*CERN Courier* May 2004 p31).

CERN

Barish presents plans for the ILC

The schedule of the Global Design Effort (GDE) for the future International Linear Collider (ILC) was an important topic at the meeting in September of CERN's Scientific Policy Committee. Barry Barish, head of the GDE, presented a report on the progress made since the International Technology Review Panel announced the technology choice for the ILC in August 2004 (*CERN Courier* October 2004 p5).

Since the first ILC workshop, which was held at KEK in November 2004, work has been progressing towards a reference design. This year a second workshop was held in August at Snowmass in the US to refine the ideas. The reference design should be completed by the end of 2006, to be followed by a technical design report two years later. By 2010 the technical design report, together with the scientific results from the Large Hadron Collider and input from the CLIC Test Facility (CTF3) at CERN, will allow a decision on the future of the ILC.



The Global Design Effort for the International Linear Collider schedule aims for a technical design report by the end of 2008 and a decision on the final shape of the project in 2010.

BUDKER INSTITUTE

KEDR adds new precision to meson mass measurements

In October 2005 the VEPP-4M collider at the Budker Institute of Nuclear Physics started its latest run with the KEDR detector. This continues a series of experiments that are exploiting the method of resonant depolarization (which was proposed and developed at the Budker Institute) to make precise measurements of masses in the region of the Ψ to Υ mesons (Skrinsky and Shatunov 1989).

Progress in understanding the resonant depolarization technique, as well as a new detection system for Touschek electron pairs (intrabeam scattering), has resulted in a significant improvement in the accuracy of the beam energy determination with KEDR. The error in a single measurement of the beam energy has reached a level of 1 keV, corresponding to a relative accuracy of 0.7 ppm. Figure 1, for example, illustrates a very clear jump in the counting rate of Touschek pairs, allowing a precise measurement of the depolarization frequency directly related to the beam energy. In 2002 this led to a measurement of the mass of the J/Ψ with a relative accuracy of 4 ppm: $M_{J/\Psi} = 3096.917 \pm 0.010 \pm 0.007$ MeV (Aulchenko *et al.* 2003). Compared with the previous experiment in 1980, this represented a sevenfold decrease in the uncertainty in the mass.

In 2004 the masses of the Ψ′ and Ψ(3770) were measured in a second run in KEDR. The results, which are shown in figure 2, were presented recently at the HEP2005 conference in Lisbon in July. The preliminary values of the masses of the Ψ′ and Ψ(3770) are $3686.117 \pm 0.012 \pm 0.015$ MeV and $3773.5 \pm 0.9 \pm 0.6$ MeV, respectively.

The precise measurement of the masses of the J/Ψ and Ψ′ mesons provides a mass scale in the energy region around 3 GeV, which forms the basis for an accurate determination of the mass for all charmed particles and the τ lepton. Since the width of the τ is proportional to its mass to the fifth power, high-precision tests of the Standard Model are very sensitive to the accuracy of this mass. At present the accuracy of the τ's mass is dominated by the accuracy of the measurement by the Beijing Spectrometer (Bai *et al.* 1996).

KEDR began the measurement of the mass of the τ in spring 2005. Using the same method as the Beijing Spectrometer, the collaboration plans to determine the mass by measuring the energy dependence of the cross-section near threshold. The aim is also to improve the statistics of τ decays, benefiting from the precise knowledge of the beam energy. In KEDR the energy is measured by two methods: resonant depolarization for a high-accuracy measurement once a day, and Compton backward scattering for monitoring the beam energy drift during data collection. Data processing is currently in progress.

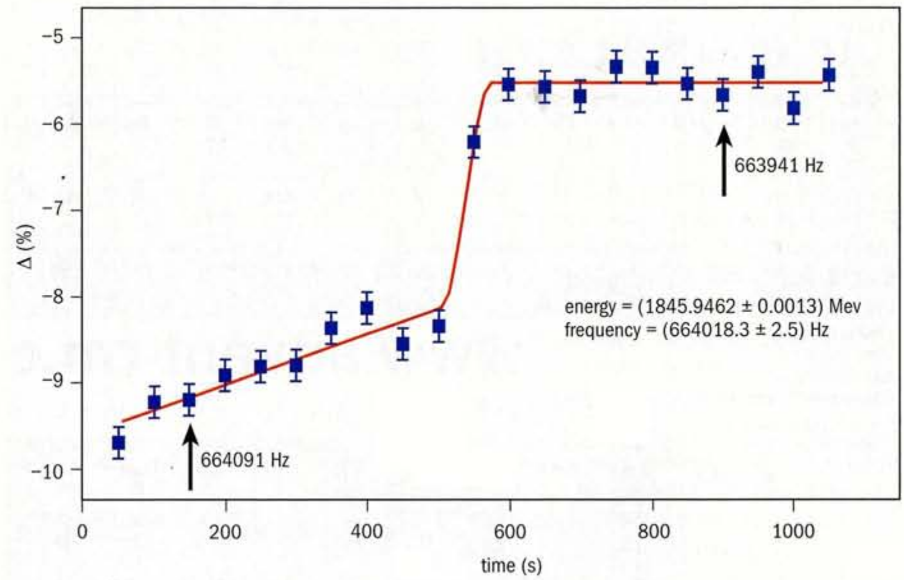


Fig. 1. The "jump" in the counting rate of Touschek electron pairs (intrabeam scattering) during a frequency scan with a depolarizer over the range 664091–663941 Hz.

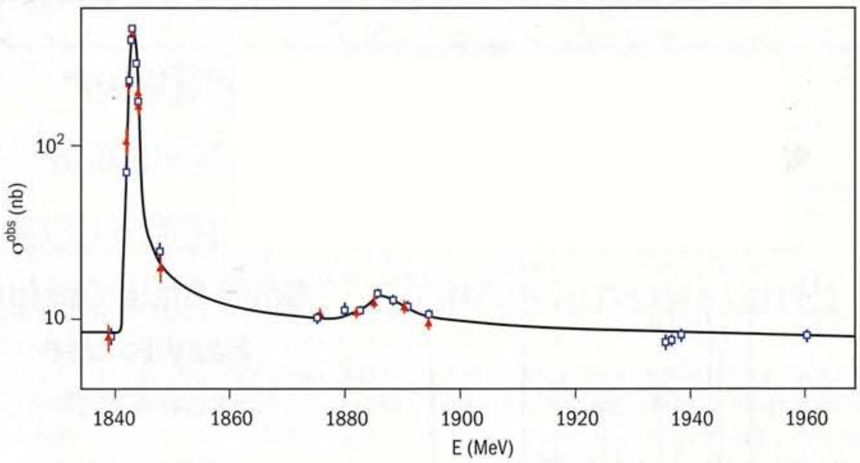


Fig. 2. The energy dependence of the visible cross-section of multihadron production shows clearly the peaks corresponding to the Ψ′ and the Ψ(3770).

Further reading

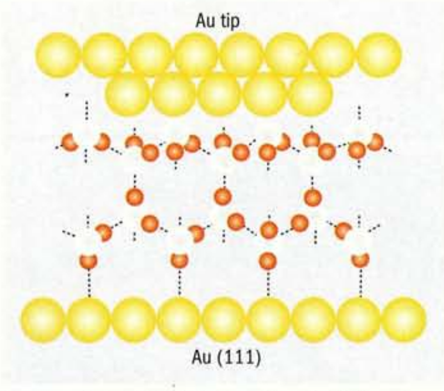
V M Aulchenko *et al.* 2003 *Phys. Lett. B* **573** 63.
J Z Bai *et al.* 1996 *Phys. Rev. D* **53** 20.
A N Skrinsky and Yu M Shatunov 1989 *Sov. Phys. Usp.* **32** 548.

Compiled by Steve Reucroft and John Swain, Northeastern University

Electric fields create hot ice

Ice at room temperature? Don't worry – this is not the deadly "ice-nine" of Kurt Vonnegut's novel *Cat's Cradle*, but rather a special state found to exist in the presence of high-electric fields. Heon Kang of Seoul National University, Korea, and colleagues were using an electrochemical scanning tunnelling electron microscope – which has an electrically charged tip – to look at how electrons move through water to a gold surface below. Measurements indicated a solid barrier, which was interpreted as the electric field driving the alignment of water molecules into a solid.

Theorists had predicted that such an effect could occur, but at about a thousand times the field strength in this experiment. Kang and colleagues observed the effect at a mere 1 million V/m, or close to the breakdown voltage for air. Fields of this strength can occur in many places, from cracks in rocks to across cell membranes, so this new type of hot ice may be more common than anyone had imagined.



The electric field between the gold tip of an STM and a negatively biased gold surface, Au (111), may align water molecules so they form ice. Here white and red spheres represent the oxygen and hydrogen atoms as they appear in the ice structure.

Further reading

Eun-Mi Choi *et al.* 2005 *Phys. Rev. Lett.* **95** 085701.

Bose–Einstein feels the Casimir effect

Two quintessentially quantum phenomena are the Casimir effect, whereby two electrically neutral objects exert forces on each other by distorting the zero-point fluctuations in the vacuum, and the Bose–Einstein condensation. Bringing these together, Eric Cornell and his colleagues at the University of Colorado, Boulder, have set up a pancake-shaped Bose–Einstein condensate of rubidium atoms, several micrometres thick, in a magnetic trap just below a silica plate.

Watching the condensate oscillate at various distances 6–10 μm from the plate, the researchers could determine the Casimir force from the way it pulled differently on the near and far sides of the pancake. The results came out in good agreement with expectations from theory, but perhaps the most interesting thing about this measurement is the shift in focus away from the condensate itself and towards interesting things that can actually be done with this novel state of matter.

Further reading

D M Harber *et al.* 2005 *Phys. Rev. A* **72** 033610.

New nanorods are harder than diamond

Natalia Dubrovinskaia of the University of Bayreuth and her colleagues have made carbon that is harder than diamond. Squeezing together buckyballs, each made of 60 carbon atoms, at 20 GPa and 2200 °C, the group reports the formation of a translucent cylinder made of diamond nanorods that is about 0.2–0.4% denser than natural diamond. This is the densest form of carbon that has been determined experimentally and may find applications in very hard coatings for tools.

Further reading

Natalia Dubrovinskaia *et al.* 2005 *App. Phys. Lett.* **87** 083106.

Nanotechnology gives new twist to measuring spin

Nanotechnology and spintronics are two technologies that are supposed to revolutionize computing. Now Anatoly Mal'shukov of the Russian Academy of Sciences, Moscow, and colleagues have suggested that merging the fields could lead to interesting new devices. The group proposes that the flow of spin-polarized electrons could be detected as a measurable torsion in a tiny crystalline bridge.

The idea builds on something that is familiar to high-energy physicists: a strained crystal can provide an electric field in its rest frame that looks like a magnetic field to particles travelling through the crystal. A twisting of the bridge in response to the current of tiny magnets (the electrons) could provide a way of measuring the spin associated with that current. So far the work is theoretical, but it could lead to very real devices.

Further reading

A G Mal'shukov *et al.* 2005 *Phys. Rev. Lett.* **95** 107203.

Amazon puts the pressure on Earth

This almost sounds like something from the era of CERN's Large Electron–Positron collider when distortions due to solid-earth tides were found to affect the beam energies. It turns out that a Global Positioning System (GPS) station in Manaus, close to the centre of the Amazon basin, has been registering an up-and-down motion of about 50–75 mm a year. A close look by Michael Bevis of Ohio State University, Columbus, tracked this down to the rising and falling levels of the Amazon river pushing the ground up and down over the course of the year. If the interpretation is correct, this is the first measurement of an elastic response of the earth to changes in weight of a river system.

Further reading

Michael Bevis *et al.* 2005 *Geophys. Res. Lett.* **32** L16308.

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

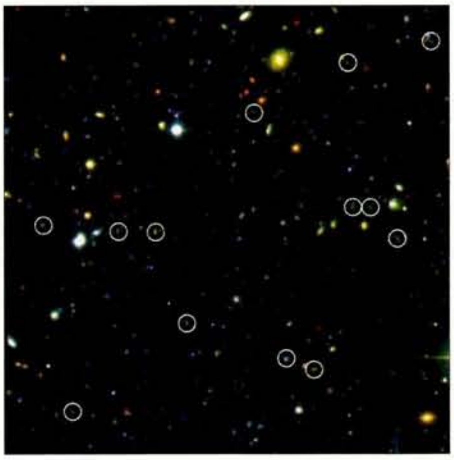
VLT astronomers discover new population of distant galaxies

A team using the Very Large Telescope (VLT) of the European Southern Observatory (ESO) has identified a much larger population of distant galaxies than previously estimated. The new population mainly consists of galaxies forming stars at a very high rate.

The determination of the number of galaxies in the universe at different epochs is crucial for constraining models of the formation and evolution of galaxies. Counting galaxies in deep astronomical images is relatively simple, but measuring their redshift – hence, their distance and the epoch in the history of the universe when we see them – requires taking a spectrum of each galaxy.

Until now, measuring the spectrum of distant and therefore faint galaxies needed a great deal of observing time on the largest telescopes. Astronomers therefore had to select carefully the candidate high-redshift galaxies based on their brightness and colour. However, it now seems that they have been too restrictive in their criteria, thus missing a large population of distant galaxies with strong ultraviolet emission.

The discovery of this population of bright and distant galaxies was made possible by the Visible Multi-Object Spectrograph (VIMOS) on Melipal, one of the four 8.2 m telescopes of the VLT. Instead of measuring the spectrum of one galaxy at a time, VIMOS can measure simultaneously the spectra of about 1000 galaxies in a single field.



This image from the Canada–France–Hawaii Telescope shows a small patch of the sky (3 × 3 arcmin) in the Cetus (the Whale) constellation. Circles indicate the 13 distant galaxies present in this small field out of the 970 identified in total by the VIMOS survey team. (Courtesy LAM-OAMP/CFHT.)

The unique capabilities of VIMOS allowed a team of French and Italian astronomers to determine systematically the redshift of all the galaxies in a given sky area and a given range of brightness. From a total of about 8000 galaxies, almost 1000 were measured at a redshift between 1.4 and 5, corresponding to looking back 9–12 billion years.

The results published by O Le Fèvre and collaborators show that the number density of galaxies at a redshift of around 3 exceeds previous estimates by a factor of 1.6 for the faintest galaxies and of 6.2 for the brightest ones. Around a redshift of 4 the number of galaxies was underestimated by a factor of 2–3.5. It seems therefore that a large population of bright galaxies at high-redshift was completely overlooked.

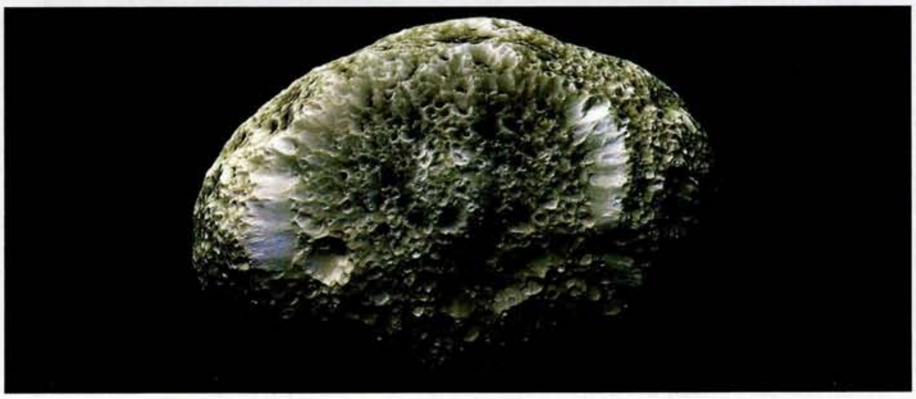
The newly identified population escaped previous studies mainly because of relatively high ultraviolet emission, which is emitted by massive young stars. The ultraviolet luminosity of these galaxies allows the estimate that their star-formation rate is in the region of 10–100 solar masses per year; currently in the Milky Way only a few solar masses of gas and dust are converted into stars every year. This discovery has profound implications for the history of star formation in the universe and for current theories of the formation and evolution of galaxies.

Further reading

O Le Fèvre *et al.* 2005 *Nature* **437** 519.

Picture of the month

This surprising view of Saturn's moon Hyperion was taken on 26 September when the Cassini spacecraft flew by at a distance of only 500 km. This small moon has a surface dotted with craters and modified by some unknown process creating a strange "spongy" appearance, unlike any other moon pictured so far. Hyperion is 266 km across, about the size of the moon Gabrielle found to be orbiting the newly discovered 10th planet, which has been dubbed Xena by its discoverers (*CERN Courier* September 2005 p12). (Courtesy NASA/JPL/SSI.)



A look back to CERN Courier vol. 2, November 1962

TRIBUTE

Niels Bohr 1885–1962

While this issue was in preparation news came of the death in Copenhagen on 18 November of Prof. Niels Bohr. World-renowned as a physicist and as a man, he is remembered here at CERN especially for the leading role he played in our foundation, and as the leader of the Theoretical Study Group, in his own Institute of Theoretical Physics, in the early days before the laboratory at Meyrin was ready, as well as for his guidance as a member of the Scientific Policy Committee.

On the day the news was received, Prof. Weisskopf, himself a former student and collaborator of Bohr's, wrote the following appreciation:

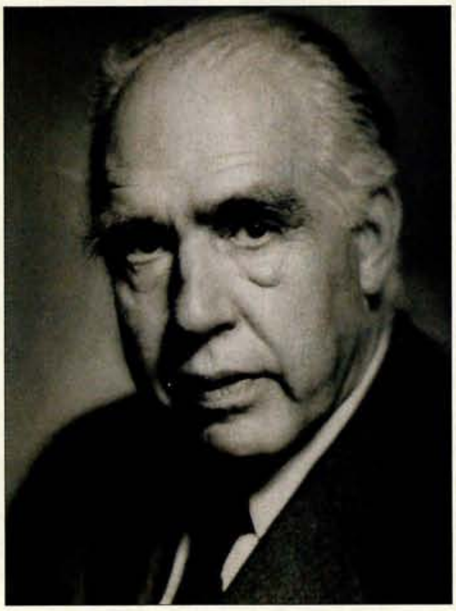
"The flags at CERN are flying at half mast. CERN has lost the greatest of its founders. The world has lost a great man.

Niels Bohr died yesterday after a life full of achievements. He discovered in 1913 the fundamental role of the quantum in the structure of the atom and since then he was the intellectual leader of the greatest scientific breakthrough in the history of human search into the nature of things.

Before Bohr, nobody knew about the structure of matter; after Bohr the material phenomena with which we are surrounded are well understood. Because of Bohr, we know how light is radiated and absorbed, how atoms join into molecules and how electricity produces its effects, and our knowledge even penetrates into the secrets of the atomic nucleus. Never before was so much explained by so few in such a short period of time as it was under Niels Bohr's leadership.

It was his way of looking at the atom which gave science a tool of comprehension, so all embracing, that it was possible for the first time to consider all natural phenomena from the hottest star to the living cell, as the effect of one fundamental principle.

His influence is felt wherever science is pursued all over the world. CERN would not exist if it had not been for the untiring efforts of Niels Bohr to bring about in the heart of Europe an international laboratory devoted to the innermost structure of matter. He always looked at science as an endeavour which goes beyond national boundaries, not only as a means for research but also as a bond between men.



Niels Bohr. (Photo courtesy of H and H Jacobsen, Copenhagen.)

The significance of Niels Bohr for humanity cannot yet be estimated. We are too near to his work and to the developments which his work has created. Future generations will recognize how his work stands out as a tower of achievement in the culture of our days."

EDITOR'S NOTE

With the death of Niels Bohr in November 1962, the world, and CERN, lost a great man. The *CERN Courier* published not only the appreciation, reprinted here, from the director-general at the time, Victor Weisskopf, but also the full text of the tribute that Weisskopf gave before the CERN staff. Up until his death, Bohr had been a member of the Scientific Policy Committee, so he would have contributed to the report presented to Council at the meeting also described here – a meeting that approved the Bannier committee's recommendations on an increasing budget.

CERN COUNCIL

Council session discusses growth of our organization

On 12 October, delegates from the 13 Member States, together with observers from Turkey and Yugoslavia, gathered at CERN for a special session of Council, under the presidency of Mr J Willems (Belgium).

Their main purpose was to discuss the report on the programme and budget, drawn up earlier this year by a working party headed by Mr J H Bannier, director of the Netherlands Organization for the Development of Pure Research (ZWO). The report, which was briefly discussed at the Council meeting last June, was approved in its broad lines. Among its proposals are recognition of the need for CERN to continue growing, with expenditure increasing by between 10 and 14 per cent per year for the next few years, and a procedure for long-term planning and budgeting. In future, planning will be on a continuing 4-year basis: each year a budget for the next year will be fixed, together with a firm estimate for the following one, and broad indications must also be given for the two years after that.

The members of the Council heard a statement by Prof. C F Powell (UK) who, as chairman of the Scientific Policy Committee, reported the assessment of CERN made by this body. "The judgement and aspiration of those who founded CERN have been most brilliantly vindicated," he said. "Every month brings important discoveries... and there can be hardly any doubt that in the next decade this process will continue and... bring radical changes in our understanding of matter and in our basic conception of it. Through the development of CERN, Europe has to make very valuable contributions to these great developments. In all the Member States, physicists see CERN as their chief place of experiment... and sometimes forego equipment and resources in order that CERN can be better supported. The Scientific Policy Committee concludes that CERN plays an indispensable part in the development of European physics and this institution can have a brilliant future."

● Extracted from a one-page report.

COMPUTING NEWS

Compiled by Hannelore Hämmerle and Nicole Crémel

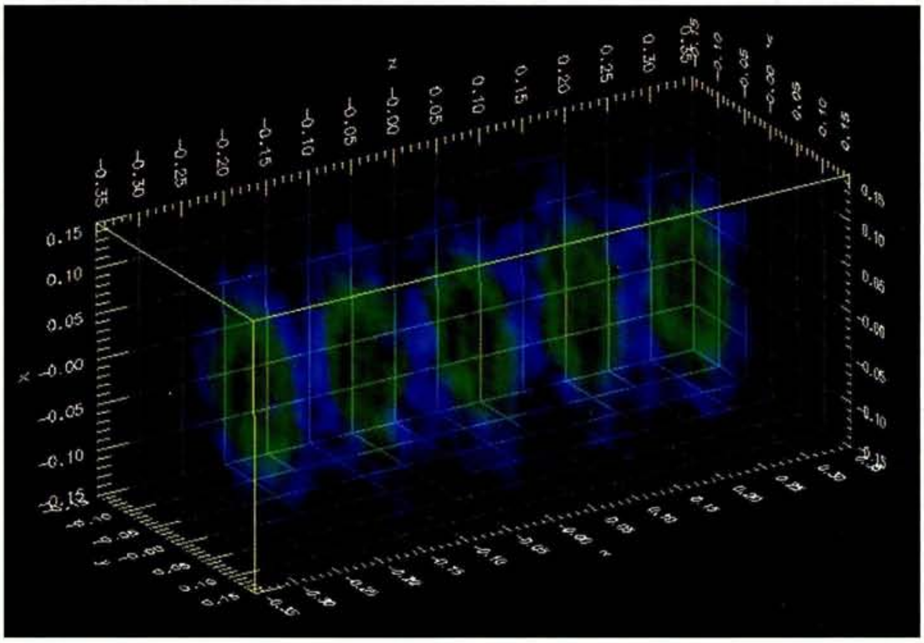
COMPUTER MODELLING

Synergia provides new 3D tool

The Synergia project has reached a major milestone with the release of Synergia version 1.0. Developed by the Advanced Accelerator Modelling team at the Fermilab Computing Division, the software simulates the behaviour of particles in an accelerator, emphasizing three-dimensional models of collective beam effects. The physics model, algorithmic implementation, interface and benchmarks are described in detail in the paper "Synergia: an accelerator modelling tool with 3-D space charge", currently in press at the *Journal of Computational Physics*.

