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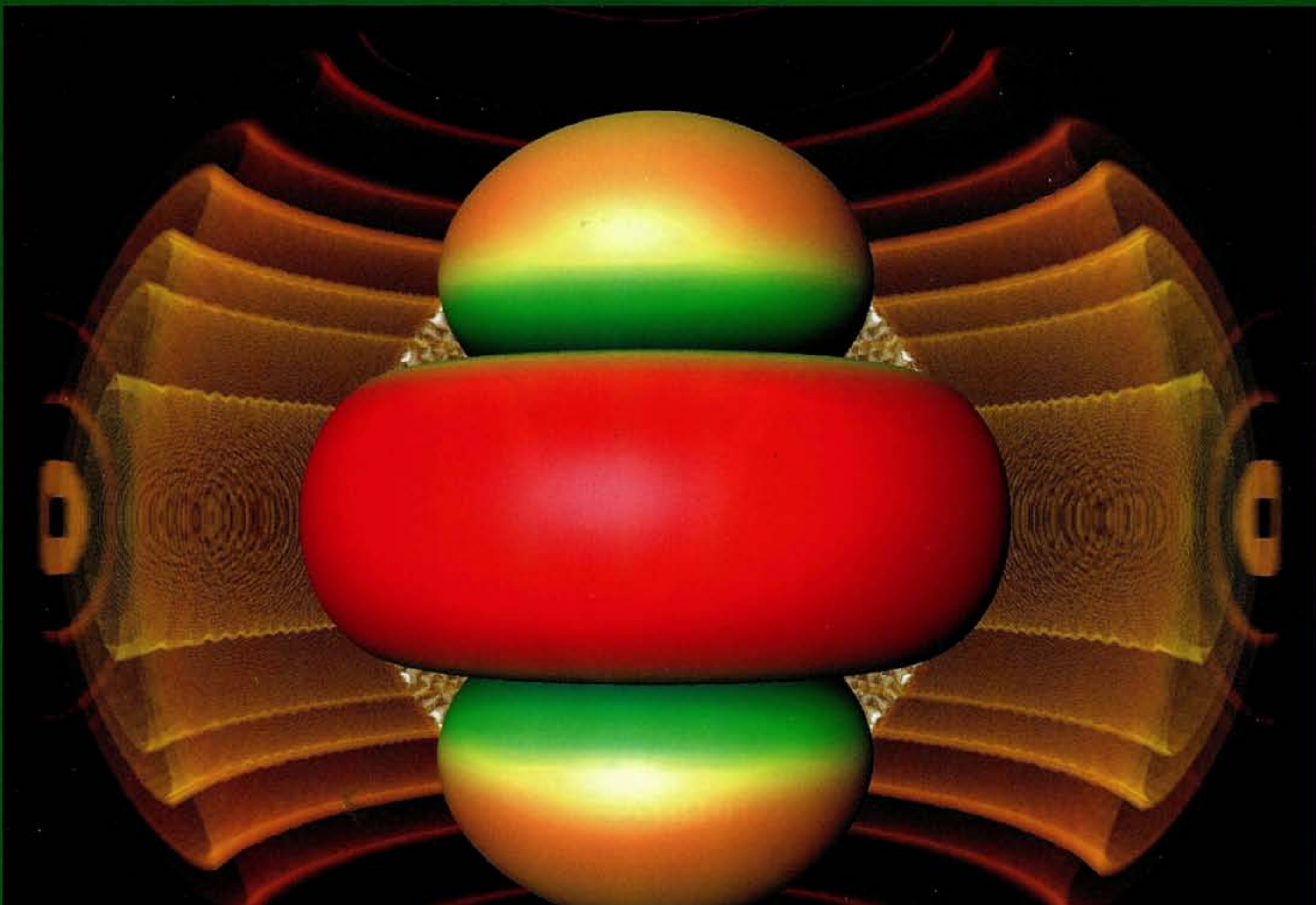

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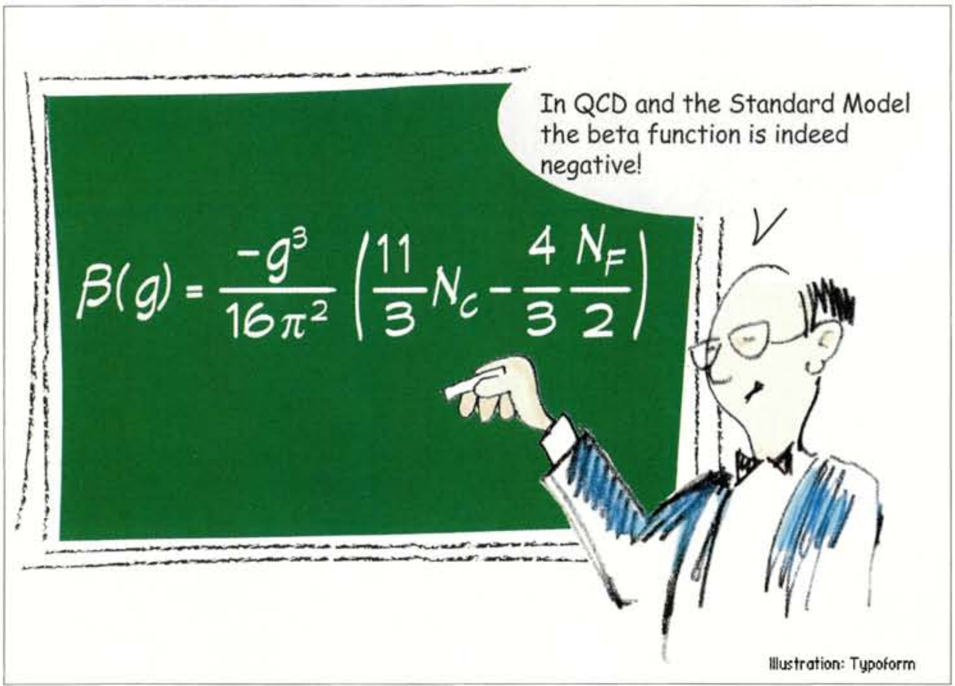
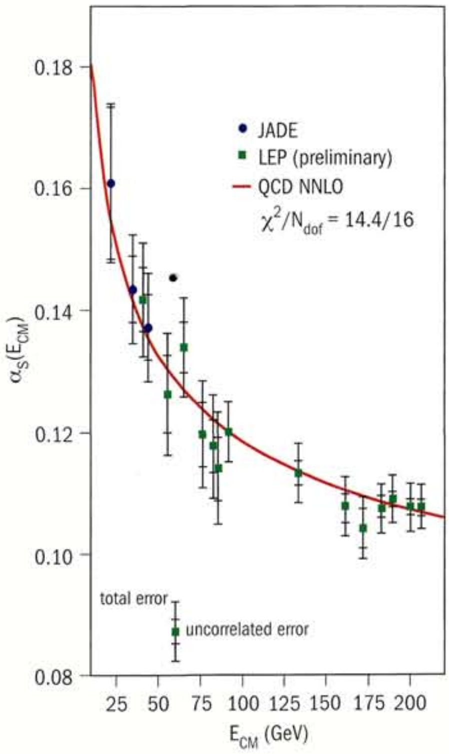
Cover: Gravitational waves as predicted by the theory of general relativity. These "Teukolski waves" represent a linearized solution to Einstein's equations, which is important for understanding the structure of space–time around black holes. Mini black holes may provide insight into these unusual conditions (p27). (Numerical simulation by Max Planck Institute for Gravitational Physics, Albert Einstein Institute [AEI]; visualization by W Benger, Zuse Institute, Berlin/AEI.)

NOBEL PRIZES

Asymptotic freedom wins Nobel



The famous beta function, which underlies asymptotic freedom, where g is the coupling constant, N_c is the number of colours (three in QCD) and N_F is the number of quarks (six in the Standard Model). (Courtesy the Royal Swedish Academy of Sciences.)



The running of the QCD coupling from low PETRA to high LEP energies compared with the prediction of asymptotic freedom.

The 2004 Nobel Prize for Physics has been awarded to David Gross, David Politzer and Frank Wilczek for their "discovery of asymptotic freedom in the theory of the strong interaction". This honour comes a year after they received the High Energy and Particle Physics Prize of the European Physical Society – and just over 30 years since they made the remarkable proposal that the interaction strength between quarks becomes weaker as they come closer together.

Politzer and Wilczek were both still graduate students in June 1973 – Wilczek working with Gross – when their work appeared in two consecutive papers in *Physical Review Letters*, in fact the last two papers of volume 30. The key factor they discovered was that the beta function, which describes how the coupling constant of an interaction changes with energy, can be negative, contrary to what was generally believed. This means that the interaction strength can decrease with increasing energy, making quarks "asymptotically free" at high energies.

Earlier, in 1970, Kurt Symanzik had shown that only a theory with a negative beta function could lead to the effect of "scaling" derived by James Bjorken (where the probability for the interaction depends on a dimensionless variable), which had been observed in electron–proton interactions at SLAC. However, this was unknown in any other theory. In quantum electrodynamics, the quantum-field theory *par excellence*, the beta function is positive – charges become free from each other's grasp as they are separated and the force between them becomes smaller. Could a quantum-field theory for the strong force, with a negative beta function, be found? The question became particularly pressing after Gerard 't Hooft's work in 1971 that overcame problems in the gauge-field theory for the unified electroweak theory.

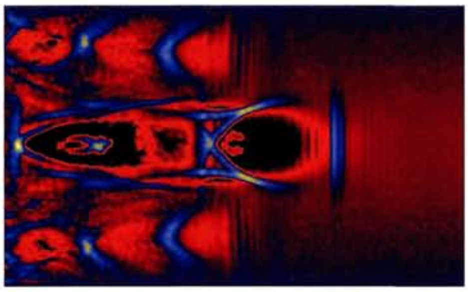
Indeed, in 1972 in a discussion with Symanzik at a conference in Marseille, 't Hooft himself realized what kind of theory could have a negative beta function. Although he did mention it at the conference, he did not follow it up (*CERN Courier* November 1998 p31). It fell to others to pursue the problem, including Gross's group at Princeton and Sidney Coleman's at Harvard, in which Politzer worked. The rest, as they say, is history, as the discovery of Gross, Politzer and Wilczek in a sense not only liberated quarks deep within the proton but also liberated theorists to develop a quantum-field theory of the strong interaction. In particular, it focused attention on the development of quantum chromodynamics (QCD), in which the strong interaction is mediated by massless spin-1 particles, the gluons (see p33).

The decrease of the strong coupling constant with energy has since been dramatically confirmed with high precision, most recently at DESY's electron–proton collider, HERA, and in studies at the mass scale of the Z boson at CERN's Large Electron Positron (LEP) collider (*CERN Courier* May 2004 p21). It is fitting that following this clear support for their original ideas, Gross, Politzer and Wilczek have now been rewarded with the Nobel prize.

ADVANCED ACCELERATORS

Laser-driven plasma waves deliver the best beams so far

Alec Thomas (left) and Stuart Mangles (right) of Imperial College London with the Astra laser used at the Rutherford Appleton Lab in work on laser wakefield acceleration.



In this simulation, a plasma channel, denser toward the edges, guides the laser and allows it to form high-quality electron beams. As the pulse travels from left to right it excites a wake in the plasma, trapping and accelerating bunches of electrons to high energies. (Courtesy Wim Leemans, Cameron Geddes and the Visualization Group in the Computational Research Division at Lawrence Berkeley National Laboratory, with the Tech-X Corporation.)

Three teams, in the UK, the US and France, have reported breakthroughs in the laser-driven plasma acceleration of electrons. For the first time researchers have been able to create conditions such that the accelerated beam has a low divergence and small spread in energy. This paves the way towards the practical development of compact "table-top" particle accelerators for a variety of applications.

The idea of harnessing the high electric fields generated in laser-driven plasma waves in order to accelerate electrons was first proposed by Toshi Tajima and John Dawson in 1979. The basic principle is to direct an intense laser pulse into a plasma, which sets the plasma electrons oscillating, so creating a relativistic plasma wave in the wake of the pulse. Fields of more than 100 GeV m^{-1} – thousands of times greater than achieved with conventional accelerators – can be set up in this way and charged particles can be accelerated as they "surf" the plasma wave. With the advent of high-brightness lasers, this technique of laser wakefield acceleration has in the past decade been demonstrated in several different experiments. In 2003, Karl Krushelnick led a European Union-funded collaboration between the Laboratoire d'Optique Appliquée at the Ecole Polytechnique in Paris, Imperial College London and the Rutherford Appleton Laboratory (RAL) that achieved electron energies of 350 MeV over distances of only 1 mm or so in a plasma driven by ultra-short, intense laser pulses. However, the beams produced have had a broad spread in energy (as much as 100%) due to wavebreaking, making them of limited practical use.

In the latest work, the three groups have found different techniques to overcome this problem and localize large numbers of electrons with respect to the plasma wave. The beams generated are much closer to being monoenergetic, with energy spreads down to less than 10%. These findings are described in successive papers in the same edition of *Nature*, following earlier reports, for example at the 11th workshop on Advanced Accelerator Concepts in June (*CERN Courier* October 2004 p48).

Krushelnick and colleagues from Imperial College, Strathclyde University, the University of California, Los Angeles, and RAL have used the Astra laser in RAL's Central Laser Facility to focus ultrashort (40 fs), intense (0.5 J) laser pulses onto a supersonic jet of helium gas. At the same time they have been able to vary the density of the plasma created by varying the pressure of the gas jet. As the plasma density is increased, "wavebreaking" starts to occur, where electrons break free from the plasma wave and can then be accelerated by the remaining wave. At densities below 7×10^{18} cm^{-3}, no energetic electrons emerged from the plasma, but at higher densities the team detected electrons with energies up to 100 MeV. Moreover, the energy spectrum measured with a magnetic spectrometer showed narrow spikes.

By carefully controlling the density and increasing the laser power, the team has produced energy spectra with single, narrow peaks, in which the energy spread is as small as 3%, for energies in the range 50–80 MeV (Mangles *et. al.* 2004). The researchers explain their observations in terms of "controlled wavebreaking". Wavebreaking is not always catastrophic and a number of the electrons in the plasma wave can break from the wave, reduce its amplitude but still maintain the wave structure. The differences in the observed spectra correspond to timing of the injected electrons into this relativistic (but decaying in amplitude) plasma wave. For high densities, the wake-field is several plasma wavelengths in duration. Successive plasma periods can accelerate trapped electron bunches to different energies, producing the multiple spikes in the spectrum. For the single spike feature, it is likely that only the first plasma oscillation is driven to breaking point.

A similar approach has been taken by Malka's group, building on their previous work in which they demonstrated that they could produce well-collimated energetic beams using laser-driven wakefields, although the beams still had a broad energy spread. In the latest work, the group creates a plasma "bubble" in the wake of a laser pulse that has been compressed by self-focusing. Wave-breaking at the walls of the bubble releases electrons that are accelerated together within the bubble. This technique has allowed the group to claim acceleration of a beam of only 10 mrad divergence, with a total charge of 0.5 ± 0.2 nC at an energy of 170 ± 20 MeV (Faure *et. al.* 2004).

In the US, meanwhile, Wim Leemans and colleagues in the L'OASIS (Laser Optics and Accelerator Systems Integrated Studies) group at the Lawrence Berkeley National Laboratory have taken a different approach. They have created a plasma density channel in hydrogen gas, which is denser towards the edges and serves to guide the driving laser pulse. This overcomes the natural weakening of the pulse caused by diffraction as it propagates thereby extending the distance available for acceleration. Although the L'OASIS team used a laser spot about ▷

ADVANCED ACCELERATORS

▷ three times smaller than the one used by the UK and French groups, and hence a diffraction distance roughly ten times shorter, the use of the plasma channels kept the laser beam tightly focused and so highly intense at the entrance of the plasma channel.

In this method, a first "igniter" pulse forms a narrow "wire" of plasma, which a second "heater" pulse enters from the side, expanding it into a broader channel. Lastly, 500 ps later, an intense "driver" pulse is sent through the channel, and this excites the plasma waves that ultimately accelerate electrons from the plasma. By carefully controlling the laser and plasma-channel parameters, the team observed acceleration of electron bunches with a narrow energy spread, for example ±2% at an energy of 86 MeV and 3 mrad (FWHM) divergence, containing around 0.3–0.5 nC of charge (Geddes *et. al.* 2004). The normalized emittance was estimated to be of the order of 1–2 π mm-mrad (rms). Once again several factors seem to be involved in keeping the energy spread small, with the most important one being the control of the acceleration distance to match the dephasing distance, i.e. the distance where the electrons start to outrun the wave. Simulations of the process with the particle-in-cell code VORPAL indicate that the laser pulse first self-steepens while propagating in the plasma. As a result larger amplitude waves are excited as the laser pulse propagates deeper into the channel. When the wave amplitude reaches levels sufficient to trap background electrons and the acceleration process is extended to the dephasing distance, momentum bunching occurs and this results in a narrow energy spread for the beam. Combined with sufficient beam loading to suppress trapping in trailing accelerating buckets, this leads to the quality of the electron beams observed, with low divergence and energy spread.

These results represent a great achievement, but all three groups point to the need for further work, on efficiency and shot-to-shot stability for example. Also it is still far from clear as to how an accelerator based on this technique could be "staged" to reach the teravolt energies now generally required for research at the high-energy frontier. However, the results provide great hope for progress towards compact, high-brightness machines operating in the giga-electronvolt region. These would have many applications, for example in materials science, ultrafast chemistry and medicine.

Further reading

C G R Geddes *et. al.* 2004 *Nature* **431** 538.
J Faure *et. al.* 2004 *Nature* **431** 541.
S P D Mangles *et. al.* *Nature* **431** 535.

NIKHEF

Muon chambers are on course for ATLAS

Assembly of a complete muon chamber for the outer layer of the ATLAS barrel muon system.

The cosmic-ray test stand at NIKHEF.

On 5 October, technicians at NIKHEF, the Dutch National Institute for Nuclear Physics and High Energy Physics, glued the last layer of aluminium drift tubes on the 101st and final ATLAS precision muon chamber to be assembled in Amsterdam. Ninety-six of these chambers make up the full set of the "Barrel Outer Large" chambers, which comprise the major part of the third and outer layer of the ATLAS barrel muon system.

During three years of chamber assembly, following many years of R&D work, some 42 000 "monitored drift tubes" 30 mm in diameter and 5 m long have been produced. A semi-automatic wiring machine equipped the tubes with a total of 200 km of tungsten sense wire, as well as 84 000 end plugs.

The tubes were then subjected to a number of tests on the precision of the wire location and wire tension, leak tightness under 3 bar pressure, and the ability to stand a high voltage on the sense wire with small dark current.

Tubes passing the quality test were glued into layers of up to 72 tubes in parallel; the full muon chambers consist of two sets of three layers of tubes each, separated by a spacer of precise dimensions.

In order to measure high-momentum muons accurately at the LHC, precision and control have been the key words in chamber assembly. Within the chamber dimensions of up to 5 x 2 m, the tubes needed to be mounted with a precision of 20 μm. In order to achieve this, precision jigs were used on a granite table inside a temperature- and humidity-controlled clean room. The positions of the tubes were constantly monitored during assembly, exploiting the NIKHEF RASNIK alignment system.

The muon chambers are currently being equipped with gas-distribution services and electronics. As from October, sets of five chambers are being routinely tested in a dedicated cosmic-ray test stand, into which the ATLAS muon-detector control system, the RASNIK alignment system and the ATLAS read-out electronics are also integrated.

From December onwards, the chambers will be shipped to CERN, where they will be mounted together with trigger chambers (resistive plate chambers) in a common support. The first of these assemblies will be mounted in ATLAS in mid-May 2005.

CERN

CERN celebrates its 50th birthday

On the date of CERN's 50th anniversary, 29 September 2004, the organization's host state authorities lit up the sky in celebration. As night fell, 24 powerful floodlights blazed up from the eight access points around the 27 km tunnel that will be occupied by the Large Hadron Collider (LHC). These beams emanating from the Geneva plain marked out the extent of the huge ring.

Floodlights from access points around the tunnel of the Large Hadron Collider light up the night sky above Geneva, making the extent of the 27 km ring easy to visualize.

Spectators were invited to a celebration above the village of Crozet, in the foothills of the Jura mountains. Before the illuminations began, speeches by local dignitaries from France and Geneva were followed by a series of live addresses by teleconference link. CERN's director-general, Robert Aymar, spoke from the CHEP 2004 conference in Interlaken, and two of his predecessors, Luciano Maiani and Chris Llewellyn Smith, joined in from Rome and London respectively. Tim Berners-Lee, inventor of the Web, also made an appearance by video link to wish CERN many happy returns. People born in 1954 were then invited to blow out the candles on an anniversary cake.

Organized by the Department of Justice, Police and Security of the Canton of Geneva, with the participation of the local council of Crozet and the support of local councils in the Canton of Geneva, the Communauté des communes of the Pays de Gex, and the Ain Préfecture, this Franco-Swiss event had great symbolic value because CERN plays host to scientific collaborations from all over the world.

The parties had in fact begun earlier in the month on 17 September, when the people at CERN and their families filled the rooms of Restaurant 1 and the terrace beyond. In a short speech the director-general Robert Aymar toasted the CERN staff, praising their competence throughout the history of the organization. He noted also how CERN's diversity of nationalities is its strength, as people from different backgrounds come to collaborate at the laboratory. For musical entertainment, the CERN Big Bang Orchestra, made up mostly of members of various CERN music clubs and l'Ensemble de Jazz de Divonne, played an original composition by Jean-François Mathieu, created especially for CERN's anniversary, called *Acceleration/Celebration*.

Part of the big-band sound assembled for the 50th anniversary staff party.

The celebrations also continued into October. The most ambitious open day in the history of the organization took place on 16 October, and was followed by the official VIP celebration on 19 October. Reports on these events will appear in the December issue of the *CERN Courier*.

To celebrate the 50th anniversary of CERN, we look back at some of the items in the early issues of *CERN Courier*

COLLABORATION

CERN–Dubna exchange begins

One of the items on the agenda of the 16th Council session concerned an exchange of scientists between our European organization and the Soviet Centre of Dubna.