Panagiotis Spenzouris and James Amundson lead the Synergia project to develop advanced accelerator-modelling tools. Accelerator modelling studies the passage of individual particles through the components of an accelerator, which act as lenses guiding the particles. Tracking individual particles requires elaborate modelling, but is not very computationally intensive. This changes dramatically when the forces created by the beam itself are taken into account. An example is the repulsive force generated when a large number of particles of the same charge are confined to a small region of space. Since modern accelerator beams contain tens of trillions of particles, modelling such collective effects is very important to optimize particle throughput and minimize particle loss. Synergia combines state-of-the-art single-particle tracking with self-consistent modelling of collective beam effects.

Synergia version 1.0 reuses and extends existing accelerator-physics codes together with new physics, integration and interface modules. The implementation is optimized for massively parallel computers because simulating collective beam effects is computationally intensive. Typical large-scale Synergia applications run on 32–512 processors on Linux clusters and the IBM SP3 at the National Energy Research Scientific Computing Center in the US. The user interface uses Python to control the simulation and specify the accelerator parameters. The accelerator components can be described using the Methodical Accelerator Design (MAD) language. Synergia provides facilities for automatically generating location-specific job description, as well as tools for job tracking and job submission.



Phase-space distribution of five linac bunches after injection in the Fermilab Booster.

Development of the next major version of Synergia is already under way. The new framework will be fully Python-driven, allowing much greater flexibility and easier addition of new physics modules.

Successful Synergia applications include the reproduction of the theoretical predictions for simple configurations, comparisons with other accelerator codes, and detailed simulations of real accelerators. Most prominent in this latter category is the study of space-charge effects during the injection phase at the Fermilab Booster accelerator. These studies included comparisons between the simulation and the results of controlled-beam experiments and provided useful insight into machine operations.

The Synergia project is partially funded by the US Department of Energy's Scientific Development through Advanced Computing (SciDAC) programme. The team works in close collaboration with Fermilab Accelerator Division personnel and SciDAC colleagues from Lawrence Berkeley National Laboratory and the TechX Corporation.

Further reading

For more information see http://cepa.fnal.gov/psm/aas/Advanced_Accelerator_Simulation.html.

Les gros titres de l'actualité informatique

AWARDS

Tim Berners-Lee receives Quadriga award

Tim Berners-Lee, W3C director and inventor of the World Wide Web, is one of the laureates of Germany's Quadriga award, a prize bestowed every year in four categories: political, economic, social and cultural.

The organizers of the award named Berners-Lee one of the most important scientists of the 20th century, second only to Albert Einstein. Berners-Lee, who was named Greatest Briton in 2004, invented the World Wide Web while he was working at CERN and made the protocols freely available.

Berners-Lee was awarded the prize in Berlin on 3 October, the date when Germany celebrates its unification in 1990. The award is named after the famous sculpture on top of the Brandenburg Gate, with the goddess of peace driving a four-horse chariot (the quadriga) representing the interplay of harmony, friendship, valour and state wisdom for the welfare of all. It reflects the Brandenburg quadriga's change from symbolizing partition to being an emblem of unification.

The quadriga on top of the Brandenburg Gate. (Copyright Pawel Jerzak/Dreamstime.com.)

The other winners of the €25 000 prize this year include former German chancellor Helmut Kohl for his achievements in reuniting Germany in 1990; the Aga Khan, for his charitable institution, the Aga Khan Development Network; and six Northern Irish women who challenged the Irish Republican Army over the murder of a Catholic man, Robert McCartney, in Belfast in January 2005.

WORLD WIDE WEB

W3C specification guidelines assist authors

The Quality Assurance (QA) Working Group of the World Wide Web Consortium (W3C) has concluded its work with the completion of *Specification Guidelines*, issued as a W3C Recommendation. This document provides clear instructions to writers and editors on how to create technical specifications that are precise and clear.

W3C launched the QA Activity in 2001, following a successful workshop, with the following goal: to improve W3C specifications by offering guidelines to W3C groups, by reviewing draft specifications for adherence to these guidelines, and by helping W3C groups develop test suites and other tools to promote interoperable implementations.

Since that time, the QA Working Group has produced six documents, including the new recommendation – *Specification Guidelines*. By identifying requirements and "good practices", these guidelines help both W3C and other specification authors create and describe technologies in ways that make it easier for developers to implement them as intended. The QA Working Group has also put together templates for writing conformance clauses as well as full specifications.

In addition the group has published the *QA Framework Primer*, *QA Test FAQ*, the *Variability in Specifications Working Draft* and the *QA Handbook*. One of the group's most famous and useful documents is the *W3C Quality Assurance Matrix*, a list of more than a hundred W3C specifications, which includes links to conformance clauses, test suites and validators.

SUPERCOMPUTERS

FZJ's new supercomputer offers extra power

A new supercomputer, Jülicher Blue Gene/L (JUBL), has been installed at the Forschungszentrum Jülich (FZJ), offering far higher performance of up to 5.6 teraflops. Stefan Krieg, of the Central Institute for Applied Mathematics (ZAM), was the first scientist to use the machine, in his studies of the forces between nature's smallest building blocks, the quarks. "Thanks to JUBL we now have the possibility to simulate the world of quarks with unprecedented accuracy," said Krieg.

JUBL, an IBM computer, currently occupies 60th place in the supercomputer ranking list, which is headed by the bigger and 30 times more powerful machine at the Lawrence Livermore Laboratory. However, JUBL's 2048 processors are connected by a variety of networks, which gives it flexibility to operate in varied areas. Not only particle physicists, but also biologists, chemists, astrophysicists and mathematicians will use JUBL to simulate their models.

Currently, about 150 groups from Germany and the rest of Europe use the supercomputer resources (now at 14.5 teraflops) at Jülich. Apart from the hardware, the FZJ also has many years of know-how and modern software tools to optimize the use of supercomputers in many fields. If the architecture of JUBL proves successful for the complex applications at Jülich, a successor 50 times more powerful could soon arrive at the ZAM.

The Blue Gene/L supercomputer provides power and flexibility. (Copyright IBM Corporation.)

PRODUCT INFORMATION

Chemical Abstracts Service and **FIZ Karlsruhe** have officially launched their new STN AnaVist software for patent and competitive intelligence analysis. STN AnaVist includes an intellectually based standardization of fielded data from patent and non-patent literature, coupled with an interactive approach for viewing data relationships. TN AnaVist was developed to meet the need to assimilate and present information more effectively to derive greater value from search results, and to support management in making business-critical decisions. Details and pricing information can be found at www.stn-international.de/stninterfaces/stnanavist/stn_anavist.html.

Toradex of Switzerland has cut the price of the 520 MHz version of its popular Colibri XScale PXA270 SODIMM-sized module. Colibri features 64 MB of SDRAM (32 Bit), 32 MB of Flash (32 Bit), 16 Bit Stereo Audio in/out, 100MBit Ethernet, 32 Bit external bus, CompactFlash/PCMCIA, LCD and touch screen control, CMOS/CCD image sensor interface, MSL (up to 416 Mbps), I2C, SPI, SDCard, Memory Stick, USB Host/Device, PWM and many digital inputs/outputs. Windows CE or Linux is included with every Colibri module. For more information see www.toradex.com/e/products.html.

Calendar of events

November

12–18 Supercomputing – High Performance Networking and Computing
Seattle, Washington, US,
http://sc05.supercomputing.org

30 – 2 December IFIP International Conference on Network and Parallel Computing (NPC 2005)
Beijing, China,
http://grid.hust.edu.cn/npc05

December

5–8 IEEE International Conference on e-Science and Grid Technologies
Melbourne, Australia,
www.gridbus.org/escience

7–9 International Symposium on Parallel Architectures, Algorithms, and Networks (I-SPAN)
Las Vegas, Nevada, US,
http://sigact.acm.org/ispan05/

February 2006

13–17 15th International Conference on Computing in High Energy and Nuclear Physics
Mumbai, India,
www.tifr.res.in/chep06/

March 2006

1–3 TridentCom 2006
Barcelona, Spain,
www.tridentcom.org

Internet growth requires new transmission protocol

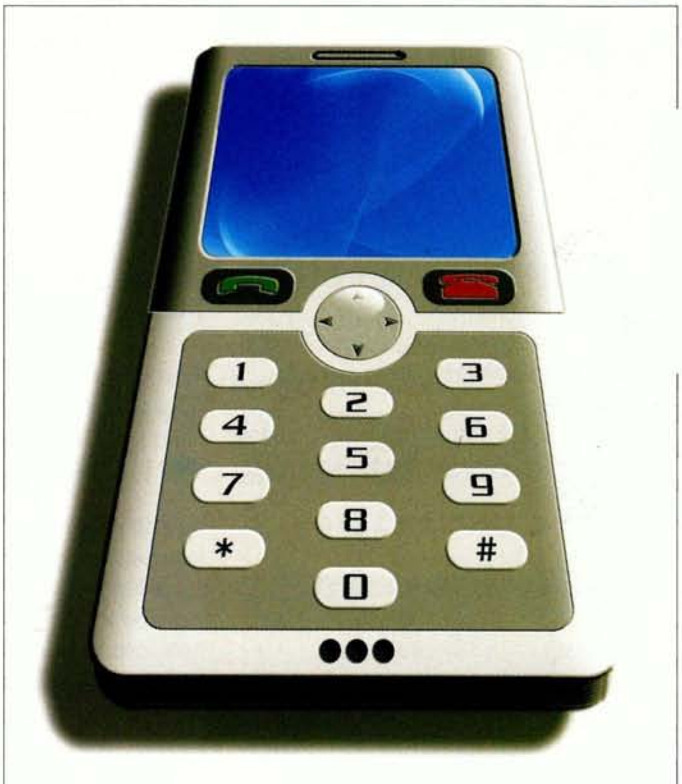
TCP governs the bulk of Internet traffic, but is struggling to keep up. **Damon Wischik** examines possible solutions to the current problems of sending data at high rates.

Since the birth of the Internet, the Transmission Control Protocol (TCP) has been phenomenally successful. Today TCP controls the transmission of most traffic on the Internet – everything from downloading web pages to peer-to-peer file sharing. TCP's development began in 1974, it was overhauled in 1988, and since then its design has served well with barely any changes, even though data rates have rocketed from 30 kbit/s to 40 Gbit/s. There is now, however, a growing feeling in the network-research community that it is time for another major overhaul. We understand better the mathematics of how data networks work, and hope that we might be able to overhaul TCP so that it is fit for a long time to come.

To understand why TCP has been so successful, and to explain why an overhaul is needed, it is useful to know more about what TCP does. TCP code sits on every computer and device connected to the Internet. It is built into Windows, Linux, mobile phones, etc. When one computer has to transmit data to another, the data are split into packets. TCP decides when to send packets and how many to send. It has two duties: to resend any packets that may have been lost on the way (for example, because of congestion, or signal interference on a wireless link), and to limit the sending rate so that the network does not become congested.

The second duty was not part of TCP's original specification. It was added in 1988 by Van Jacobson at the Lawrence Berkeley National Laboratory (LBNL). In October 1986, the data rate between the University of California at Berkeley and LBNL – 400 m apart – collapsed from 32 kbit/s to just 40 bit/s. Jacobson and colleagues realized the problem: the network was congested, which caused packets to become lost in transit; TCP sent those packets again, and made the congestion worse. Jacobson's grand idea was that TCP could control congestion (Jacobson 1988). He proposed an extension to TCP: it should steadily increase its transmission rate when the network seems uncongested, and reduce the rate whenever it detects a lost packet (figure 1, p21).

Arguably, Jacobson's congestion control is what has made the Internet succeed. In 1988, "proper" networks like national telephone networks were very different from the Internet. Someone sitting in the network control centre monitored traffic; when links came close to overload, traffic was rerouted – and when this was not enough your telephone call was simply blocked. In the Internet there is no central control, yet Jacobson's TCP achieves a similar effect, using the collected decentralized intelligence of all the computers connected to the Internet.



TCP controls how data are sent over the Internet, across systems that nowadays reach even to mobile phones. Transmission speeds range from kilobits per second on mobile phones to gigabits per second on Internet routers. (Image copyright Daniel Gilbey/Dreamstime.com.)

Congestion is a fundamentally difficult problem, and the Internet was the first large-scale demonstration that it could be solved without central control. This allowed the Internet to grow to become a global network. Nevertheless, network control centres are not out of business yet; Jacobson's TCP does not attempt to balance traffic across different parts of a network, nor to provide the speedy delivery that real-time voice and video need. These are still problems for which we need central control.

However, Jacobson's TCP is beginning to show its age. A driving

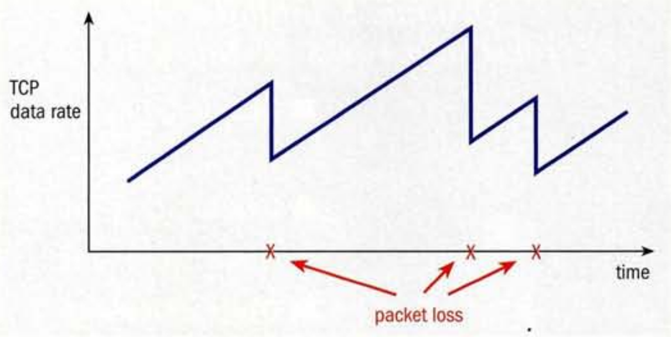


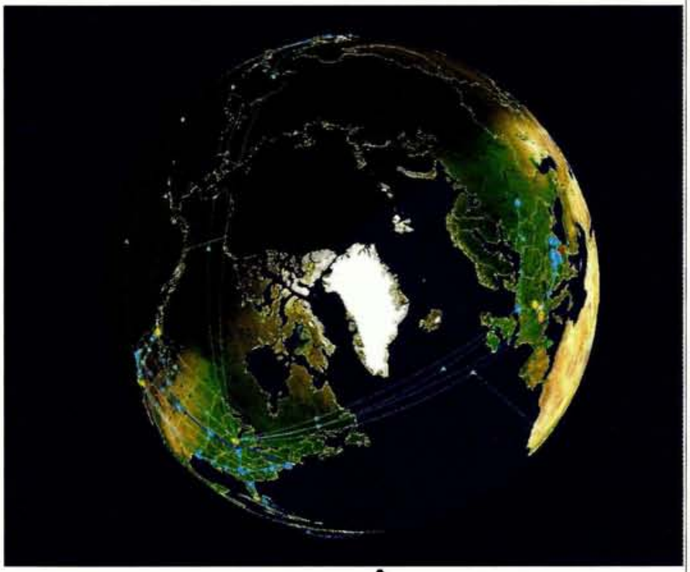
Fig. 1. Jacobson's TCP increases its data rate steadily when the network is uncongested, and cuts its data rate when packets are lost, indicating congestion.

problem is the difficulty of getting high data rates, even when capacity is available. Consider a physicist in CERN trying to send data to SLAC in California. The round-trip time (RTT), i.e. the time it takes to send a packet from CERN to SLAC and to receive an acknowledgement that the packet arrived, is a little over 200 ms. When the network is working smoothly and no packets are lost, TCP increases its data rate by one packet per RTT, every RTT – to achieve a data rate of 100 Mbit/s therefore takes 333 s. On the other hand, every time a packet is lost in transit, TCP cuts its data rate by half. That means that it takes 167 s to recover from a single packet loss. To achieve a sustained average data rate of 100 Mbit/s, no more than 1 in 1.9 million packets can be lost. But cosmic rays and imperfections in the optical fibre links are likely to corrupt at least one packet in every 1 million! TCP needs to change if it is to support such high data rates – but injudicious changes could bring about another congestion collapse.

The scientific approach is to devise mathematical models for congestion control, and to test them experimentally. The approach that physicists have developed for studying complex systems seems to work well for the Internet: first explore the detailed rules of interaction between atomic entities (like TCP connections), then formulate high-level laws about the behaviour of large collections of these entities (e.g. with differential equations), then investigate the consequences of these laws.

Indeed, Richard Feynman himself studied communications systems in this spirit. Daniel Hillis describes Feynman's work at the Thinking Machines Corporation (Hillis 1989): "By the end of that summer of 1983, Richard had completed his analysis of the behaviour of the router, and much to our surprise and amusement, he presented his answer in the form of a set of partial differential equations. To a physicist this may seem natural, but to a computer designer, treating a set of Boolean circuits as a continuous, differentiable system is a bit strange. Feynman's router equations were in terms of variables representing continuous quantities such as 'the average number of 1 bits in a message address.'"

In the past few years our theoretical understanding of Internet congestion control has blossomed. We now have a variety of mathematical models that help us evaluate how the network behaves, and what the consequences will be of rapidly growing communications capacity. Frank Kelly from the Statistical Laboratory in Cambridge has made a major contribution, which won him the IEEE Koji Kobayashi prize (Kelly 2000). Research groups in computer science, engineering and mathematics are pushing the boundary at Berkeley, Caltech, Stanford, Cambridge, Turin, Paris, the University of Massachusetts, University College London, MIT and elsewhere.



Data transfers from CERN monitored by the MonALISA system.

Theoretical models now exist for alternatives to TCP that can be mathematically proved not to cause congestion collapse, and work is ongoing to test these models experimentally. Some of these alternatives promise to balance traffic across the Internet, and to deliver high data rates and much better quality of service for services like voice-over-Internet-Protocol (VoIP) and live video – all at the same time. It seems likely that these theories will find their way into the mainstream Linux and Windows kernels within the next five years or so, and we hope that they will serve for many years to come.

Further reading

For further information see Sally Floyd's High Speed TCP website at www.icir.org/floyd/longpaths.html.

W Daniel Hillis 1989 *Physics Today* **42** (2) 78.
V Jacobson 1988 *ACM SIGCOMM Computer Communication Review* **18** (4) 314.
F P Kelly 2000 *Phil. Trans. Roy. Soc.* **A358** 2335.

Résumé

Pas de bouchons sur l'Internet de la prochaine génération

Le protocole TCP de contrôle de la transmission, qui commande la manière dont les données sont lancées dans le réseau, a connu un succès phénoménal et il régit aujourd'hui l'essentiel de la circulation sur l'Internet. Cependant, on pense de plus en plus qu'une révision complète s'impose pour faire face à un trafic toujours croissant. On dispose maintenant des modèles théoriques et des preuves mathématiques montrant que des solutions autres que TCP existent et qu'elles n'entraînent pas de blocage total. Des travaux sont en cours pour en faire la démonstration expérimentale.

Damon Wischik, *University College London.*

Experiments finally unveil a precise portrait of the Z

After six years of preparation, a 300 page article combining thousands of measurements from five different experiments presents a precision study of the properties of the Z boson.

From 1989 to 1995, the Large Electron–Positron collider (LEP) at CERN provided collisions at centre-of-mass energies, 88–94 GeV. This range includes the mass of the Z boson, which is thus produced as a resonance, the Z pole (figure 1). In this first phase of LEP running (LEP-1), the four large state-of-the-art detectors ALEPH, DELPHI, L3 and OPAL recorded 17 million Z decays. Over a similar period, from 1992 to 1998, the SLD experiment at SLAC in the US collected 600 000 Z events at the world's first high-energy linear collider, the SLAC Linear Collider (SLC), with the added advantage of a longitudinally polarized electron beam.

Now, the five big experimental collaborations have submitted a joint paper for publication in *Physics Reports*. Signed by 2500 authors, "Precision electroweak measurements on the Z resonance" summarizes and combines thousands of cross-section and asymmetry measurements. The data sample consists of the world set of electron–positron interactions at the Z pole. The Z boson decays to all kinematically accessible fermion–antifermion pairs, i.e. all leptons and quarks, except the top quark. Hence the collected data allow very detailed investigations of the properties of the Z-boson and Z-to-fermion couplings.

Combining the wealth of measurements has been a long and painstaking task. The large data sample has demanded advanced analysis techniques to reduce systematic measurement uncertainties in the sophisticated detectors to below the statistical precision. This is one of the main reasons for the long delay between the end of data-taking at Z-pole energies and the publication of this report. Any measurement used in the combined review had to have been published in a journal beforehand. Furthermore, to exploit the power of the combined data sets of the experiments, it was necessary to investigate how each measurement could be meaningfully and properly combined with other measurements, while accounting for correlated systematic effects.

Early in the LEP programme, the high-precision measurements resulting from complex analyses made it clear that a dedicated effort by experts was required to tackle such inter-collaborational aspects of the scientific work. This led to the formation of the LEP Electroweak Working Group (LEP-EWWG), the first of several LEP-wide working groups. The LEP-EWWG consists of members from the experimental collaborations and is responsible for properly combining both published and preliminary results of the LEP experiments. It makes use of the expertise of its members in scrutinizing the measurements for combination purposes, in particular in evaluating correlations between measurements. The group also maintains close contact with many theorists, who are advancing calculations of the many observables and their radiative corrections, thus reducing the theoretical uncertainties to the level required by the precision of the data. The great success of the LEP-EWWG has spawned similar efforts at other accelerators, for example, between experiments at B-factories and between experiments at Fermilab's Tevatron.

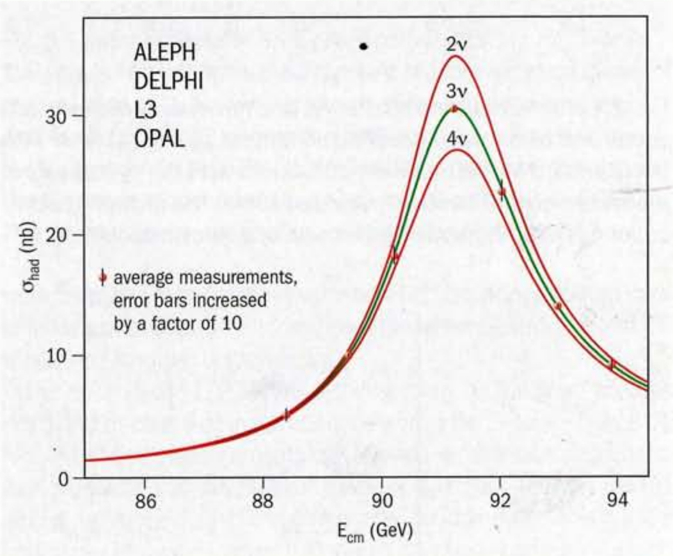


Fig. 1. Measurements of the hadron production cross-section around the Z resonance. The curves indicate the predicted cross-section for two, three and four neutrino species with Standard Model couplings and negligible mass.