Three Soviet scientists arrived at Meyrin on 18 July for a period of six months, during which time they will co-operate in various aspects of the exploitation of the particle accelerators and in theoretical studies.

Two of the physicists, Vladimir Meshcheryakov and Rostislav Ryndin, are from the Theoretical Physics Laboratory of Dubna. They have naturally been attached to CERN's Theoretical Study Division, where they will continue work begun in the USSR before their departure.

Meshcheryakov is the youngest: he was born on 20 September 1932 in Leningrad and graduated from Moscow University in 1953. He is married and since 1958 has been working at Dubna, where among other work he has been studying the "field of application of Mandelstam's representation".

Ryndin also comes from Leningrad, where he was born on 20 January 1920. He studied at the Leningrad State University, where he obtained his doctorate in 1952. He then entered the Dubna Nuclear Study Centre, where his latest work was on "Low-energy bremsstrahlung from high-energy electron–proton collisions". Ryndin is married and has one child.

S A ff Dakin, the director of administration, welcoming the Russian scientists who arrived at CERN on 18 July: Vladimir Meshcheryakov, Yuri Sherbakov and Rostislav Ryndin.

EDITOR'S NOTE

An important part of CERN's mission is to encourage communication between scientists in different countries, helping to overcome political differences. These extracts show links during the Cold War with both the US and the USSR, in particular with the research organization at Dubna, as described also on p25.

Yuri Sherbakov, the third scientist, is an experimental physicist who has been attached to the Russian Centre of Dubna since 1953. At CERN he will take part in the exploitation of the 600 million electronvolt (600 MeV) synchrocyclotron.

He was born at Valsk on the Volga in August 1925, and was a student at the Moscow Institute of Technology, studying physics under Professor Kosadev. He went to Dubna in 1953 and has been working there for five years on the 680 MeV synchrocyclotron.

• Taken from *CERN Courier* July 1960 p2.

OTHER PEOPLE'S ATOMS

Particle physics in the United States

G Kenneth Green is in charge of building the 30 GeV synchrotron at the Brookhaven Research Laboratory in the United States. On 5 February last year, referring to the inauguration of the 28 GeV CERN synchrotron, he said: "The energy range beyond 20 GeV seems very promising. We hope to join you there soon!"

They have. The following telegram arrived at CERN during the night of 29 July: "We finally made it. Went through half integral to thirty one."

Three official telegrams were sent off on the CERN telex:

• "Congratulations from all CERN on your success. Nice to have company." from S A ff Dakin and G Bernardini, in the absence of J B Adams.

• "Sincerest congratulations from the members of the PS Machine Group for your great success." from P Germain.

• "31 000 congratulations to you from us all. Best of luck in the next stages." from the members of the Parameter Committee.

Two months – as in the case of CERN – after the first beam had been once round the machine, the Brookhaven proton synchrotron is operating at full energy. This is wonderful news for the scientific world.

Two giant accelerators will now share in the study of the infinitely small. A full programme can now be undertaken in co-operation. All physicists will be delighted at this, even though the title of "biggest in the world" has once again crossed the Atlantic...

The 184 inch synchrocyclotron at Berkeley

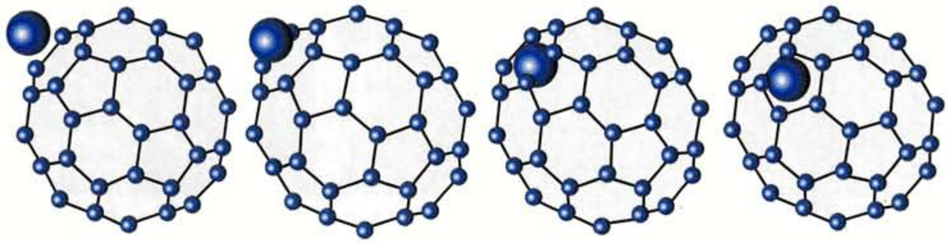
Because of the heavy demand for experimental time on the 184 inch cyclotron at the Lawrence Radiation Laboratory, this accelerator was placed on three-shift, 24-hour-day operation early in 1959. The experimental physics programme at the cyclotron was concerned mainly with the study of the interactions and decays of pi and mu mesons. An intense beam of positive pions, or pi mesons, has been formed at the 184 inch cyclotron in order to perform experiments relating to the scattering of pi mesons from protons. The analysis of these experiments promises to provide detailed information on this fundamental process.

An experiment has also been performed to study the production of an additional pi meson by the collision of a pi meson with a proton. The results of this experiment indicate that a much greater number of pi mesons are created than had been expected on the basis of prior theoretical predictions. New theoretical ideas, which include the effects of interactions between the pi mesons, are in reasonable agreement with experimental results.

• Taken from *CERN Courier* July 1960 p3.

Compiled by Steve Reucroft and John Swain, Northeastern University

Buckyball hastens beryllium's demise



Snapshots of a simulation of the capture of ^7Be in a six-membered ring of C_{60}; once in the carbon buckyball cage the lifetime of the beryllium is reduced.

Researchers in Japan have found that the lifetime of radioactive beryllium-7 goes down by nearly 1% if it is caged inside a carbon buckyball (C_{60}). While chemical shifts of nuclear decay rates have been known for a long time, they still come as a surprise to many people. Moreover, they are typically much smaller than 1%.

Tsutomu Ohtsuki of Tohoku University in Sendai, and colleagues there and at Yokohama National University, have measured the lifetimes for the isotope both in bulk metal and in carbon-60. They found a discrepancy of approximately 10 hours out of 53 days. Beryllium-7 decays by electron capture, so what the researchers are seeing are chemical effects on electrons that change their wavefunctions enough for them to spend significantly more time in the nucleus, and hence be prone to capture.

Further reading

T Ohtsuki *et al.* 2004 *Phys. Rev. Lett.* **93** 112501.

Solid helium turntable leaves things standing at 230 mK

If you were to put an object on a rotating turntable you would expect the object to be dragged round; but what if the turntable were made of solid helium-4? The answer is perhaps surprising. According to the prediction made by A F Andreev and I M Lifschitz in 1969, the turntable would keep turning without affecting the object. Dubbed "nonclassical rotational inertia", or NCRI, this failure of friction was observed in superfluid liquid helium back in 1967. Now, for the first time, the analogue has been seen in a solid.

E Kim and M H W Chan of Pennsylvania State University made the tricky measurements at a chilly 230 mK and confirmed the prediction of Andreev and Lifschitz. A detailed interpretation of the underlying physics is still not complete, but it could be linked to a Bose–Einstein condensate in the solid and could revolutionize theories of solid helium.

Further reading

E Kim and M H W Chan 2004 *Science* **305** 1941.

Rotating grains form fluid bands

We often think of fluids in the continuum limit, while knowing full well that they are really made of molecules. This immediately raises questions like: "In what ways do sand and other granular substances flow like liquids?" Now Stephen L Conway of Rutgers, the State University of New Jersey, and colleagues have shown that if you put granular material between two concentric cylinders and rotate them sufficiently quickly, the Taylor bands, which have been known in fluids since 1923, appear.

While this characteristic instability occurs in the sand, much as it does in liquids, it turns out to be accompanied by new mixing–segregation transitions that have no direct counterparts in normal fluid mechanics. The work has potential applications in understanding countless geological problems as well as in industry, where mixing of powders is a common task.

Further reading

S L Conway, T Shinbrot and B J Glasser 2004 *Nature* **431** 433.

Finding the real world in a foam bath

A new approach to simulating quantum geometry suggests that starting with a random froth, one might expect a world of three dimensions of space and one of time to appear naturally at large scales. J Ambjørn of the Niels Bohr Institute in Copenhagen, J Jurkiewicz of Jagellonian University in Krakow, and R Loll of Utrecht University have added one crucial ingredient to the randomness – causality, or a speed limit of the speed of light – and this turns out to be enough to yield a world much like the one we live in. The authors comment that to their knowledge this is the "first example of a theory of quantum gravity that generates a quantum space–time with such properties dynamically."

Further reading

J Ambjørn, J Jurkiewicz and R Loll 2004 *Phys. Rev. Lett.* **93** 131301.

Compiled by Marc Türler, INTEGRAL Science Data Centre

Do gamma rays indicate galactic dark matter?

The HESS array of four Cherenkov telescopes (one is shown here) has pinpointed high-energy gamma emission to the galactic centre, and cast doubt on its origin in dark-matter particles.

Is the recent detection of very-high-energy gamma rays from the galactic centre revealing the presence of dark matter? Or, is dark matter at the origin of the electron–positron annihilation in our galaxy? The possibility is not excluded, but it would imply that dark-matter particles are even more exotic than previously thought.

It is well known that positrons annihilate with electrons near the centre of our galaxy; the associated emission line at 511 keV was detected more than 30 years ago. The spatial extent of the emission as seen by the European Space Agency's INTEGRAL gamma-ray satellite is smooth and corresponds roughly to the bulge of our galaxy. Such a more or less spherical cloud of positrons agrees well with the expected distribution of dark matter in our galaxy, so it has been suggested that light-weight dark-matter annihilation could produce the observed positron population (Boehm *et al.* 2004).

Is it possible, however, that dark-matter particles in the 1–100 MeV range could decay into electron–positron pairs without leaving a detectable signal other than the 511 keV line? This question has indeed been addressed by some researchers, who show that such a decay would inevitably produce gamma rays via an internal "bremsstrahlung" process (Beacom *et al.* 2004). This emission should have been detected by the high-energy instruments of the Compton Gamma-Ray Observatory, unless the dark-matter particles have masses below about 20 MeV.

Another claim for the possible detection of dark matter has followed the discovery of very-high-energy gamma rays emitted by the galactic centre. The gamma rays, at an energy above 100 GeV, are detected by ground-based telescopes observing the faint Cherenkov light emitted by the electromagnetic shower that results from the interaction of a gamma-ray photon with the terrestrial atmosphere.

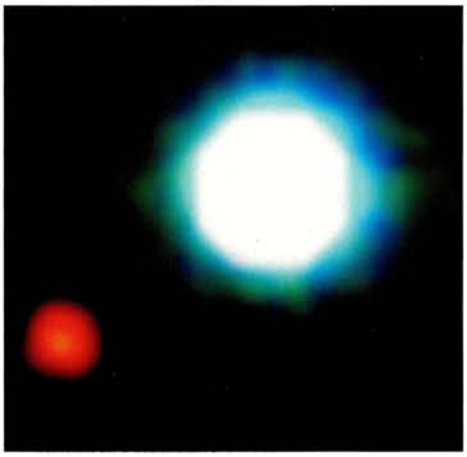
The first measurements by the American Whipple telescope and the Australian–Japanese CANGAROO observatory had relatively large uncertainties on the actual position of the gamma-ray source. The results were therefore compatible with a diffuse emission as expected from the annihilation of dark-matter particles. Recent measurements by the European–African High-Energy Stereoscopic System (HESS), a new array of four Cherenkov telescopes in Namibia (*CERN Courier* November 2002 p7), have shown with a more than 10 times better spatial accuracy that the emission is really bound to the galactic centre.

If dark-matter particles are responsible for these gamma rays observed by HESS, then they must have masses of more than 12 TeV and be very concentrated within a few tens of light-years from the galactic centre (Horns 2004). Although it cannot be firmly excluded that dark matter is at the origin of the galactic gamma-ray emission observed at 511 keV and/or at TeV energies, this would imply particle masses either much below (< 20 MeV) or much above (> 12 TeV) the expectations of most models of non-baryonic dark matter. Fortunately, other less-exotic phenomena occurring in supernovae or black holes are promising alternatives to solve the gamma-ray mystery in the heart of our galaxy.

Further reading

C Boehm *et al.* 2004 *Phys. Rev. Lett.* **92** 101301.
J F Beacom *et al.* 2004 www.arxiv.org/abs/astro-ph/0409403.
D Horns 2004 www.arxiv.org/abs/astro-ph/0408192.

Picture of the month



Is this the first image of an extrasolar planet? To be sure, ESO's Very Large Telescope has to take a few more such infrared images in the course of the year to see whether the red object is indeed orbiting the main source. This discovery would certainly be a major step in the study of exoplanets (*CERN Courier* October 2004 p19), even though this star–planet couple does not at all resemble our solar system. The reddish planet would be five times more massive than Jupiter and would orbit the bluish star – a brown dwarf 42 times lighter than the Sun – at a distance exceeding Pluto's orbit. (ESO.)

COMPUTING NEWS

Compiled by Hannelore Hämmerle and Nicole Crémel

LCG@TAIWAN

Fostering Grid computing in Asia

The participants of the 2004 International Symposium on Grid Computing, which was held in Taiwan in July in conjunction with the first LCG Asia Workshop.

In June 2004 the ATLAS experiment at the Large Hadron Collider (LHC) launched Data Challenge 2 (DC2) for the LHC Computing Grid (LCG). The job-distribution statistics that were recently released at September's ATLAS Software Workshop showed that Taiwan has produced 12% of the total ATLAS DC2 simulation data – submitted through the LCG resource broker – which is second only to the 14% produced at CERN. In fact, more than 700 Gbytes of input data were replicated and stored in the system located at the Academia Sinica Computing Centre (ASCC) in Taiwan.

With more than 70 sites joining in the LCG project, Taiwan plays a leading role in Asia. The Institute of Physics at the Academia Sinica, the National Taiwan University and the National Central University are involved in the ATLAS and CMS experiments, whereas the ASCC provides the Grid-related technology and resource support. The ASCC has been actively participating in the LCG project through various activities ranging from strategic planning to infrastructure deployment and services.

Acting as the Grid operation centre and global Grid user support, the ASCC not only helps to facilitate LCG installation in other Asian countries, such as China and Singapore, but also provides Grid-related training courses and symposia. Since 2002 the ASCC has hosted the annual International Symposium on Grid Computing, which introduces Grid concepts, technology and applications to Taiwan and neighbouring countries. Supported by CERN, and in conjunction with the 2004 Grid symposium, the first LCG Asia Workshop was held in July to further collaboration in Asia.

"The next step for the ASCC is to extend Grid technology to fields such as bioinformatics, digital archives and biodiversity informatics, which have large enough amounts of data to require a solution from Grid computing," said Simon C Lin, director of the ASCC. For the moment the ASCC has already built applications and prototypes for these fields based on LCG software infrastructure. With the experiences gained from the LCG, Asia envisages a solid future platform in the context of a worldwide Grid.

E-SCIENCE

New infrastructure to aid collaboration

Diligent

A DIgital Library Infrastructure on Grid ENabled Technology

On 1 September the three-year DILIGENT project started with a kick-off meeting in Pisa, Italy. Building on past activities in both the Grid and digital-library domains, the project will develop a digital-library infrastructure to allow members of dynamic virtual organizations to exploit shared knowledge and physical resources.

Research groups today often consist of people from institutes spread around the world who form virtual organizations to share their resources for the duration of the collaboration. The DILIGENT project aims to support this new operational mode for research by creating an infrastructure that will allow members of the virtual organizations to access shared knowledge, services and computational resources in a secure, co-ordinated and cost-effective way.

By merging Grid and digital-library technologies, DILIGENT will provide the foundations for collaboration environments that will be able to serve many different research and industrial applications. The Grid framework will also enable new functions, whose implementation has until now been limited by high cost in terms of computational, storage and data-transfer capacity, such as multimedia document and geographic information processing, 3D handling or spatial data manipulation.

DILIGENT will be built upon efforts by the EGEE (Enabling Grids for E-science in Europe) project, which will deliver a Grid production infrastructure in the next two years. The DILIGENT testbed will be demonstrated and validated by two complementary real-life application scenarios from the environmental e-Science and the culture heritage domain.

It is expected that a Grid-based digital-library infrastructure will be adopted and extended by several other communities – some of which have already registered as observers – to serve different application areas. Regular training sessions and workshops will be conducted to disseminate the results and experiences of the DILIGENT project to both scientists and potential DILIGENT users.

● Information on the project and how to become a DILIGENT observer will be made available at www.diligentproject.org.

E-SCIENCE UK

All Hands Meeting spreads the word

In early September the LHC Computing Grid (LCG) project was demonstrated to Grid researchers from other disciplines at the UK e-Science All Hands Meeting held in Nottingham. Members of GridPP, the UK's contribution to the LCG, showed conference delegates a map that monitors jobs moving around the Grid in real time. The monitor is a Java applet that represents the jobs' location and status using coloured blocks, and gives options to identify the virtual organization the jobs are from and the output of different resource brokers.

"It can be difficult for people who have never seen a Grid working to imagine what it does," said Dave Colling from Imperial College, London, whose team built the map. "Our map is an easy way to show the Grid visually and to demonstrate the scale of the LCG. It's also useful for experts, who can see at a glance how well the Grid is working."

Visitors at the Global Grid Forum stand at the All Hands Meeting in Nottingham.

Apart from several talks on UK aspects of LCG development, Bob Jones from CERN gave a well-received plenary lecture on the EGEE (Enabling Grids for E-science in Europe) project. GridPP were also pleased to win an award at the conference for best UK e-Science project website. Steve Lloyd, the GridPP collaboration chair, said: "We had a really successful conference. Grid scientists in the UK now have a much better idea of what the LCG has achieved so far and where it's going. Scientists from other disciplines were also very interested in the EGEE project and we hope that many of them will get involved."

● The monitor applet can be accessed at www.hep.ph.ic.ac.uk/e-science/projects/demo/index.html.

US GRID PROJECTS

A production Grid infrastructure for science

More than 90 members of the Open Science Grid (OSG) consortium met recently in Boston to plan for the deployment of a production Grid infrastructure for science in the US. The OSG will provide a coherent environment for the peta-scale data management and computational needs of diverse scientific teams, from those with a single member to those with thousands of members. The goals of the OSG are to integrate existing and emerging processing and storage facilities, to provide a production-quality scalable supporting Grid infrastructure and to enable effective throughput of a broad range of scientific analyses.

Participants in the consortium come from the scientific communities and include Grid technologists and institutions and projects with experience in Grid technologies, deployment and applications. The OSG is an evolution of Grid3, which has been supporting a general load of around 800 simultaneous jobs for US-ATLAS and US-CMS 2004 data challenges, and up to 1200 jobs including astrophysics, gravitational physics, bioinformatics and computer-science applications. In particular, the opportunistic computing benefits of Grid3 have already stimulated the US-ATLAS and US-CMS teams to share their resources and accommodate each others' priorities and schedules. The first deployment of OSG is planned for 2005 and the infrastructure will be based on the evolution of the Virtual Data Toolkit, which is already the common basis for Grids for particle physics. Grid3 will be extended to include resources and applications from a broader mix of applications from other sciences, as well as those from particle-physics experiments already running or in production (e.g. CDF, D0, BaBar, STAR etc).

The OSG roadmap was proposed in a white paper in the summer of 2003. The first workshop in January 2004 served to demonstrate a broad level of community support for the direction the map outlines. This was followed by the formation of several technical working groups, increased alignment of related ongoing activities in the US with the longer term direction, and further discussions with the Department of Energy and National Science Foundation sponsors.

An important focus of the OSG is to federate and overlap with other Grid projects – multi-disciplinary computing facilities, university and regional campus Grids, large high-energy and nuclear physics facilities (at Fermilab, Brookhaven, LBNL and SLAC), and national infrastructures such as Teragrid. In particular, all the working groups of the consortium collaborate with their peers in the LCG and EGEE projects towards a coherent global infrastructure for physics at the LHC.

The Boston workshop provided the opportunity to take the next steps in solidifying the technical programme, increasing the involvement of a broad range of participants and in formulating the organization of the OSG consortium itself.

● For further information, see http://opensciencegrid.org/events/meetings/boston0904/index.html.

RESOURCE SHARING

Processor farm grows at Berkeley

Shane Canon (right) and Iwona Sakrejda installing a new processor node for PDSF.

The Parallel Distributed Systems Facility (PDSF) computing cluster at Lawrence Berkeley National Laboratory's National Energy Research Scientific Computing Center (NERSC) is expanding. In September new high-performance processors and increased disk space were added to serve the growing needs of diverse experiments in high-energy, nuclear and astrophysics. The expansion will bring PDSF's computer count to 380 nodes with 760 CPUs with a peak aggregate speed of about 1.3 TFlops (floating point operations per second). The processors are complemented by 180 Tbytes of disk. Users also have access to the centre's High Performance Storage System, which currently has a capacity of more than 8 Pbytes of data.

PDSF is currently used by the ATLAS and ALICE experiments, the Collider Detector at Fermilab, the STAR detector at Brookhaven, the KamLAND neutrino experiment, Sudbury Neutrino Observatory and the SuperNova Factory. Several newer experiments, such as IceCube and SNAP, are also beginning to tap PDSF's capabilities. By sharing hardware among many user groups, users can call on tremendous resources during their peak computing periods. Funded by the US Department of Energy, LBNL manages PDSF and provides dedicated computer and office space, as well as a fraction of the system administration. With this support, PDSF is able to serve 650 users from 15 different projects with only four members of staff.

One unique aspect of PDSF is its economic model. Users "buy in" by paying for a certain number of disk vaults and processors, and receive the corresponding storage and CPU cycles. The present expansion clearly demonstrates PDSF's popularity among users, who in essence vote with their dollars.

PDSF started out with about 30 Sun and HP UNIX workstations rescued from the Superconducting Supercollider computer centre, but has since migrated to commodity Intel/AMD processors running Linux. This year's purchase consists of dual-processor Xeon and Opteron systems with 2 Gbytes of memory and 18 Tbytes in disk vaults. The Opteron systems mark the start of a move to 64-bit computing, although they will initially run mostly 32-bit code. Generally, PDSF increases capacity by about 25% each year, with older machines relegated to secondary uses such as software testing, and eventual decommissioning.

Although hardware growth occurs in steps, PDSF continually upgrades its software to meet the needs of its user community. The challenge is that different experiments need different versions of operating systems, tools and application software. To solve this problem PDSF's Shane Canon has developed CHOS, a utility that allows users to switch the operating system transparently, so different users on the same machine can see different operating systems. With CHOS, PDSF can support several versions of Red Hat Linux, SUSE Linux and Scientific Linux. PDSF also supports multiple versions of common packages, such as the gcc compilers, python, CVS and ROOT.