One of the first and foremost combined measurements of the Z resonance at LEP concerns the mass and total decay width of the Z boson and the number of light neutrino species (figure 1). The determination of these quantities is based on total cross-sections measured accurately at precisely known centre-of-mass energies; here the LEP beam-energy calibration is crucial. In 1986, during the preparation of the LEP physics programme, it was estimated that the Z-boson mass and width could possibly be measured to an accuracy of about 50 MeV. Today, the Z-pole report shows that an accuracy nearly 25 times better has been finally achieved. The ▷

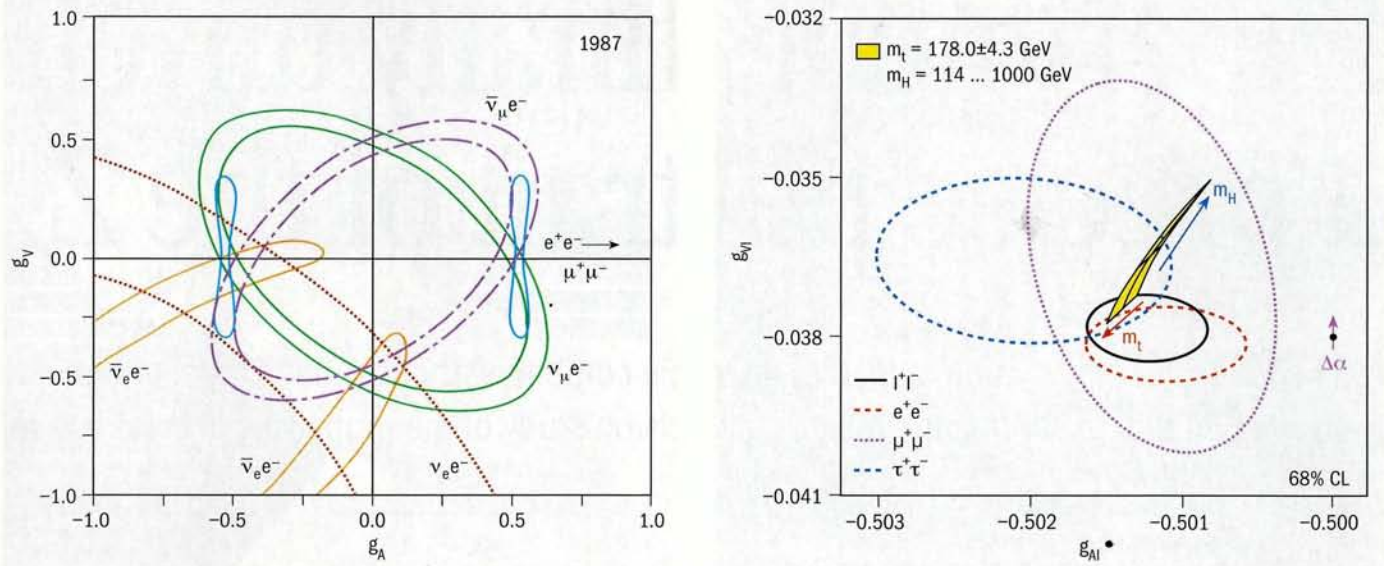


Fig. 2. Left: the neutrino scattering and low-energy e^+e^- annihilation data available in 1987 constrained the values of the effective vector and axial-vector coupling constants, g_V and g_A, to lie within broad bands. Their intersections helped establish the validity of the Standard Model and were consistent with the hypothesis of lepton universality. Right: the results of the LEP/SLD measurements at a much expanded scale. The flavour-specific measurements demonstrate the universal nature of the lepton couplings unambiguously on a scale of approximately 0.001.

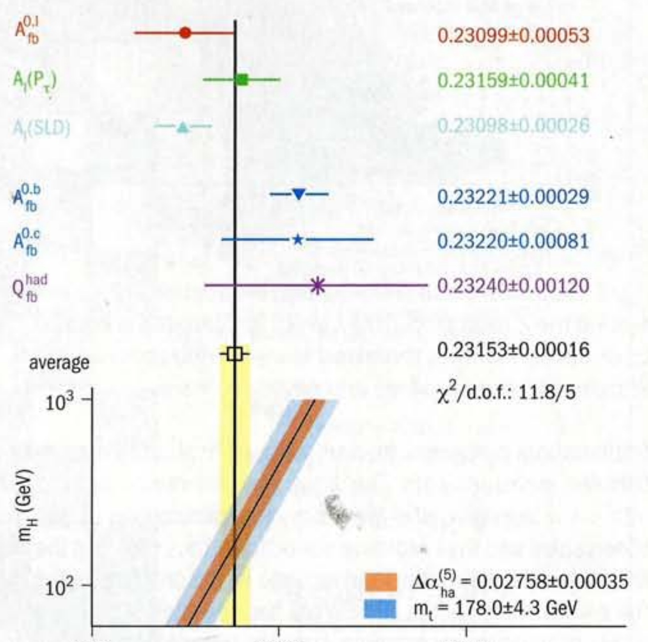


Fig. 3. Comparison of the effective electroweak mixing angle $\sin^2\theta_{eff}^{lept}$ derived from measurements depending on lepton couplings only (top) and on quark couplings as well (bottom). Also shown is the Standard Model prediction for $\sin^2\theta_{eff}^{lept}$ as a function of the Higgs mass, m_H. The additional uncertainty of the prediction is parametric and dominated by the uncertainties in hadronic vacuum polarization, $\Delta\alpha_{had}^{(5)}$, and the mass of the top quark, m_t, shown as bands. The total width of the two bands is the linear sum of these effects.

mass of the Z is now known with a relative precision of 2.3×10^{-5}, $M_Z = 91187.5 \pm 2.1$ MeV – approaching that of the Fermi constant – and the Z width is known to better than 1‰, $\Gamma_Z = 2495.2 \pm 2.3$ MeV. Precision luminosity measurements for normalizing the total cross-section measurements were indispensable in determining to better than 3‰ accuracy the number of light neutrino species, and thus the number of fermion families, to be the three known, with $N_\nu = 2.9840 \pm 0.0082$.

In measurements of Z decays to heavy quarks, beauty and charm, the SLD experiment, despite smaller Z statistics, has made competitive measurements by virtue of the small beam spot and beam-pipe size of the SLC. This allowed the vertex detector to be positioned very close to the interaction point, in turn leading to precision tagging of b and c quarks produced in Z decays. The LEP-EWWG is therefore collaborating intensively and successfully with colleagues from SLD in the area of heavy-quark production at the Z pole.

By measuring production cross-sections and forward–backward asymmetries both for the inclusive hadronic final state and for identified charged lepton and quark flavours, the experiments scrutinized the couplings between fermions and the Z boson in great detail. While the LEP experiments provided high-statistics measurements, SLD with beam polarization made a unique contribution in measuring both left–right and left–right forward–backward asymmetries. With both sets of measurements, the effective vector and axial-vector coupling constants for leptons and quarks have now been determined with a precision several orders of magnitude better than before (figure 2). The comparison in terms of the effective electroweak mixing angle is shown in figure 3. The two most precise determinations of this quantity, based on the left–right asymmetry measured by SLD and the $b\bar{b}$ forward–backward asymmetry measured at LEP, differ by 3.2σ. Both measurements are still statistics-dominated, but is this the first hint of new physics or just a fluctuation?

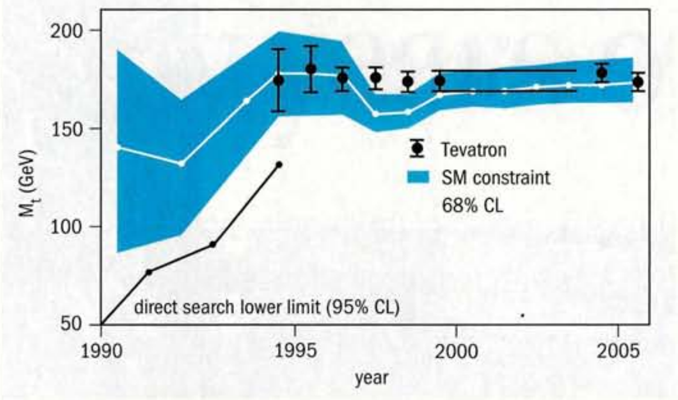


Fig. 4. Comparison of direct and indirect determinations of the mass of the top quark, m_t, as a function of time. The shaded area denotes the indirect determination of m_t at 68% confidence level derived from the analysis of radiative corrections within the framework of the Standard Model using precision electroweak measurements. The dots with error bars at 68% confidence level denote the direct measurements of m_t performed by the Tevatron experiments CDF and DO. Also shown is the 95% confidence-level lower limit on m_t from the direct searches before the discovery of the top quark. Predictions and measurements are in close agreement.

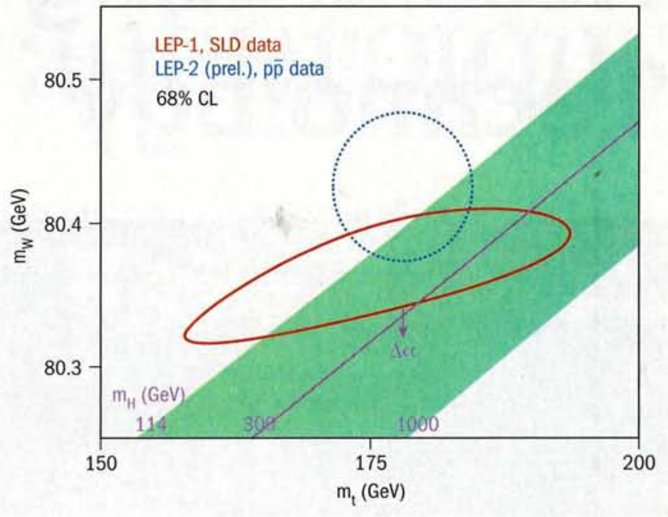


Fig. 5. Contour curves of 68% probability in the (m_t, m_W) plane. The shaded band shows the Standard Model prediction based on the value of G_F for various values of the Higgs-boson mass and fixed $\Delta\alpha^{(5)}_{had}(m_Z^2)$; varying the hadronic vacuum polarization by $\Delta\alpha^{(5)}_{had}(m_Z^2) = 0.02758 \pm 0.00035$ yields an extra uncertainty on the Standard Model prediction shown by the arrow labelled $\Delta\alpha$. The direct measurement of m_W used here is preliminary.

The precision of the results is such that small changes with respect to the Born-term expectation are measured quantitatively. These electroweak radiative corrections are sensitive to all kinds of virtual particles, notably the top quark and the Higgs boson, neither of which is directly produced at Z-pole energies. Analysing the precision measurements within the framework of the Standard Model, particularly once LEP started up, allowed good predictions of the mass of the top quark a few years before the quark itself was discovered and its mass measured by the Tevatron experiments CDF and D0 in 1995 (figure 4). The close agreement between prediction and direct measurement is one of the greatest triumphs of particle physics. Similar agreement is found in the case of the W-boson mass.

Based on this success in predicting the masses of heavy particles, the precision electroweak measurements are now also used to predict the mass of the as yet unobserved Higgs boson, in the framework of the Standard Model, in conjunction with measurements of the mass and width of the W boson at LEP-2 and the Tevatron and the mass of the top quark measured at the Tevatron. These analyses predict the Higgs boson to weigh at most a few hundred giga-electron-volts (figure 5), but we must wait for the Large Hadron Collider to show if this prediction is correct.

The Z-pole report has been in the works for the past six years, pushed forward by a team of editors: Richard Kellogg, Klaus Moenig, Günter Quast, Mike Roney, Peter Rowson, Pippa Wells and Martin Grünewald (chair of the LEP-EWWG and lead editor), and in the early stages Robert Clare and Roger Jones. Meetings on reviewing the status, discussing the draft, and planning the next steps were held every few months at CERN, with participants attending in person, by videoconference or by telephone. In fact, some of the editors have yet to meet each other in person – an event is foreseen later this year. This work proceeded in parallel with the regular LEP-EWWG work, involving many more physicists, which provides updated combinations of both published and preliminary results twice a year, for winter and summer conferences.

The effort of the LEP-EWWG will now focus on electron–positron collisions at centre-of-mass energies above the Z-pole – the LEP-2 running. These measurements test fermion–antifermion and boson-pair production at the highest possible energies, thereby investigating the properties of the charged W bosons – the mass, width and decay properties, as well as gauge couplings between the electroweak gauge bosons – in similar detail to that achieved for the Z boson. With the analyses using the available Z-pole data now concluded, the combined Z-pole results will stand for a long time, to be improved only if a future linear collider takes physics data at the Z resonance.

● The paper (CERN-PH-EP/2005-041 and SLAC-R-774) can be found at www.arXiv.org/abs/hep-ex/0509008. For more about the LEP-EWWG see www.cern.ch/LEPEWWG.

Résumé

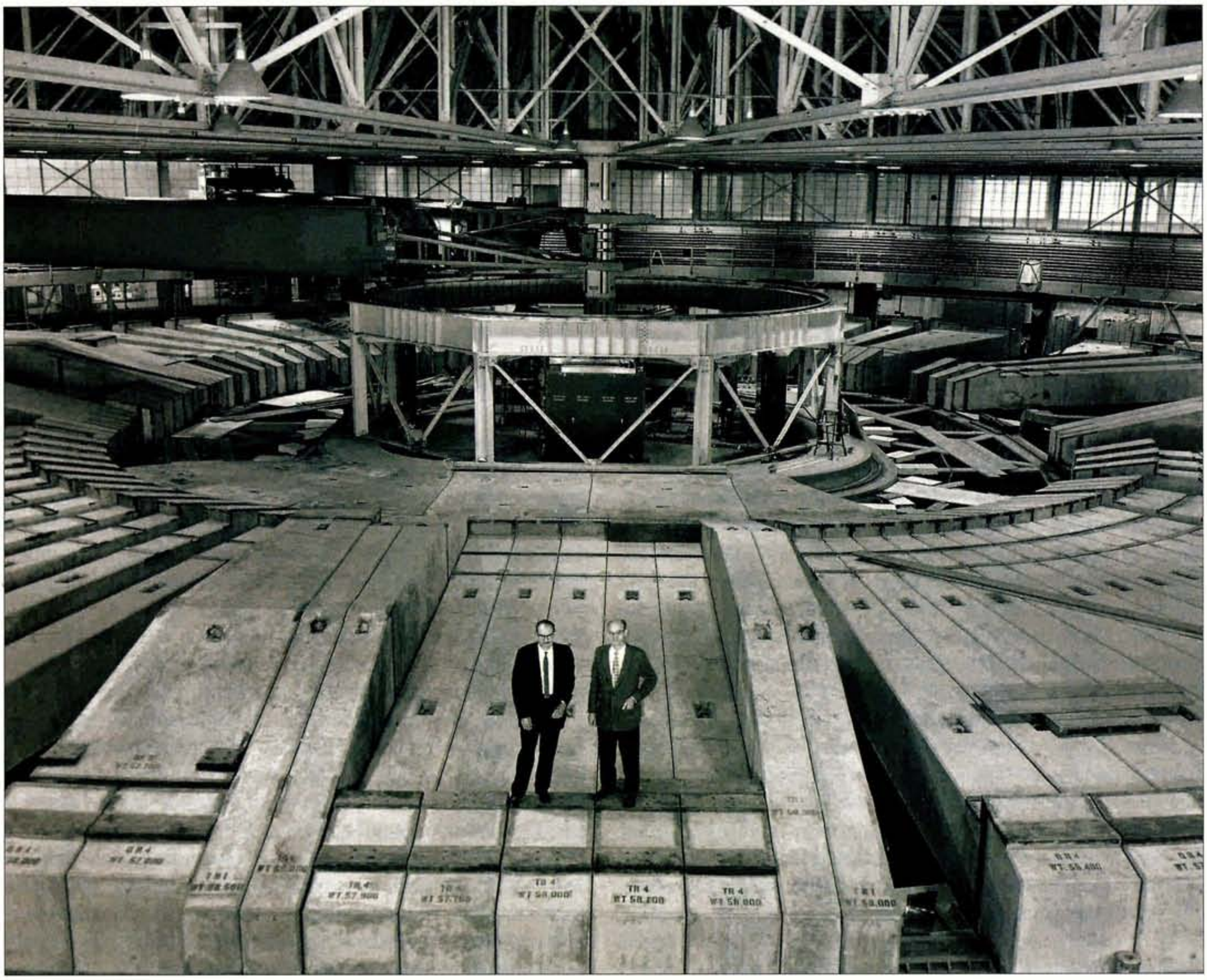
Le boson Z vu sous haute résolution

Au terme de six ans de préparation, les collaborations ALEPH, DELPHI, L3 et OPAL au CERN et la collaboration SLD au SLAC ont soumis pour publication dans Physics Reports *un article coordonnant des milliers de mesures. Cet article de 300 pages, signé par 2500 auteurs, résume et combine les mesures de sections efficaces et d'asymétries du Grand collisionneur électron–positon LEP du CERN et du collisionneur linéaire du SLAC dans une méta-analyse qui offre un portrait à haute résolution du boson Z.*

Martin Grünewald, *University College Dublin.*

Fifty years of antiprotons

It is 50 years since Emilio Segrè, Owen Chamberlain and their group first created an antiproton. **Lynn Yarris** describes their achievement at Berkeley's Bevatron in 1955.



Berkeley physicists Edward McMillan and Edward Lofgren, shown here on the shielding of the Bevatron, were part of the team that was put together by Ernest Lawrence to ensure that the new synchrotron would reach the 6.5 GeV needed to produce an antiproton. (All photographs in this article courtesy of Ernest Orlando Lawrence Berkeley National Laboratory.)

On 1 November 1955, *Physical Review Letters* published the paper "Observation of antiprotons" by Owen Chamberlain, Emilio Segrè, Clyde Wiegand and Tom Ypsilantis, at what was then known as the Radiation Laboratory of the University of California at Berkeley. This paper, which announced the discovery of the antiproton (for which Chamberlain and Segrè would share the 1959 Nobel Prize for Physics), had been received only eight days earlier. However, the story of the discovery of the antiproton really begins in 1928, when the eccentric and brilliant British physicist, Paul Dirac, formulated a theory to describe the behaviour of relativistic electrons in electric and magnetic fields.

Dirac's equation was unique for its time because it took into consideration both Albert Einstein's special theory of relativity and the effects of quantum physics proposed by Edwin Schrödinger and ▷

The team that discovered the antiproton at the Bevatron included, from left to right, Emilio Segrè, Clyde Wiegand, Edward Lofgren, Owen Chamberlain and Thomas Ypsilantis.

In 1955 the newly commissioned Bevatron was the world's most powerful particle accelerator, able to propel protons to energies of about 6.5 GeV.

Werner Heisenberg. While it worked well on paper, Dirac's rather straightforward equation carried with it a most provocative implication: it permitted negative as well as positive values for the energy *E*. Initially few physicists seriously considered Dirac's idea because no-one had ever observed particles of negative energy. From the standpoint of both physics and common sense, the energy of a particle could only be positive.

Attitudes towards Dirac's equation changed dramatically in 1932, when Carl David Anderson reported the observation of a negatively charged electron in a project at the California Institute of Technology that originated with his mentor, Robert Millikan. Anderson named the new particle the "positron". Both Dirac and Anderson would win Nobel Prizes for Physics for their discoveries. Dirac shared the 1933 Nobel prize with Schrödinger, and Anderson shared the 1936 Nobel prize with Victor Hess. However, the existence of the positron, the antimatter counterpart of the electron, raised the question of an antimatter counterpart to the proton.

As Dirac's theory continued to explain successfully phenomena associated with electrons and positrons, it followed – from the revised standpoints of both physics and common sense – that it should also successfully explain protons. This would then demand the existence of an antimatter counterpart. The search for the antiproton was under way, but it would get off to a very slow start, as it would be another two decades before a machine capable of producing such a particle became available.

Enter the Bevatron

Anderson discovered the positron with a cloud chamber during investigations of cosmic rays, but it was extremely difficult, if not impossible, to use the same approach for finding the antiproton. If physicists were going to find the antiproton, they were first going to have to make one.

However, even with the invention of the cyclotron in 1931 by Ernest Lawrence, earthbound accelerators were not up to the task. Physicists knew that creating an antiproton would require the simultaneous creation of a proton or a neutron. Since the energy required to produce a particle is proportional to its mass, creating a proton–antiproton pair would require twice the proton rest energy, or about 2 billion eV. Given the fixed-target collision technology of the times, the best approach for making 2 billion eV available would be to strike a stationary target of neutrons with a beam of protons accelerated to an energy of about 6 billion eV.

In 1954, Lawrence commissioned the Bevatron accelerator to reach energies of several billion electron-volts – then designated as BeV (now universally known as GeV) – to be built at his Radiation Laboratory in Berkeley. (Upon Lawrence's death in 1958, the laboratory was renamed the Lawrence Berkeley National Laboratory.) This weak-focusing proton synchrotron was designed to accelerate protons up to 6.5 GeV. Though never its officially stated purpose, the Bevatron was built to go after the antiproton. As Chamberlain noted in his Nobel laureate lecture, Lawrence and his close colleague, Edwin McMillan, who co-discovered the principle behind synchronized acceleration and coined the term "synchrotron", were well aware of the 6 GeV needed to produce antiprotons and made certain the Bevatron would be able to get there.

Armed with a machine that had the energetic muscle to make antiprotons, Lawrence and McMillan put together two teams to go after the elusive particle. One team was led by Edward Lofgren, who managed operations of the Bevatron. The other was led by Segrè and Chamberlain. Segrè had been the first student to earn his physics degree at the University of Rome under Enrico Fermi. He had, with the aid of one of Lawrence's cyclotrons, discovered technetium, the first artificially produced chemical element. He was also one of the scientists who determined that a plutonium-based bomb was feasible, and his experiments on the scattering of neutrons and protons and proton polarization broke new ground in understanding nuclear forces. Chamberlain had also studied under Fermi, and under Segrè as well. He was Segrè's assistant on the Manhattan Project at Los Alamos while still a graduate student, and later joined Segrè at Berkeley to collaborate on the nuclear-forces studies.

Making an antiproton was only half the task; no less formidable a challenge was to devise a means of identifying the beast once it had been spawned. For every antiproton created, 40 000 other particles would be created. The time to cull the antiproton from the surrounding herd would be brief: within about 10^{-7} s after it appears, an antiproton comes into contact with a proton and both particles are annihilated.

According to Chamberlain, again from his Nobel lecture, it was understood from the start that at least two independent quantities would have to be measured for the same particle to identify it as an antiproton. After considering several possibilities, it was decided that they should be momentum and velocity.

Measuring momentum

To measure momentum, the research team used a system of magnetic quadrupole lenses, which was suggested to them by Oreste Piccioni, an expert on quadrupole magnets and beam extraction, who was then at Brookhaven National Laboratory. The idea was to set up the system so that only particles of a certain momentum interval could pass through. As the Bevatron's proton beam struck a target in the form of a copper block, fragments of nuclear collisions would emerge in all directions. While most of these fragments were lost, some would pass through the system. For specifically defined values of momentum, the negative particles among the captured fragments would be deflected by the magnetic lenses into and through collimator apertures.

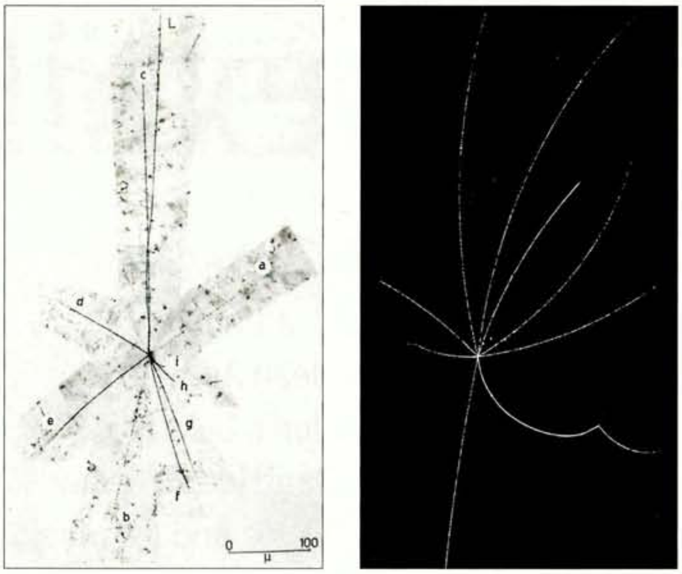
To measure velocity, which was used to separate antiprotons from negative pions, the researchers deployed a combination of scintillation counters and a pair of Cherenkov detectors. The scintillation counters were used to time the flight of particles between two sheets of scintillator, 12 m apart. Under the specific momentum defined by Segrè, Chamberlain and their collaborators, relativistic pions traversed this distance 11 ns faster than the 51 ns it took for the more ponderous antiprotons. Signals from the two scintillators were set up to coincide only if they came from an antiproton. However, because it is possible for two pions to have exactly the right spacing to imitate the signal from an antiproton, the researchers also used the Cherenkov detectors.