PDSF is part of the Grid3 collaboration, a group of about 20 US and Korean sites that share resources via the Grid. Although only a small percentage of PDSF's resources are devoted to Grid3, this is likely to grow with time. Grid3 follows PDSF's philosophy of resource sharing perfectly, but on a national scale.

ANNIVERSARY

A look back at the pioneers of the net

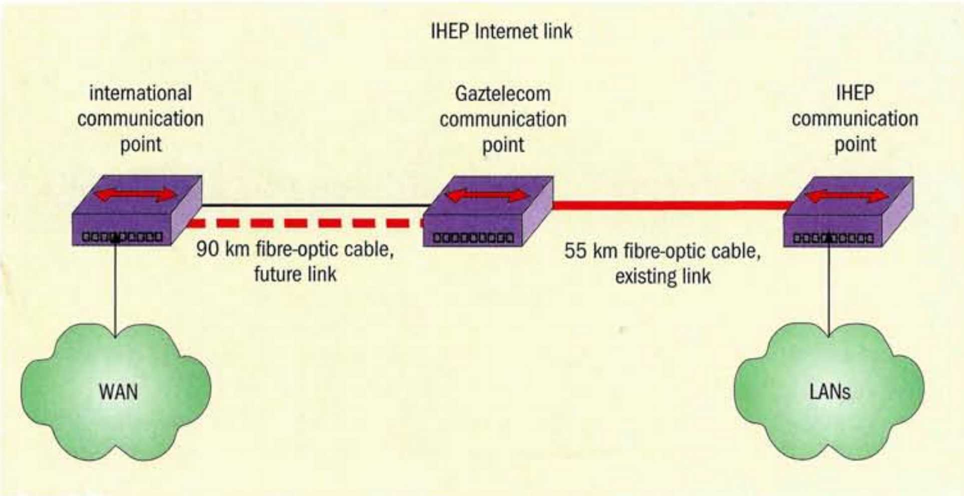
On 2 September 1969 a team of researchers at UCLA connected the first host computer to a network switch, known as an Interface Message Processor, creating the first node of the "ARPANET". This was named after the Advanced Research Projects Agency (ARPA), which had been created in 1958 as a reaction to the Soviet Sputnik satellite. ARPA officials reasoned that by connecting the existing computers via a data network the community of scientists would be able to gain access to each others' computers, allowing the sharing of resources and more effective communication.

The second node of ARPANET was connected only a month later at the Stanford Research Institute (SRI) and the first host-to-host message was sent on 29 October – but not without problems. Attempting to login to the SRI computer from the one at UCLA, the system crashed as the letter "G" of LOGIN was entered. Nevertheless, the network expanded quickly and the first international connections to ARPANET were set up in 1973. ARPANET and several other packet networks came together to form the embryonic Internet later that year with the installation of the TCP/IP protocols.

To mark these early steps on a road that later became the information superhighway, UCLA organized a special forum with some of the Internet's early pioneers on 29 October.
● See www.internetanniversary.com.

RUSSIA

IHEP launches fast Internet channel



The new high-speed IHEP communication channel is based on fast Ethernet – 100BaseFX (FD) – technology running on fibre-optic cable.

Until recently the Russian Institute for High-Energy Physics (IHEP), which is located in the town of Protvino, 100 km from Moscow, had an Internet connection with a data rate of only 6 Mbit/s. This left much to be desired for IHEP, which collaborates with physics centres around the world, including CERN, Fermilab, Brookhaven National Laboratory and DESY, among others. High-speed networking over the Internet is becoming more and more important as CERN and other laboratories move to the new Grid technologies to store and process data. The slow connection to IHEP was therefore becoming a big problem, in particular for participation in work on the Large Hadron Collider (LHC) Computing Grid (LCG), Data Challenge and other projects. Now, however, all this is set to change.

During the past two years IHEP has installed more than 50 km of optical cable, using its own resources, and has created a fast Ethernet channel for connection with the communication node of the Gaztelecom company (part of Gazprom enterprises). Furthermore, IHEP uses one channel, leased from Gaztelecom, to gain access to the Internet through the international communication node in Moscow.

This new high-speed communication channel is particularly important now that IHEP has become a full participant in the international EGEE (Enabling Grids for E-science in Europe) project, in which many European countries and CERN are collaborating in order to build a production-quality Grid for science. Since starting to use the new channel only a month ago, the average load has achieved 50% of its maximum value. The users of the channel have reported high reliability and rapid access to Internet resources.

The use of fibre-optic technology enables the productivity of the communication channel to be considerably increased if necessary, and should completely satisfy the constantly growing communication needs of IHEP. This is possible due to the agreement with Gaztelecom to organize a channel using gigabit Ethernet technology and to lease out so-called "dark" optical fibres for the extension of the IHEP optical cable to the international communication node in Moscow. The IHEP scientific community collaborating on the LHC, LCG, EGEE and other projects, now has the opportunity to participate fully in these international ventures.

Calendar of events

November

8 5th IEEE/ACM International Workshop on Grid Computing Pittsburgh, PA, www.gridbus.org/grid2004

22–26 EGEE 2nd Conference The Hague, the Netherlands, http://public.eu-egee.org/conferences/2nd

December

19–22 HiPC 2004, 11th Annual International Conference On High Performance Computing Bangalore, India, www.hipc.org

February 2005

7–11 GlobusWORLD 2005 Boston, MA, www.globusworld.org

14–16 European Grid Conference Amsterdam, the Netherlands, http://genias.biz/egc2005

21–25 Tridentcom 2005, First International Conference on Testbeds and Research Infrastructures for the Development of Networks and Communities Trento, Italy, www.tridentcom.org

PRODUCT INFORMATION

NEXCOM International has released the NexBlade HS416 blade server bundled with the new AMD Opteron 64-bit solution. One prominent feature of this processor is the flexibility of computing at 64- or 32-bit, combining current popular 32-bit computing with higher capacity in the 64-bit processor. The NexBlade HS416 is scalable and holds up to eight hot-swappable server blades with the integration of storage, power and networking. For further information see www.nexcom.com.

Altair Engineering is offering campus and department licences to academic institutions for its Grid computing solution PBS Pro. The licences range from 150 to 5000 CPUs and are available from under £5 (~€7) per CPU for large sites. The campus and department licences now on offer for PBS Pro include full e-mail and telephone support, as well as an entitlement to all new software versions and updates released during the licence term. More details can be found at www.altairgrid.co.uk.

Rewind

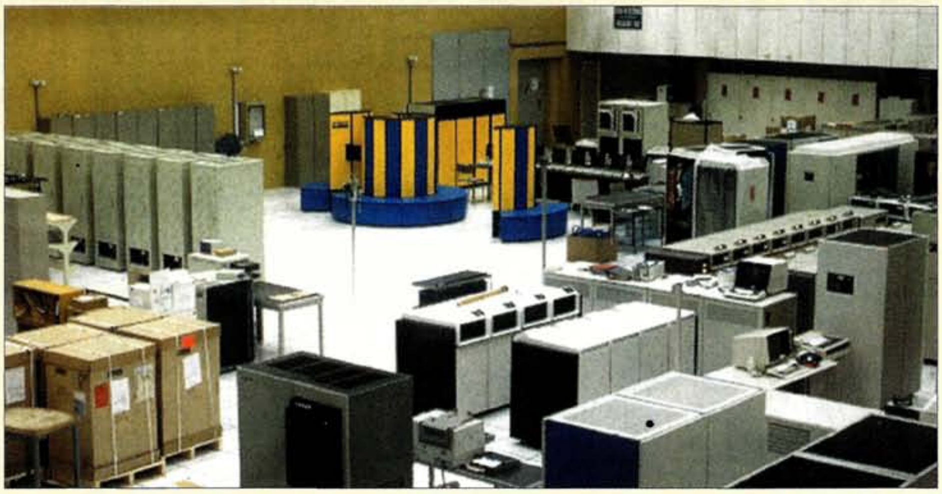
As CERN looks back over 50 years of history, we recall some of the moments in the life of CERN's computer newsletter.

15 years ago: first mention of TCP/IP
TCP/IP is now the standard protocol for the Internet, but for a long time it was very much the outsider in major computing centres and was competing against more established rivals.

"After about a year of consultation with our UK colleagues and other users it has been jointly decided that the Blue Book service [a pre-Web information service] on the GIFT system will be discontinued on the 3rd of April.

To offer an alternative to possible isolated users of Blue Book software outside the UK, who are currently exchanging files with CERNVM through the GIFT and the INTERLINK system, direct access to the Blue Book application on CERNVM will be organized through the CERN X.25 service. Blue Book will also remain installed on the central VAX cluster (VXCRNA/B). Other additional file-transfer services (such as FTAM and TCP/IP FTP) are also being considered."

• From *CNL* 194 January–March 1989.



A view of the CERN computer centre, with the colourful CRAY X-MP/48 supercomputer located near the rear wall of the building, in the early days of TCP/IP.

Science helps bring nations together

Established to pursue fundamental science, both CERN and its Russian counterpart JINR have an important role in breaking down international barriers. This success is now providing a model for a third organization in the Middle East.

CERN and the Joint Institute for Nuclear Research (JINR) in Dubna are celebrating their 50th anniversaries within a year and a half of each other. During the past 50 years both centres have become famous for their first-class achievements at the forefront of natural science – the origin and structure of the universe. Their fundamental results have been achieved through the joint efforts of scientists from many countries, who were united by one common goal – to gain new knowledge about nature and to enhance their understanding of it. At the same time these efforts have also helped bring together nations of widely differing cultures.

It was in 1949 at the European Cultural Conference in Lausanne, Switzerland, that the distinguished French scientist Louis de Broglie first proposed the idea for a European research laboratory: "...Our attention has turned to the question of developing this new international unit, a laboratory or institution where it would be possible to carry out scientific work above and beyond the framework of the various nations taking part...This body could be endowed with greater resources than those available to the national laboratories and could then embark upon tasks whose magnitude and nature preclude them from being done by the latter on their own." The following year Isidor Rabi took up this theme at the Fifth General Conference of UNESCO (the United Nations Educational, Scientific and Cultural Organization), and a series of meetings held under the auspices of UNESCO led ultimately to the establishment of CERN in 1954 (*CERN Courier* October 2004 p11).

CERN has since evolved to become the world's largest particle-physics laboratory, exploring some of nature's most fundamental questions. Today CERN's membership comprises 20 European countries, and more than half the world's particle physicists use CERN's facilities. This international collaborative effort has enabled CERN to become greater than the sum of its parts and a centre of excellence in research. Over the years the accelerator complex has allowed many discoveries by researchers at CERN, including in the 1970s the discovery of weak neutral currents and in the 1980s the W and Z bosons that carry the weak interaction. In the 1990s the Large Electron Positron collider (LEP), in a tunnel 27 km in circumference and 100 m underground, contributed significantly to establishing the current Standard Model of particles and their interactions. Now LEP has been dismantled and the Large Hadron Collider (LHC) is being installed in its place.

Dubna 1982: the then director-general of CERN Herwig Schopper (left) with JINR director Nikolai Bogoliubov.

The LHC project, including its four major detectors, is being implemented by the efforts of more than 400 research laboratories from dozens of countries around the world. These include Russia, which as an observer state of CERN is actively participating in the LHC construction and experiment collaborations. Around 20 scientific institutions belonging to various agencies and more than 30 industrial enterprises from Russia are involved in the work on this large-scale project.

Russia also has its own success story in fundamental research and international collaboration. JINR, located in the picturesque town of Dubna on the bank of the Volga river, has been closely collaborating with CERN for nearly half a century. The first contacts began in the mid-1950s, immediately after the foundation of JINR ▷

Dubna 2004: CERN's current director-general Robert Aymar (second from the left) at JINR, where Mikhail Itkis (first on the right), director of the Flerov Laboratory of Nuclear Reactions, and Alexei Sissakian (centre), vice-director of JINR, present the laboratory's scientific achievements.

in 1956, with conferences and the first visits of scientists. In 1958 the distinguished Russian physicist Nikolai Nikolaevic Bogoliubov, director of the JINR Laboratory of Theoretical Physics, suggested that there should be systematic exchanges of scientists between JINR and CERN. This idea was given impetus at an informal meeting on international co-operation in the field of high-energy accelerators held at CERN in 1959, which was attended by senior scientists from the US, Russia and Western Europe. In the 1960s and 1970s co-operation with CERN was developed further with the organization of joint seminars, summer schools for young scientists and a wider exchange of scientists (see p9).

During the 48 years of its existence JINR, like CERN, has played the role of a bridge between East and West, contributing to the development of international scientific co-operation among dozens of countries. Now JINR has scientific relations with nearly 700 research centres and universities in 60 countries.

In the early 1990s, after the disintegration of the USSR, JINR entered a new stage of its development. Eighteen countries became its member states, and bilateral agreements at governmental levels were concluded with Germany, Hungary and Italy. In 1992 JINR established an international scientific council, whose membership included leading scientists from the world's largest research laboratories. Independent and international programme advisory committees were also established. For the first time representatives of the JINR member states have been able to indicate which specific fields of research were for them the most interesting and important.

JINR today offers a unique choice of experimental facilities: the Nuclotron, which is the only superconducting accelerator for nuclei and heavy ions operating in Russia; the U400 and U400M cyclotrons with record beam parameters, which are used for experiments on the synthesis of heavy and exotic nuclei; the unique pulsed neutron reactor IBR-2, and the Phasotron, a proton accelerator used for hadron therapy. JINR also has powerful and high-performance computing facilities integrated into the global computing network.

As a recognition of the achievements of JINR's research staff, in 1997 the International Committee of Pure and Applied Chemistry awarded the name "Dubnium" to element 105 of the periodic table. The international scientific community was impressed by the experiments carried out during 1999–2003 at the U400 cyclotron of the JINR Flerov Laboratory of Nuclear Reactions on the synthesis of new elements with atomic numbers 114, 116, 118, 115 and 113. Today JINR is a world-recognized leader in this area of research.

In the past few years the positive experiences accumulated by CERN and JINR in overcoming political barriers through mutually beneficial scientific co-operation has been successfully used in the development in Jordan, again under the auspices of UNESCO, of a new international centre for research and advanced technology "in the image and likeliness of CERN and JINR". The Synchrotron light for Experimental Science and Applications in the Middle East (SESAME) project will produce synchrotron radiation over a broad range of wavelengths from the infrared to X-rays, with various fields of application (*CERN Courier* November 2002 p6). Its participants include Israel, the Palestinian National Authority, Iran, Jordan, Turkey, Egypt and other countries. The president of the council of the SESAME centre is German physicist Herwig Schopper, who is playing the key role in the realization of this project. In the past Schopper served as CERN director-general (1981–1988), and was president of the European Physical Society (1994–1996) and a member of the JINR Scientific Council (1993–2002). He was awarded the Russian Order of Friendship in 1997.

The establishment of the new international SESAME centre will not only make a significant contribution to the scientific, technical and economic development of the Middle East countries but will also undoubtedly promote the coming together of the people of this region, the mutual understanding of people with different traditions, religious and political views, and, hopefully, the peaceful settlement of existing conflicts.

SESAME is thus set to continue the tradition of co-operation begun by CERN and JINR, who are justly called a "permanently operating peace congress", as they have never stopped their extensive collaboration, even during the gloomiest years of the Cold War. Today, the world at large recognizes that the major merits of JINR and CERN are not only their remarkable achievements in the field of basic science but also their extremely important contributions to the rapprochement and understanding among nations. By their practical activities over the decades these two international laboratories have proved that the fundamental principles that were declared at their foundation, namely the openness and peaceful nature of joint scientific research, the equality of all member states, and wide applications of scientific results for the benefit of mankind, have turned out to be most profound, humane and promising for the future.

Roger Cashmore, *former director of research, CERN, now at Oxford University, and* **Mikhail Kirpichnikov**, *former Russian minister for science and technology, now vice-rector at the Moscow State University.*

The case for mini black holes

Tiny black holes could offer a richer view of physics than their better known, more massive relations, as **Aurélien Barrau** and **Julien Grain** explain.

Unification is the dream of high-energy physicists. Attaining this conceptual – and actual – convergence undoubtedly constitutes the fundamental challenge in the search for elementary objects and interactions. There have been many successes in this area. If, however, it sometimes looks as if the main pieces of the puzzle have yet to be put together, it is because the opportunities nature gives us to attain an all encompassing and global view of the most disparate properties – described by the general theory of relativity and quantum mechanics – are extremely rare.

The early universe is often considered to be the only instance of a situation in which quantum and gravitational processes are equally important. However, black holes with small masses could also provide insight into these unusual conditions and would certainly constitute, if they exist, the only objects in today's cosmos where such extreme physical processes can occur. Even if it remains speculative, the search for small black holes is certainly warranted, especially since many models predict their existence in fundamentally different frameworks and contexts.

Geodesics in Kerr space–time, as predicted by the theory of general relativity. Small black holes produced, for example at colliders, are expected to be spinning. (Numerical simulation by Max Planck Institute for Gravitational Physics, Albert Einstein Institute (AEI); visualization by W Benger, Zuse Institute, Berlin/AEI.)

From the astrophysics point of view, it is thought that only massive black holes – with masses several times that of the Sun – are possible, as they are the only ones able to form in the final stages of stellar evolution. Although they have many fascinating properties, these large black holes are not as rich as their smaller cousins could be. The lighter the black hole the greater its surface gravity – and the more interesting the associated physical effects. This is simply due to the fact that Newton's gravitational force is linearly dependent on mass but quadratically dependent on the inverse distance (which is itself proportional to the Schwarzschild radius of the black hole). In particular, the phenomenon of Hawking evaporation is significant only in the case of small black holes: the tidal effect becomes so great near the surface that the particle pairs produced by quantum vacuum fluctuations may be broken, one particle falling into the black hole and the other being projected outwards. This process has yet to be observed, precisely because astrophysical black holes are too massive and therefore too cold, but it is certainly one of the most important predictions of quantum field theory in curved space–time. Contrary to the usual ideas of general relativity, black holes are capable of emitting particles. They can even be very hot and very bright if their mass is sufficiently small. Indeed, the principles of thermodynamics apply to black holes, the essential variables being temperature, entropy and internal energy, as opposed to surface gravity, area and mass in the case of general relativity.

Where can we find mini black holes?

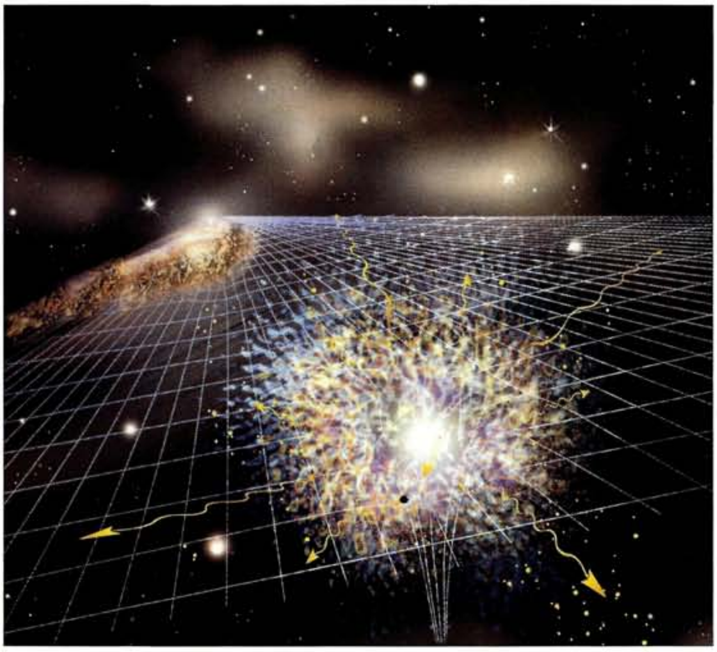
The absence of notable excesses of particles in cosmic radiation – especially in the form of antiprotons or gamma rays – compared with the fluxes expected in a "standard" astrophysics context allows strict constraints to be placed on the density of black holes evaporating in today's universe. In particular, it can be deduced that their contribution to the total mass of the universe is today no higher than one ten millionth. As these small black holes are likely to have been produced in the early cosmos thanks to the fluctuations in density present at that time – and with masses that were arbitrarily low – it is possible to obtain vital information about the universe's ▷

degree of inhomogeneity shortly after the period of inflation. This route of investigation is all the more remarkable in that the relevant scales for the black holes of the early universe are completely beyond the usual observables of cosmology, namely the 3K background radiation and large-scale structure. There is therefore a genuine complementarity between these approaches. Many cosmological scenarios – involving phase transitions, the breaking of scale invariance, blue power spectra, positive running of the spectral index of scale fluctuations, phases of double inflation, topological defects, collisions of bubbles of "real" vacuum in a background of "false" vacuum and softening of the equation of state – may be excluded or severely constrained by the study of small black holes.

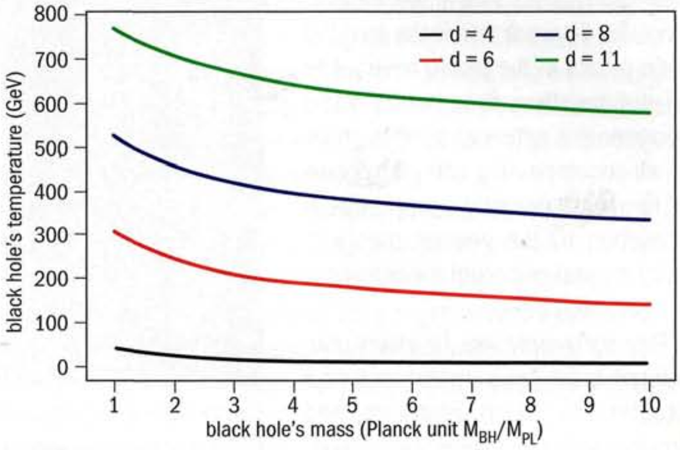
In addition to these astrophysical and cosmological aspects, there is another route of investigation that is particularly promising for microscopic black holes, namely at particle accelerators. In response to the persistent problem of hierarchy – why is the Planck scale 16 orders of magnitude higher than the electroweak scale? – a hypothesis put forward a few years ago offers a neat and efficient lead: the existence of large extra dimensions. The novelty of this idea lies in the fact that it is no longer necessary to assume that these dimensions are of sizes close to the Planck length ($\sim 10^{-33}$ cm). Rather, they can be as large as around a millimetre if we suppose that the fields of matter live in the 3+1 dimensional hypersurface of our 3-brane and that only gravity can benefit from new dimensions. The constraints ($\sim 10^{-16}$ cm) usually derived via the interactions of gauge bosons in extra dimensions can therefore be ignored and only experiments involving the direct measurement of Newtonian gravity put limits on the size of extra dimensions to a value of less than a few tenths of a millimetre. Using such an approach, the traditional Planck energy, $E_{Pl} \sim 10^{19}$ GeV, is no more than an effective scale and the real D-dimensional fundamental Planck scale is given by $E_D = (E_{Pl}{}^2/V_{D-4})^{1/(D-2)}$, where V_{D-4} is the volume associated with the D−4 extra dimensions. For D = 10 and radii associated with the extra dimensions of the Fermi scale, we obtain $E_D \sim$ TeV. If this model has any meaning, it is effectively a natural choice (and not an arbitrary one based on phenomenological motivations) because it essentially resolves the problem of hierarchy. This approach uses the geometrical properties of space to link completely different energy scales.

A spectacular consequence of such a model is the possibility of being able to produce black holes with the next generation of particle colliders. If the centre-of-mass energy of two elementary particles is indeed higher than the Planck scale E_D, and their impact parameter b is lower than the Schwarzschild radius R_H, a black hole must be produced. If the Planck scale is thus in the TeV range, the 14 TeV centre-of-mass energy of the Large Hadron Collider (LHC) could allow it to become a black-hole factory with a production rate as high as about one per second. Many studies are underway to make a precise evaluation of the cross-section for the creation of black holes via parton collisions, but it appears that the naive geometric approximation $\sigma \sim \pi R_H^2$ is quite reasonable for setting the orders of magnitude.

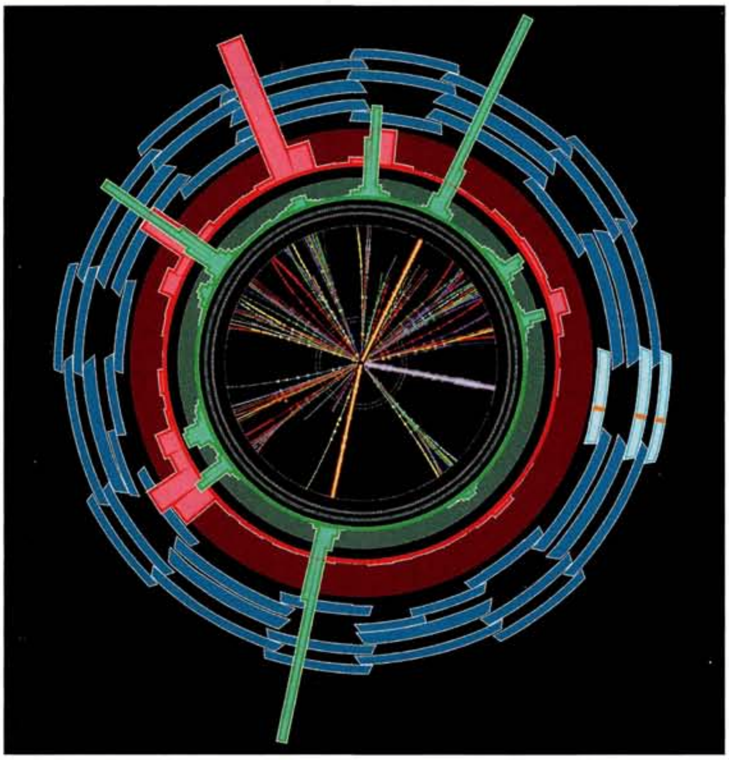
The possible presence of extra dimensions would be doubly beneficial for the production of black holes. The key point is that it allows the Planck scale to be reduced to accessible values, but it also allows the Schwarzschild radius to be significantly increased, thus making the condition $b < R_H$ distinctly easier to satisfy. It is important to note that the resulting mini black holes have radii that are much smaller (of the order of 10^{-4} fm in the case of those that can be expected from the LHC) than the size of extra dimensions, and that they can therefore be considered as totally immersed in a D-dimensional space, which has, to a good approximation, a time dimension and D−1 non-compact space dimensions. The black hole thus acts like a quasi-selective source of S waves and sees our brane in the same way as the "bulk" associated with the extra dimensions. As the particles residing in the brane greatly outnumber those living in the bulk (essentially gravitons), the black hole evaporates into particles of the Standard Model. Its lifetime is very short (of the order of 10^{-26} s) and its temperature (typically about 100 GeV here) is much lower than it would be with the same mass in a four-dimensional space. The black hole nevertheless retains its characteristic spectrum in the form of a



An artist's impression of the evaporation of a black hole in the early universe. (Aurore Simonet.)



The temperature of a black hole as a function of its mass for different numbers of extra dimensions.



A simulation of the evaporation of a black hole in the ATLAS detector at the Large Hadron Collider.

quasi-thermal law peaked around its temperature. From the point of view of detection, it is not too difficult to find a signature for such events: they have a high multiplicity, a large transverse energy, a "democratic" coupling to all particles and a rapid increase in the production cross-section with energy.

Particle physics and mini black holes

At first glance the production of black holes in colliders could be bad news. It could mean the end of particle physics since the presence of a horizon would obscure all the microphysics processes that could occur behind it. However, it would in fact open up very good opportunities.

First of all the reconstruction of temperature (determined by the energy spectrum of the particles emitted when the black hole evaporates) as a function of mass (determined by the total energy deposited) allows information to be gained about the dimensionality of space– time. In the case of Planck scales close to the TeV mark, the number of extra dimensions could thus be revealed quite easily by the characteristics of the emitted particles. However, one can go further. In particular, quantum gravity effects could be revealed, as behaviour during evaporation in the Planck region is sensitive to the details of the gravitational theory used.

Approaches of the Gauss-Bonnet type, which include quadratic terms in scalar curvature in the Lagrangian, are good candidates for a description beyond general relativity as they can be supported both by theoretical arguments (heterotic strings in particular) and by phenomenological arguments (Taylor expansion in curvature). In such a case, the coupling constant of the Gauss-Bonnet term, namely the quantum character of the gravitational theory used (and the link with the underlying string theory) can also be reconstructed and the LHC would become a very valuable tool for studying speculative gravitation models.

Other promising avenues are also being investigated for new physics. Firstly, the black holes formed may be excellent intermediate states for highlighting new particles. When the collision energy is higher than the Planck scale E_D, the cross-section for the creation of black holes is quite large (~500 pbarn) and has no suppression factor. Moreover, when the temperature of the black hole is higher than the mass of a particle, the particle must be emitted during evaporation in proportion to its number of internal degrees of freedom. There is thus a definite potential for the search for the Higgs or for supersymmetric particles in the evaporation products of black holes, possibly with cross-sections much greater than for the direct processes. Finally, taking account of a D-dimensional cosmological constant also modifies the evaporation law. If the constant is sufficiently high – which is possible without contradicting the low value measured in our brane – the temperature and the coupling coefficients with the entities emitted could be the signature of this particular structure of space–time. It would be quite neat and certainly surprising that a measurement of the cosmological constant in the bulk should come from the LHC!

Microscopic black holes are thus a paradigm for convergence. At the intersection of astrophysics and particle physics, cosmology and field theory, quantum mechanics and general relativity, they open up new fields of investigation and could constitute an invaluable pathway towards the joint study of gravitation and high-energy physics. Their possible absence already provides much information about the early universe; their detection would constitute a major advance. The potential existence of extra dimensions opens up new avenues for the production of black holes in colliders, which would become, de facto, even more fascinating tools for penetrating the mysteries of the fundamental structure of nature.

Postscript

It should be stated, in conclusion, that these black holes are not dangerous and do not threaten to swallow up our already much-abused planet. The theoretical arguments and the obvious harmlessness of any black holes that, according to these models, would have to be formed from the interaction of cosmic rays with celestial bodies, mean that we can regard them with perfect equanimity.

Further reading

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Aurélien Barrau *and* **Julien Grain**, *Grenoble Laboratory of Subatomic Physics and Cosmology (CNRS/Joseph Fourier University).*

ICTP at 40: the centre

The 40 year history of the ICTP, marked by international co-operation and understanding, provide

The Abdus Salam International Centre for Theoretical Physics (ICTP) is celebrating its 40th anniversary this year. The anniversary conference, "Legacy for the Future", took place on 4–5 October in the centre's main building, which is adjacent to the Adriatic Sea about 10 km from Trieste in northeastern Italy. Some 300 scientists, many of whom are long-time associates and friends of ICTP, came to Trieste to celebrate the anniversary of an institution that is widely respected and revered. Among them were four Nobel laureates: Walter Kohn of the University of California at Santa Barbara; Rudolph A Marcus and Ahmed H Zewail of the California Institute of Technology; and John Nash, Jr, of Princeton University.

Exactly 40 years earlier, on 5 October 1964, a group of public officials, largely from Italy, joined eminent scientists from around the world at the Jolly Hotel in downtown Trieste for the inaugural meeting of the newly created ICTP. A seminar on plasma physics served as the scientific platform from which the centre was officially launched. Abdus Salam, who had led the effort for the creation of the centre, hosted the meeting. Marshall Rosenbluth, professor of physics at the University of California, San Diego, and a former student of Edward Teller, served as one of the main organizers. Sigvard Eklund, director-general of the International Atomic Energy Agency (IAEA) was there. So too were Guido Gerin, the Italian government's representative to IAEA, and Begum Liaquat Ali Khan, Pakistan's ambassador to Italy. In all, more than 70 scientists were in attendance, representing 14 countries in the West, five in the East and 12 from the South.

Four years later, on 7–29 June 1968, ICTP had organized a star-studded symposium on contemporary physics. The event took place not in downtown Trieste but in the centre's then newly completed main building, not far from Miramare Castle Park, which was once the private estate of Maximilian, younger brother of the Hapsburg Emperor Franz Josef who had ruled the Austro-Hungarian empire from 1848 to 1916. The symposium, attended by nearly 300 scientists from some 40 countries, brought 21 current and future Nobel prize winners to Trieste. Eminent scientists in attendance included Hans Bethe, Francis Crick, Paul Dirac, Werner Heisenberg and Eugene Wigner.

During the four years leading up to the creation of the centre and the first four years of its existence, many of the principles and programmes that have guided ICTP ever since were put in place. The centre has evolved over the past 40 years, but that evolution has unfolded within the context of its long-standing mandate. Indeed the centre's guiding principles have remained remarkably unchanged throughout its history. These include:

- Promoting and, where possible, providing world-class research facilities for scientists from the developing world.
- Conducting and fostering advanced scientific research at a high

The first session of the ICTP Scientific Council, which took place at the Intern Atomic Energy Agency headquarters in Vienna in May 1964. Manuel Sando Vallarta, on the left, was chairman. On his left is Victor Weisskopf, and on his Robert Oppenheimer. Abdus Salam is on Weisskopf's left. (ICTP Photo Archi

Main building of the Abdus Salam International Centre for Theoretical Ph

's legacy for the future

s valuable and enduring lessons that are as relevant today as they were at the centre's inception.

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ICTP houses one of Europe's most important specialized libraries, containing more than 100 000 volumes in physics and mathematics. With a subscription base of 650 print and nearly 3000 electronic journals, it serves as an invaluable resource to ICTP's visiting scientists. (ICTP Photo Archives, Massimo Silvano.)

sics near Trieste in Italy. (ICTP Photo Archives, Massimo Silvano.)

level, especially in theoretical physics and mathematics.

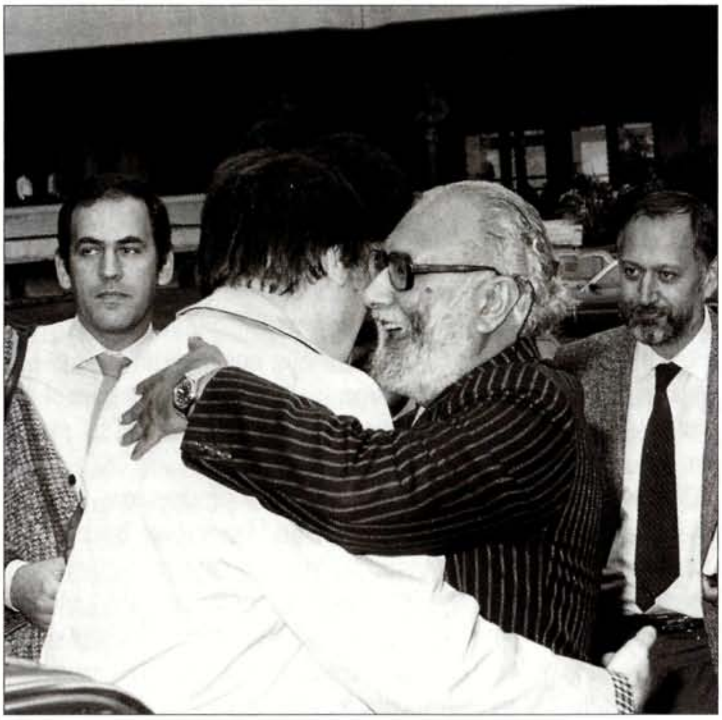
- Creating an international forum for the exchange of scientific information through courses, workshops and seminars in high-energy physics, condensed-matter physics, mathematics and a host of disciplines in which physics and mathematics play a critical role in analyses and research.

ICTP achieves its goals through a variety of programmes, many of which were established in the 1960s and have since become the "standard models" for efforts to build scientific capacity in developing nations. One of the most notable initiatives has been the Associateship Programme, which enables scientists from the developing world to visit ICTP for extended periods several times over a number of years (under the current rules each associate may visit three times for at least 40 days over a six-year period). The strategy is designed to enable scientists to keep abreast of developments within their fields without having to leave their home countries permanently. Over the past four decades nearly 2000 scientists from 77 developing nations have been appointed ICTP associates. Many have gone on to distinguished careers both as scientists and as science administrators.

Other ICTP programmes include the Federation Scheme, which enables institutions to regularly send members of their research staff to ICTP; the Office of External Activities, which sponsors a variety of research activities in developing countries; the Diploma Course Programme, which provides young students with a year's training in Trieste, leading to a certificate that is equivalent to a master's degree; and the Training and Research in Italian Laboratories Programme, which offers scientists in the developing world opportunities to work in scientific institutions in Italy. Over the past 40 years some 100 000 scientists from more than 170 countries have participated in ICTP's schools, workshops and conferences or have come to the centre as visiting scientists with the opportunity to pursue their own research and forge new collaborations.

Today the centre sponsors more than 40 research and training activities annually that attract on average a total of 4000 scientists. Another 1000 come to ICTP each year to participate in activities that the centre hosts for other organizations, including local institutions and organizations both in Italy and around the world.

In today's world, when it comes to economic and social well being, developing nations face the dual challenge of trying to catch up with developed countries while simultaneously keeping abreast of the latest technologies. While the statistics provide precise indicators of the centre's success they fail to reveal how ICTP has been able to do what it does, the challenges that it has faced and its ability to adapt to changing circumstances. The centre's early history and its struggles and triumphs during the 1960s and 1970s not only shed revealing light on ICTP, but also on how much science, ▷



The day that Carlo Rubbia received the news that he had been awarded the Nobel Prize in Physics for 1984 he was at ICTP. This photo shows Abdus Salam (right) hugging Rubbia just outside the ICTP main building. (ICTP Photo Archives.)

particularly science in the developing world, has changed over the past four decades – and how much it hasn't.

The centre's roots lie post-World War Two, in an era marked by a conflicting sense of heady optimism and deep concern. On the one hand the end of the colonial era laid the groundwork for developing countries to seek independence and to pursue initiatives that would provide their citizens with the necessary skills that their nations would need to succeed on their own, including improved abilities in science and technology. On the other hand the rise of the Cold War, which in many respects reached its most heated moments during the 1960s, sparked tensions between East and West that continually threatened to erupt into global armed conflict between the world's two superpowers, both of which had extensive nuclear arsenals. ICTP was a response to both of these global concerns.

Abdus Salam, a Pakistani-born prodigy, who had earned a PhD from the University of Cambridge in the UK under a programme designed to assist gifted young scientists from developing countries in the Commonwealth, called for the creation of an institution that would allow developing-world scientists to avoid the dilemma he had faced as a young scientist in the 1950s: to remain in his native Pakistan and forego his career or to return to the UK to continue his research and teaching in an environment that would allow him to reach his full potential. As a member of the Pakistani delegation to the IAEA General Conference in 1960 in Vienna, Austria, he used his position to seek the agency's support for his proposal to create an international physics centre that would provide training and research opportunities for scientists from the developing world. His goal was to enable scientists from the South to pursue their careers without having to leave their home countries.

At the same time Paolo Budinich, professor of physics at the University of Trieste and an Italian citizen born in what became part of Yugoslavia after World War One, set his sights on creating an institution that would serve as an open forum for scientists from the East and West, especially from the United States and the Soviet Union.

Budinich and his colleagues at the University of Trieste were keen to locate the proposed centre in Trieste. World War Two had left this once-proud port city stranded at the southern edge of the "iron curtain", a circumstance that was fuelling poisonous nationalist sentiments. One of the few remedies, envisioned by Budinich, was to establish cultural collaborations, especially in science, that would help part the curtain that had been drawn between East and West.

It was this vision of an international physics centre serving as an intellectual crossroads between north, south, east and west that gave the proposal its broad purpose and appeal. Nevertheless the debate over the utility of such an institution was fierce.

Critics contended that the goals of the proposed centre could be better met by establishing special research and training programmes for developing-world scientists within existing centres – for example, the Princeton Institute for Advanced Study in the United States or the Joint Institute for Nuclear Research in Dubna in the Soviet Union (see p25). Others argued that the developing world should focus on more pressing social and economic concerns – for example, combating hunger or alleviating poverty. Still others maintained that physics conducted by third-world scientists would fall short of international standards, relegating the proposed institution to third-rate status.

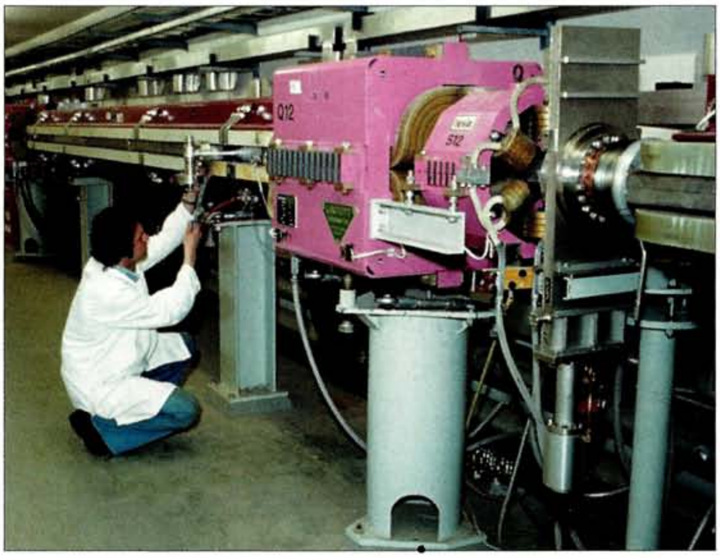
Despite the opposition, Salam and Budinich's persistence eventually won the day. After nearly three years of discussion and debate the IAEA board of governors decided to back the proposal, providing United Nations (UN) approval for the concept. At the same time the Italian government agreed to supply sufficient funding – some $275 000 annually for the first four years of the centre's existence – to ensure that the initiative would be able to function, at least at a base level, during its early years. IAEA, in addition to providing the UN's endorsement, agreed to provide $55 000 a year to ICTP. In 1970 the United Nations Educational, Scientific and Cultural Organization (UNESCO) joined the effort as an additional partner.

The agreement, signed in 1963, between the Italian government and IAEA represented a sterling example of global co-operation – proof that governments and international organizations can work together on initiatives capable of achieving sustainable progress.

Given the events of the past few years, marked by a fraying of global alliances and an overall coarsening of the dialogue between nations, it is good to remember a time when our global community came together to advance the cause of international harmony and understanding. The business of ICTP is science – and more specifically physics and mathematics – but its "legacy for the future" extends far beyond the scientific community to our global society itself (see p58). That is just one more reason to celebrate the 40th anniversary of ICTP.

Daniel Schaffer, *public information officer, Abdus Salam International Centre for Theoretical Physics.*

Twenty-five years of gluons



The PETRA electron–positron storage ring at DESY as it was in the early 1980s. (Photo courtesy of DESY Hamburg.)

This summer DESY celebrated the discovery in 1979 of the first direct evidence for gluons in experiments at the electron–positron collider, PETRA. Talks at a special symposium provided some personal views of 25 years of quarks, gluons and quantum chromodynamics.

On 7 June DESY celebrated the 25th anniversary of the discovery of the gluon with a special colloquium entitled "Gluons and Quantum Chromodynamics". Speakers included (from left to right): Hermann Schunck from the German Federal Ministry of Education and Research, DESY's director-general Albrecht Wagner, Harald Fritzsch from Munich and Gerard 't Hooft from Utrecht. (Photo DESY Hamburg.)

Twenty-five years ago experiments at DESY provided the first evidence for a very special kind of particle collision: an electron–positron annihilation process with three "coplanar jets", i.e. three collimated bundles of particles heading away in the same plane from the electron–positron collision point, rather like the prongs of the Mercedes symbol. Using the PETRA storage ring, which had been completed only the previous year, the teams working at PETRA had found the first direct experimental proof of the existence of the gluon – the particle that transmits the strong force. Analysis of the three-jet events showed that two of the three particle jets were produced by a quark–antiquark pair; the third was generated by a gluon.