One Cherenkov detector was somewhat conventional in that it used a liquid fluorocarbon medium. It was dubbed the "guard counter" because it could measure the velocity of particles moving faster than an antiproton. The second detector, which was designed by Chamberlain and Wiegand, used a quartz medium, and only particles moving at the speed predicted for antiprotons set it off.

In conjunction with the momentum and velocity experiments, Berkeley physicist Gerson Goldhaber and Edoardo Amaldi from Rome led a related experiment using photographic-emulsion stacks. If a suspect particle was truly an antiproton, the Berkeley researchers expected to see the signature star image of an annihilation event. Here the antiproton and a proton or neutron from an ordinary nucleus, presumably that of a silver or bromine atom in the photographic emulsion, would die simultaneously.

Success!

The antiproton experiments of Segrè and Chamberlain and their collaborators began in the first week of August, 1955. Their first run on the Bevatron lasted five consecutive days. Lofgren and his collaborators ran their experiments for the following two weeks. The Segrè and Chamberlain group returned on 29 August and ran experiments until the Bevatron broke down on 5 September. On 21 September, a week after operating crews had revived the Bevatron, Lofgren's group was to begin a four-day run, but instead it ceded its time to Segrè and Chamberlain. That day, the future Nobel laureates and their team found their first evidence of the antiproton based on momentum and velocity. Subsequent analysis of the emulsion-stack images revealed the signature annihilation star that confirmed the discovery. In all, Segrè, Chamberlain and their group counted a total of 60 antiprotons produced during a run that lasted approximately 7 h.



Left: the first annihilation star imaged in the photographic-emulsion stack experiments, led by Gerson Goldhaber of the Segrè group, which confirmed the discovery of the antiproton. An antiproton enters from the top of the image and travels about 430 μm before meeting a proton. Nine charged particles emerge from the annihilation. Right: bubble-chamber image where an antiproton enters at the bottom. When it strikes a proton, four positive and four negative pions are created.

The public announcement of the antiproton's discovery received a mixed response. The *New York Times* enthusiastically proclaimed "New Atom Particle Found; Termed a Negative Proton", while the particle's hometown newspaper, the *Berkeley Gazette*, sombrely announced "Grim new find at UC". The Berkeley reporter had been told that should an antiproton come in contact with a person, that person would blow up. Today, 50 years on, antiprotons have become a staple of high-energy physics experiments, with trillions being produced at CERN and Fermilab, and no known human fatalities.

Résumé

Les 50 ans de l'antiproton

Le 1er novembre 1955, la revue Physical Review Letters *publiait un article annonçant la découverte de l'antiproton par une équipe du Radiation Laboratory de l'Université de Californie à Berkeley. L'expérience cruciale s'était déroulée auprès de l'accélérateur Bevatron. Elle avait innové avec l'utilisation de lentilles magnétiques quadripolaires et de détecteurs Chérenkov pour débusquer cette particule dont la théorie proposée par Dirac 20 ans auparavant impliquait l'existence.*

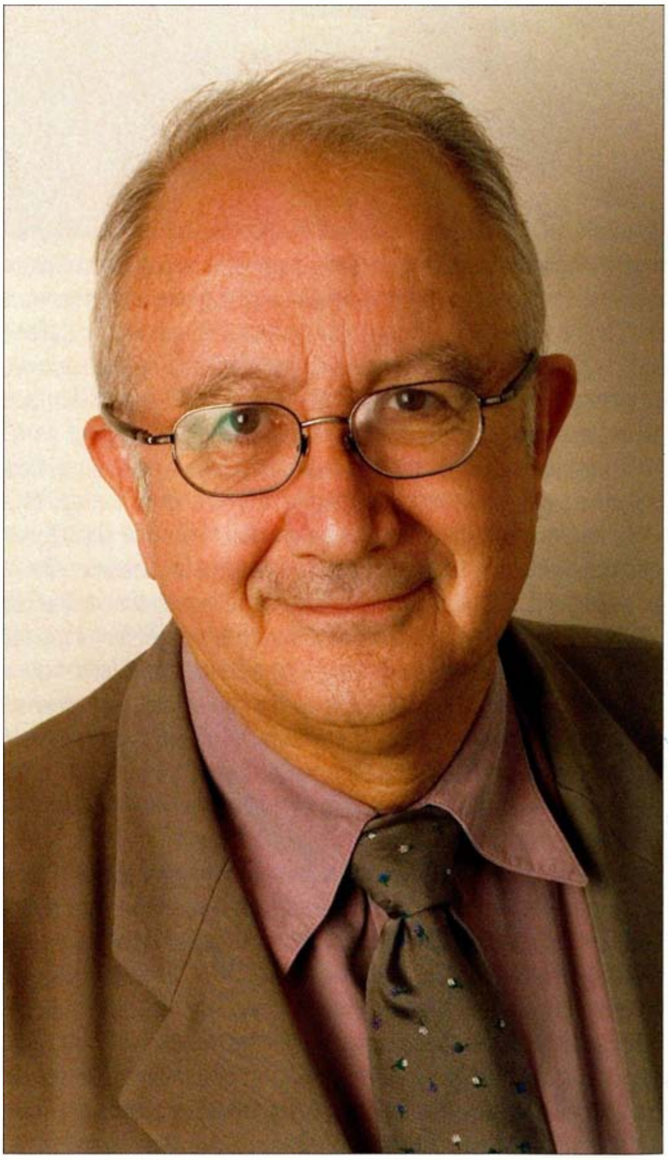
Lynn Yarris, *Lawrence Berkeley National Laboratory.*

New exhibition unites

The 1st European Research and Innovation Exhibition, held in Paris, attracted 24 000 visitors. Astrophysicist Jean Audouze, chairman of the exhibition's Scientific Committee, talked to **Beatrice Bressan** about the event's objectives and its impact.

The 1st European Research and Innovation Exhibition – the Salon Européen de la Recherche et de l'Innovation – took place in Paris on 3–5 June 2005 under the patronage of Jacques Chirac, president of France. The aim of the exhibition, which is to become an annual event, is to provide a place for players from a broad sector of activities to come together, creating a crossroads where people and ideas from both the public sector and the corporate world can meet. This year, the 130 exhibitors included CERN, the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) of the Centre National de la Recherche Scientifique (CNRS), and the Dapnia laboratory of the Commissariat á l'Energie Atomique, who together presented a stand showing examples of technology transfer.

Jean Audouze, senior CNRS researcher, is the founder and chairman of the exhibition's Scientific Committee. Consisting of scientific leaders in the world of research and innovation, this committee is responsible for the programme of events, in particular conferences and round-table discussions. Audouze himself has had a great deal of experience in communicating physics on the highest and broadest levels, as scientific adviser to the president of France (1989–1993) and as director of Paris's well known science museum, the Palais de la Découverte (1998–2004).



Jean Audouze, chairman of the Scientific Committee of the European Research and Innovation Exhibition.

The Te

How would you describe the role of research today, in the World Year of Physics?

Research is the driving force behind economic, cultural and social progress. The French government, much as the other European political leaders, has set a goal of devoting 3% of gross domestic product to research and development by 2010. Together, France and Europe are actively preparing for the future to meet the dynamic momentum of countries like the US, China and Japan, with whom competition is already very fierce. According to the OECD [Organization for Economic Co-operation and Development], gross domestic expenditure on research and development by member countries amounted to over $650 billion in 2001. The countries of the European Union contributed about $185 billion of this amount. France spent about $31 billion on research and development, which places it in second position in Europe and fourth worldwide, behind the US, Japan and Germany. Many researchers have started their own companies since 1999. Business incubators are playing a crucial role in the development of new companies, assisted by organizations that provide financing specifically for the creation of innovative companies. The biotechnology and nanotechnology sectors are at present leading in terms of the creation of new businesses.

Can you explain the event's objectives?

The exhibition combined information from fundamental research with its applications. It provided an opportunity for researchers, public and private institutions, universities and the top engineering and business schools in France (les grandes écoles), industrial and commercial companies, R&D departments, incubators, financing organizations, laboratory suppliers, local governments, technology parks

s people and ideas

World Year of PHYSICS 2005
www.physics2005.org

chnology Transfer stand of CERN, IN2P3 and Dapnia at the 1st European Research and Innovation Exhibition, held in Paris on 3–5 June 2005.

(technopoles), research associations and foundations to meet. They could present their activities, develop contacts to encourage professional development, discuss the establishment of new projects, start new partnerships, and negotiate financing for new businesses or research programmes.

What was the outcome of the three days?

The final balance is very positive. A total of around 24 000 people attended the event. In addition, the presence of many visitors at the conferences, at the round tables concerning the European research programme and the diffusion of scientific culture in Europe, and at events with the participation of the Nobel laureates in physics has shown the strong interest the public has in scientific topics.

How have politicians reacted to the measures required to maximize the value of scientific research?

The politicians have responded well to the scientists' needs, indeed a few programmes have received specific financing allocations. They appreciated the creative way the technological developments were presented to the public, and the debates on social impact to arouse awareness of the importance of science for everyday life.

What is the outlook for continuing the dialogue in research, education and industrial promotion? ▷

The perspective for the future is to make this event an annual rendezvous with the participation of other European institutions and national stands.

The World Year of Physics 2005 is an international celebration of physics. Events throughout the year have been highlighting the vitality of physics and its importance in the coming millennium, and have commemorated Einstein's pioneering contributions in 1905. How can the World Year of Physics bring the excitement and impact of physics, science and research to the public?

I am convinced that the World Year of Physics has been a success in terms of popularizing physics and in conveying enthusiasm for the subject among a large public. In each country, and especially in France, many very exciting events were set up with that goal and have attracted quite big audiences. We astrophysicists have a project to make 2009, the 400th anniversary of the use of the astronomical lens by Galileo, the World Year of Astronomy and Astrophysics.

How can worldwide collaborations and fundamental research laboratories such as CERN, CNRS and Dapnia inspire future generations of scientists?

This inspiration is induced by at least two factors: first, CERN, CNRS and Dapnia are involved in the most exciting aspects of fundamental research, e.g. the very nature of matter and the universe; second, their research programmes are planned for the coming decades: the forthcoming operation of the Large Hadron Collider at CERN and projects like VIRGO (which aims to detect gravitational waves) for CNRS and Dapnia should be very enticing for European newcomers to science.

● The CERN, IN2P3 and Dapnia stand showed examples of technology transfer and was prepared by CERN's Technology Transfer and Communication groups. In addition, CERN's Daniel Treille gave a talk "Miroirs brisés, antimatière disparue, matière cachée: le CERN mène l'enquête".

Further reading

For more information see www.salon-de-la-recherche.com.

Résumé

Recherche, innovation et affaires: un nouveau carrefour

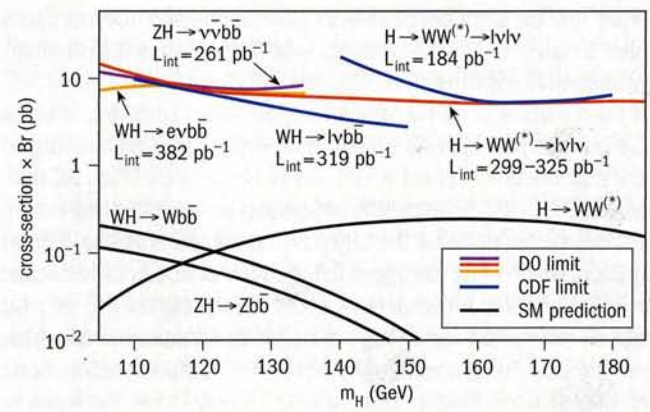
Le premier Salon européen de la Recherche et de l'Innovation (www.salon-de-la-recherche.com) s'est tenu à Paris en juin. Il avait pour objectif de rassembler les acteurs d'une large gamme d'activités et de créer un lieu d'échange afin de favoriser la réunion des personnes et des idées venues du secteur public et des secteurs industriels. Dans cet entretien, l'astrophysicien Jean Audouze, Président du Comité Scientifique du Salon, parle des objectifs scientifiques du salon et de son impact.

Beatrice Bressan, *CERN.*

Uppsala 2005: leptons, photons and a lot more

The biennial Lepton-Photon conference was held in Uppsala on 30 June – 5 July. The talks erected the impressive edifice known as the Standard Model and showed that experimental ingenuity has not yet shaken its foundations. **Francis Halzen** summarizes.

Attendees at Lepton-Photon 2005 queue to register in the entrance of the main hall at Uppsala University, Sweden.



Preliminary limits on Higgs physics from 380 pb^{-1} of Run II data in the CDF and D0 experiments at the Tevatron. Improved luminosity and analysis will push the limits down towards the Standard Model (SM) predictions.

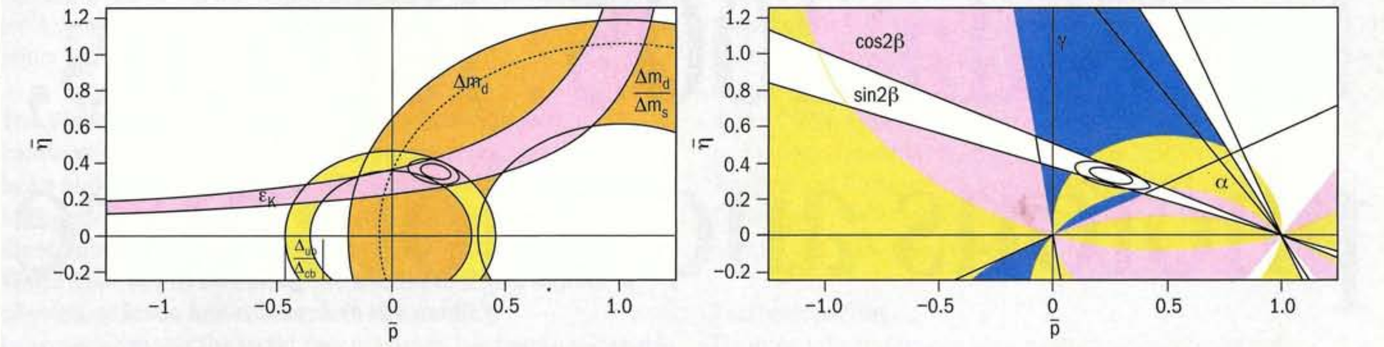
Twenty-five years ago at the Rochester meeting held in Madison, Leon Lederman said, "The experimentalists do not have enough money and the theorists are overconfident." Nobody could have anticipated then that experiments would establish the Standard Model as a gauge theory with a precision of one in 1000, pushing any interference from possible new physics to energy scales beyond 10 TeV. The theorists can modestly claim that they have taken revenge for Lederman's remark. However, as the Lepton-Photon 2005 meeting underlined, there is no feeling that we are now dotting the i's and crossing the t's of a mature theory. All the big questions remain unanswered; worse still, the theory has its own demise built into its radiative corrections.

The electroweak challenge

The most evident of unanswered questions is why are the weak interactions weak? In 1934 Enrico Fermi provided an answer with a theory that prescribed a quantitative relation between the fine-structure constant, α, and the weak coupling, $G \sim \alpha/M_W^2$, where M_W can be found from the rate of muon decay to be around 100 GeV (once parity violation and neutral currents, which Fermi did not know about, are taken into account). Fermi could certainly not have anticipated that his early phenomenology would develop into a renormalizable gauge theory that allows us to calculate the radiative corrections to his formula. Besides regular higher-order diagrams, loops associated with the top quark and the Higgs boson also contribute, and are consistent with observations.

One of my favourite physicists once referred to the Higgs as the "ugly" particle. Indeed, if one calculates the radiative corrections to the mass appearing in the Higgs potential, the same gauge theory that withstood the onslaught of precision experiments at CERN's Large Electron–Positron collider, the SLAC linear collider and Fermilab's Tevatron grows quadratically. Some new physics is needed to tame the divergent behaviour, at an energy scale, Λ, of less than a few tera-electron-volts by the most conservative of estimates. There is an optimistic interpretation, just as Fermi anticipated particle physics at 100 GeV in 1934, that the electroweak gauge theory requires new physics at 2~3 TeV, to be revealed by the Large Hadron Collider (LHC) at CERN and, possibly, the Tevatron.

Dark clouds have built up on this sunny horizon, however, because some electroweak precision measurements match the Standard ▷



Analysis from the UTfit collaboration, using no angles (left) and angles only (right), illustrates the precision – and redundancy – now achieved with the new measurements from the B-factories, Belle at KEK and BaBar at SLAC.

Model predictions with too high a precision, pushing Λ to around 10 TeV. Some theorists have panicked and proposed that the factor multiplying the unruly quadratic correction, $2M_W^2 + M_Z^2 + M_h^2 - 4M_t^2$, must vanish exactly. This has been dubbed the Veltman condition. It "solves" the problem because the observations can accommodate scales as large as 10 TeV, possibly even higher, once the dominant contribution is eliminated.

If the Veltman condition does happen to be satisfied, it would leave particle physics with an ugly fine-tuning problem reminiscent of the cosmological constant; but this is very unlikely. The LHC must reveal the "Higgs" physics already observed via radiative corrections, or at least discover the physics that implements the Veltman condition, which must still appear at 2~3 TeV although higher scales can be rationalized for other tests of the theory. Supersymmetry is a textbook example. Even though it elegantly controls the quadratic divergence by the cancellation of boson and fermion contributions, it is already fine-tuned at a scale of 2~3 TeV. There has been an explosion of creativity to resolve the challenge in other ways; the good news is that all involve new physics in the form of scalars, new gauge bosons, non-standard interactions, and so on.

Alternatively, we may be guessing the future while holding too small a deck of cards, and the LHC will open a new world that we did not anticipate. The hope then is that particle physics will return to its early traditions where experiment leads theory, as it should, and where innovative techniques introduce new accelerators and detection methods that allow us to observe with an open mind and without a plan.

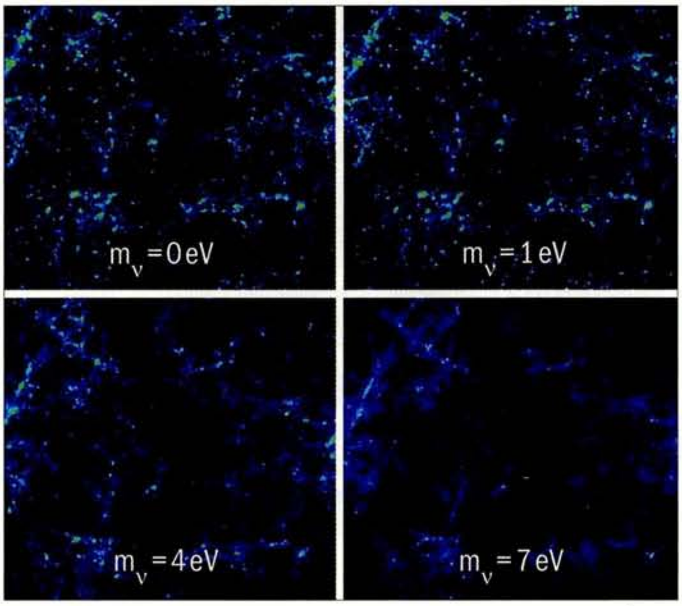
CP violation and neutrino mass

Another grand unresolved question concerns baryogenesis: why are we here? At some early time in the evolution of the universe quarks and antiquarks annihilated into light, except for just one quark in 10^{10} that failed to find a partner and became us. We are here because baryogenesis managed to accommodate Andrei Sakharov's three conditions, one of which dictates CP violation. Precision data on CP violation in neutral kaons have been accumulated over 40 years, and the measurements can, without exception, be accommodated by the Standard Model with three families of quarks. History has repeated itself for B-mesons, but in only three years, owing to the magnificent performance of the experiments at the B-factories – Belle at KEK and BaBar at SLAC. Direct CP violation has been established in the decay $B_d \rightarrow K\pi$ with a significance in excess of 5σ. Unfortunately, this result and a wealth of data contributed by the CLEO collaboration at Cornell, DAFNE at Frascati and the Beijing Spectrometer (BES) fail to reveal evidence for new physics. Given the rapid progress and the better theoretical understanding of the expectations in the Standard Model relative to the kaon system, the hope is that improved data will pierce the Standard Model's resistant armour. Where theory is concerned, it is worth noting that the lattice now does calculations that are confirmed by experiment (*CERN Courier* July/August 2005 p13).

A third important question concerns neutrino mass. A string of fundamental experimental measurements has led progress in neutrino physics. Supporting evidence from reactor and accelerator experiments, including first data from the reborn Super-Kamiokande detector, has confirmed discovery of oscillations in solar and atmospheric neutrinos. High-precision data from the pioneering experiments now trickle in more slowly, although evidence for the oscillatory behaviour in L/E of the muon neutrinos in the atmospheric-neutrino beam has become very convincing.

Nevertheless, the future of neutrino physics is undoubtedly bright. Construction at Karlsruhe of the KATRIN spectrometer, which by studying the kinematics of tritium decay will be sensitive to an electron-neutrino mass as low as 0.02 eV, is in progress, and a wealth of ideas on double beta decay and long-baseline experiments is approaching reality. These experiments will have to answer the great "known unknowns" of neutrino physics: their absolute mass and hierarchy, the value of the third small mixing angle and its associated CP-violating phase, and whether neutrinos are really Majorana particles. Discovering neutrinoless double beta decay would settle the last question, yield critical information on the absolute-mass scale and, possibly, resolve the hierarchy problem. In the meantime we will keep wondering whether small neutrino masses are our first glimpse of grand unified theories via the seesaw mechanism, or represent a new Yukawa scale tantalizingly connected to lepton conservation and, possibly, the cosmological constant.

Information on neutrino mass has also emerged from an unexpected direction – cosmology. The structure of the universe is dictated by the physics of cold dark matter and the galaxies we see today are the remnants of relatively small overdensities in its nearly uniform distribution in the very early universe. Overdensity means overpressure that drives an acoustic wave into the other components that make up the universe, i.e. the hot gas of nuclei and photons and the neutrinos. These acoustic waves are seen today in the temperature fluctuations of the microwave background, as well as in the distribu-



Simulations show that adding hot neutrino dark matter with a mass above about 1 eV begins to wipe out the small-scale structures in the universe.

tion of galaxies in the sky. With a contribution to the universe's matter similar to that of light, neutrinos play a secondary, but identifiable role. Because of their large mean-free paths, the neutrinos prevent the smaller structures in the cold dark matter from fully developing and this effect is visible in the observed distribution of galaxies.

Simulations of structure formation with varying amounts of matter in the neutrino component, i.e. varying neutrino mass, can be matched to a variety of observations of today's sky, including measurements of galaxy–galaxy correlations and temperature fluctuations on the surface of last scattering. The results suggest a neutrino mass of no more than 1 eV, summed over the three neutrino flavours – a range compatible with the one deduced from oscillations.

The imprint on the surface of last scattering of the acoustic waves driven into the hot gas of nuclei and photons also reveals a value for the relative abundance of baryons to photons of $6.5^{+0.4}_{-0.3} \times 10^{-10}$ (from the Wilkinson Microwave Anisotropy Probe). Nearly 60 years ago, George Gamow realized that a universe born as hot plasma must consist mostly of hydrogen and helium, with small amounts of deuterium and lithium added. The detailed balance depends on basic nuclear physics, as well as the relative abundance of baryons to photons: the state-of-the-art result of this exercise yields $4.7^{+1.0}_{-0.8} \times 10^{-10}$. The agreement of the two observations is stunning, not just because of their precision, but because of the concordance of two results derived from totally unrelated ways of probing the early universe.

The physics of partons

Physics at the high-energy frontier is the physics of partons, probing the question of what the proton really is. At the LHC, it will be gluons that produce the Higgs boson, and in the highest-energy experiments, neutrinos interact with sea-quarks in the detector. We can master this physics with unforeseen precision because of a decade of steadily improving measurements of the nucleon's structure at HERA, DESY's electron–proton collider. These now include experiments using targets of polarized protons and neutrons.

HERA is our nucleon microscope, tunable by the wavelength and the fluctuation time of the virtual photon exchanged in the electron–proton collision. With the wavelengths achievable, the proton has now been probed with a resolution of one thousandth of its 1 fm size. In these interactions, the fluctuations of the virtual photons survive over distances $ct \sim 1/x$, where x is the relative momentum of the parton. In this way, HERA now studies the production of chains of gluons as long as 10 fm, an order of magnitude larger than, and probably totally insensitive to, the proton target. These are novel structures, the understanding of which has been challenging for quantum chromodynamics (QCD).

Theorists analyse HERA data with calculations performed to next-to-next-to-leading order in the strong coupling, and at this level of precision must include the photon as a parton inside the proton. The resulting electromagnetic structure functions violate isospin and differentiate a u quark in a proton from a d quark in a neutron because of the different electric charge of the quark. Interestingly, the inclusion of these effects modifies the extraction of the Weinberg angle from data from the NuTeV experiment at Fermilab, bridging roughly half of the discrepancy between NuTeV's result and the value in the *Particle Data Book*. Added to already anticipated intrinsic isospin violations associated with sea-quarks, the NuTeV anomaly may be on its way out.

While history has proven that theorists had the right to be confident in 1980 at the time of Lederman's remark, they have not faded into the background. Despite the dominance of experimental results at the conference, they provided some highlights of their own. Developing QCD calculations to the level at which the photon structure of the proton becomes a factor is a *tour de force*, and there were other such highlights at this meeting. Progress in higher-order QCD computations of hard processes is mind-boggling and valuable, sometimes essential, for interpreting LHC experiments. Discussions at the conference of strings, supersymmetry and additional dimensions were very much focused on the capability of experiments to confirm or debunk these concepts.

Towards the highest energies

Theory and experiment joined forces in the ongoing attempts to read the information supplied by the rapidly accumulating data from the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. Rather than the anticipated quark–gluon plasma, the data suggest the formation of a strongly interacting fluid with very low viscosity for its entropy. Similar fluids of cold ^{6}Li atoms have been created in atomic traps. Interestingly, theorists are exploiting Juan Maldacena's connection between four-dimensional gauge theory and 10-dimensional string theory to model just such a thermodynamic system. The model is of a 10D rotating black hole with Hawking–Beckenstein entropy, which accommodates the low viscosities observed. This should give notice that very-high-energy collisions of nuclei may prove more interesting than anticipated from "QCD-inspired" logarithmic extrapolations of accelerator data. Such physics is relevant to analysing cosmic-ray experiments.

A century has passed since cosmic rays were discovered, yet we do not know how and where they are accelerated. Solving this mystery is very challenging, as can be seen by simple dimensional analysis. A magnetic field B of size R can accelerate a particle with electric charge q to an energy $E < \Gamma qvBR$, with velocity $v \sim c$, and ▷

no higher (where Γ is a possible boost factor between the frame of the accelerator and ourselves). This is the Hillas formula. Note that it applies to our man-made accelerators, where kilogauss fields over several kilometres yield 1 TeV, because the accelerators reach efficiencies that can come close to the dimensional limit.

Opportunity for particle acceleration to the highest energies in the cosmos is limited to dense regions where exceptional gravitational forces create relativistic particle flows, such as the dense cores of exploding stars, inflows on supermassive black holes at the centres of active galaxies, and so on. Given the weak magnetic field (microgauss) of our galaxy, no structures seem large or massive enough to yield the energies of the highest-energy cosmic rays, implying instead extragalactic objects. Common speculations include nearby active galactic nuclei powered by black holes of 1 billion solar masses, or the gamma-ray-burst-producing collapse of a supermassive star into a black hole.

The problem for astrophysics is that in order to reach the highest energies observed, the natural accelerators must have efficiencies approaching 10% to operate close to the dimensional limit. This is so daunting a concept that many believe that cosmic rays are not the beams of cosmic accelerators but the decay products of remnants from the early universe, for instance topological defects associated with a grand unified theory phase transition near 10^{24} eV.

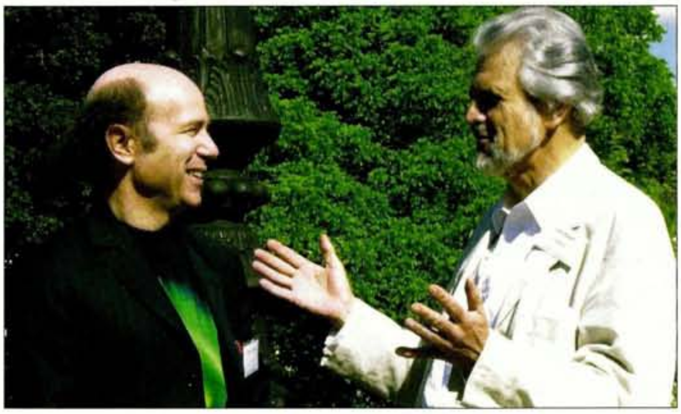
There is a realistic hope that this long-standing puzzle will be resolved soon by ambitious experiments: air-shower arrays of 10 000 km^2, arrays of air Cherenkov detectors, and kilometre-scale neutrino observatories. While no definitive breakthroughs were reported at the conference, preliminary data forecast rapid progress and imminent results in all three areas.

The air-shower array of the Pierre Auger Observatory is confronting the problem of low statistics at the highest energies by instrumenting a huge collection area covering 3000 km^2 on an elevated plane in western Argentina (*CERN Courier* March 2002 p6). The completed detector will observe several thousand events a year above 10 EeV and tens above 100 EeV, with the exact numbers depending on the detailed shape of the observed spectrum.

The end of the cosmic-ray spectrum is a matter of speculation given the somewhat conflicting results from existing experiments. Above a threshold of 50 EeV cosmic rays interact with cosmic microwave photons and lose energy to pions before reaching our detectors. This is the origin of the Greissen–Zatsepin–Kuzmin cutoff that limits the sources to our supercluster of galaxies. This feature in the spectrum is seen by the High Resolution Fly's Eye (HiRes) in the US at the 5σ level but is totally absent from the data from the Akeno Giant Air Shower Array (AGASA) in Japan.

At this meeting the Auger collaboration presented the first results from the partially deployed array, with an exposure similar to that of the final AGASA data. The data confirm the existence of events above 100 EeV, but there is no evidence for the anisotropy in arrival directions claimed by the AGASA collaboration. Importantly, the Auger data reveal a systematic discrepancy between the energy measurements made using the independent fluorescent and Cherenkov detector components. Reconciling the measurements requires that very-high-energy showers develop deeper in the atmosphere than anticipated by the particle-physics simulations used to analyse previous experiments. The performance of the detector foreshadows a qualitative improvement of the observations in the near future.

Cosmic accelerators are also cosmic-beam dumps producing secondary beams of photons and neutrinos. The AMANDA neutrino telescope at the South Pole, now in its fifth year of operation, has steadily improved its performance and has increased its sensitivity by more than an order of magnitude since reporting its first results in 2000. It has reached a sensitivity roughly equal to the neutrino flux anticipated to accompany the highest-energy cosmic rays, dubbed the Waxman–Bahcall bound. Expansion into the IceCube kilometre-scale neutrino observatory is in progress (*CERN Courier* May 2005 p17). Companion experiments in the deep Mediterranean are moving from R&D to construction with the goal of eventually building a detector the size of IceCube.



Nobel laureate Frank Wilczek (left) from MIT, who gave a well received public lecture, "The universe is a strange place", chats with Tord Ekelöf from Uppsala University, chair of the local co-ordinating committee of Lepton-Photon 2005.

However, it is the HESS array of four air Cherenkov gamma-ray telescopes deployed under the southern skies of Namibia that delivered the particle-astrophysics highlights at the conference. This is the first instrument capable of imaging astronomical sources in gamma rays at tera-electron-volt energies, and it has detected sources with no counterparts in other wavelengths (*CERN Courier* January/February 2005 p30). Its images of young galactic supernova remnants show filament structures of high magnetic fields that are capable of accelerating protons to the energies, and with the energy balance, required to explain the galactic cosmic rays. Although the smoking gun for cosmic-ray acceleration is still missing, the evidence is tantalizingly close.

• The next Lepton-Photon conference will take place in Daegu, Korea, in 2007.

Résumé

Uppsala 2005: leptons, photons et bien plus

La conférence lepton-photon bisannuelle s'est tenue à Uppsala du 30 juin au 5 juillet. Les exposés ont érigé l'impressionnant édifice du modèle standard et montré que, malgré toute leur ingéniosité, les expérimentateurs ne parviennent toujours pas à ébranler cette forteresse. Cependant, comme l'a souligné la réunion, le sentiment ne prévaut nullement que nous portons actuellement les dernières touches à une théorie définitive: les grandes questions du moment restent sans réponse.

Francis Halzen, *University of Wisconsin.*

Close nucleon encounters

Jefferson Lab may have directly observed short-range nucleon correlations, with densities similar to those at the heart of a neutron star. **Mark Strikman** explains.

Scientists believe that the crushing forces in the core of neutron stars squeeze nucleons so tightly that they may blur together. Recently, an experiment by Kim Egiyan and colleagues in Hall B at the US Department of Energy's Jefferson Lab (JLab) caught a glimpse of this extreme environment in ordinary matter here on Earth. Using the CEBAF Large Acceptance Spectrometer (CLAS), the team measured ratios of the cross-sections for electrons scattering with large momentum transfer off medium and light nuclei in the kinematic region that is forbidden for scattering off low momentum nucleons. Steps in the value of this ratio appear to be the first direct observation of the short-range correlations (SRCs) of two and three nucleons in nuclei, with local densities comparable to those in the cores of neutron stars.

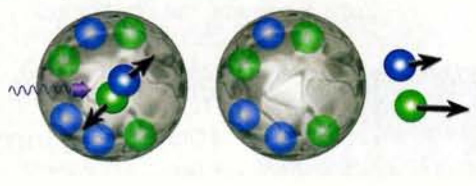


Fig. 1. Scattering of a virtual photon off a two-nucleon correlation, $x>1.5$, before (left) and after (right) absorption of the photon.

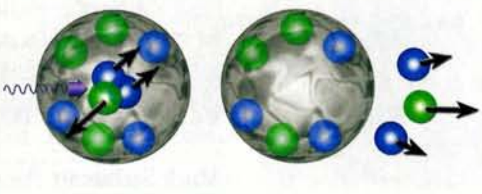


Fig. 2. Scattering of a virtual photon off a three-nucleon correlation, $x>2$, before (left) and after (right) absorption of the photon.

SRCs are intimately connected to the fundamental issue of why nuclei are dilute bound systems of nucleons. The long-range attraction between nucleons would lead to a collapse of a heavy nucleus into an object the size of a hadron if there were no short-range repulsion. Including a repulsive interaction at distances where nucleons come close together, ≤0.7 fm, leads to a reasonable prediction of the present description of the low-energy properties of nuclei, such as binding energy and saturation of nuclear densities. The price is the prediction of significant SRCs in nuclei.

For many decades, directly observing SRCs was considered an important, though elusive, task of nuclear physics; the advent of high-energy electron–nucleus scattering appears to have changed all this. The reason is similar to the situation encountered in particle physics: though the quark structure of hadrons was conjectured in the mid-1960s, it took deep inelastic scattering experiments at SLAC and elsewhere in the mid-1970s to prove directly the presence of quarks. Similarly, to resolve SRCs, one needs to transfer to the nucleus energy and momentum ≥1 GeV, which is much larger than the characteristic energies/momenta involved in the short-distance nucleon–nucleon interaction. At these higher momentum transfers, one can test two fundamental features of SRCs: first, that the shape of the high-momentum component (>300 MeV/c) of the wave function is independent of the nuclear environment, and second, the balancing of a high-momentum nucleon by, predominantly, just one nucleon and not by the nucleus as a whole.

An extra trick required is to select kinematics where scattering off low momentum nucleons is strongly suppressed. This is pretty straightforward at high energies. First, one needs to select kinematics sufficiently far from the regions allowed for scattering off a free nucleon, i.e. $x=Q^2/2q_0m_N<1$, and for the scattering off two nucleons with overall small momentum in the nucleus, $x<2$. (Here Q^2 is the square of the four momenta transferred to the nucleus, and q_0 is the energy transferred to the nucleus.) In addition, one needs to restrict Q^2 to values of less than a few giga-electron-volts squared; in this case, nucleons can be treated as partons with structure, since the nucleon remains intact in the final state due to final phase-volume restrictions.

If the virtual photon scatters off a two-nucleon SRC at $x>1$, the process goes as follows in the target rest frame. First, the photon is absorbed by a nucleon in the SRC with momentum opposite to that of the photon; this nucleon is turned around and two nucleons then fly out of the nucleus in the forward direction (figure 1). The inclusive nature of the process ensures that the final-state interaction does not modify the ratios of the cross-sections. Accordingly, in the region where scattering off two-nucleon SRCs dominates (which for $Q^2\geq1.4$ GeV^2 corresponds to $x>1.5$), one predicts that the ratio of the cross-section for scattering off a nucleus to that off a deuteron should exhibit scaling, namely it should be constant independent of x and Q^2 (Frankfurt and Strikman 1981). In the 1980s, data were collected at SLAC for $x>1$. However, they were in somewhat different kinematic regions for the lightest and heavier nuclei. Only in 1993 did the sustained efforts of Donal Day and collaborators to interpolate these data to the same kinematics lead to the first evidence for scaling, but the accuracy was not very high.

An experiment with the CLAS detector at JLab was the first to take data on ^{3}He and several heavier nuclei, up to iron, with identical kinematics, and the collaboration reported their first findings in 2003 (Egiyan *et al.* 2003). Using the 4.5 GeV continuous electron beam available at the lab's Continuous Electron Beam Accelerator Facility (CEBAF), they found the expected scaling behaviour for the cross-section ratios at $1.5\leq x\leq2$ with high precision.

The next step was to look for the even more elusive SRC of three nucleons. It is practically impossible to observe such correlations in intermediate energy processes. However, at high Q^2, it is straightforward to suppress scattering off both slow nucleons and two-nucleon SRCs. One needs only to reach the $x\geq2$ region where scattering off a deuteron is kinematically forbidden. Here, the experiment typically ▷

probes scattering off a fast nucleon with momentum opposite to the virtual photon, with two nucleons balancing the fast nucleon's momentum (figure 2, p37).

Again, a scaling of the ratios was expected. In this case, however, the ratios of the cross-sections for a pair of nuclei of masses A_1 and A_2 and with $A_1 > A_2$ was predicted to be higher for $2 \leq x \leq 3$ than for $1.5 \leq x \leq 2$. This is because there is a high probability for a nucleon to have two nearby nucleons in a heavier, denser nucleus. Hence, one expected to find two steps. This is exactly what the CLAS experiment observed in data recently reported for these kinematics and shown in figure 3 (Egiyan *et al.* 2005). Moreover, the iron:carbon ratios for $x \sim 1.7$ and 2.5 are consistent with the expectation that the probability of two- and three-nucleon SRCs should increase with A as the square and cube, respectively, of the nuclear density. For iron, the probability of two-nucleon SRCs reaches about 25%.

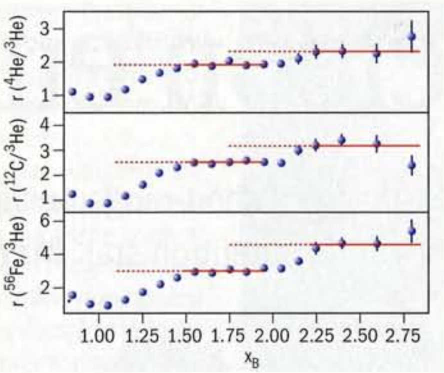


Fig. 3. Cross-section ratios of ^{4}He, ^{12}C and ^{56}Fe to ^{3}He, normalized to mass A, as a function of x for $Q^2 > 1.4$ GeV^2. The horizontal lines indicate two scaling levels of the cross-section ratios. Solid parts of the lines show the scaling regions used to calculate the per-nucleon probabilities for two- and three-nucleon correlations in helium-4, carbon and iron.

More data for exploring SRCs have already been taken at JLab, and several more efforts are already planned to study this interesting region of nuclear physics, which has important implications for the dynamics of the cores of neutron stars.

Further reading

K Sh Egiyan *et al.* 2003 *Phys. Rev. C* **68** 014313.
K S Egiyan *et al.* 2005 http://arxiv.org/abs/nucl-ex/0508026.
L L Frankfurt and M I Strikman 1981 *Nucl. Phys. B* **181** 22.

Résumé

Rencontres étroites de nucléons

Une équipe du Laboratoire Jefferson a réalisé ce qui pourrait bien être la première observation directe de corrélations à courte portée dans des noyaux présentant des densités comparables à celles du cœur des étoiles à neutrons. Utilisant le spectromètre CLAS de grande acceptance du CEBAF, cette équipe a mesuré les rapports des sections efficaces de diffusion des électrons à grande impulsion tranversale par des noyaux légers et moyens. La variation par paliers de ce rapport semble indiquer des corrélations à courte portée de deux et trois nucléons dans les noyaux.

Mark Strikman, Penn State University.

Wisdom generation in the Alps: a student's tale

Sezen Sekmen describes her experience as a student at the European School for High Energy Physics, which was hosted this year by Austria in the scenic town of Kitzbühel.

"Seventy per cent of today's successful particle physicists have attended this school – which means you have a high chance to be one of them in the future," says a joyful Egil Lillestøl as he welcomes us to the 2005 European School for High Energy Physics. Instantly more than 100 glasses rise, accompanied by a cheerful applause. We all feel lucky to be here.

We are in Kitzbühel, a peaceful town with green and beautiful surroundings in south-west Austria, to witness a curious learning experience and to contribute to its spirit as much as we can. The first evening's dinner sweeps away any clouds of anxiety we might have, and observations of the first encounters have provided more than 5σ evidence of a great event.

On the first morning, just as rain is refreshing the beauty of the mountains outside, the overhead projector starts to light up the first fields and interactions on the screen. Wilfried Buchmüller from DESY provides us with the most fundamental piece of knowledge we will ever need – the Standard Model itself. The school's academic programme is like a perfect *PhD Student's Guide to High-Energy Physics*, as if to advise "don't panic" in the wide and diverse realm of this exciting subject, "we will show you the route".

Our appetite for learning grows as cosmology slowly makes peace with precision in the lectures by Rocky Kolb from Fermilab. He calmly strides through the whole universe, from its brilliant but furious past to its settled and gloomy present, from its simply overwhelming dark side to its modest but comforting light side.

Then enters Larry McLerran from Brookhaven, who introduces us to the colour glass condensate and the quark–gluon plasma, which happen to be two rather unusual forms of strongly interacting matter. He tells us the ancient tales of the good old days when quarks and gluons used to enjoy their freedom, and how the Relativistic Heavy Ion Collider came along at Brookhaven with the aim of capturing a few memories of such eras. On the other hand, Gerhard Ecker from Vienna draws a somewhat more familiar portrait of strong interactions as he systematically goes through quantum chromodynamics, explaining the usual quarks and gluons, and showing the remarkable detail hidden behind even the simplest approaches in this theory.

The school's participants, including Sezen Sekmen, who is seated on the left, enjoy a day out in Salzburg.

The students study each other's work during the poster session.

The evenings call for our creativity in the discussion sessions (which might also be considered as gentle warnings for us to stay awake during the lectures). Having received our daily lecture notes we are divided into six discussion groups, where we are supposed to make an account of the day's learning and remove any obscurities in the lectures. Encouraged by the friendly attitudes of our discussion leaders, who are all young and willing theorists, and of the visiting lecturers, any shyness disappears and the first hints of inspiration begin to appear as ideas, questions and comments bravely ▷

The European School of High Energy Physics comes to Austria

For the first time in its 40 year history, the European School of High Energy Physics was hosted by Austria in 2005. Organized jointly by CERN and the Joint Institute for Nuclear Research (JINR) in Dubna, the school took place from 21 August to 2 September in the town of Kitzbühel.

Beginning as the CERN School of Physics in 1962, when it was aimed at those using emulsion techniques at CERN, the school quickly evolved to place its emphasis on teaching theoretical particle physics to young experimentalists, and to rotating among the member states. From 1970 the school was organized every two years, jointly with JINR, and in 1991 it became the European School of High Energy Physics, organized each year by CERN and JINR. Every year the school assembles around 100 young experimentalists for a unique opportunity to improve their understanding of physics. Outstanding theorists lecture the students on the various aspects of high-energy particle physics. A special feature is the discussion sessions moderated by young theorists, which allow open questions to be clarified in smaller groups.

On a typical day of this year's school, there were two lectures in the morning and one in the late afternoon, followed by a discussion session. A long break after lunch allowed the students to meet new friends – participants had come from all over the world, from more than 30 different nations – to discuss physics and other topics, and to explore the beautiful surroundings of Kitzbühel. In addition to the lectures that are described in the main article, Jos Engelen and Alexey Sissakian also gave overviews of the experimental programmes at CERN and JINR, respectively.

Public relations is an important issue for particle physicists, so the local organizers of the school – Emmerich Kneringer and Andreas Salzburger from Innsbruck and Laurenz Widhalm and Manfred Jeitler from Vienna – took advantage of the occasion to reach out to the general public by presenting an exhibition prepared by the Vienna Institute of High Energy Physics. The school's long-standing director, Egil Lillestøl, opened the exhibition on the last day of the school. High-ranking representatives arrived from CERN, Vienna and Innsbruck, and both lecturers and students helped to explain to the local population what particle physicists do and why.

make their way into the discussions.

It is now Thursday night and the poster session begins, transforming modest students into proud physicists who share the outcomes of their current research with great skill and enthusiasm. As well as discovering new ideas, we also see some different approaches to familiar subjects. For example, as someone who wrote an MSc thesis on the analysis of miniature black holes in the CMS experiment at CERN, I am delighted to come across a poster on a similar study for ATLAS. I discover that our friends from Oxford suffered the same problems we did, and so over discussions we decide to support each other in any future studies of these ruthless objects. Best of all though, is to have the vision that through all of these diverse contributions the goals of physics today can indeed be fulfilled.

The sound of music

But it's not all work. We also have enough time to answer the irresistible call of the great Alps or to relax in the pleasant atmosphere of the historic town of Kitzbühel. On Saturday we visit Salzburg, the town enchanted by the graceful hand of Mozart.

The second week brings new lectures and new lecturers. After convincing us that Buchmüller's Standard Model is fine but definitely insufficient, John Ellis from CERN goes on to reveal the vast worlds beyond, which are ruled by brilliant scientific imagination, with of course some rightful emphasis placed on the unavoidable elegance of supersymmetry. His presence is an invaluable gift, especially for me, as my current research happens to be on supersymmetric dark matter. Inspired by his lectures, as devoted experimentalists, we even go on a dangerous quest for dark matter on the nearby Schwarzsee at night.

Later, Robert Fleischer, also from CERN, explains how a nasty complex phase destroyed the beautiful CP symmetry and introduced some excitement into our universe, which would otherwise be less

Rocky Kolb, from Fermilab, talks on spontaneous symmetry breaking during his lecture on astrophysics and cosmology.

interesting; and how it also caused a few headaches among the physicists trying to explore the rich phenomenology of the Cabibbo–Kobayashi–Maskawa matrix and its unitarity triangles. We then discover some "CP violating terms" in the local organizing committee as two of its members from Vienna, Manfred Jeitler and Laurenz Widhalm, in addition to their efforts to offer us an outstanding experience, present lectures on experimental aspects of B- and K-physics, respectively. Then Manfred Lindner from Munich describes the ghostly neutrinos and the many consequences of their mischievous behaviour, and gives a long list of the global endeavours to discover their nature experimentally.

There are even some lectures not on particle physics. Wolfram

Müller from Graz gives instructions on the physics of ski jumping, which seems quite appropriate in Kitzbühel, and Herbert Pietschmann from Vienna shows us our fate on the way to knowledge in his delightful lecture on physics and philosophy.