This summer DESY commemorated the discovery with a special colloquium, "Gluons and Quantum Chromodynamics", which was held in the laboratory's main auditorium on 7 June. In his opening address to the 400 guests, Hermann Schunck, the representative of the German Federal Ministry of Education and Research, emphasized the consequence of the finding. "The discovery of the gluon at PETRA here at DESY marks a truly epochal point in the history of physics – mirroring the pivotal role of the gluon in the realm of physics comparable to the other exchange particles, the photon and the W and Z bosons," he said. He then left the floor to the three scientific speakers of the colloquium – Harald Fritzsch from Munich, Gerard 't Hooft from Utrecht and Albrecht Wagner, the director-general of DESY. In turn, they recalled the emergence of the ideas of quarks, gluons and quantum chromodynamics (QCD), described the structure of QCD theory and reviewed the ground-breaking experiments that led from the discovery of the gluon to the establishment of QCD as the accepted theory of the strong interaction.

The emergence of QCD

As Fritzsch emphasized, QCD is a most exceptional theory in that it generates an enormous complexity out of a very simple Lagrangian – describing for instance all atomic nuclei out of essentially one parameter. It is well established today and has moved on from the era of testing into the realm of precision physics. The route, however, has been long and often paved with misunderstandings and false starts. After the success of quantum electrodynamics in describing the electromagnetic interaction in the 1940s, the general mood turned to one of confusion. Particle after particle appeared in experiments and the particle-physics garden, which had seemed so ▷

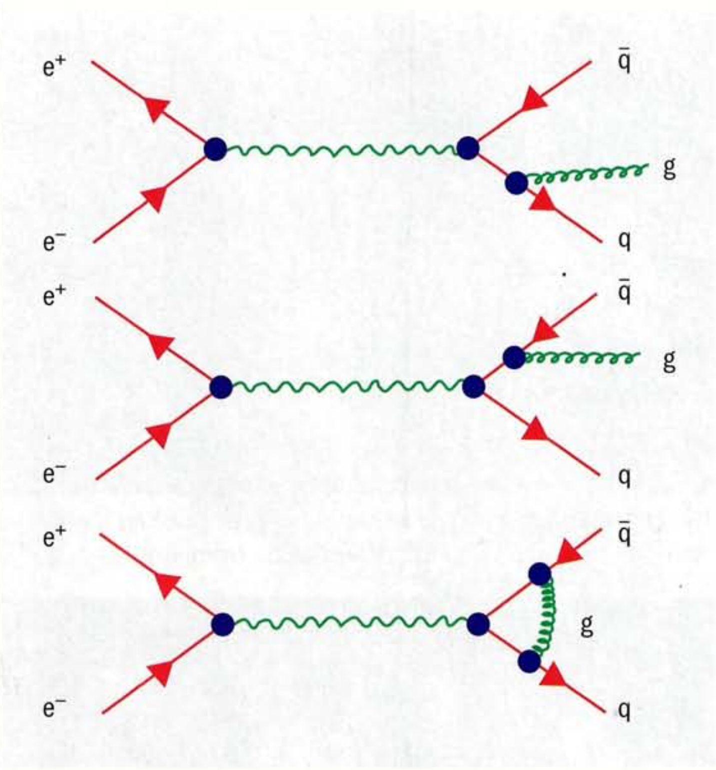


Fig. 1. The process of "gluon bremsstrahlung": the incoming electron and positron annihilate to form a photon, which in turn generates a quark–antiquark pair that fragments into hadrons and appears in the detector as two back-to-back hadron jets. These outgoing quarks can however also radiate a gluon, which creates a third hadron jet lying in the same plane as the other two.

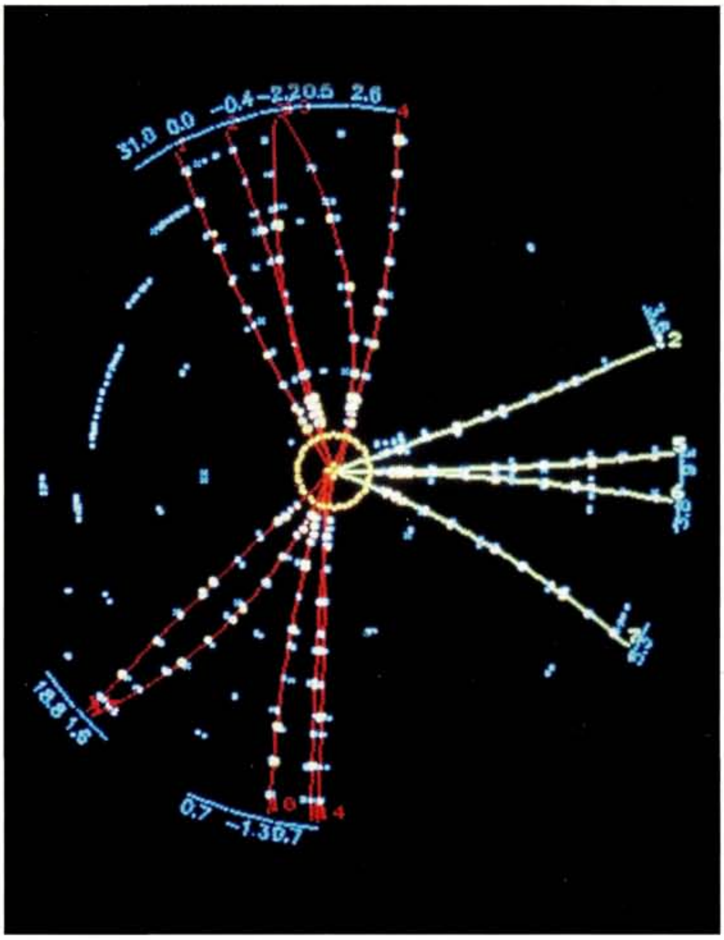


Fig. 2. A typical three-jet event observed in TASSO. (Oxford PPU.)

tidy in the 1940s, grew into a jungle during the 1960s. A major breakthrough came in 1964, when Murray Gell-Mann and George Zweig proposed that all hadrons are in fact composed of even more elementary constituents, which Gell-Mann called quarks. At the end of the 1960s deep-inelastic scattering experiments at the Stanford Linear Accelerator Center (SLAC) showed for the first time that these quarks were not just hypothetical mathematical entities, but indeed the true building blocks of hadrons.

There was a theoretical objection to the quark model, however; it appeared to violate the Pauli exclusion principle, which states that no two particles with half-integer spin can occupy the same state. Thus the Δ^{++} particle, which was supposed to consist of three identical quarks in the same state, seemed to be inconsistent with the Pauli principle. A solution to the problem was proposed in 1964 by Oscar Greenberg, and later elaborated in its final form by Fritzsch, Gell-Mann and Heinrich Leutwyler. They suggested that quarks actually come in three "colours", and that the only stable states formed by them are colourless combinations – a hypothesis that sounded at first like sleight of hand, but which in fact proved to be a most fruitful idea, providing the basis for what later became known as QCD, the mathematical description of the strong interaction.

The quark model, and with it the QCD gauge theory of the strong interaction, gained further impetus in the 1970s, as 't Hooft described at the colloquium. In seminal work that revolutionized the theoretical background of particle physics and earned him the 1999 Nobel Prize in Physics together with Martinus Veltman, 't Hooft showed in 1971 that such "non-abelian" gauge theories are renormalizable. He thus eliminated a fundamental problem that had hampered the development of a mathematical description of the strong interaction for years, and paved the way for the development of the complete gauge theory of QCD by Fritzsch and Gell-Mann in 1972. Two years later the discovery of the J/ψ meson marked what became known as the November revolution – the discovery of a fourth type of quark, and as such an eminent confirmation of the quark model and QCD.

The discovery of the gluon

In the late 1960s and early 1970s experiments had thus provided evidence for the reality of the quarks. The gauge theories describing the various interactions, however, predicted the existence of mediator bosons that transmit the forces between the particles. Of these, only the photon was definitely known at that time. A first hint of gluons, the mediators of the strong force, came from deep-inelastic scattering experiments, which had shown that only half of a proton's momentum is carried by the quarks. The missing momentum fraction was interpreted as being carried by electrically neutral constituents, presumably the gluons. But how could the actual existence of these gluons be demonstrated experimentally?

As Wagner – himself an experimenter on the JADE experiment at PETRA at the time – recollected in his talk, by the end of the 1970s it was widely accepted that the annihilation of an electron and a positron and the subsequent formation of a quark–antiquark

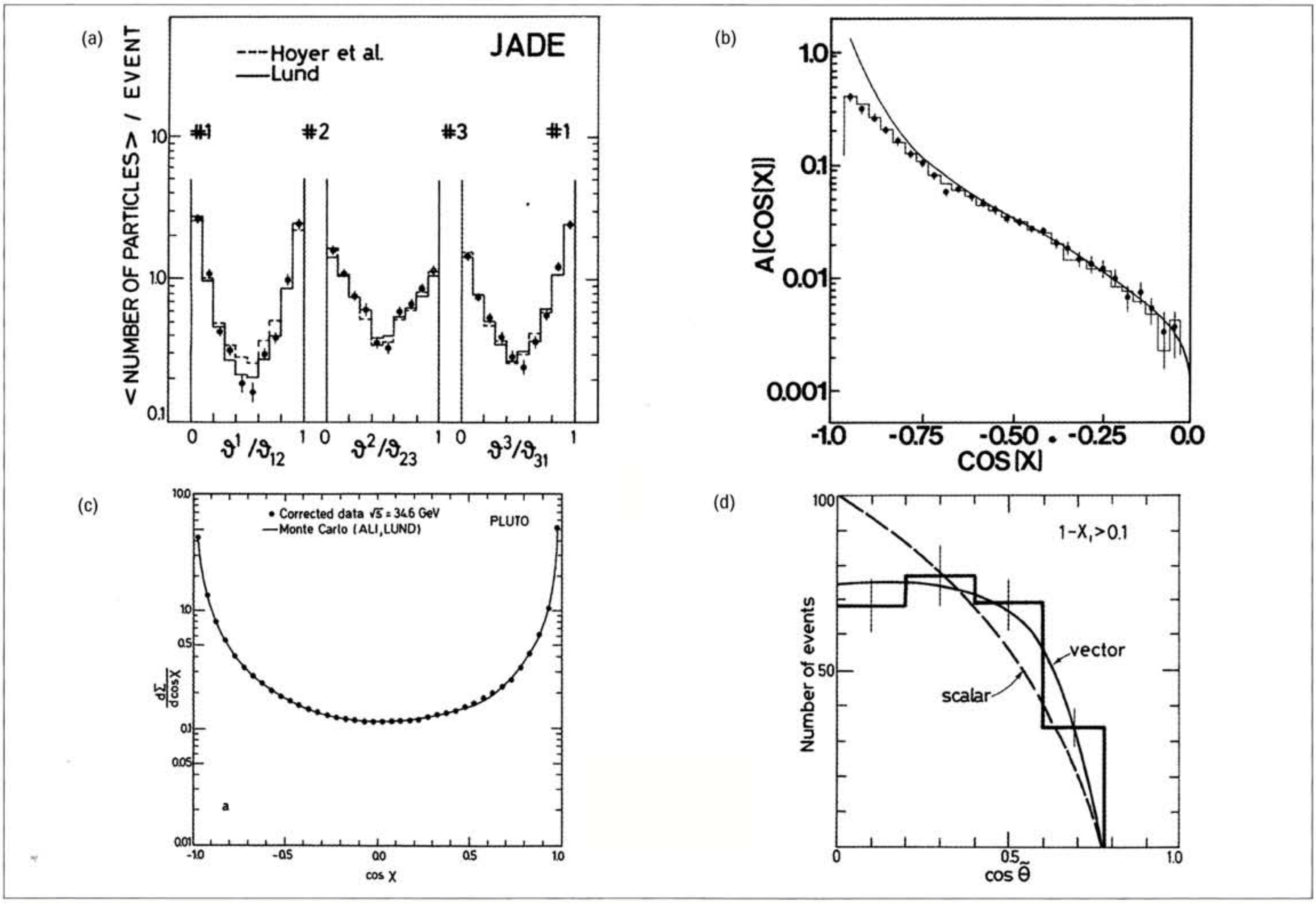


Fig. 3. Tests of QCD predictions for "gluon bremsstrahlung" at PETRA: (a) the JADE Collaboration's measurement of the average number of particles per event between jet axes provided striking evidence for the string effect (JADE Collaboration 1981); (b) the MARK J Collaboration's asymmetry distribution of the energy–energy correlation function (MARK J Collaboration 1983) and (c) the PLUTO Collaboration's energy–energy correlation function (PLUTO Collaboration 1985) compared with second-order QCD calculations; (d) the first verification of the vector nature of the gluon by the TASSO Collaboration (TASSO Collaboration 1980).

pair proceeded primarily via the exchange of a photon. The generated quark–antiquark pair would then fragment into hadrons, which would appear in the detector as two back-to-back hadron jets with limited transverse momentum and increasing momenta along the jet axis. Such events with two hadron jets had been discovered at the SPEAR storage ring at SLAC in 1975, and were later analysed in detail at DESY's 5 GeV storage ring, DORIS. Interestingly, just before PETRA appeared on the scene, the PLUTO experiment at DORIS, running on the Y(1S) b-$\bar{b}$ resonance, showed event topologies that were distinctly different from those generated in the nearby continuum, suggestive of the conjectured three-gluon decay of the 1S b-$\bar{b}$ state.

The idea of searching for gluon jets had actually been proposed by John Ellis, Mary Gaillard and Graham Ross in a seminal paper that appeared in 1976. Under the apparently imperative title "Search for Gluons in e^+–e^- Annihilation", the authors suggested the existence of "hard-gluon bremsstrahlung", which should give rise to events with three jets in the final state. According to the laws of field theory, the outgoing quarks can radiate field quanta of the strong interaction, i.e. gluons, which should in turn fragment into hadrons and thus create a third hadron jet forming a plane with the other two (see figure 1). At the particle energies of up to 15 GeV per beam delivered by DESY's newly built PETRA electron–positron storage ring, the probability for such hard-gluon bremsstrahlung processes to occur might amount to a few percent.

The PETRA machine had been completed by the summer of 1978 after only two years of construction. While still being commissioned, it had delivered the first events for $e^+e^- \rightarrow$ hadrons to the detectors at the end of 1978. Six months later, at the International Neutrino Conference in Bergen, Norway, on 18 June 1979, Bjørn Wiik reported on an event that had been observed in the TASSO detector at PETRA only a few days earlier. It had been analysed in detail by his colleague Sau Lan Wu and her co-worker Georg Zobernig. While the TASSO team was observing abundant events with the expected two-particle jets created by the outgoing quark–antiquark pair, Wu and Zobernig – who had designed a fast algorithm for the analysis of more complicated event topologies, in particular multi-jet structures – had uncovered something new: an event that clearly involved three jets whose momenta lay in a plane. When Paul Söding, who belonged to the same team, travelled to Geneva two weeks later for the European ▷

Physical Society (EPS) conference, he was already able to present a few of these three-jet events (see figure 2, p34). Moreover, a whole variety of plots displaying various analyses gave convincing evidence that bremsstrahlung of the gluon, which had been postulated as the boson mediating the strong force, had indeed been discovered.

Over the past 25 years QCD has emerged as the uniquely successful theory of the strong interaction, and it is as such a full part of the Standard Model of particle physics.

Shortly afterwards similar three-jet event topologies were announced by JADE, MARK J and PLUTO, the other groups working at PETRA. All four collaborations presented their data at the Lepton–Photon Symposium at Fermilab in Chicago in August 1979. The corresponding publications by TASSO, MARK J and PLUTO followed in autumn 1979, while the JADE Collaboration published an extended analysis, which included a first determination of the strong coupling constant $\alpha_S(q^2)$, in spring 1980 (MARK J Collaboration, PLUTO Collaboration and TASSO Collaboration 1979; JADE Collaboration 1980). Sixteen years later, in July 1995, the discovery of the gluon was honoured by the EPS, which awarded its Prize for High Energy and Particle Physics to four physicists representing the TASSO Collaboration: Paul Söding, Bjørn Wiik, Günter Wolf and Sau Lan Wu. A special complementary prize was also awarded to the four collaborations in recognition of their combined work, since, as the EPS statement reads, the "definite existence (of the gluon) emerged gradually from the results of the TASSO Collaboration and the other experiments working at PETRA, JADE, MARK J and PLUTO".

As Wagner emphasized, the results obtained by the four experiments and the speed with which they were achieved would have been impossible without the initiative of DESY's director-general at the time, Herwig Schopper, and the outstanding work of the accelerator physicists and engineers under the leadership of accelerator division director Gustav-Adolf Voss, who managed to complete the accelerator on budget and in record time, six months ahead of schedule.

The discovery of the gluon marked the beginning of intensive tests of QCD at PETRA. These included the determination of the spin of the gluon, which proved to be a vector particle; the so-called string effect, i.e. the hadronization of quarks and gluons via the formation of colour strings; various tests of second-order QCD calculations (see figure 3); and precise determinations of the running strong coupling constant α_S. At the end of the 1980s the baton passed on to CERN's Large Electron Positron (LEP) collider. Although it was primarily built to perform precision tests of the electroweak force through the production and decays of Z and W bosons, due to the very large event sample, LEP became an excellent testing ground for QCD (*CERN Courier* May 2004 p21). For example, whereas the experiments at PETRA were unable to distinguish between quark–quark–gluon and gluon–gluon–gluon vertices, these differences were measured at LEP's OPAL experiment using a sample of 4×10^6 Z^0 decays.

The discovery of the gluon would not have been possible without the outstanding work of the then director of the DESY accelerator division Gustav-Adolf Voss (centre), under whose leadership the PETRA crew completed the accelerator on budget and in record time, six months ahead of schedule. With him at the colloquium are Johannes Kouptsidis (left), then leader of the PETRA vacuum group, and Voss's deputy Hermann Kumpfert (right). (Photo DESY Hamburg.)

Today, QCD is put through its most stringent tests at the Tevatron proton–antiproton collider at Fermilab and at DESY's electron–proton collider, HERA. The advances made have been remarkable, ranging from an extremely precise determination of the proton structure function to the study of the origin of nucleon spin, the exploration of the non-perturbative nature of the strong interaction, or the problem of quark confinement. Over the past 25 years QCD has thus emerged as the uniquely successful theory of the strong interaction, and it is as such a full part of the Standard Model of particle physics. As Fritzsch concluded in his talk at the colloquium, "The phenomena of the strong interaction are now 'in principle' understood." With the advent of new theoretical approaches such as QCD lattice calculations and new experiments at future accelerators, the "still impressive list of unsolved QCD problems" is set to shrink fast.

Further reading

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Ilka Flegel *and* **Paul Söding**, *DESY.*

Sergei Vavilov: luminary of Russian physics

Sergei Vavilov, whose research led to the discovery of Cherenkov radiation, contributed greatly to establishing a strong base for physics in the USSR, especially during the difficult years of the 1930s. In particular his efforts led to the founding of the Lebedev Physics Institute in Moscow 70 years ago.

Sergei Vavilov (right), whilst on leave from the front in Moscow in 1916, with his mother.

Sergei Vavilov was born in Moscow in 1891. His father, a prosperous textile merchant, gave a good education to his two sons and hoped they would inherit and continue his business. However, Sergei and his elder brother Nikolai both decided to become scientists. Nikolai chose biology, while in 1909 Sergei entered the Department of Physics and Mathematics at Moscow University. As a second-year student he started work in the laboratory of Pyotr Nikolaevich Lebedev (1866–1912), who was famous for his experiments on the pressure of light on solids and gases. Vavilov became a great admirer of Lebedev's style of work – an interest in the fundamental problems of physics blended with careful experiments.

After graduating with honours in 1914, Vavilov was called up for military service; a month later the First World War began. Vavilov served in various technical regiments, but by the end of 1917 the Russian front had collapsed because of the revolution and he was taken prisoner. He was interrogated by a German officer who happened to be a physicist and they spent all night discussing physics, especially Max Planck's new theory of light. By morning the officer had helped Vavilov escape, and in February 1918 he appeared in Moscow. His father had by then lost all his property and emigrated from Russia, but Sergei and Nikolai did not want to leave their country; they realized that they had to coexist with the Soviet government as many other Russian scientists did. The government had decided that use should be made of scientific and technical specialists "in spite of the fact that they have been nourished upon capitalist ideology". The 1920s were thus a period of great liberty for Russian scientists, despite civil war, widespread famine and economic collapse.

Bouger's law and non-linear optics

In 1918 Vavilov started to work in the Physics and Biophysics Institute headed by Pyotr Petrovich Lazarev, a disciple of Lebedev who proposed that Vavilov pursue the topic of physical optics. He also lectured at Moscow University. From the start Vavilov was fascinated by the fundamental questions of the nature of light. He began with photoluminescence studies of solutions of organic dye molecules, and in 1919 conceived the idea for an experiment to confirm Max Planck's quantum theory of light by measuring the coefficient of light absorption in optical media. According to Bouger's law, this coefficient does not depend on its intensity; however, if Planck's theory were correct it should be possible to see quantum fluctuations at very low or very high intensities of light, thus violating the law. Using dye solutions Vavilov and his students verified the law over a large range of incident light power, 10^{-11}–10^{8} erg/cm^2/s, and in 1920 they published a negative result; they did not see a violation of Bouger's law.

During the following years Vavilov and his co-workers elucidated the principal laws of luminescence, introducing the term "luminescent yield" as the ratio of the luminescent energy to the energy of exiting light. They also investigated the mechanisms of luminescent quenching and Vavilov pioneered work on the development of new and economical light sources – luminescent lamps.

Continuing the work on the quantum nature of light, Vavilov decided to use an optical medium with a very-long-lived molecular excitation state to make it possible to see a violation of Bouger's law. After a long search his team found a uranium glass with a glow lasting hundreds of thousands of times longer than that of dye solutions, and in 1926 Vavilov and Vadim Levshin finally discovered a violation of Bouger's law at high intensities. They found a reduction in the absorption of light by uranium glass as the intensity of the light increased. Now known as the photorefractive effect, this was explained as resulting from the depopulation of the ground state by the incident beam. Vavilov introduced the term "non- ▷

linear optics", which has since become a special subject of physics.

At the beginning of the 1930s the political climate in the USSR changed abruptly for the worse as Stalin consolidated his power. Numerous scientists were persecuted in Moscow, Leningrad and other cities. In March 1931 Lazarev was suddenly arrested and later exiled in the Urals. Colleagues lost their jobs at the institute, including Vavilov, although he kept his position as university professor. Academicians trying to preserve the Lebedev–Lazarev scientific school recommended Vavilov as a full member of the USSR Academy of Sciences, and he was elected in 1932.

Around the same time the director of the Optical Institute in Leningrad, Dmitri Rojdestvenski, invited Vavilov to join the staff in a bid to save the scientific programme from being stopped by the government to make way for the production of optical apparatus, especially for the military. Vavilov accepted and in 1932 was appointed head of research of the State Optical Institute. The same year he was asked by the Academy of Sciences to take charge of the academy's small Physics Department in Leningrad. Vavilov invited several young physicists to join and organized investigations on the properties of neutrons, radiation-induced luminescence and coloured crystals.

This photograph taken in the Lebedev Physics Institute in 1938 shows, clockwise from top left, Dmitry Skobeltsyn, Sergei Vavilov, Irène Joliot-Curie, Abram Ioffe and Frédérick Joliot-Curie.

The Vavliov–Cherenkov effect

In 1932 Vavilov and Eugeny Brumberg developed a photometric technique using the human eye as an instrument for measuring low light intensities close to the threshold of vision. This visual photometric method was very useful at a time when photomultipliers did not yet exist, and it was used in experiments performed in 1932–1941 that confirmed the statistical character of fluctuations in line with the ideas of quantum theory.

The same visual technique played a large role in the discovery of the Vavilov–Cherenkov effect. In 1933 Vavilov proposed to his postgraduate student, Pavel Cherenkov, the PhD topic: "The luminescence of the uranyl salt solutions under the influence of hard gamma radiation." The task was to compare to what extent the luminescence properties of a salt solution in sulphuric acid exposed to gamma rays coincide with the previously studied luminescence of the same solution under light and X-ray irradiation.

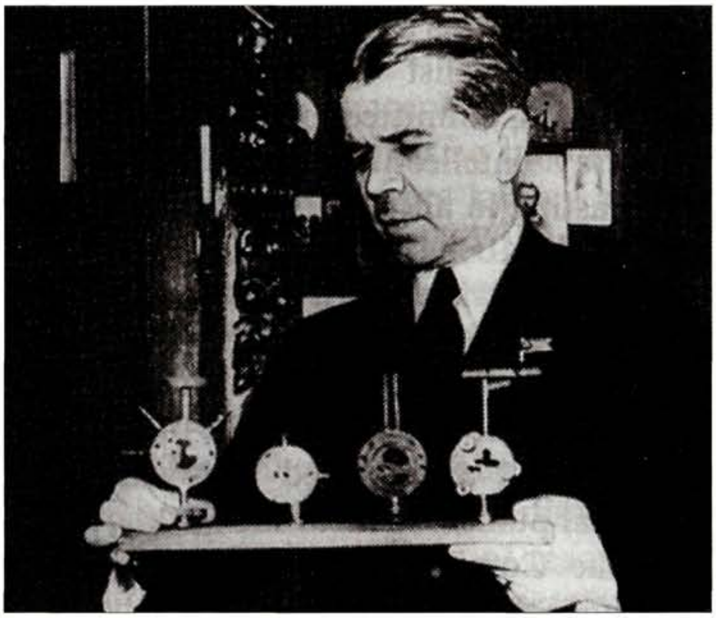
The observed blue light was very weak, and to adapt his eyes Cherenkov had to stay in a totally dark room for an hour or more. In the course of measurements he found that a glow is emitted not only by the salt solution but by pure sulphuric acid as well. This situation proved to be a great nuisance to Cherenkov, who considered the glow to be a background obscuring the luminescence of the uranyl salt, so he asked to change the topic of his thesis. But Vavilov persuaded Cherenkov to continue the experiments and carefully purify the acid. When this did not help, Vavilov proposed checking if other pure solvents also emit light. Cherenkov investigated 16 different solvents of very high purity and found that the pure liquids all gleamed with nearly equal intensities under the action of gamma rays. Despite attempts to quench it by various means the mysterious radiation persisted.

Vavilov analysed all the measurements and arrived at the firm conclusion: "This is not a luminescence, this is a new optical phenomenon not known to science." He also presented a first explanation – that the new radiation was produced by Compton electrons knocked out from the atoms of the liquid by gamma rays. In 1934 two articles were published in the same volume of the *Reports of the Academy of Sciences*, one signed by Cherenkov with his experimental results, the other by Vavilov in which he correctly postulated fast electrons as the origin of the new phenomenon.

In 1934 the Academy of Sciences moved from Leningrad to Moscow, and Vavilov's Physics Department moved there too, to occupy what had been Lazarev's building. Vavilov was determined to turn the small Physics Department into an institute covering the most important fields of physics. He obtained financial support from the government and began to organize the new Physics Institute of the Academy of Sciences. He was appointed as the first director and suggested that the new institute be named after Lebedev. He invited distinguished physicists to head the divisions he intended to create and some excellent young physicists to join the staff.

Though the 1930s were a very difficult time of political persecutions in the USSR, Vavilov managed to preserve a positive internal ambience in the Lebedev Institute, allowing the possibility for productive work. Vladimir Veksler wrote later: "I was lucky in that as a young scientist I was invited in 1936 to join the staff of the Lebedev Institute. An exciting atmosphere of complete commitment to science prevailed in the institute. My first impression of Vavilov was that his attitude was extremely affable and straightforward."

In the laboratory of the Atomic Nucleus Division, Vavilov and Cherenkov continued to explore in detail the new radiation. They established that the radiation is emitted in a narrow cone close to the direction of the incident gamma-ray flux and is polarized along this direction. A magnetic field deflected the radiation, confirming Vavilov's claim that it originated with charged particles. Vavilov constantly discussed the results of the experiments with theorists in the institute, trying to push them to work on the theory of effect. Finally, Ilya Frank and Igor Tamm became interested and in 1937 they gave a complete theoretical interpretation. "Vavilov enthralled me by his fascination with Cherenkov experiments," Frank later wrote. In 1946 Vavilov, Cherenkov, Frank and Tamm were awarded the USSR State Prize in Science (the Stalin prize) for this discovery, and in 1958,



Sergei Vavilov with optical apparatus used by Lebedev.

seven years after Vavilov's death, Cherenkov, Frank and Tamm received the accolade of the Nobel Prize in Physics. In his Nobel lecture Tamm said: "I should perhaps explain that we in the USSR use the name 'Vavilov–Cherenkov radiation' instead of just 'Cherenkov radiation' in order to emphasize the decisive role of the late Professor S Vavilov in the discovery of this radiation."

By the 1930s Soviet nuclear physicists had reached a high level, mainly in the Leningrad Physics-Technical and Radium institutes and in Kharkov's Polytechnical Institute. After visiting the USSR in 1936 Victor Weisskopf wrote: "Soviet physicists did not lag behind in their understanding of nuclear structure." In 1938 Vavilov wrote a report about nuclear physics for the presidium of the Academy of Sciences, who decided to set up the Nuclear Physics Committee with Vavilov as chairman and Abram Ioffe, Igor Kurchatov, Pyotr Kapitza and Abram Alikhanov among its members.

Vavilov believed that experiments in nuclear physics required an accelerator bigger than the Radium Institute's 10 MeV cyclotron, so in 1940 he organized a "cyclotron group" in the Lebedev Institute, consisting of young physicists whose goal was to find a way to construct a big cyclotron. When the members of this group told Vavilov about the huge difficulties, the answer was: "I don't think there is no possibility of jumping over the relativistic barrier." Then in 1944 Veksler wrote his famous two papers about the principle of phase stability, used in all modern particle accelerators. Vavilov immediately recommended them for publication and the decision was taken to start the construction of a 30 MeV synchrotron at the Lebedev Institute.

It was around this time that Vavilov was struck with the blow of the arrest, and later death, of his older brother Nikolai (1887–1943), an outstanding plant breeder and geneticist. The two brothers loved and influenced each other all their lives. Both were men of encyclopaedic knowledge, retentive memory, prodigious energy and personal charm, with a deep devotion to science. In the 1920s Nikolai had carved out a brilliant carrier in Russia. He was elected president of the Agricultural Academy and was at the head of research institutes of plant breeding in Leningrad and genetics in Moscow. He organized many expeditions throughout the world and created a huge seed collection. He also preserved and set up many experimental stations in different regions of the USSR and directed their programmes. However, Nikolai gained enemies driven by agronomist Trophim Lysenko and Marxist philosopher Isaak Present. Lysenko promised quick crop improvements, compared with Nikolai's slow process of systematic hybridization and selection, and from 1935 Nikolai had to bear constant accusations of holding "idealist" Mendelian theories. Thousands of his colleagues and followers were removed from their teaching and research positions; many were arrested and some were shot. Nikolai's agricultural programme was devastated and in 1940 he was arrested, tortured, tried and sentenced to be shot "for sabotaging Soviet agriculture and spying for England". (He had worked on genetics in the UK in 1913–1914.) A year later the sentence was commuted to 20 years of forced labour and in 1943 he died of starvation in Saratov prison. After Nikolai's death, Sergei actively helped the family of his brother, and two of Nikolai's sons became cosmic-ray physicists at the Lebedev Institute.

Not all of the sciences suffered as badly as biology, but Marxist philosophers assailed the "idealism" inherent in quantum mechanics and relativity theory. In 1937–1938 many physicists were arrested, and some were persecuted in the Lebedev Institute. Vavilov shielded the head of the Optics Division, Grigori Landsberg, the head of the Theory Division, Tamm (whose brother, the chief engineer of the chemical factory, was arrested), and others; he wrote directly to the chief prosecutor when Sergei Rytov, head of the Radiophysics Division, was arrested in 1937 (he was released in 1939).

Towards the hydrogen bomb

When Soviet physicists learned about the discovery of nuclear fission in 1939 they immediately proceeded to investigate the new phenomenon experimentally and theoretically. Most, including Ioffe and Kapitza, were sceptical about the possibility of utilizing atomic energy, but Tamm is reported to have said in August 1939, upon hearing a talk by Yakov Zeldovich and Yuly Khariton on their calculations of the number of neutrons emitted by fission: "Do you know what this discovery means? It means a bomb can be built that will destroy a city out to a radius of maybe ten kilometres." (Halloway 1994.) Soviet authorities at the time thought that nuclear physics was a useless science, but Vavilov had a notion that in future it would be very significant. He had himself stayed as head of the Atomic Nucleus Physics Division of the Lebedev Institute until 1938, and gathered a team including Frank and Veksler. Later, in 1945, an engineer from the munitions plant, Andrei Sakharov, became Tamm's postgraduate student.

On 22 June 1941 German armies unexpectedly crossed the Soviet border and rapidly progressed towards Leningrad and Moscow. This led the government to organize the evacuation of vital economic organizations towards the east of the country. By the end of July the Lebedev Institute was moved to Kazan and the Optics Institute was evacuated from Leningrad to a town 300 km from Kazan. Vavilov was appointed as adviser on optics to the USSR State Defence Committee and many research themes were changed to military tasks – every division in both institutes tried to produce equipment useful for the army. ▷

In 1942 the Soviet government endorsed an atomic-bomb research programme and appointed Igor Kurchatov as its head. After the war Vavilov was ordered to participate in the state's nuclear-weapons programme and he persuaded Tamm to create a special group including Vitaly Ginsburg and Sakharov. In 1948 Vavilov wrote to the government to inform them that significant results had been obtained in Tamm's group on the development of the physical principles of a hydrogen bomb. The group was moved to the classified town of Arzamas-16, and on 12 August 1953 the world's first compact hydrogen bomb, deliverable by plane or rocket, was successfully tested in the USSR, to the great surprise of Western physicists. Earlier, in 1950, Tamm and Sakharov created the theoretical basis for controlled thermonuclear fusion, so thermonuclear power could be used for peaceful means. Twenty-five years later, Sakharov, who had played a crucial role in the development of the Soviet hydrogen bomb, was awarded the Nobel Peace Prize for his championship of human rights, beginning in the 1960s. He was the sixth Lebedev physicist to be awarded the Nobel prize. (In 1964 Alexandre Prokhorov and Nikolai Basov received the Nobel Prize in Physics for the construction of oscillators based on the maser-laser principle.)

Sergei Vavilov's brother, Nikolai, seen here as vice-president of the VI International Congress on Genetics in the US in 1932. He was tried and imprisoned for "sabotaging Soviet agriculture and spying for England" in 1940 and died in prison in 1943.

President of the Academy of Sciences

Vavilov was elected president of the USSR Academy of Sciences in July 1945. Many academicians thought there was not another scientist of so high a cultural level and such a provident, skillful administrator as Vavilov, and some recommended him for presidency. However, this could only have taken place if he were Stalin's choice, so it was very hard for him to accept, as his brother Nikolai had been murdered by Stalin's regime. The opinion of people close to Vavilov is that he accepted the post because he considered it his duty to serve science and the nation, rather than Stalin. During the time he was president he accomplished much to foster science in the USSR – the laboratories were better supplied with equipment and instruments, and the salaries of the researchers were increased.

Vavilov initiated the establishment of tens of new scientific and cultural institutions (research institutes, publishing houses, societies) but he understood and accepted the fact that he could do so only if the Communist Party saw them as useful politically or militarily. He briefed the authorities on the possibilities of new institutions and bargained to obtain the support he needed. In so doing he often had to act against his conscience and agree to distasteful compromises. Academician Leon Orbeli said in 1945: "Sergei Vavilov is a victim. He stayed on as head of the academy to save what could still be saved." It was common knowledge that Vavilov was a kind and responsive person, and if he were able to help somebody by writing or signing a letter, acting as an intercedent or finding them a job, he would do so.

Vavilov was not only a distinguished researcher. From 1932 until the end of his life he had to spend part, and later most of his time, performing administrative functions in science and supervising young scientists. He made a great contribution to the growth of the State Optics Institute, which now bears his name, and the Lebedev Physics Institute.

All his life he was greatly interested in the history and popularization of science. He wrote popular books on optics and scientific biographies of Galileo, Grimaldi, Huygens, Faraday, Michelson, Newton, Euler, Lomonosov, Lebedev, Lazarev and others. He also translated Newton's *Optics* and *Lectures on Optics* and Lucretius' *De rerum Natura* from Latin to Russian, and published them with his own comments.

In the end, being president of the academy under the brutal dictatorial regime of Stalin was a source of appalling stress. Vavilov's health was seriously damaged and he died of a heart attack in 1951, two months before his 60th birthday (and two years before Stalin's death).

Frank preserved his respect and affection for his beloved teacher until the end of his days. He compiled and edited a collection of reminiscences about Vavilov, which was published in three volumes. Frank was very ill when he was working on the third volume in 1991 and afraid he would die without finishing the work. When he completed the manuscript he emerged from his study at home and joyfully informed his family that the book had been finished, adding: "Now at last I can die." He died a few days later.

Frank wrote: "What [Vavilov] did during his five-year presidency is so beautiful and extensive that future generations will remember him with deep respect and gratitude."

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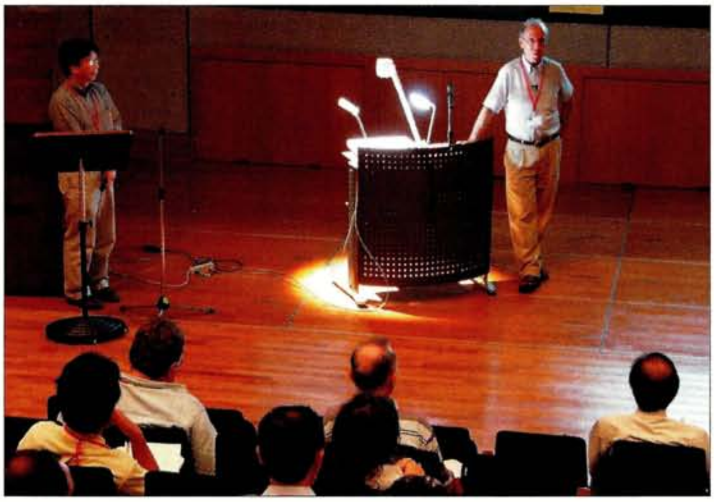
Boris M Bolotovski, Yuri N Vavilov, Alevtina P Shmeleva,
Lebedev Physics Institute, Moscow.

Preparing for physics at J-PARC



Avraham Gal, from the Hebrew University in Jerusalem, speaking on strangeness physics in a plenary session that was chaired by Jen-Chieh Peng of Illinois (standing left).

Participants at a recent workshop discussed future physics and management issues at the J-PARC facility, which is now under construction in Japan.

Tokai in Japan, which is located on the Pacific coast about 140 km northeast of Tokyo and 70 km northeast of the KEK laboratory, is the site of J-PARC, the Japan Proton Accelerator Research Complex. This new facility is based on a 50 GeV proton synchrotron (PS) and, with a beam power of 0.6 MW, will be the most powerful machine at such energies when it starts operation in 2008. Under construction since 2001, J-PARC is being built jointly by two institutes, KEK and the Japan Atomic Energy Research Institute (JAERI). On 2–4 August this year potential users had the opportunity to find out more about the facility when the 3rd International Workshop on Nuclear and Particle Physics at J-PARC (NP04) was held in Tokai.

NP04 followed two similar workshops, in 2001 in Tsukuba and in 2002 in Kyoto, but was special in that it provided the first occasion for future users to discuss a wide range of issues, including the expected performance of the machine and the arrangement of beam lines. They could also voice their wishes and concerns about the type of organization that will govern relationships between them and the J-PARC management. In addition, the workshop provided a wide *tour d'horizon* of the future physics programmes.

The workshop was divided roughly into four wide domains: strangeness nuclear physics, nuclear hadron physics, kaon rare decays and muon rare decays. When there was overlap between these topics some of the parallel sessions were given in joint sessions covering two or three topics. These physics programmes represent the backbone of research in nuclear and particle physics at the new facility, and most are a continuation of the physics for which KEK has earned its high reputation. The presentations did not include other important programmes for the future facility, in particular neutrino oscillations, which were covered in a separate workshop at KEK on 24–26 August, and a wide range of more application-oriented studies involving neutrons, muon spin rotation and transmutation of nuclear waste.

Participants listen intently during one of the sessions.

The first day consisted of plenary sessions devoted to overviews of the accelerator, projected beam lines and physics topics. These were followed by parallel sessions on the mornings of the second and third days. On the afternoon of the second day a visit to the J-PARC construction site gave the participants, most of whom will be future users, the opportunity to view the tremendous progress made by the construction team.

The afternoon of the third and final day was devoted to a discussion of institutional matters. Shoji Nagamiya, director of the J-PARC project, presented the overall framework, and relations with users were discussed by Tadafumi Kishimoto from Osaka University. Kishimoto is a member of a new body called the J-PARC Users Consultative Committee, which is made up of representatives of the different fields, including three representatives from industry and non-voting members of the J-PARC management.

Jen-Chieh Peng from Illinois explained the role of the Nuclear and Particle Physics Facility Committee (NPFC). This is in effect a pre-programme advisory committee, whose duty has been until now to review the 30 letters of intent involving more than 480 authors – including around 60% from foreign institutions – and to advise J-PARC management about machine and beam-line issues based on this review. One of the special tasks of the NPFC was to review the neutrino proposal – whose temporary name is T2K, for Tokai-to-Kamioka, in analogy with the now famous K2K (KEK-to-Kamioka) ▷

The construction work for the hadron experimental hall was on view to the participants during a tour of the J-PARC site.

experiment – which aims to shoot a high-energy neutrino beam towards the SuperKamiokande detector located 295 km away near the coast of the Sea of Japan. Following this review, and the high grade given by the NPFC to the proposal, this project has been funded as an additional facility by the Japanese government.

The NPFC was also charged with classifying the letters of intent into three categories: Day 1 experiments, Phase I experiments and Phase II (and beyond) experiments. Day 1 experiments were selected for their outstanding interest coupled with the fact that they can be realized at the start of J-PARC, within the timeline and budget available for the experimental facilities. Two projects were selected that make partial use of equipment already used at KEK for strangeness nuclear physics.

Phase I experiments are those of great scientific interest that can be done with J-PARC Phase I – PS energy of 30 GeV, maximum beam power of 0.45 MW for the slow-extracted beam in the hall of initial size – but which require beam lines and/or detectors that are not yet available or financed. Phase II experiments will require not only an extended hall and upgraded beam lines but also the final performance of J-PARC when the injection energy will be pushed to 400 MeV, instead of 180 MeV in Phase I, and the PS will reach its ultimate energy of 50 GeV. Many letters of intent proposed far-reaching additions to the initial facility, including muons (as in the PRISM project) and high-intensity neutrino beams and antiprotons.

The final session was a lively discussion between users and J-PARC management about the roles in the new organization of KEK and JAERI – who finance about 43 and 57% of the new facility, respectively – and about their relationship with the J-PARC Centre, the future body for J-PARC management. An important issue being through which channel future experimental equipment will be funded.

In conclusion, all the participants seemed enthusiastic about the organization and the high level and number of exchanges during this historic workshop. The three days were densely packed, with not much time for tourist distractions, the exception being the beautiful banquet, a much-appreciated Japanese tradition. Another workshop will be organized in 2005 or 2006 as J-PARC comes closer to final completion, and all physicists interested in the new facility will be encouraged to attend.