Meanwhile, the interactions increase, just as predicted by the famous "Summer Student Group Theory". Although we have grown up under the strict hands of scientific work, the children within us still seek fun and adventure. We make the most of a colourful international community formed without prejudices and borders. The coffee breaks, which seemed a little long in the beginning, now fly swiftly by with cheerful conversations. I feel a significant improvement in my debating skills, especially after all the "SUSY and beyond" discussions with several expert theorist friends.

Grand finale

However, the inescapable end is close. In order to avoid becoming too melancholy and to create a glorious finale, we amalgamate all our creativity in preparing an unforgettable farewell night. This time we are on stage, giving so-called lectures on "serious subjects" (that cannot be mentioned here!), singing, acting and doing all sorts of things to entertain our audience. But finally we have to say difficult goodbyes to all of our friends (yes, we are friends now), and leave the cosy Hotel Kitzhof, where our hosts, through their patience and goodness, have somehow managed to survive our two-week occupation.

I know that all of us share the same feeling of gratitude towards everyone who made this school possible. I am especially indebted, as a student coming from an observer state who had the privilege of being supported through the generosity of CERN. We are greatly thankful for the endless support and kindness we received from Egil Lillestøl (CERN schools director), Danielle Métral (CERN schools secretary), Tatyana Donskova (JINR schools secretary), all the local organizers plus all the other representatives of CERN and JINR who were with us during the school. We have been thoroughly enriched as a result of their sincere efforts. This worthy tradition must continue, as long as physics has new puzzles to offer us and as long as we can respond through willing fresh minds.

Résumé

Une génération de sages dans les Alpes: une étudiante raconte

Chaque année, l'Ecole européenne de physique des hautes énergies rassemble une centaine de jeunes expérimentateurs en leur offrant une occasion unique d'améliorer leur compréhension de la physique des particules grâce aux cours d'éminents théoriciens. L'Ecole se distingue par ses séances de discussion en petits groupes pour clarifier divers sujets. Organisée cette année par le CERN et l'Institut unifié de recherche nucléaire (IURN) de Doubna, elle se tenait à Kitzbuhel, Autriche. Sezen Sekmen décrit son expérience d'étudiante.

Sezen Sekmen, *Middle East Technical University, Ankara, Turkey.*

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APPOINTMENTS

Wormser takes the reigns at LAL

Guy Wormser has been named director of the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay, with effect from 1 September 2005. He succeeds Bernard D'Almagne.

Wormser joined LAL in 1977, when he was newly graduated from the Paris Ecole Normale Supérieure. During his time at the laboratory he has worked at CERN and has also forged extensive ties in the US, in particular at SLAC. At the end of the first phase of the Large Electron Positron (LEP) collider project, where he worked on the DELPHI experiment, Wormser participated in the PEP-II project at SLAC and persuaded French researchers to join the nascent BaBar collaboration, thus contributing to the new era of international collaboration at SLAC.

Since then, Wormser's leadership has extended to other areas, including computing with the DataGRID and Enabling Grids for E-science projects. A member and chairman of numerous international committees, he was named deputy director of IN2P3 from 1999 to 2003. He recently created and chairs a new panel of the International Committee for Future Accelerators, which is devoted to the international coordination of computing in high-energy physics, and he co-chairs the French Global Design Effort for the International Linear Collider (ILC).

Guy Wormser, the new director of LAL.

With more than 300 people, including 100 physicists, LAL is the largest laboratory of CNRS/IN2P3 devoted to particle physics and enjoys strong links with Paris XI University. It plays a major role, both at the construction stage and in data analysis, in many particle-physics experiments at CERN, DESY and in the US. It is also involved in neutrino physics and is making major contributions to astroparticle and cosmology projects. In addition, the laboratory is a key participant in long-term machine projects, such as the German XFEL, the ILC and the Compact Linear Collider at CERN, where the LAL accelerator group is a major partner for R&D and construction, as it was for LEP.

Under Wormser's influence, LAL will undoubtedly retain its impact on present and future research in particle physics, and remain one of the main European centres for particle physics and cosmology, committed to excellence and international partnerships.

AWARDS

Italian Physical Society honours theorists of gravity

Sergio Ferrara and Gabriel Veneziano of CERN, and Bruno Zumino of the University of California, Berkeley, have been awarded the 2005 Enrico Fermi prize of the Italian Physical Society. The trio of Italians were said to have "honoured Italian physics with their discoveries, which have contributed in substantial ways to the development of the modern theories of gravity."

In particular, Ferrara receives the award for his contribution to the discovery of supergravity theory; Veneziano for the discovery of dual models, which were recognized subsequently as the theoretical base of the string theory version of quantum gravity; and Zumino for his contributions to the theory of supersymmetry and supergravity.

CERN theorists Sergio Ferrara (left) and Gabriel Veneziano after the award ceremony on 26 September at the annual meeting of the Italian Physical Society in Catania.

AWARDS

IEEE dedicates Milestone plaque at CERN...

At a ceremony on 26 September at CERN, W Cleon Anderson, president of the Institute of Electrical and Electronics Engineers (IEEE), formally dedicated a "Milestone" plaque in recognition of the invention of electronic particle detectors at CERN. The plaque was unveiled by Anderson and Georges Charpak, the Nobel-prize winning inventor of wire-chamber technology at CERN.

With the attribution of this IEEE Milestone, CERN finds itself in good company. There are currently more than 60 Milestones around the world, awarded for such momentous achievements as the landing of the first transatlantic cable, code breaking at Bletchley Park during the Second World War, and the development of the Japanese bullet train, the Tokaido Shinkansen.

W Cleon Anderson (right), president of the Institute of Electrical and Electronics Engineers, unveils the Milestone plaque at CERN, together with Georges Charpak.

Particle-physics research was revolutionized in 1968 when Charpak published a paper describing the multi-wire proportional chamber, a forerunner to many of the particle detectors in use today. This invention, which paved the way for new discoveries in particle physics, also made it possible to increase the rate of data collection by a factor of one thousand.

Charpak, who received the Nobel Prize for Physics in 1992 for his invention, has also actively contributed to the use of this type of detector in various applications in medicine and biology. The value of fundamental research institutes such as CERN in fostering innovation of this kind was a recurring theme of the ceremony. Charpak himself stressed the importance of intellectual freedom, saying of his time at the laboratory, "CERN was a fantastic place because of the freedom I had, which permitted me to do a lot of things that were unexpected."

...and honours Romeo Perin with superconductivity award

CERN engineer Romeo Perin has been awarded the IEEE Council on Superconductivity Award for Significant and Continuing Contributions to Applied Superconductivity. He has been recognized for his work in "the field of large-scale applications of superconductivity, in particular for his many contributions in both the design and construction of magnets for particle accelerators."

Perin's contributions include the realization of magnets for the Large Hadron Collider, from the design of the first models and prototypes through the critical phase of industrialization; the design and construction of quadrupoles for the Intersecting Storage Rings; and the leadership of the magnet group, which is responsible for developing magnets and superconductors at CERN.

IEEE award winner Romeo Perin.

Perin received the award on 19 September at the International Conference on Magnet Technology in Genoa, when René Flükiger of the University of Geneva was also rewarded for his work in applied superconductivity. Flükiger was recognized for his contribution to the development of useful superconductor cables, with both low and high critical temperature.

ANNIVERSARY

RFQ pioneer celebrates 80th birthday

Vladimir Teplyakov, who is 80 in November.

Vladimir Teplyakov, one of the leading scientists at the Institute for High Energy Physics (IHEP) in Protvino, celebrates his 80th birthday on 6 November. A distinguished expert in accelerator and beam physics and engineering, he is well known for his invention in the late 1960s, together with Ilya Kapchinsky of ITEP-Moscow, of the radio-frequency quadrupole (RFQ) linear accelerator. This versatile device, which bunches, focuses and accelerates lower energy protons and ions using only RF fields, has been put into operation in many labs throughout the world.

After being drafted into the Red Army and serving in the Second World War, Teplyakov graduated from the Polytechnic Institute, and in the 1950s began his career in the Moscow-based Institute for Chemical Physics of the National Academy of Sciences. While there, he was involved in feasibility studies for a high-current proton linear accelerator. In 1966 Teplyakov moved with his team to IHEP in Protvino, where he was charged with commissioning and running a 100 MeV Alvarez drift-tube linac, the I-100. This machine has served for 20 years as an injector to the 70 GeV proton synchrotron, the U-70, which was the world's largest when it started up.

In 1969 Teplyakov and Kapchinsky put forward the concept of the RFQ, for which they received the Lenin prize, the top award of the former USSR, in 1988. The American Physical Society has also honoured the achievement. Since then, Teplyakov has contributed greatly to extending RFQ focusing to higher beam energies by developing various RFQ drift-tube structures and RF cavities to drive them. In 1985 the world's only all-RFQ 30 MeV linear accelerator, the URAL-30, was put into operation and is still being employed as an injector to the fast-cycling 1.5 GeV booster synchrotron in the upgraded injector chain of the U-70. Now, a modified successor, named URAL-30M, is being assembled and subjected to pre-commissioning bench testing.

Teplyakov has authored more than 100 scientific papers and many patented inventions, and is co-author of the fundamental book *Linear Accelerators of Ions,* used by several generations of accelerator scientists in Russia. He is still active in science and full of new ideas. His friends and colleagues wish him good health and many more years of creative research.

ISAPP 2005

Third school for astroparticle physicists of the future

The participants of ISAPP 2005, which was held in Belgirate, Italy, in July.

At the beginning of July, more than 60 European doctoral students gathered in Belgirate, on Lake Maggiore in Italy, to attend the third International School on Astroparticle Physics (ISAPP 2005). The school is part of the activities of the ISAPP network, which includes 23 universities, institutes and laboratories from France, Germany, Israel, Italy, Russia and Spain. It is different from other schools in that it is dedicated to European doctoral students from two fields – nuclear and particle physics, and cosmology and astrophysics – whose students do not traditionally mix, and so aims to create new astroparticle physicists.

The format of the school begins with two days dedicated to parallel introductory lessons on topics that some of the students are less familiar with, while the "core" lessons, common to all the students, provide an in-depth look at specific areas of astroparticle physics. This year the main topic concerned high-energy cosmic rays, while previously there were in-depth lectures on neutrinos in physics and astrophysics, dark matter and dark energy, and gravitational waves.

Time is also set aside during the school for formal and informal discussions and short seminars by the students. Care is taken to have the speakers stay for the full length of the school and at the same location as the students, so as to encourage the exchange of experiences and ideas.

This year's school was attended by students from 11 countries, with a majority of non-Italians, and there was also a large number of women, who constituted half the participants. Next year the school is planned to take place in Germany.

● For more information on the ISAPP network, together with complete lists of the school's programme, organizers, teachers and lessons, see www.mi.infn.it/ISAPP.

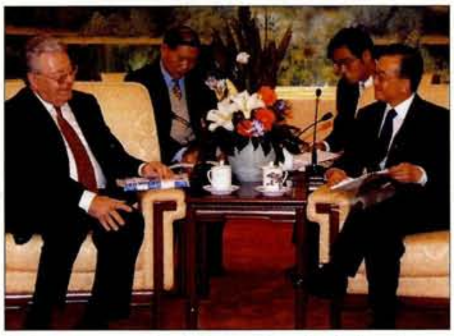
INTERNATIONAL COLLABORATION

China and CERN look to strengthen co-operation in high-energy physics

Over the past 30 years, the Chinese high-energy particle-physics community has become an important participant in CERN's experimental physics programme, with formal co-operation agreements signed in the 1990s between CERN and the Chinese government, the Chinese Academy of Sciences (CAS), and the National Natural Science Foundation of China (NSFC). Since the signature of a renewed co-operation agreement between the Chinese government and CERN early in 2004, contacts have intensified at the highest level, for example with the visit of the president of CAS, Yongxiang Lu, to CERN, and a meeting between China's premier, Jiabao Wen, and CERN's director general Robert Aymar.

To establish closer ties in high-energy physics, as well as in the associated computing and accelerator technologies, it was agreed to organize a China–CERN workshop in China. Its aim was that all Chinese scientific institutions with a potential interest in either high-energy physics or accelerator technology could meet with representatives from CERN to review the scope of the CERN–China collaboration and explore opportunities to strengthen further, and possibly also enlarge, the partnership on a longer term.

Organized by the Institute for High-Energy Physics (IHEP), at the request of China's Ministry of Science and Technology (MOST), the China–CERN workshop took place in Beijing on 14–15 May 2005. It was attended by more than 70 scientists from 16 different scientific institutions in China, as well as high-level representatives of MOST, the Ministry of Education (MOE), the NSFC and CAS. The CERN delegation, led by Robert Aymar, included CERN's chief scientific officer Jos Engelen, the advisor on relations with non-member states, the spokespersons of the Large Hadron Collider (LHC) experiments (ALICE, ATLAS, CMS and LHCb), a representative for LHC Grid Computing, and the leaders of the Compact Linear Collider (CLIC) and Superconducting Proton Linac (SPL) studies.



Chinese premier Jiabao Wen (right) and CERN's director general Robert Aymar (left) met on 17 November 2004.

Participants await the opening session of the China–CERN workshop in May 2005.

Following the opening by Jie Zhang, the director of CAS's Bureau of Basic Sciences, the vice-minister of science and technology, Jinpei Cheng, reviewed co-operation between CERN and China since its beginnings in the early 1970s. He acknowledged the mutual benefits arising from a strengthened co-operation to both China and the scientific community working at CERN, and pledged a sustained effort by the Chinese government to support this endeavour. Aymar responded by acknowledging the participation of Chinese scientists in activities at CERN and invited China to deepen and extend this co-operation.

The director of IHEP, Hesheng Chen, then presented an outline of particle-physics research in China, and summarized China's participation in international research programmes, recognizing CERN as one of China's most significant partners. Aymar and Engelen followed with an overview of the ongoing and future research programmes at CERN, pointing out where Chinese physicists already participate, and presented the opportunities to extend or deepen China's participation.

The workshop heard more detailed reports on the status and future plans for the LHC experiments and for LHC Grid Computing from the spokespersons and leaders of the teams participating from China. The first part of the workshop then concluded with presentations on accelerator projects and studies, including the SPL study at CERN, China's Spallation Neutron Source project, the Beijing Electron-Position Collider (BEPC), studies on CLIC at CERN, and China's involvement in the International Linear Collider.

Further discussions took place in six parallel sessions dedicated to the four LHC experiments, to LHC Grid Computing, and to accelerator studies and projects. The conclusions were finally presented in a plenary session. The workshop ended with a closed session between CERN's management and representatives of Chinese funding agencies (MOST, MOE, CAS and NSFC).

The China–CERN workshop was useful for providing CERN and its Chinese colleagues, as well as the Chinese government and funding agencies, with a comprehensive overview of the current status of co-operation between CERN and China, and it helped to identify areas where this co-operation could grow. It was an opportunity for CERN's management to meet with the relevant Chinese officials, but it was also an opportunity for scientists to establish new contacts and exchange new ideas, as the necessary condition for the future growth of scientific co-operation between China, CERN and the international science community, collaborating through CERN.

Diether Blechschmidt, CERN, and Sijin Qian, Peking University.

COMMUNICATION

Global Design Effort for the ILC launches new website and online publication

The Global Design Effort (GDE) for the International Linear Collider (ILC) has launched a new website, *www.linearcollider.org*, together with *ILC NewsLine*, a weekly electronic newsletter reporting news and information about the next-generation particle accelerator from around the world.

ILC NewsLine is written for the global particle-physics community and non-scientists, and is available online and e-mailed free to subscribers. It includes news about the latest ILC developments, reports from conferences and workshops worldwide, statements from the GDE director and regional directors, and profiles about the international scientists and engineers that are collaborating to design a future particle accelerator. The website includes ILC news, a calendar of upcoming events, announcements and technical and scientific documents.

ILC NewsLine is jointly written and produced on behalf of the global ILC community by the GDE communicators in the Americas, Europe and Asia, who welcome submissions and ideas for newsletter content. To subscribe to *ILC NewsLine*, see www.linearcollider.org/newsline.

LETTERS

CERN Courier welcomes letters from readers. Please e-mail cern.courier@cern.ch. We reserve the right to edit letters.

Sponsoring open access: more than just wry amusement

I am delighted to witness the high interest in open access that exists and has been demonstrated by the series of letters on the topic recently published in these pages. In addition, a well-attended debate on "The changing publishing model" held at CERN in September shows that physicists are concerned with this issue.

Following the endorsement of the new CERN publishing policy in March, the library has taken certain steps to support open access where it can. It is therefore my pleasure to announce that CERN will be, as of 2006, the first European financial sponsor of *Physical Review Special Topics – Accelerators and Beams*. I hope publishers and editors of journals in particle physics will also consider a similar model: in the current climate a publishing model based on sponsorship shows significant potential, at least for the mega-sciences.

For the future, I would like to propose that we do not mix peer-review and long-term archiving into the debate. Both are of obvious importance, but neither is relevant to the difference between open-access publishing and the traditional model. The open-access model can of course incorporate peer-review, and with regards to archiving, even traditional subscription journals will most likely be electronic-only in a few years. The real debate is how to finance publishing activities and at the same time ensure equal access for everyone to results from publicly funded research.

A change to full open-access publishing cannot be made by one of the actors in the publishing chain alone. CERN is therefore hosting, in December, a tripartite meeting, which will include funding agencies, research organizations and publishers who already implement some form of open-access publishing. At the workshop we will hope to use our years of open-access experience to work out a common strategy for the transition to the new publishing paradigm.

Corrado Pettenati, CERN Library.

George Placzek revisited

The physics community will welcome Jan Fischer's article "George Placzek – an unsung hero of physics" (*CERN Courier* Sept 2005 p25) on the life and work of Jewish physicist George Placzek, who was born in Brno in 1905.

As an addendum to the article, I would like to tell readers of Placzek's brief appointment in the physics department of the newly established Hebrew University in Jerusalem (opened in 1925). Placzek worked there for just six months during the academic year 1934–1935. Before arriving, he had received an unusual request from the university. In August 1934 Leonard Ornstein informed him that the language of teaching in Jerusalem is Hebrew, but the use of another language is permitted for one year (I Unna 2000 *Phys. Perspect.* **2** 336).

Placzek's difficulty in using Hebrew to teach physics was also mentioned by Otto Frisch (O R Frisch 1979 *What Little I Remember* Cambridge University Press). Frisch wrote: "We later had numerous communications from [Placzek in] Israel; how at first he had to fend off the persistent requests from the university authorities that he should give his lectures in Hebrew, which he had not yet learned. They gave him a year to learn Hebrew. (He learned Arabic as well.) When at the end of that year he still wouldn't give lectures in Hebrew – he felt the language couldn't cope with modern physics – and they insisted on it, there was a telegram "Through with Jews for ever", and he came back to Denmark."

Min-Liang Wong, College of Veterinary Medicine, National Chung-Hsing University, Taichung, Taiwan.

OBITUARIES

Cesare Mansueto Giulio Lattes 1924–2005

Cesare Mansueto Giulio Lattes, the last pioneer of the pion discovery, died on 8 March 2005 at Campinas, São Paulo State, Brazil.

Born in Curitiba, Brazil, Lattes studied at São Paulo University, where he was a student of Giuseppe Occhialini, graduating in 1943. In 1946 he joined Occhialini in Cecil Powell's group at the University of Bristol, where together with Hugh Muirhead they made the historic discovery of the pion in studies of cosmic rays (*CERN Courier* October 1987 p11). At the end of 1947 Lattes moved to Berkeley to work with Eugene Gardner at the 184 inch cyclotron, where, in Lattes' own words: "The beam of α-particles was only 380 MeV (95 MeV/nucleon), an energy insufficient for producing pions. I took my chance on the 'favourable' collisions in which the internal momentum of a nucleon in the α and the momentum of the beam provided sufficient energy in the centre-of-mass system." The method proved successful and produced both positive and negative pions. Later, around February 1949, just before leaving the US, Lattes was asked by Edwin McMillan to look at some plates exposed to gamma-rays from the 300 MeV electron synchrotron, and found a dozen pions of both charges, surely the first artificial photoproduced pions ever detected.

Despite many invitations to join research institutions in other countries, Lattes returned to Brazil in 1949 to take part in the establishment of a Brazilian Center for Research in Physics (CBPF). His international prestige attracted many well known researchers to the institution, which also benefited from the contributions of other prominent scientists such as Gert Molière, Léon Rosenfeld and Richard Feynmann. Lattes was scientific director from the centre's foundation until 1955, after which, from 1955 to 1957, he served as a research associate at the universities of Chicago and Minnesota. He was also a visiting professor from 1964 to 1965 in Pisa, where he became interested in geochronology research.

Meanwhile, in 1947, Lattes had found out at Bristol's Department of Geography that there was a meteorological station 5500 m above sea level on Mount Chacaltaya in Bolivia, which was easily reachable by car. There he exposed borax-loaded emulsion plates to cosmic rays and obtained a mass for the pion. Lattes always said the observation of the pion was facilitated by both the borax-loaded emulsion plates and Mount Chacaltaya, the true discoveries concerned. In the 1950s he constructed an observatory at Chacaltaya, with a budget obtained with some difficulty from the National Council of Technological and Scientific Development (CNPq).

Cesare Lattes, left, with Eugene Gardner and the nuclear emulsion positioning apparatus for the 184 inch cyclotron. (Courtesy Lawrence Berkeley National Laboratory.)

In 1958 Hideki Yukawa wrote to Lattes to propose uniting the efforts of Japanese and Brazilian cosmic-ray groups in order to study multiple meson production at the Mount Chacaltaya Observatory. The Brazil–Japan Collaboration on Cosmic Rays in Chacaltaya Emulsion Chamber Experiments (the B–J Collaboration) began in 1962. The work of the B–J Collaboration was appreciated by the international community, particularly at CERN where the proposal for the UA1 experiment by Carlo Rubbia mentions the collaboration's observation of "fire-balls". The so-called Centauro events, also observed by the collaboration, are still under study in both cosmic-ray and accelerator experiments.

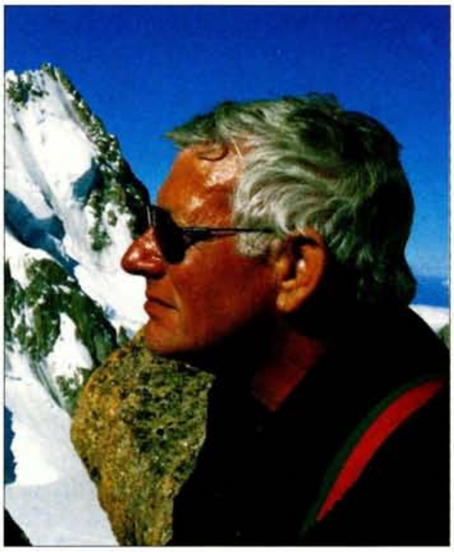
In 1967 Lattes joined the State University of Campinas (UNICAMP) in São Paulo State, where he started the Institute of Physics, with its first research laboratory dedicated to studies of geochronology and cosmic rays through inexpensive experiments. This was one of Lattes' characteristics: he had a profound faith that the real facts of nature are observable even with inexpensive experiments, a lesson he learned early as a student at São Paulo University. Today UNICAMP is one of the most important institutions in Brazil.

Lattes received many awards from South American countries, as well as the 1987 Physics Award from the Third World Academy of Sciences. Probably the most important reward to him, however, was the recognition of the Brazilian scientific community of his enthusiasm for modern science in Brazil, which nowadays accounts for 1% of the world's scientific research, despite the still small number of Brazilian scientists and some modest budgets. The discovery of the pion brought attention to the role of science in Brazil, where the scientific community's debt to Lattes has been recognized by the CNPq through its database of researchers' curricula in all areas of knowledge, the "Plataforma Lattes".