Jacques Arvieux, *Institut de Physique Nucléaire d'Orsay.*

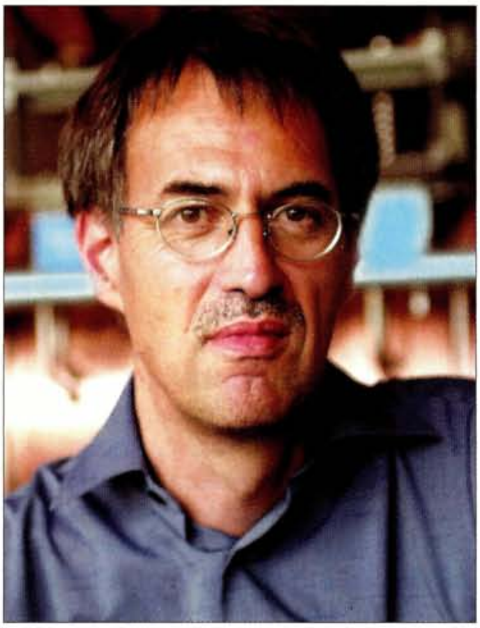
APPOINTMENTS

Linde to take over as director of NIKHEF

Frank Linde has been appointed as the director of NIKHEF, the Dutch national institute for subatomic physics, as from 1 December. Linde succeeds Karel Gaemers, who had taken over *ad interim* in January (*CERN Courier* January/February 2004 p46).

After taking part in the TPC/two-gamma experiment at SLAC and in the L3 experiment at LEP, Linde has been the project coordinator of all Dutch ATLAS efforts since 1995. More generally, he has played a leading role in the research and development of the precision chambers for the ATLAS muon spectrometer.

A full professor in elementary particle physics at the University of Amsterdam, Linde also actively contributes to outreach activities for high-school students, and is currently involved in the Dutch activities for the World Year of Physics 2005. He has also been a member of the ECFA study group on the future of accelerator-based particle physics.

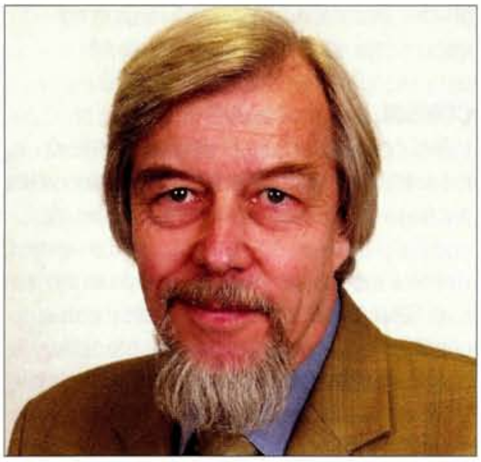


Frank Linde has been appointed as the new director of NIKHEF as from December.

DESY announces Heuer as new research director

The Administrative Council of the Helmholtz Centre, DESY, has appointed Rolf-Dieter Heuer as the new research director for high-energy physics. He takes over on 1 December from Robert Klanner, who has decided to return to teaching and research after a five-year term of office.

Heuer first worked at DESY on the DORIS electron–positron storage ring, where he investigated the neutral decay modes of the Ψ', and later joined the JADE experiment on the larger PETRA electron–positron collider. In 1984 he moved to CERN, where he worked at the Large Electron Positron collider on the OPAL experiment, of which he was the spokesperson for many years. He returned to DESY in 1998 as professor for experimental physics at the University of Hamburg. A central point of his work at DESY has been to establish a new research group, "Research at Lepton Colliders". This now plays a leading role in the European and worldwide research efforts directed towards the physics potential of the future International Linear Collider, and the development of the complex precision measuring instruments that are required.



Rolf-Dieter Heuer's new role at DESY will be as research director for high-energy physics.

Canadian IPP appoints Trischuk

William Trischuk has been appointed to a five-year term as director of the Institute of Particle Physics (IPP) of Canada. Trischuk, who is professor in the Physics Department at the University of Toronto, has led the Canadian group on the CDF experiment for the past six years. Prior to that he was a member of the scientific staff at CERN.

The IPP is a non-profit organization owned by several academic and research institutions throughout the country, and has responsibility for coordinating and supporting Canadian involvement in research in subatomic physics, both within the country and abroad. It employs eight research scientists who work at member institutions and has approximately 150 individual members.

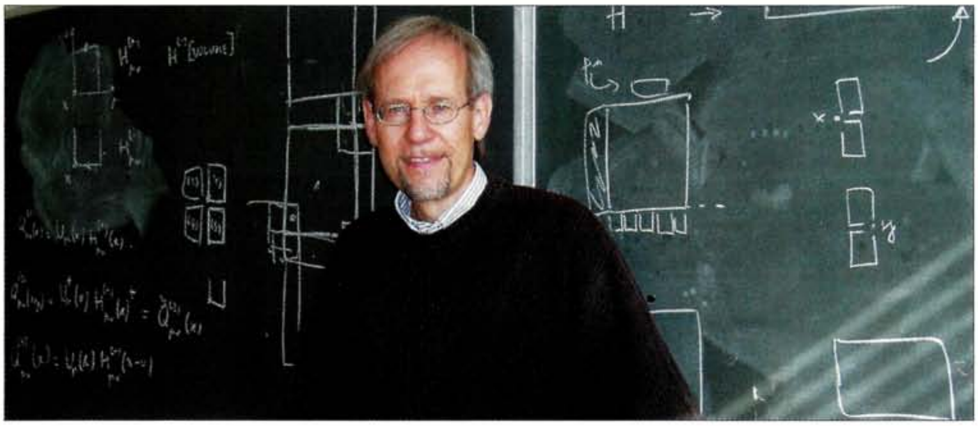
William Trischuk is the new leader of the Canadian Institute of Particle Physics.

One of the IPP's major roles is to coordinate Canada's participation in subatomic physics on the world scene, and the director plays a role in representing Canada on such bodies as the Global Science Forum of the Organization for Economic Cooperation and Development and the International Committee for Future Accelerators. The IPP also participates in the organization of international conferences at home and abroad.

PRIZES

Greinacher prize won by lattice-gauge theorist

Martin Lüscher from CERN will receive the prestigious Swiss Greinacher prize on 19 November at the Physikalisches Institut in Bern. The prize has been awarded "in recognition of his exceptional work in the field of lattice-gauge theory", that is, work on exact chiral symmetry, chiral gauge theory and topology on the lattice, running coupling constant, volume dependence and non-perturbative improvement. Lattice QCD was suggested about 30 years ago and now plays a major role in the quantitative understanding of quark interactions and quark confinement inside hadrons.


Martin Lüscher from CERN has been awarded the Swiss Greinacher prize.

Call for nominations for accelerator prize

The US Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology honours individuals by recognizing outstanding achievements over the full range of accelerator physics and technology. Two prizes are awarded every two years, one of which goes to a young scientist under the age of 45.

Each winner will receive a certificate of merit and a cash award of $3000, made possible by donations from Brookhaven Science Associates, John Wiley and Sons Publishers, the Southeastern Universities Research Association and the Universities Research Association. The prizes will be awarded at the 2005 Particle Accelerator Conference to be held on 16–20 May 2005 in Knoxville, Tennessee.

Nominations should include the name and institution of the candidate, a description of his/her accomplishment and supporting documents, as well as three letters of recommendation. Nominations are international and open to all. The prizes are awarded on a competitive basis without regard to race, sex or nationality.

The deadline for nominations is 15 December 2004. Please submit nominations and documentation to: US Particle Accelerator School, Fermilab MS #125, PO Box 500, Kirk Rd & Wilson St, Batavia IL 60510, USA.

- For more information, please visit http://uspas.fnal.gov/prize.html, or contact the USPAS Office at uspas@fnal.gov; tel: +1 630 840 3896; or fax: +1 630 840 8500.

NEW PRODUCTS

Acqiris is offering a new stand-alone Multichannel Acquisition Software package, AcqirisMAQS, which simplifies the monitoring and control of data-acquisition systems with multiple data channels, as in high-energy physics and astrophysics. It is extremely flexible and can be used for the remote operation of multiple acquisition systems at different locations. For further information, see www.acqiris.com.

COMSOL has announced the release of a MEMS (micro electro mechanical systems) module for its FEMLAB mathematical modelling package. MEMS allows engineers to design and build systems on the scale of micrometres. The new module works as an add-on to the core FEMLAB package and extends its base capabilities to enable microscale modelling. A library provides ready-to-use models illustrating the principles and design of real devices. For more details, tel: +44 20 7348 9000, or see www.uk.comsol.com.

Isis Cryogenic Engineering (ICEoxford) is a new company that can supply innovative, high-quality, bespoke low-temperature and ultra-low-temperature systems. Together with its strong network of associates, ICEoxford has in excess of 250 years of collective practical knowledge and cryogenic experience in the design, manufacture, test and installation of low-temperature and ultra-low-temperature instrumentation. For further information, please see the website at www.iceoxford.com.

MEETINGS

LRT2004, a Topical Workshop in Low Radioactivity Techniques, will be held at the Laurentian University campus in Sudbury, Canada, on 12–14 December. The goal is to bring together experts in the field for presentations and discussion broadly covering issues of low-radioactivity techniques. The intention is to foster collaboration and resource sharing for the new generation of detectors to be developed at underground facilities. Underground tours of SNO can be arranged on 14 December. Please send a short e-mail to lrt2004@snolab.ca to express your interest in participating. For information and registration, see http://LRT2004.snolab.ca.

CORRECTION

In the September issue of *CERN Courier* two authors were incorrectly affiliated. In the "The high-intensity frontier" article Peter Butler (p31) is in fact currently with CERN, and in "When quarks and gluons become free" Peter Seyboth (p41) is with MPI für Physik, Munich. Apologies to all concerned.

ANNIVERSARIES

Golutvin and Onuchin celebrate 70th birthdays

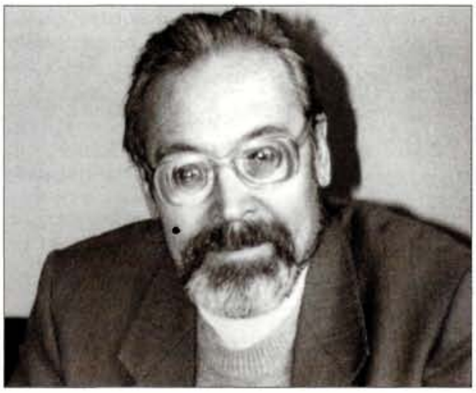
Igor Golutvin, one of the leading scientists of the Joint Institute for Nuclear Research (JINR) in Dubna, celebrated his 70th birthday in August. More recently, Alexei Onuchin, one of the pioneers of colliding-beam experiments from the Budker Institute of Nuclear Physics (BINP), also celebrated his 70th on 3 October.

Golutvin is well known as the constructor of several generations of large-scale experiments at JINR, at the Institute of High Energy Physics in Protvino, and at CERN, most recently with CMS. He began to develop and study wire spark chambers for neutrino experiments during his first visit to CERN in October 1964. This was a time of rapid development in electronics, when computers were used to register events online for the first time. With the experience gained at CERN he was able to implement electronic recording methods in experiments on elastic πp scattering at the JINR Synchrophasotron and the $K^0-\bar{K}^0$ regeneration beam at the U-70 accelerator in Protvino.

Ten years later, in 1974, Golutvin was among the group of physicists delegated to CERN to establish a joint JINR–CERN experimental programme. He came to work on the R-605 experiment led by Carlo Rubbia, which searched for charmed particles at the Instersecting Storage Rings. His successful work with the JINR team promoted the development of co-operation between the two centres. The result was the approval, in 1975, of the first joint experiment, NA4, on the study of the structure of the nucleon by the BCDMS (Bologna–CERN–Dubna–Munich– Saclay) collaboration. Golutvin led the R&D on the large proportional chambers and for two years led the development and construction of the experiment.

In Dubna Golutvin organized a powerful methodical basis for the R&D and production of wire chambers of different types and their electronics. Drift and proportional chambers constructed under his leadership were used in the SIGMA experiment and in two neutrino detectors at Protvino, as well as three generations of the ANOMALON experiment at the JINR Synchrophasotron. The large-area drift chambers made at Dubna were used in NA4 at CERN and HERA-B at DESY. In 1988 he initiated the Dubna silicon programme to develop radiation-hard silicon detectors for a wide range of applications in experiments at colliders.

Leading JINR scientist Igor Golutvin.



Budker Institute pioneer Alexei Onuchin.

For the past decade Golutvin has participated in the organization of international co-operation on the CMS experiment at CERN, and has been a spokesperson of the RDMS (Russia and Dubna Member States) group since 1994. This group, which involves 24 research institutes from Russia and JINR member states, contributes significantly to CMS.

During his work at JINR Golutvin also set up a scientific school and brought together active physicists and engineers who are well recognized in the global scientific community.

Alexei Onuchin's whole scientific career has related to the BINP, where he has worked since 1959. His PhD thesis in 1965 on the luminosity measurement by small-angle scattering was one of the first experiments at the colliding-beam facility, and in 1966 he was author of a pioneering work on a test of quantum electrodynamics in large-angle electron–electron elastic scattering. He then became one of the leaders of the experiment performed at the VEPP-2 e^+e^- collider in the 1.18–1.34 GeV energy range that had two important results in 1970. The discovery of multihadron production, simultaneously with Frascati, was one of the first indications of the existence of light quarks, while a detected excess in the pion and kaon form factors over theoretical predictions became a step to a later observation of ρ', ω' and φ' mesons.

From 1980 to 1985 Onuchin led the MD-1 experiment at the VEPP-4 e^+e^- collider operating in the Υ resonance energy range. One of its well known results is the measurement of the cutoff of large impact parameters in bremsstrahlung (the "MD effect"). The results on the leptonic width of the U(1S), R and the total cross-section for $\gamma\gamma \rightarrow$ hadrons are still the most precise. In 1989 he shared the USSR State Prize with a group from the BINP for high-precision measurements of particle masses.

Onuchin is one of the founding fathers of the KEDR detector for experiments at the upgraded VEPP-4M collider. He suggested and, together with colleagues, successfully realized the 30 tonne liquid-krypton calorimeter project. His group also constructed a drift chamber using "cold" DME (dimethyl ether) gas providing 100 μm resolution. He is now one of the leaders of the Novosibirsk group in the BaBar experiment at the SLAC B-factory.

His long-standing love for Cherenkov counters started with the pioneering water-threshold counters in the experiment at VEPP-2. He later developed the MD-1 Cherenkov counters filled with ethylene pressurized to 25 bars, and finally suggested the aerogel counters with wavelength shifters (ASHIPH) now operating in KEDR. All this clearly shows his talent and creativity.

For many years Onuchin has taught and supervised students at the Novosibirsk state and technical universities. Previous students include many highly qualified physicists, among whom are professors, group leaders, a deputy-director and a corresponding member of the Russian Academy.

Onuchin continues to remain fit and well and is still a good skier. His friends and colleagues wish him good health and many years of creative research.

SCHOOLS

BNL hosts summer school on QCD spin physics

The participants at the 1st Summer School on QCD Spin Physics, which was held in June.

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) is a doubly unique machine. It provides collisions between heavy ions at the highest known energies, thereby permitting the study of matter in the extreme conditions that prevailed in the earliest moments of the universe. It also provides head-on collisions between beams of 100 or 250 GeV/c polarized protons, so extending the study of spin-dependent dynamics into a totally new kinematic regime, and thereby opening a new chapter in the study of the structure of the nucleon. The 1st Summer School on QCD Spin Physics, held at Brookhaven from 5–12 June, aimed to provide a pedagogical introduction to the field and to the exciting research programme underway at RHIC.

Spin, in a relativistic context, is a very subtle concept and is intricately connected with the structure of the dynamical theory, in this case QCD. In the 1960s, when physicists were wrestling with the analytical properties of Feynman diagrams, it was something of a relief to pretend that spin was "an inessential complication". But in reality the role of spin is quite central in a dynamical theory; the history of particle physics is littered with the graves of theories that seemed to describe unpolarized reactions quite well but came to grief when attempting to explain spin-dependent experimental data.

A prime example of spin-related surprises in strong interaction physics is the "spin crisis in the parton model" resulting from the EMC experiment at CERN in the late 1980s. To this day our understanding of how nucleon spin is carried by the quark and gluon constituents is very incomplete. Several lepton–nucleon scattering experiments at DESY (HERMES), CERN (COMPASS) and Jefferson Laboratory are dedicated to exploring further the nucleon spin. Now a key player in the field is RHIC, where the polarization of gluons in the proton will be probed with precision.

In the case of QCD there are several reactions where large spin-dependent asymmetries have been measured, but where a straightforward application of perturbative QCD would predict zero asymmetry. These difficulties are usually blamed on energies and momentum transfers being too small to justify a perturbative approach. It is again RHIC, with its huge energy, that should settle the issue.

The 1st Summer School on QCD Spin Physics was aimed at graduate students and those beginning postdoctoral research in both theory and experiment. Being the first in what it is hoped will become a regular series, it was difficult to predict the make-up of the participants; in the event there was a surprising range, from first-year PhD students to mature researchers.

After a welcome address by the director of BNL, Praveen Chaudhari, the school got underway. The number of lectures per day was kept small to allow plenty of time for discussion, and there were informal "get togethers" in the evenings, which included some theory versus experiment football matches (which proved to be disastrous for the theorists!).

The school began with pedagogical introductions to perturbative QCD, to spin in a relativistic context and to polarized proton–proton collider physics, and ended with a description of the exciting research programme at RHIC. Correspondingly, the lectures covered both theory (including, for example, non-perturbative models of the nucleon, spin sum rules and form factors, and lattice QCD), the practical physics of the collider and the relevant experimental programme at RHIC and elsewhere. In addition, the story "The Beginnings of RHIC Spin" was related by Gerry Bunce and the "Future of Spin" was foretold by Abhay Deshpande. One of the highlights was an evening lecture by Maurice Goldhaber, one of the pioneers of elementary particle physics, a co-worker of Rutherford's and sometime director of BNL.

Although the school was organized by a committee, its great success was largely due to the extraordinary efforts of Werner Vogelsang and Pam Esposito.

- For further details about the school, see www.bnl.gov/qcdsp.

COLLABORATION

Hadrons in Georgia: physicists meet in Tbilisi

There has been a long tradition of high-energy physics collaborations in Georgia, especially with JINR and CERN (p25), but one of their major efforts since 1992 has been in intermediate-energy physics at the Cooler Synchrotron (COSY) at the Institut für Kernphysik (IKP) of the Forschungszentrum Jülich, Germany. To enhance and develop this co-operation further, the first Caucasian–German School and Workshop in Hadron Physics was held in Tbilisi on 30 August – 4 September. Organized jointly by the High Energy Physics Institute (HEPI) of Tbilisi State University (TSU) and the IKP, the meeting was also supported by the UNESCO Regional Bureau for Science in Europe. With 70 participants, about one-third of whom were students, it was the largest physics gathering held in Georgia since the country gained its independence in 1990.

Illustrating the co-operation behind the meeting, it was opened by the president of the Georgian Academy of Sciences, Albert Tavkhelidze; the rector of the TSU, Roin Metreveli; the UNESCO representative, Merab Eliashvili; and the deputy of the German ambassador, Mirko Schilbach.

In the introductory talk the director at IKP, Hans Ströher, described how hadronic physics programmes at accelerators such as COSY would lead to new opportunities at future machines, especially at the Facility for Antiproton and Ion Research (FAIR) at GSI-Darmstadt. This balance between current research and new opportunities was maintained throughout the subsequent seven review lectures and 40 specialized talks, where particular emphasis was given to meson and strange isobar production, and experiments with polarized protons and deuterons. The latter led naturally to discussions on the possibilities for polarized antiprotons at FAIR.

The Shuamta church in east Georgia provided an example of the country's cultural heritage.

A particular local interest was the proposal, put forward by Revaz Shanidze, for the creation of a regional centre for applied research in the Caucasus region, called TANDEM (The Accelerator based Nuclear Dating and Environmental Monitoring), in co-operation with Erhard Steffens at the University of Erlangen. Further current research by HEPI members was also presented, with a 45 minute exposé of life for a Georgian physicist working in Germany given in Georgian by Andro Kacharava, the principal organizer of the meeting.

No meeting in Georgia could fail to explore its vast cultural heritage of churches and monasteries set in a beautiful mountainous landscape. Museum directors explained the details of Georgian architecture, jewellery dating back to before the golden fleece and showed the remains of the earliest humans found in Europe.

The meeting, whose proceedings will be published by the Forschungszentrum Jülich, has already proved itself to be a scientific success through its strengthening of collaborations between Georgian and other European physicists. The director of HEPI, Mikheil Nioradze, therefore proposed that such workshops should be held on a regular basis, on a two-year cycle, and this met with general approval.

● For the proceedings of the school, see www.fz-juelich.de/ikp/cgswhp.

RECRUITMENT

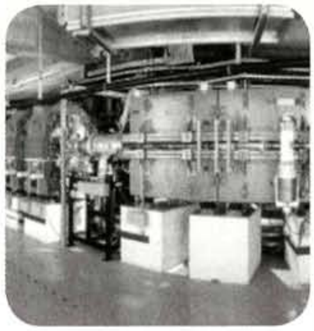
Postdoctoral positions
are available at the
Department of Physics, Ben Gurion University
in the fields of
High Energy Astrophysics,
Plasma Astrophysics,
Particle Astrophysics and Cosmology.
Applications arriving by December 31, 2004 will be considered.
Send applications to one of the following:
David Eichler [eichler@bgumail.bgu.ac.il],
Yuri Lyubarsky [lyub@bgumail.bgu.ac.il],
Michael Gedalin [gedalin@bgumail.bgu.ac.il],
Ramy Brustein [ramyb@bgumail.bgu.ac.il], or
Eduardo Guendelman [guendel@bgumail.bgu.ac.il].

GSI Darmstadt invites applications for the position of

Head of Information Technology

Ref. No.: 2300-04.50

GSI Darmstadt



GSI, the National German Heavy Ion Research Center, a member institute of the Helmholtz-Society of German Research Centers, operates a system of heavy ion accelerators to perform research in the areas of nuclear and hadron physics, atomic physics, physics of dense plasmas, radiation biology, and related subjects.