E H Shibuya, State University of Campinas, Brazil.

OBITUARIES

P Gregers Hansen 1933–2005



Gregers Hansen, who died on 20 July 2005, spent a large part of his scientific life connected to CERN and its ISOLDE programme. Since 1995 he was the John A Hannah distinguished professor of physics at Michigan State University (MSU).

Gregers was born in Svendborg, Denmark, and studied at the Technical University of Denmark before being employed for a decade at the Niels Bohr Institute and Risø National Lab. His work there earned him the degree of doctor of science from the University of Copenhagen in 1965. He then became professor of experimental physics at the University of Aarhus in Denmark in 1966, a chair that he held until 1995. At Aarhus he almost immediately became involved in the experimental programme at the newly constructed ISOLDE facility at CERN, coming to CERN as senior physicist in 1969. He became ISOLDE group leader in 1970 and stayed in this position until the end of 1978. During 1974–1977 he also acted as deputy division leader in CERN's Experimental Physics Division. Gregers' first-hand experience of nuclear structure physics at CERN formed the basis of his account of this period in *History of CERN, III*.

Gregers had a very broad interest in several fields of physics. The main themes of his work were the nuclear structure and beta decay of exotic nuclei, but he also wrote papers in atomic physics about inner-shell processes and the beta-decay effects of X-rays, and in particle physics and general physics. Besides experiments at CERN, he also conducted experiments at the LISE3 Facility at GANIL and at the ALAIN-LAND setup at GSI. At MSU Gregers worked on physics with radioactive beams and studied in particular one- and two-knockout reactions from exotic projectiles. He wrote several seminal papers about the structure of exotic nuclei.

Gregers' work received widespread recognition. He was a member of the Royal Danish Academy of Sciences and Letters and served in many advisory functions, including CERN's Scientific Policy Committee. He was also president of the Danish Physical Society (1984–1986) and chaired the Proton Synchrotron and Synchrocyclotron Committee at CERN (1981–1985). He was an inspiration for many scientists working with exotic nuclei, and his ability to express penetrating insight in elegant but clear language was admired, as well as feared.

Even though Gregers' life was devoted to science, he possessed an intellect of wide scope and also enjoyed the outdoors. His life ended much too early, but he had the privilege to work with physics every day until he died.

Björn Jonson, Chalmers University of Technology, and Karsten Riisager, CERN.

NEW PRODUCTS

Burle Electro-Optics Inc has announced a patent award for its high-performance, high-speed BiPolar Time-of-Flight detectors for mass spectrometry applications. Providing up to 10 kV of post acceleration, the detector is enclosed in a low-profile assembly combining a highly sensitive microchannel plate and electro-optically isolated output signal. For further details, tel. +1 800 648 1800, +1 508 347 4000, or e-mail sales@burle-eo.com.

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Oxford Instruments and Quantum Design have launched a jointly developed innovative compact dilution refrigerator, model P850. The novel continuously circulating ^{3}He/^{4}He refrigerator is fully automated and valveless and installs easily into Quantum Design's Physical Property Measurement System (PPMS), extending the minimum temperature to 50 mK. For further information, tel. +44 1865 393 200, e-mail superconductivity@oxinst.co.uk or visit www.oxford-instruments.com.

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CORRECTION

The article about the award of the 2005 Einstein Medal to Murray Gell-Mann, on p40 of the October issue, incorrectly stated that the president of the Swiss Confederation, Samuel Schmid, had presented the award to Gell-Mann. The presentation was in fact made by Peter Minkowski, president of the Albert Einstein Society. Many apologies to all concerned.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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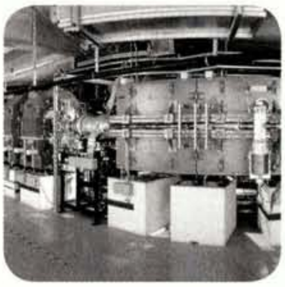

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Additional information may be found on the web site http://www.fnal.gov/pub/forphysicists/fellowships/peoples.html.

Communications may be sent to: Peoples Fellows Committee, Fermi National Accelerator Laboratory, MS341, Attn: Eva Clark, PO Box 500, Batavia, IL 60510-0500, peoples_fellowship@fnal.gov.

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Lawrence Berkeley National Laboratory (LBNL) has an excellent opportunity available for a Director of the Accelerator and Fusion Research Division (AFRD) who will be responsible for a broad spectrum of experimental and theoretical research in accelerator science and related technologies.

AFRD is funded primarily by the U.S. Department of Energy's (DOE) Office of Science to advance accelerator-based research in high energy and nuclear physics, in development and operation of intense photon sources, in heavy-ion-driven inertial fusion, and in ion beam technologies. AFRD with an annual budget of ~$30 M has a staff of ~ 100 scientists, engineers, technical, and administrative personnel, as well as participating faculty and students from the nearby U.C. Berkeley campus and other world-renowned universities and research institutions. For more information about AFRD's scientific programs, visit: **http://www-afrd.lbl.gov**.

Reporting to the Laboratory Director, the Director of AFRD will be responsible to provide scientific leadership and advocacy for the Division's research programs, develop new directions that address the national needs of accelerator-based science and will be the chief spokesperson for the Division. The Director will be responsible for all areas of management within the Division including safe operations, administration, budget, staffing and human resources.

The ideal candidate will have a distinguished record of scientific accomplishments and leadership in multiple disciplines relevant to the research of AFRD; experience with program management and program development; and a demonstrated ability to interact effectively with funding agencies such as DOE. Strong management and administrative skills are necessary. Must also have creativity in decision-making and problem solving along with experience in human resources and financial management. Ph.D. in a scientific discipline relevant to AFRD is strongly preferred.

Applicants are requested to submit their curriculum vitae, a list of publications, a statement of research accomplishments and interest (including management experience), and the names and contact information of at least five references to afrd-director@lbl.gov or via mail to:

Dr. James Siegrist, Chair, AFRD Director Search Committee
Lawrence Berkeley National Laboratory
One Cyclotron Road, MS: 50-4049
Berkeley, CA 94720-8204

Also apply online at: **http://jobs.lbl.gov**. Please reference Job Number 018386 and note it on all documents.

Berkeley Lab is an Affirmative Action/Equal Opportunity Employer committed to the development of a diverse workforce. For more information about Berkeley Lab and its programs, visit: **http://www.lbl.gov**.

NOTE: This position is also subject to the financial disclosure requirements of the California Political Reform Act of 1974.

BERKELEY LAB

University of Cambridge Department of Physics (Cavendish Laboratory)

Research Engineer or Physicist for Instrumentation in Experimental Particle Physics (Senior Technical Officer/Technical Officer)

Applications are invited from electronic engineers or detector physicists for a research position that will provide expertise and leadership in the design, development and implementation of state-of-the-art electronics and particle detectors for the experimental programme of the Cambridge particle physics group. This currently encompasses the ATLAS and LHCb experiments at the CERN Large Hadron Collider, and their future upgrades, R&D for the International Linear Collider through the CALICE and LC-ABD collaborations, and the MINOS experiment at Fermilab.

The successful candidate will have a degree or higher qualification either in electronic engineering, with experience in designing and building fast electronics, or in physics, with a track record in instrumentation. In either case, previous experience in particle physics instrumentation would be advantageous. The post is permanent to the retiring age, subject to satisfactory completion of a probationary period. The stipend will be that of a Senior Technical Officer (£24,820 - £35,883) or Technical Officer (£21,640 - £29,127) according to the qualifications and experience.

Applications, consisting of a supporting statement, a full CV, the names and contact details of three referees, and a completed form PD18 obtainable from www.admin.cam.ac.uk/offices/personnel/forms/pd18, should be sent by mail or email to The Registrar, Cavendish Laboratory, Madingley Road, Cambridge, CB3 0HE, UK, (email:cll30@phy.cam.ac.uk) from whom further details can be obtained. Informal enquiries should be directed to Professor Janet Carter by email, jrc1@hep.phy.cam.ac.uk. The closing date for the receipt of applications is 18th November 2005.

The University is committed to equality of opportunity.

THE UNIVERSITY OF CHICAGO
ENRICO FERMI INSTITUTE

ENRICO FERMI POSTDOCTORAL RESEARCH FELLOWSHIP AND THE ROBERT R. MCCORMICK POSTDOCTORAL RESEARCH FELLOWSHIP

These postdoctoral research fellowships are intended to attract outstanding young scientists to the University of Chicago at an early stage in their career. We expect to award two fellowships each year at the rank of Research Associate from a pool of international candidates. To date, there have been 93 such fellows, many of whom have gone on to careers as influential scientists.

The initial appointment is for one year, renewable annually, for up to three years. The appointment carries a salary of $52,500 per annum with an additional allocation of up to $6,000 per annum for independent research support. Appointees are given the freedom of either working independently or associating with EFI faculty in a research area of common interest.

The Enrico Fermi Institute is an interdisciplinary research unit within the Division of Physical Sciences of the University of Chicago. The Institute's activities include the following: string theory and theoretical high energy physics, experimental high energy physics, theoretical astrophysics and cosmology, experimental astrophysics and space physics, infrared and optical astronomy, cosmic microwave background observations, general relativity, cosmochemistry, scanning electron & ion microscopy, secondary ion mass spectrometry.

Applying for the Enrico Fermi and/or the Robert R. McCormick Postdoctoral Research Fellowship at the rank of Research Associate:

One application is sufficient to be considered for both research fellowships.

Candidates should apply on line at https://jobopportunities.uchicago.edu, using requisition number: 070992.

They will be asked to supply the following documents:

a. Curriculum Vitae
b. Bibliography of publications and preprints
c. Description of research interests to be pursued at the University

In addition, candidates should ensure that three letters of recommendation are sent to: **Director, Enrico Fermi Institute, 5640 S. Ellis Avenue, RI-183, Chicago, Illinois 60637** or by fax to: **(773) 702-8038**. Letters should be from faculty members or senior research scientists who are active in the field of study in question.

Material provided on-line need not be sent to the Fermi Institute, however, it is the candidate's responsibility to see that the letters of support are sent to the Enrico Fermi Institute *no later than November 11, 2005*. Review of applications will begin at that time. Candidates will be notified of the results by late December. **Contact Nanci Carrothers at: n-carrothers@uchicago.edu in case of questions.**

The University of Chicago is an Affirmative Action/Equal Opportunity employer. It also participates in the Exchange Visitor Program and will facilitate the granting of visas to foreign applicants.

McGill

Postdoctoral Research Position in Ground-based Gamma-ray Astronomy with VERITAS

The high energy astrophysics group at McGill University is seeking applications for a research associate postion in ground-based gamma-ray astronomy. We are members of the VERITAS collaboration, which is constructing an array of four 12 metre air-Cherenkov telescopes near Tucson, Arizona. This will be used to carry out observations of astrophysical sources in the energy range above 100 GeV.
The McGill team comprises two faculty members, a post-doctoral research associate and several graduate students.

We seek individuals with a recent PhD in particle astrophysics, experimental particle physics, or a related discipline. The position is initially for two years with an opportunity for extension. The successful candidate will be based in Montreal and will be expected to travel to Arizona periodically. Salary will be commensurate with experience.

Please send a CV and arrange to have three letters of reference sent to:
Professor D. Hanna, Physics Department, McGill University, 3600 University Street, Montreal, QC H3A 2T8, Canada

hanna@physics.mcgill.ca

Applications will be considered until the position is filled.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. However all qualified individuals are encouraged to apply.
McGill University is committed to equity in employment.

CANFRANC UNDERGROUND LABORATORY (LSC)

SENIOR PHYSICIST FOR DIRECTOR OF THE LABORATORY

The **Canfranc Underground Laboratory (LSC)** is a new facility for Underground Science. It is conceived as a Consortium of the **Spanish Ministry of Education and Science**, the **Aragon Regional Government** and the **University of Zaragoza.** Located under the Pyrenees' mountain "El Tobazo", the overburden at the site provides 2500 Meters Water Equivalent (MWE) of shielding from cosmic rays and offers a low background environment for the next generation of experiments exploring the frontiers of astroparticle physics.

Construction of the new facility will be finished in September 2005 and the Laboratory is expected to be available for installation of experiments during the first half of 2006.

Fields of research being considered for **LSC** include (but are not limited to): dark matter searches, neutrinoless double beta decay, low-energy solar neutrinos, nuclear reactions of astrophysical interest, low counting facility, geophysics, biophysics and other topics. A first Call for Expressions of Interest was announced in July 05. Details may be found in the web page **http://www.unizar.es/lsc**

The CANFRANC UNDERGROUND LABORATORY (LSC) seeks a

DIRECTOR

The Director reports to the Governing Council and is responsible for managing laboratory operations and maximizing its readiness and effectiveness for scientific research. The Director will have the advice of a Scientific Advisory Committee.The Director is responsible for recruiting and maintaining high quality scientific, technical and administrative staff, developing an annual budget for review and approval, and proposing the short- and long-range plans for the Laboratory.

The Director oversees the scheduling for science and engineering associated with the different experiments and acts as the primary interface with the user community. The Director maintains effective liaison with the Council and its Executive Committee, and the Scientific Advisory Committee. The Director is also responsible for the general maintenance of theLaboratory, for maintaining a public outreach office and for pursuing and managing public and private fund-raising activities, with guidance from Council.

Salary range and starting date are to be negotiated. Review of applications will begin on **January 15th, 2005**, and the recruitment will remain open until the position is filled.

Applications together with names of two referees should be submitted by e-mail to the Chair of the interim Scientific Advisory Committee, Prof. J. Bernabeu (**Jose.Bernabeu@uv.es**) with copy to the coordinator of the Spanish National Programme on Particle Physics Prof. D. Espriu (**espriu@ecm.ub.es**).

Post Doctoral Fellow

Experimental Cosmology

The Physics Division of the Lawrence Berkeley National Laboratory has an opening for a postdoctoral fellow in experimental cosmology. This is a two-year position with the possibility of renewal. Our program includes high red-shift supernova studies using ground- based telescopes and the Hubble Space telescope, simulation and optimization of a next generation satellite experiment to study dark energy using supernovae and weak lensing, and R&D on advanced instrumentation for next generation telescopes.

This position requires a PhD or equivalent experience in Astronomy or Physics. Experience in astronomical data analysis, simulation techniques, solid-state detectors or electronics is highly desirable. More information is available at **http://supernova.lbl.gov** and **http://snap.lbl.gov**. Contact Natalie Roe, **naroe@lbl.gov**, for more information. Please send all applications, including CV, list of publications, description of research interests and skills, and three letters of recommendation, to **supernova_postdoc@lbl.gov** and apply on line at **http://jobs.lbl.gov**. Please reference Job # 018377 in the subject line. LBNL is an equal opportunity employer committed to developing a diverse workforce.

BERKELEY LAB

SCHOOL OF ENGINEERING AND DESIGN

Research Fellow(s)

Ref: DCL0221-1

Brunel University has an established record of excellent research achievement with '5' ratings in both General Engineering and in Applied Mathematics in the most recent UK Research Assessment Exercise.

The SIRE Group is heavily involved in the preparation of parts of the CMS detector, which will operate at the Large Hadron Collider from 2007 onwards. One post is to support our commitment to the electromagnetic endcap calorimeter and to prepare for analysis of the first data.

Posts: The role of the appointed person is to contribute within a sizable collaborative team based in the UK and at CERN, Switzerland to the commissioning and operation of the endcap electromagnetic calorimeter of the CMS detector at the LHC.

Applicants should be prepared to make a significant contribution to the analysis of early data from the CMS detector in an area in which the UK has a strong involvement (Higgs physics, triple gauge couplings and the gluon structure of the proton).

Applicants should be experienced in using Object Oriented programming in C++ or Java languages, and be familiar with large-scale computing for data analysis and Monte Carlo simulation.

A further post to work on novel data analysis techniques may be funded when candidates are interviewed. In this case, a further appointment may be made.

Applicants will have, or be about to receive, a PhD in particle physics or a closely related subject. Previous experience of data analysis or Monte Carlo simulation is desirable.

The salary will be within the RA1A (£19,640 to £29,128) scale for a minimum of one and maximum of three years. The salary and initial contract period will be dependent on qualifications and experience.

For a downloadable application form and further details of the post, please visit Brunel web Pages on www.brunel.ac.uk/about/job Alternatively for an application form email to the address below. Closing date for receipt of applications: 28 October 2005.

RecruitDEA, Human Resources, Brunel University, Uxbridge, Middlesex UB8 3PH or email: recruitdea@brunel.ac.uk

Informal enquiries may be made to: Professor Peter Hobson or Professor Steve Watts, School of Engineering and Design, Brunel University, Uxbridge, Middlesex UB8 3PH, UK. Tel: +44 (0)1895 274000.

Email: peter.hobson@brunel.ac.uk, Stephen.Watts@brunel.ac.uk

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Brunel UNIVERSITY WEST LONDON

http://www.brunel.ac.uk/about/job/

CERN COURIER

Classified advertising

CERN Courier and cerncourier.com offer the only print and online recruitment service that has a direct route to highly skilled job seekers in high-energy physics and related areas.

"*CERN Courier* is one of the best media to reach and attract the cutting-edge scientific profiles we're looking for at the ESRF. Advertising in *CERN Courier* adds value to our recruitment."
Cécile Davan, *Recruitment advisor, ESRF*

"DESY has chosen *CERN Courier* to advertise in because of the popularity of the magazine – it is read all over the world. It is a great opportunity to advertise in such a prestigious publication and to reach outstanding scientists and fellows."
Christina Grimm, *Human Resources, DESY*

For further information please contact
Adam Hylands
Tel: +44 (0)1179 301 027
Fax: +44 (0)1179 200 726
E-mail: adam.hylands@iop.org

Drexel UNIVERSITY

Faculty Position in Experimental Particle Physics

Drexel University

The Department of Physics at Drexel University invites applications for a tenure-track faculty position in Experimental Particle Physics starting in the Fall of 2006. We seek a candidate who will establish an active research program while participating in our ongoing neutrino physics program in KamLAND or Double Chooz. The successful candidate must also be committed to excellence in education at both undergraduate and graduate levels. The appointment is expected to be made at the level of Assistant Professor, but an appointment at a more senior level may be considered.

Applicants should send a Curriculum Vitae, a Plan of Research, a Statement of Teaching Philosophy, and arrange for 3 letters of reference to be sent to:

Particle Physics Search Committee, Department of Physics, Drexel University, 3141 Chestnut St., Philadelphia PA 19104, USA

Applications received by January 15, 2006 will receive full consideration.

For more information, see **http://www.physics.drexel.edu/hiring**

Drexel University is an Affirmative Action/Equal Opportunity Employer.

TECHNISCHE UNIVERSITÄT DRESDEN

An der **Fakultät Mathematik und Naturwissenschaften** ist an der **Fachrichtung Physik** zum **nächstmöglichen** Zeitpunkt die

Professur (W2) für Experimentelle Hadronenphysik

zu besetzen. Die Stelle ist im Institut für Kern- u. Teilchenphysik angesiedelt. Der/Die Bewerber/in soll das Forschungsspektrum des Instituts in optimaler Weise ergänzen u. Erfahrungen in der Planung, Organisation, Durchführung u. Auswertung von Experimenten der Kern-, Hadronen- oder Teilchenphysik, insb. auch im Detektorbau, vorweisen. Die Bereitschaft zu einer Kooperation mit Forschungseinrichtungen im weiteren Umfeld ist wünschenswert. Der/Die Stelleninhaber/in soll in der Lehre im Grundstudium Experimentalphysik – auch für Studierende mit Physik im Nebenfach – u. im Hauptstudium Kern- u. Teilchenphysik vertreten. Der/Die Bewerber/in muss die Einstellungsvoraussetzungen gemäß § 40 Sächsisches Hochschulgesetz vom 11. Juni 1999 erfüllen.

Frauen sind ausdrücklich zur Bewerbung aufgefordert. Bewerbung Schwerbehinderter werden bei gleicher Eignung bevorzugt berücksichtigt. Ihre Bewerbung mit tabellarischem Lebenslauf u. wiss. Werdegang, Lichtbild, Liste der wiss. Arbeiten, Kopie der Urkunde über den erworbenen höchsten akademischen Grad u. Sonderdrucken von 5 jüngeren Publikationen richten Sie bitte bis zum **30.11.2005** an: **TU Dresden, Dekan der Fakultät Mathematik und Naturwissenschaften, Herrn Prof. Dr. rer. nat. J. Weber, 01062 Dresden.**

JobsWatch@cerncourier.com

The Cockcroft Institute

An International Centre for Research in Accelerator Science and Technology

Two Faculty Positions and Two Research Positions

The Cockcroft Institute (http://www.lancs.ac.uk/cockcroft-institute/) is a newly created centre for Accelerator Science and Technology in the UK. It is a joint venture of Lancaster, Liverpool and Manchester Universities, the Daresbury and Rutherford Appleton Laboratories (CCLRC), the Particle Physics and Astronomy Research Council (PPARC), and the North West Development Agency (NWDA). It will soon be situated in a purpose-built building on the Daresbury Laboratory campus. The Institute's aim is to provide the intellectual focus, the educational infrastructure, and the essential scientific and technological facilities for scientists and engineers to take a leading role in in global projects concerned with accelerator design, construction and operation for the foreseeable future. New, research-led, positions are now available. They all provide an exciting and unique opportunity to take a major role in the realisation of the Institute's vision.

LANCASTER UNIVERSITY
Celebrating 40 Years of Excellence

Lecturer in Accelerator Physics

Quote ref: A550

Salary: £23,643 – £35,883 p.a. **Closing date: 5th December 2005**

The University of Lancaster intends to make an appointment to a position of Lecturer in the Physics Department. The successful candidate will join the new multi-disciplinary Accelerator Science and Technology (AST) group in the Departments of Physics (http://www.physics.lancs.ac.uk/home/index.asp) and of Engineering (http://www.engineering.lancs.ac.uk/home/index.asp), and will initiate and pursue R&D concerned with particle acceleration and beam handling as part of the programme of the Cockcroft Institute and of the High Energy Physics and Mathematical Physics groups of the Department of Physics. AST work in Lancaster presently includes experimental design and evaluation work concerned with the International Linear Collider (ILC) within the framework of the LC-ABD and EuroTeV initiatives both in the experimental High Energy physics group (http://www.lancs.ac.uk/depts/physics/research/particle/epgroup.html/) and in the Microwave Engineering group (http://www.comp.lancs.ac.uk/engineering/), and theoretical work concerned with relativistic spin and particle beam dynamics and with the relativistic electro-hydrodynamics of charged plasmas in the Mathematical Physics group (http://www.lancs.ac.uk/depts/imgg/). There are strong links with accelerator projects worldwide through collaboration with CLIC at CERN, with 4GLS at Daresbury, with the ILC, and with European industry.

Innovative contributions to undergraduate and postgraduate teaching in the Department of Physics and in the Cockcroft Institute will be part of the Lecturer's duties.

The position is available immediately from appointment.

Candidates are encouraged to contact **Professors Peter Ratoff (p.ratoff@lancaster.ac.uk, phone +44 1524 593086)** and **Robin Tucker (r.tucker@lancaster.ac.uk, phone +44 1524 593610)** for informal discussions.

Research Position in Accelerator Engineering

Quote ref: A538

Starting salary up to £29,128 pa **Closing date: 5th December 2005**

Applications are invited from highly motivated scientists and engineers for a new position in the Accelerator Science R&D programme of the Institute. The successful applicant will work at the Institute with the Microwave Research Group in the Department of Engineering (http://www.comp.lancs.ac.uk/engineering/) of Lancaster University.

The successful candidate will focus on the continuation of the development of techniques for the suppression of multipactor discharge in accelerator components. The work addresses this phenomenon using theoretical, numerical and experimental methods to develop generic techniques for suppressing multipactor discharge in situations where traditional techniques fail or are prohibited by cost or operation. The successful applicant will be expected to devote a portion of her/his time contributing to related work in the growing research programme of the Cockcroft Institute.

The position is available immediately from appointment for an initial period of 2 years with a possible extension of 1 year, and the successful candidate will be eligible to join the USS pension scheme.

Informal enquiries can be addressed to **Professor Richard Carter (r.carter@lancaster.ac.uk, tel: +44 1524 593086)** and to **Dr Rebecca Seviour (seviour@unix.lancs.ac.uk, tel: +44 1524 593824) Engineering Department, Lancaster University, Lancaster LA14YR, UK.**

Further particulars and details of the application procedure for both positions are available from the **Director of Personnel, Lancaster University, Lancaster LA14YW**

Applications should be made on the form available at **http://www.lancs.ac.uk/users/personnel/apply.htm** and should reach the Director of Personnel, from whom further information may be obtained, not later than 5th December 2005.

THE UNIVERSITY *of* LIVERPOOL

Lecturer in Accelerator Physics

Quote ref: B577

Salary: £23,643 – £35,883 p.a. **Closing date: 5th December 2005**

An appointment is to be made to a position of Lecturer in the Department of Physics (http://www.ph.liv.ac.uk/). The successful candidate will initiate and lead innovative R&D in the science and technology of particle acceleration and beam handling as part of the programme of the Cockcroft Institute. The successful applicant will also be a member of the new Accelerator Science group in the Physics Department, consisting of five academic staff members, including the Director of the Institute.

The Department has strong, established, and internationally recognized, research profile in High Energy Physics, in Nuclear Physics, and in Condensed Matter Physics. Close collaboration is already well established with the 4GLS and ERLP projects at Daresbury Laboratory (http://www.4gls.ac.uk/index.htm). The High Energy Physics group has a growing involvement in the design and construction of the positron source for the International Linear Collider in collaboration with CCLRC ASTeC (http://www.astec.ac.uk/) and with partners in Germany, Russia and the US. The infrastructure available locally both in the Liverpool Physics Department and at CCLRC Daresbury Laboratory constitutes a uniquely comprehensive resource in support of this position.

Innovative contributions to undergraduate and postgraduate teaching in the Department of Physics and in the Cockcroft Institute will be part of the Lecturer's duties.

The position is available immediately from appointment.

Informal enquiries can be made to **Prof. John Dainton (jbd@hep.ph.liv.ac.uk, tel: +44 151 794 7769, fax: +44 151 794 3444)**, and to the Head of Department **Prof. Paul Nolan, (pjn@ns.ph.liv.ac.uk, tel: +44 151 794 3377, fax: +44 151 794 3362) Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, GB.**

Further particulars and details of the application procedure are available from the **Director of Personnel, The University of Liverpool, Liverpool L69 3BX on +44 151 794 2210 (24 hr answer-phone), via email: jobs@liv.ac.uk,** or at **http://www.liv.ac.uk/university/jobs.html**

MANCHESTER 1824
The University of Manchester

Research Position in Accelerator Physics

Quote ref: EPS/257/05

Starting salary to £29,128 p.a. **Closing date: 5th December 2005**

Applications from highly motivated scientists and engineers are invited for a new position in the Accelerator Science R&D programme of the Cockcroft Institute. The successful applicant will work at the Institute on the production, transport and disposal of disrupted beams (ref: EPS/257/05). The work is centred in the research interests of the Manchester University group working in the Institute on the beam delivery system for the ILC in the LC-ABD and EuroTeV initiatives.

The successful applicants will have, or will be about to obtain, a PhD in physics, electrical engineering or computational science. A demonstrated ability to program in either Fortran, C++ or C is essential. Familiarity with Python and Mathematica will be considered an asset. The successful applicants will be expected to devote a portion of her/his time contributing to related work in the growing research programme of the Institute.

The position is available immediately following appointment and for a fixed term of initially 2 years with a possible extension of 1 year, and the successful candidate will be eligible to join the USS pension scheme.

Informal enquires may be made to Dr Rob Appleby (email: r.b.appleby@dl.ac.uk) or Prof Roger Barlow (roger.barlow@manchester.ac.uk). An application form is available at: http://www.man.ac.uk/news/vacancies/research.html#EPS203. Applications, marked 'Confidential – Staff Application', including a full curriculum vitae, a list of publications, a brief description of research interests and the names of three referees should be addressed to **Professor Roger Barlow, School of Physics and Astronomy, The University of Manchester, Oxford Road, Manchester M13 9PL** or by fax to **+44 (0)161-2735867**.

BOOKSHELF

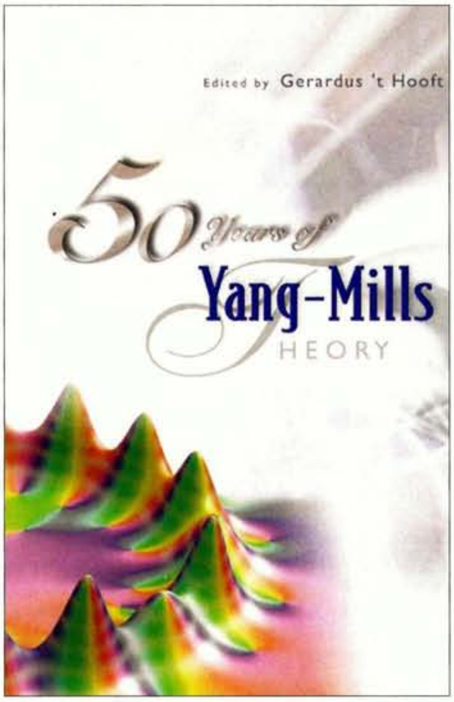
50 Years of Yang–Mills Theory by Gerardus 't Hooft (ed), World Scientific. Hardback ISBN 9812389342, £51 ($84). Paperback ISBN 9812560076, £21 ($34).

Anniversary volumes usually mark a significant birthday of an individual, or perhaps an institution. But this fascinating compilation celebrates the golden jubilee of a theory – namely, the type of non-Abelian quantum gauge field theory first published by Chen Ning Yang and Robert L Mills in 1954, and now established as a central concept in the Standard Model of particle physics. It was a brilliant idea (by the editor, Gerardus 't Hooft, I assume) to signal the 50th birthday of Yang–Mills theory by gathering together a wide range of articles by leading experts on many aspects of the subject. The result is a most handsome tribute of both historical and current interest, and a substantial addition to the existing literature.

There are 19 contributions, only two of which have been published elsewhere. They are grouped into 16 sections ("Quantizing Gauge Fields", "Ghosts for Physicists", "Renormalization" and so on), each accompanied by brief but illuminating comments from the editor. The style of the contributions ranges from an equation-free essay by Frank Wilczek, to a paper by Raymond Stora on gauge-fixing and Koszul complexes. Somewhere in between lie, for example, François Englert's review of "Breaking the Symmetry", and Stephen Adler's exemplary account of "Anomalies to All Orders".

One recurrent theme is how unfashionable quantum field theory was in the 1950s and 1960s. As 't Hooft puts it: "In 1954, most of those investigators who did still adhere to quantum field theory were either stubborn, or ignorant, or both. In 1967 Faddeev and Popov not only had difficulties getting their work published in Western journals; they found it equally difficult to get their work published in the USSR, because of Landau's ban on quantized field theories in the leading Soviet journals." One of the most interesting papers in the book is the 1972 English translation of their 1967 "Kiev Report", produced via an initiative of Martinus Veltman and Benjamin Lee. It is more detailed than their famous 1967 paper in *Physics Letters*, and includes a discussion of the gravitational field.

Alvaro De Rújula inimitably brings to life the strong interactions between theorists and experimentalists in the heady days of



1973–1978. He includes a candid snap of Howard Georgi and Sheldon Glashow, circa 1975, which made me wish there were more such shots of the leading players from that era. De Rújula's is the only contribution to address the experimental situation, despite the editor's admission that the lasting impact of Yang–Mills theory depended on "numerous meticulous experimental tests and searches". But, after all, this is a volume celebrating the birthday of a theory.

Many contributors look to the future, as well as the past. These include Alexander Polyakov on "Confinement and Liberation", Peter Hasenfratz on "Chiral Symmetry and the Lattice", and Edward Witten on "Gauge/String Duality for Weak Coupling".

I have only had space enough to (I hope) whet the reader's appetite. This unusual and elegant *festschrift* is a treat for theorists – and, as a bonus, you get a full-colour representation on the cover of a 17-instanton solution of the Yang–Mills field equations (designed by the editor).
Ian Aitchison, Oxford University.

High p_T Physics at Hadron Colliders by Dan Green, Cambridge University Press. Hardback ISBN 0521835097, £70 ($110).

Over the past several years, Fermilab physicist Dan Green has developed an excellent course on "High p_T Hadron Collider Physics". This is now published as a Cambridge monograph that successfully traces the important past and future roles of hadron colliders in testing and probing the limits of the Standard Model for electroweak and strong interactions. In so doing, it provides an accessible and pedagogic introduction to key features of parton–parton collisions in pp or $\bar{p}p$ interactions. It is not, however, an up-to-date survey of the field. Rather, the centre-piece of Green's book concerns the motivation and experimental strategy for detecting, and subsequently studying, the Higgs scalar particle (the last undetected element of the minimal Standard Model).

Written by an experimentalist, the book is qualitative in nature and can even be enjoyed by final-year undergraduates, although to profit from it formal introductions to particle-physics phenomenology and quantum field theory are essential. (Such courses are fortunately part of most relevant Master's programmes, and the reader is directed to excellent texts on the subject.) A key feature is the use of dimensional (heuristic) arguments to estimate key production and decay processes in hadron collisions. In addition, and uniquely, the COMPHEP freeware program has been extensively used to back up the dimensional arguments with lowest order computations. Despite some incompatibilities of nomenclature, this innovation is (to the reviewer) extremely successful.

The first chapter presents a concise summary of the Standard Model particles and their couplings, as well as a description of the Higgs mechanism for mass generation of the W and Z bosons. It lays out the key properties of the Higgs boson, and concludes with a list of issues that are not answered by the Standard Model. These issues are (rather superficially) discussed in chapter six, with chapters two to five directed towards experimental and phenomenological issues relevant to the Higgs search.

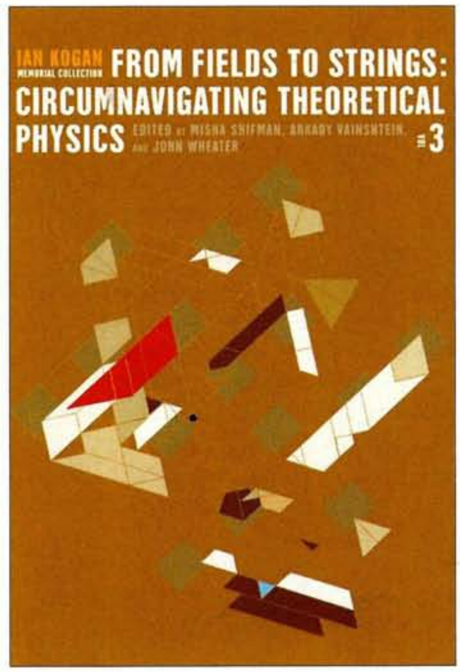
Chapter two describes, in an extremely accessible way, the detector requirements for identifying key high-p_T parton–parton collision processes and the associated instrumental or irreducible physics-related backgrounds. The treatment of jet energy reconstruction and di-jet mass reconstruction is excellent. Inevitably, given the author's background in the D0 and CMS experiments at Fermilab, the book leans towards examples of these experiments. In a few cases, some important instrumental innovations are not given adequate space (e.g. the real-time selection of heavy quarks as in the CDF experiment). Students could also have benefited from a description of the relative merits of the CDF and D0 experiments, and of course of the future ATLAS and CMS detectors at CERN's Large Hadron Collider (LHC).

The third chapter is good reading for any new graduate student. Green introduces key features of collider physics: the central rapidity plateau and its energy dependence; the basic parton–parton collision processes and their kinematics; the main gauge boson and gauge-boson pair production processes; and jet fragmentation. In all cases experimental data (usually not the latest) are used to justify heuristic arguments and COMPHEP calculations. A series of exercises complements the chapter.

Chapters four and five concentrate respectively on the more important results from Fermilab's Tevatron and on the Higgs search strategy at the LHC experiments (for which chapter four's material is invaluable as a guide to the experimental backgrounds to be expected from any Higgs signal at the LHC). As a reviewer, I enjoyed the experimental approach of these two chapters and their highly readable nature. However, the extremely important sections on heavy-quark (b and t quark) production were rather incomplete, given the unique measurements at the Tevatron and the important implications for the LHC. While the somewhat arbitrary choice of figures in chapter four (taken in most cases from the experiments) is adequate for lecture notes, it detracts from the book's quality that an effort was not made to include the latest available data, and to combine data from the CDF and D0 experiments. Chapter five concerns the experimental strategy for detecting and studying the Standard Model Higgs particle at the LHC, and relies heavily on relevant preparatory studies from the ATLAS and CMS experiments.

Finally, the concluding sixth chapter discusses extensions to the Standard Model such as supersymmetry, as well as some of the open questions alluded to in chapter one. While extensions relevant to the LHC physics programme must be discussed, it felt as if this was a hurried addition. Judy Garland's quotation from *The Wizard of Oz*: "Toto, I've a feeling we're not in Kansas anymore," is rather appropriate.

Published at a time when the CDF and D0 experiments are increasing their data samples by more than an order of magnitude, and in advance of the LHC, Green's book has limited shelf life in its present edition. However, despite some shortcomings, its core is an excellent introduction for any graduate student starting out in experimental hadron-collider physics and can be strongly recommended. Dan Green should be congratulated on the overall quality of his text. Presumably, any new edition beyond 2007 will provide some interesting updates.
Allan Clark, University of Geneva.



From Fields to Strings: Circumnavigating Theoretical Physics (Ian Kogan Memorial Collection) by Misha Shifman, Arkady Veinshtein and John Wheater (eds), World Scientific. Hardback ISBN 9812389555 (three volume set), £146 ($240).

On the morning of 6 June 2003, Ian Kogan's heart stopped beating. It was the untimely departure of an outstanding physicist and a warm human being. Ian had an eclectic knowledge of theoretical physics, as one can easily appraise by perusing the list of his publications at the end of the third volume of this memorial collection.

The editors of these three volumes had an excellent idea: the best tribute that could be offered to Ian's memory was a snapshot of theoretical physics as he left it. The response of the community was overwhelming. The submitted articles and reviews provide a thorough overview of the subjects of current interest in theoretical high-energy physics and all its neighbouring subjects, including mathematics, condensed-matter physics, astrophysics and cosmology. Other subjects of Ian's interest, not related to physics, will have to be left to a separate collection.

The series starts with some personal recollections from Ian's family and close friends. It then develops into a closely knit tapestry of subjects including, among many other things, quantum chromodynamics, general field theory, condensed-matter physics, the quantum-hole effect, the state of unification of the fundamental forces, extra dimensions, string theory, black holes, cosmology and plenty of "unorthodox physics" the way Ian liked.

These books provide a good place to become acquainted with many of the new ideas and methods used recently in theoretical physics. It is also a great document for future historians to understand, first hand, what physicists thought of their subject at the turn of the 21st century. There is much to learn and profit from this trilogy. Circumnavigating theoretical physics is indeed fun. It is unfortunate, however, that it had to be gathered in such sad circumstances.
Luis Alvarez-Gaume, CERN.

The dark side of computing power

Urs Hölzle from Google points out that while the performance of commodity computer clusters continues to increase, so does their electrical power consumption.

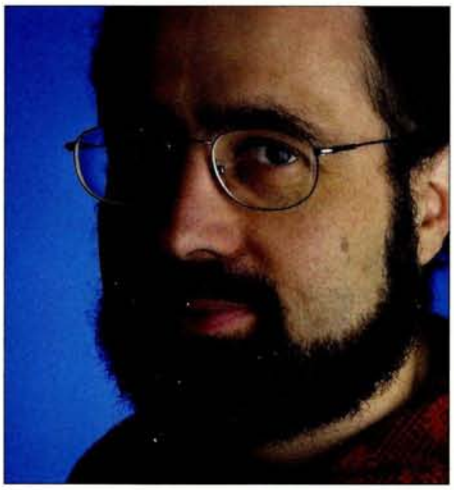
On a recent visit to CERN, I had the chance to see how the high-energy physics (HEP) community was struggling with many of the same sorts of computing problems that we have to deal with at Google. So here are some thoughts on where commodity computing may be going, and how organizations like CERN and Google could influence things in the right direction.

First a few words about what we do at Google. The Web consists of more than 10 billion pages of information. With an average of 10 kB of textual information per page, this adds up to around 100 TB. This is our data-set at Google. It is big, but tractable – it is apparently just a few days' worth of data production from the Large Hadron Collider. So just like particle physicists have already found out, we need a lot of computers, disks, networking and software. And we need them to be cheap.

The switch to commodity computing began many years ago. The rationale is that single machine performance is not that interesting any more, since price goes up non-linearly with performance. As long as your problem can be easily partitioned – which is the case for processing Web pages or particle events – then you might as well use cheaper, simpler machines.

But even with cheap commodity computers, keeping costs down is a challenge. And increasingly, the challenge is not just hardware costs, but also reducing energy consumption. In the early days at Google – just five years ago – you would have been amazed to see cheap household fans around our data centre, being used just to keep things cool. Saving power is still the name of the game in our data centres today, even to the extent that we shut off the lights in them when no-one is there.

Let's look more closely at the hidden electrical power costs of a data centre. Although chip performance keeps going up, and performance per dollar, too, performance per watt is stagnant. In other words, the total



power consumed in data centres is rising. Worse, the operational costs of commercial data centres are almost directly proportional to how much power is consumed by the PCs. And unfortunately, a lot of that is wasted.

For example, while the system power of a dual-processor PC is around 265 W, cooling overhead adds another 135 W. Over four years, the power costs of running a PC can add up to half of the hardware cost. Yet this is a gross underestimate of real energy costs. It ignores issues such as inefficiencies of power distribution within the data centre. Globally, even ignoring cooling costs, you lose a factor of two in power from the point where electricity is fed into a data centre to the motherboard in the server.

Since I'm from a dotcom, an obvious business model has occurred to me: an electricity company could give PCs away – provided users agreed to run the PCs continuously for several years on the power from that company. Such companies could make a handsome profit!

A major inefficiency in the data centre is DC power supplies, which are typically about 70% efficient. At Google ours are 90% efficient, and the extra cost of this higher efficiency is easily compensated for by the reduced power consumption over the lifetime of the power supply.

Part of Google's strategy has been to work with our component vendors to get more energy-efficient equipment to market earlier. For example, most motherboards have three DC voltage inputs, for historical reasons. Since the processor actually works at a voltage different from all three of these, this is very inefficient. Reducing this to one DC voltage produces savings, even if there are initial costs involved in getting the vendor to make the necessary changes to their production. The HEP community ought to be in a similar position to squeeze extra mileage out of equipment from established vendors.

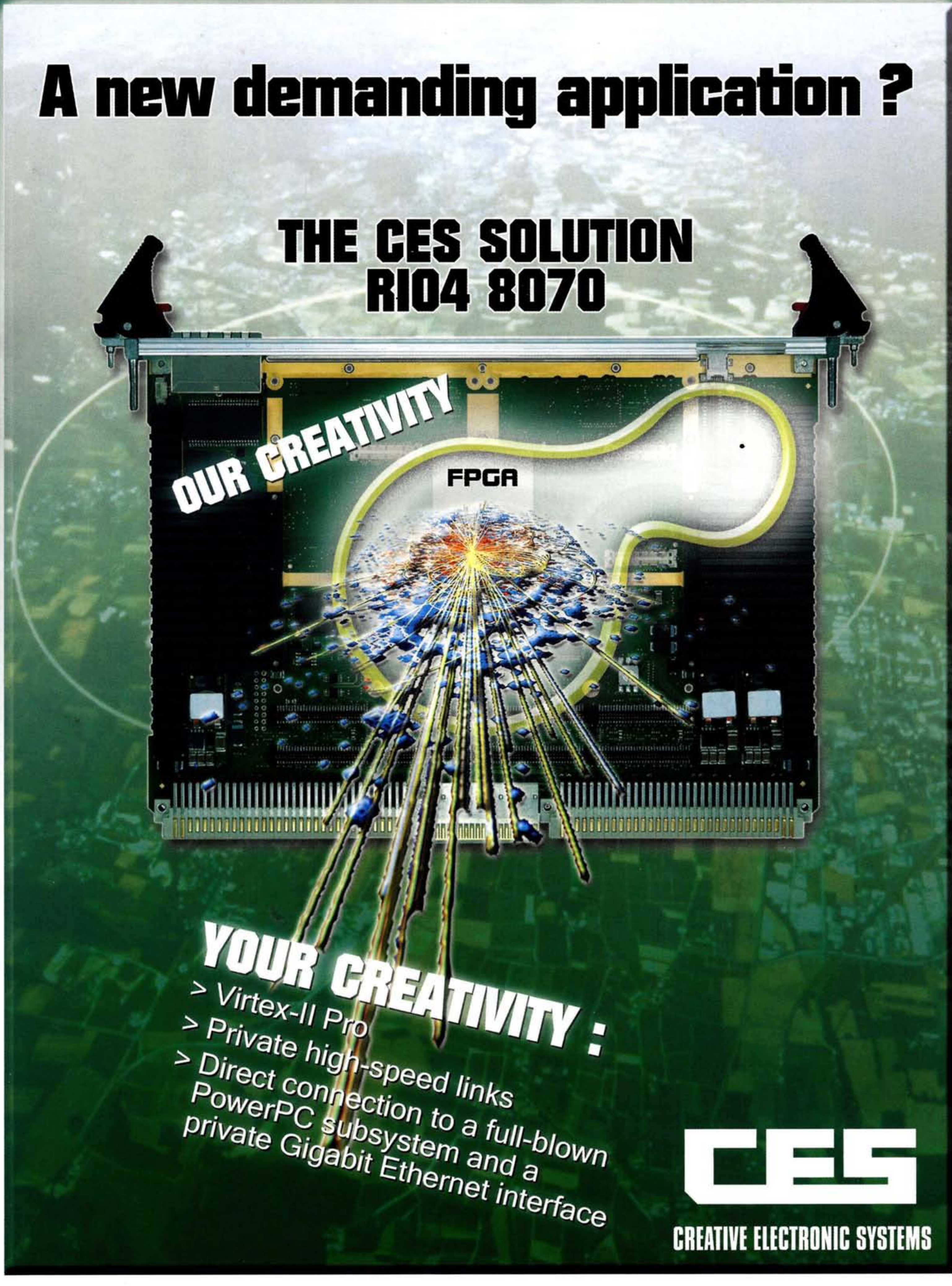
Tackling power-distribution losses and cooling inefficiencies in conventional data centres also means improving the physical design of the centre. We employ mechanical engineers at Google to help with this, and yes, the improvements they make in reducing energy costs amply justify their wages.

While I've focused on some negative trends in power consumption, there are also positive ones. The recent switch to multicore processors was a successful attempt to reduce processors' runaway energy consumption. But Moore's law keeps gnawing away at any ingenious improvement of this kind. Ultimately, power consumption is likely to become the most critical cost factor for data-centre budgets, as energy prices continue to rise worldwide and concerns about global warming put increasing pressure on organizations to use electrical power more efficiently.

Of course, there are other areas where the cost of running data centres can be greatly optimized. For example, networking equipment lacks commodity solutions, at least at the data-centre scale. And better software to turn unreliable PCs into efficient computing platforms can surely be devised.

In general, Google's needs and those of the HEP community are similar. So I hope we can continue to exchange experiences and learn from each other.

Urs Hölzle, vice-president of operations, Google.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