The IT section is embedded within the „Department of Scientific and Technical Infrastructure" with a staff of about 35 members. Its main responsibilities are the design and operation of large LINUX clusters for scientific computing in close collaboration with the research groups, the development of new concepts for high performance computing, and the running and maintenance of distributed office PC's. Emphasis is placed on the handling and storage of large (Pbytes) data samples and the implementation of complex data bases. The applicant should be able to develop new concepts for computing and grid applications, especially also for the future FAIR project. He/she has several years of experience in IT areas based in a physics environment and is capable to lead this important section of GSI in innovative and collegiate manner. Experience in running complex projects would be an asset.

GSI is an equal opportunity employer committed to the development of a diverse workforce.

Disabled applicants will be given preference over applicants with comparable qualifications.

Further information concerning GSI can be found under http://www.gsi.de.

Applications quoting the reference number should include a CV, list of publications, and the name of three references. All applications must be returned by **January 15, 2005** to:

Gesellschaft für Schwerionenforschung mbH
Personalabteilung
Kennziffer 2300-04.50
Planckstraße 1
D-64291 Darmstadt

POSTDOCTORAL RESEARCH FELLOWS

The Division of Medical Imaging Physics of the Russell H. Morgan Department of Radiology and Radiological Science at the Johns Hopkins University is seeking applicants for several new Postdoctoral Research Fellow positions.

Candidates with a Ph.D. in medical physics, other specialties of physics, engineering, mathematics and related fields are encouraged to apply. The successful applicants will join a Division currently consisting of 5 faculty members, 2 Research Associates and ~10 Research Assistants/Trainees who are actively involved in medical imaging physics and engineering research especially in the areas of quantitative radiography, interventional radiology/vascular imaging, CT, nuclear medicine imaging, SPECT and PET, and angiography and 3D imaging in the setting of interventional radiology. Active research projects include medical imaging instrumentation, Monte Carlo simulations, computer phantom design, quantitative 2D, 3D and 4D image reconstruction methods, internal dosimetry, small animal CT, SPECT and PET imaging techniques, image quality assessment, engineering analysis of human and animal bones using 2D and 3D image data, observer performance experiments and ROC analysis, and clinical trials of image reconstruction and processing methods, and 3D imaging in the setting of interventional radiology.

Experience in these and related areas is desirable but not essential. Strong computer, communication, and writing skills are desirable as is a willingness to work in a multidisciplinary collaborative environment. The projects are supported by several federal and industry research grants and contracts.

For further information, please contact Benjamin M. W. Tsui, Ph.D. (Tel: 443-287-4025, E-mail: btsui1@jhmi.edu). Johns Hopkins University is an equal opportunity employer.

UNIVERSITY OF TORONTO

Experimental High Energy Physics

POSTDOCTORAL RESEARCH ASSOCIATE POSITIONS

Applications are invited for postdoctoral research associate positions in the University of Toronto Experimental High Energy Physics group. The group has active participation in both the ATLAS and CDF experiments and there are three positions available. One of these positions is exclusively associated with ATLAS, and two are initially associated with CDF, with the possibility of a transfer of activities to ATLAS at a later date. Our group is a major participant in the construction, installation and commissioning of the hadronic sections of the ATLAS forward calorimeter. In the coming years the focus will be on the understanding of the performance of the calorimeter system, and preparations for the turn on of the LHC in 2007. In CDF the group has a very active physics programme covering electroweak physics, the top quark, and searches for beyond-the-standard- model physics. For more information about the group's activities please refer to our website at **hep.physics.utoronto.ca**. Candidates should supply a resume, a description of research interests and three letters of reference, to

Ms. Winnie Kam, Department of Physics,
University of Toronto, 60 St. George Street,
Toronto, Ontario M5S 1A7, Canada.

For information about the ATLAS position send email to **orr@physics.utoronto.ca**, and for the CDF positions to **savard@physics.utoronto.ca**. The review of applications will begin on 30th November, but applications will be accepted until the positions are filled.

In accordance with Canadian immigration regulations, this advertisement is directed in the first instance to Canadian citizens or permanent residents. Nonetheless, all qualified applicants are encouraged to apply. The University of Toronto strongly encourages applications by women and members of minority and aboriginal groups.

Department of Physics

Carleton UNIVERSITY

Faculty Position in Particle Physics

Applications are invited for a tenure-track faculty position in particle physics at the rank of Assistant Professor in the Department of Physics at Carleton University, to begin on July 1, 2005. Candidates in both experimental and theoretical particle physics will be considered.

The Department has a strong particle physics research group. The experimental program includes significant roles in the Sudbury Neutrino Observatory and the SNOLAB project, the ATLAS collaboration at the LHC, and detector development for the International Linear Collider. The theory group interests are primarily in particle physics phenomenology, including electroweak and Beyond the Standard Model physics, in particle astrophysics and string theory. There is a strong and mutually beneficial interaction between the theory and experimental groups. Candidates in experimental particle physics or with expertise in particle physics phenomenology are encouraged to apply. In addition, the Department has an active medical physics research group with comprehensive links to Ottawa's medical physics community.

Applicants for this position must possess a Ph.D. and have established an excellent track record in particle physics. We invite applications from outstanding scientists who have demonstrated research creativity and have the ability to attract co-workers and students. Applicants must be committed to effective teaching at the undergraduate and graduate levels. The successful candidate will be expected to develop a strong, externally-funded research program, supervise students, and develop and teach undergraduate and graduate courses. This position is subject to final budgetary approval.

Candidates should send a curriculum vitae and a statement of their research and teaching interests, and should arrange for letters from three referees to be sent to:

Prof. Pat Kalyniak, Chair, Department of Physics, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada

Tel: (613) 520-2600, x4376 FAX: (613) 520-4061

E-mail: kalyniak@physics.carleton.ca www.physics.carleton.ca

The deadline for applications is December 15, 2004; however applications will continue to be accepted until the position is filled. All qualified candidates are encouraged to apply; however, Canadian citizens and Permanent Residents will be given priority. Carleton University is committed to equality of employment for women, aboriginal peoples, visible minorities, and people with disabilities. Persons from these groups are encouraged to apply.

Experimental and Theoretical Research Associates

The Kavli Institute for Particle Astrophysics and Cosmology at Stanford University (KIPAC) ***is currently recruiting*** **for Experimental and Theoretical Research Associates for fall 2004.** The appointments are for a 3-year fixed period and are reviewed annually.

KIPAC is a joint venture between the Stanford Department of Physics and Stanford Linear Accelerator Center (SLAC). Research is focused at the interface between physics and astronomy on experimental, computational, observational and theoretical topics and successful applicants will have the opportunity to collaborate with other research groups and projects at Stanford.

These positions are highly competitive and require a background of research in one of the fields of interest for the Institute. Applicants should have, or should be in the process of completing, a PhD and should possess a strong research background, including evidence of excellent future research potential.

Applicants should send a letter stating their research interests along with a CV and three letters of reference to J.L. Formichelli, c/o Stanford Linear Accelerator Center, 2575 Sand Hill Road, M/S 29, Menlo Park, CA 94025 or email to jlf24@slac.stanford.edu.

The deadline for applications is December 1, 2004.
Late applicants may still be considered.

Stanford University is an Affirmative Action/Equal Opportunity Employer.

SLAC
STANFORD LINEAR ACCELERATOR CENTER

Deutsches Elektronen-Synchrotron

HASYLAB-Research

DESY

DESY is world-wide one of the leading accelerator centres exploring the structure of matter. The main research areas range from elementary particle physics over various applications of synchrotron radiation to the construction and use of X-ray lasers.

Particle accelerators produce high intensity radiation for most diverse, innovative applications. DESY plans to upgrade its existing PETRA storage ring into a most modern synchrotron radiation source and to construct free electron lasers for the X-ray regime. With these projects and the existing facilities DESY will become a leading laboratory for experiments with photons. For a research program at the Hamburg synchrotron radiation laboratory HASYLAB we seek a

Scientist (PhD)
MTV Ib

The successful candidate will participate in a new research program with coherent X-rays dedicated to the study of dynamic phenomena in the time domain. You will cover selected areas in soft or hard condensed matter research according to your interest and expertise.
You hold a degree in physics or in a related field. Experience in novel instrumentation, data evaluation procedures and/or 2-D detectors is desirable. If you are interested in this position, please send your complete application papers to our personnel department. For further information, please contact Dr. Grübel on +49 40/8998-2484.

The position is limited for 3 years (in the field of the Tenure Track Program). The possibility for a permanent employment exists.

Salary and benefits are commensurate with public service organisations. DESY operates flexible work schemes, such as flexitime or part-time work. DESY is an equal opportunity, affirmative action employer and encourages applications from women. DESY has a Betriebskindergarten.

Deutsches Elektronen-Synchrotron DESY
member of the Helmholtz Association
code: 86/2004 · Notkestraße 85 · D-22603 Hamburg · Germany
Phone 040/8998-3392 · www.desy.de
email: personal.abteilung@desy.de

Deadline for applicants: 01.12.2004

Access **Physics**Jobs

@

physicsweb.org

GSI Darmstadt invites applications for the position of

Head of the detector laboratory

Ref. No.: 2400-04.48

GSI, the National German Heavy Ion Research Center, a member institute of the Helmholtz-Society of German Research Centers, operates a system of heavy ion accelerators including a linear accelerator (UNILAC), a synchrotron (SIS18), and an experimental storage ring (ESR) to perform research in the areas of nuclear and hadron physics, atomic physics, physics of dense plasmas, radiation biology, and related subjects.

The detector laboratory deals with the design and construction of complex devices for the detection of particle radiation in research and for the diagnosis of particle beams. Currently running projects include the readout chambers for the ALICE TPC and TRD at the CERN LHC as well as the development of gas detectors for ion therapy. Detector design and construction for projects in the FAIR project will shape the laboratory in the future.

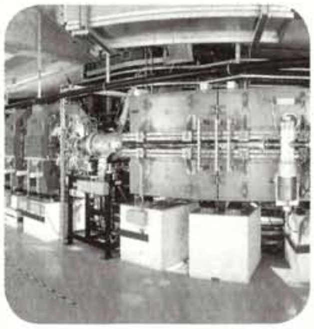
The successful candidate has a PhD in physics and significant and internationally recognized expertise in the physics and technology of particle detectors. He/she has experience in running complex projects and will lead a team of physicists, engineers and technicians in close collaboration with the research and accelerator division.

GSI is an equal opportunity employer committed to the development of a diverse workforce. Disabled applicants will be given preference over applicants with comparable qualifications.

Further information concerning GSI can be found under http://www.gsi.de.

Applications quoting the reference number should include a CV, list of publications, and the name of three references. All applications must be returned by **Dec. 10, 2004** to:

GSI Darmstadt



Gesellschaft für Schwerionenforschung mbH
Personalabteilung
Kennziffer 2400-04.48
Planckstraße 1
D-64291 Darmstadt

CORNELL

TENURE-TRACK ASSISTANT or ASSOCIATE PROFESSOR OF PHYSICS in Accelerator Physics

Cornell University

We are seeking an outstanding individual for a tenure-track assistant or associate professor position in accelerator physics. In addition to teaching undergraduate and graduate courses, responsibilities will include supervision of graduate students and participation in the research program of the Lab for Elementary-Particle Physics. Currently based largely on the CESR storage ring, the research program has expanded to include the International Linear Collider and an Energy Recovery Linac for the production of synchrotron radiation. A PhD in physics with experience in accelerators or in elementary-particle physics is required. The position will be available in September 2005, or earlier by negotiation, with an initial appointment of three years. Please send an application and at least three letters of reference to

Search Committee Chair, Newman Laboratory,
Cornell University, Ithaca, NY 14853.

Applications should include a curriculum vitae, a publication list and a short summary of teaching and research experience.

Electronic mail inquiries may be addressed to SEARCH@LEPP.CORNELL.EDU.

Cornell is an equal opportunity/affirmative action employer.

Research Associate Position (faculty position)

at Kamioka Observatory, Institute for Cosmic Ray Research(ICRR), University of Tokyo

ICRR of the University of Tokyo invites applications for a university research associate position (faculty position) at the Kamioka Observatory. The candidate for research associate is expected to work on physics research at the Super-Kamiokande facility and for the future projects of the Observatory, including the T2K (Tokai to Kamioka) long baseline neutrino experiment, the XMASS project searching for dark matter using the liquid xenon technique, and a future large volume detector project for neutrino physics and the search for nucleon decay. The candidate is expected to commence the work on or before April 1, 2005.

Interested applicants should send

(1) curriculum vitae (including a description of his/her experienced research),

(2) a list of publications and reprints (or copies) of his/her major papers (less than 5 papers),

(3) a statement of research interests (less than or equal to two pages),

(4) the possible date of taking the position, and

(5) letters of recommendation from two physicists.

The documents should be sent to : **Yoichiro Suzuki, Director of Institute for Cosmic Ray Research, University of Tokyo, 5-1-5 Kashiwa-no-ha, Kashiwa City, Chiba 277-8582, Japan** before January 11, 2005.

An interview will be expected on 29th of January, 2005 at the Kashiwa campus of ICRR (Travel expenses will not be provided).

For inquiries please contact Y.Suzuki (suzuki@icrr.u-tokyo.ac.jp).

UNIVERSITY OF TORONTO

Faculty of Arts and Science

Chair, Department of Physics

The Faculty of Arts and Science of the University of Toronto seeks a highly qualified candidate to serve as Chair of the Department of Physics.

With a complement of approximately 50 faculty across three campuses, the Department of Physics is one of the leading research departments in North America. Excellent facilities support research across a wide spectrum, from exploration geophysics to theoretical cosmology, from condensed matter to particle physics. Opportunities for interdisciplinary research are abundant, as many of the graduate faculty in Physics are cross-appointed to other Departments and Institutes of the University, such as the Departments of Chemistry, Astronomy and Astrophysics and Geology and the prestigious Canadian Institute for Theoretical Astrophysics (CITA).

We seek an individual with a reputation as an outstanding scientist with a vigorous research program, demonstrated leadership and administrative abilities and a commitment to excellence in research and teaching as measured by the highest standards of the discipline. The successful candidate will be a strong leader and advocate for the Department within the University and on the national and international scenes.

The Faculty welcomes applications and nominations. Nominations should include the reasons for the nomination and a list of appropriate referees. Applicants should include a letter describing a vision for a large and diverse department, a current curriculum vitae and the names of four referees (or arrange for four letters of reference to be sent to the address below). Applications and nominations should be addressed to

Professor Pekka K. Sinervo F.R.S.C., Dean,
Faculty of Arts and Science, University of Toronto, Room 2005,
100 St. George Street, Toronto, Ontario, Canada M5S 3G3.

Review of applications and nominations will begin in December and will continue until the position is filled. Those received by December 15, 2004 will be given first consideration. For more information about the Department, the Faculty and the University, we invite you to access the following web sites: **www.physics.utoronto.ca/**; **www.artsandscience.utoronto.ca**; and **www.utoronto.ca**

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

Department of Physics University of California, Davis

Faculty Position in High Energy Theoretical Physics

The Department of Physics at the University of California at Davis invites applications for a faculty position in theoretical high energy physics. The targeted starting date for appointment is July 1, 2005.

The appointment will be at the tenure-track Assistant or tenured Associate Professor level as determined by qualifications and experience.

The successful candidate will be the second (the first being John Terning) of three appointments in the High Energy Frontier Theory Initiative (HEFTI), which focuses on the exciting new ideas and challenges associated with the interface between formal theory and phenomenology. Priority will be given to candidates with recognized leadership in this area and the ability to help plan and implement HEFTI. The successful candidate should also have a strong interest in interpreting new phenomena as the relevant experimental data become available. Interaction and overlap with the particle cosmology group is anticipated.

The existing high energy group consists of five theoretical and eight experimental faculty. The theorists have a broad spectrum of interests including supercollider physics and phenomenology, supersymmetric modeling and superstring phenomenology, Higgs physics, brane models, lattice QCD, weak-interaction and heavy quark physics, solvable models, and quantum gravity. The experimentalists have major efforts at Fermilab and are active members of the LHC CMS collaboration.

The successful candidate will have a Ph.D. in physics or the equivalent and be expected to teach at the undergraduate and graduate levels.

This position is open until filled; but to assure full consideration, applications should be received no later than January 3, 2005. To initiate the application process, please mail your curriculum vitae, publication list, research statement, and the names (including address, e-mail, fax, and phone number) of three or more references to:

Professor Shirley Chiang, Chair
Department of Physics
University of California, Davis
One Shields Avenue
Davis, CA 95616-8677

Further information about the department may be found on our website at **http://www.physics.ucdavis.edu**.

The University of California is an affirmative action/equal opportunity employer.

FACULTY POSITION

Experimental Particle Physics
Indiana University

The Department of Physics invites applications for a tenure-track faculty position in collider-based high-energy particle physics to start Fall 2005. The Department has a strong experimental particle physics program at the energy frontier with faculty members playing leading roles in experiments currently taking data and preparing for the future: the D0 experiment at Fermilab, the ATLAS experiment at CERN, and R&D for a future e+e- linear collider. More information is available at http://physics.indiana.edu/xxx. We seek candidates with a Ph.D. in physics, outstanding leadership qualities, and proven or potential excellence in both research and teaching. Applicants should submit a curriculum vitae, list of publications, statement of research interests and proposed activities, and arrange for at least three letters of reference to be sent to:

HEP Search Committee
Attn: Prof. Rick Van Kooten
Physics Department, Swain West 117
Indiana University
Bloomington, IN 47405 USA

Applications will be reviewed beginning December 15, 2004 until the position is filled. E-mail inquiries and questions may be addressed to:

search_hep@hep.physics.indiana.edu

Indiana University is an Affirmative Action/Equal Opportunity Employer. Applications from women and minorities are particularly encouraged.

SURVEY AND ALIGNMENT ENGINEER

Berkeley Lab seeks a strong mechanical engineer to lead the survey and alignment section that supports the accelerators and beamlines at the Advanced Light Source (ALS). Reporting to the Mechanical Engineering Deputy for Beamlines and Experimental Systems, you will ensure maximum efficiency and accuracy in data acquisition and analysis, minimize operational down time and exercise independent judgment to select methods, techniques and evaluation criteria for optimizing the alignment of the storage ring and related components. You will also coordinate and conduct facility surveys, including operation of a Leica LTD500 laser tracker system, theodolites and optical tooling, adjust accelerator and beamline components for ideal location, and collaborate with ALS engineering staff, accelerator physicists and external users to ensure a close coupling with survey and alignment requirements. As leader of the section, you will be expected to assign work, review quality, provide training and evaluate performance.

This opportunity requires a proven leader with 6-8 years of professional technical survey and alignment experience and a strong working knowledge of mechanical engineering principles and practices. The ability to interpret technical job requirements and translate them into operational instructions, a thorough understanding of coordinate systems and the ability to transform survey data into different systems, and knowledge/understanding of computer-based survey data acquisition systems and instruments are essential. To qualify, you should be a team player who is also able to work independently with good judgment and effective communication skills. A Bachelor's degree in Engineering or equivalent is preferred. This is a two-year term position with a possibility for renewal or the possibility of conversion to a career position.

For consideration, send your resume to sdjobs@lbl.gov, fax to 510-486-5066 or apply online at http://jobs.lbl.gov, referencing Job # EG/017313/JCERN. Berkeley Lab is an AA/EEO Employer, committed to a diverse workforce.

BERKELEY LAB

THE UNIVERSITY *of* LIVERPOOL

Department of Physics

LHCb Vertex Detector Software Developer

£19,460 - £21,640 pa

You will join the Liverpool activity on the LHCb experiment, contributing to the development of the reconstruction software for the Vertex Detector being constructed at Liverpool. You will develop the software to reconstruct the trajectories of the particles through the detector and to determine the position of each of the sensors. The code will be written in C++ in a framework developed for LHCb. Details of the LHCb vertex detector can be found at http://hep.ph.liv.ac.uk/lhcb/. You should possess a PhD in Experimental Particle Physics or equivalent. One or more posts are supported by PPARC for three years.

Informal enquiries to Professor T Bowcock, on +44 151 794 3360, email: tjvb@hep.ph.liv.ac.uk or Dr D E Hutchcroft, on +44 151 794 3416, email: hutchcroft@hep.ph.liv.ac.uk

Quote ref: B/359/C **Closing Date: 29 November 2004**

Further particulars and details of the application procedure should be requested from the Director of Personnel, The University of Liverpool, Liverpool L69 3BX on 0151 794 2210 (24 hr answerphone), via email: jobs@liv.ac.uk or are available online at http://www.liv.ac.uk/university/jobs.html

COMMITTED TO EQUAL OPPORTUNITIES

LEDERMAN FELLOWSHIP

Experimental Particle or Accelerator Physics

The Fermi National Accelerator Laboratory (Fermilab) has an opening for a postdoctoral Lederman Fellow in experimental particle physics or accelerator physics. The successful candidate must have demonstrated outstanding ability in research. In recognition of Leon Lederman's commitment to the teaching of physics at all levels, he or she will be expected to participate, for a small fraction of the time, in physics outreach. The successful candidate will have a choice among experiments, which include Tevatron and LHC collider experiments, neutrino experiments, other fixed target experiments and astroparticle physics experiments, or research on accelerators. See **http://www.fnal.gov/** for more information.

Candidates should have obtained a Ph.D. in experimental particle or accelerator physics after August 31st 2003. The appointment is normally for three years with an extension possible. To apply write to **Dr. Michael Albrow (Chair of Lederman Fellowship Committee), Fermi National Accelerator Laboratory, MS 122, P.O.Box 500, Batavia, IL 60510-0500**. Applicants should send a letter including their research experience and noting any experience or interest in teaching and outreach, a curriculum vita, publication list and the names of at least four references. The deadline for applications is **December 10, 2004**.

Fermilab

Max Planck Institute for Physics
(Werner Heisenberg Institute)

MAX-PLANCK-GESELLSCHAFT

The Max-Planck-Institute of Physics invites applications for a

Postdoctoral position

for the GERDA project, a new experiment to be located at the Gran Sasso National Laboratory.

The GERDA experiment is designed to investigate the nature of the neutrino and its absolute mass-scale by searching for the neutrinoless double-beta decay of ^{76}Ge. The goal is to either establish the Majorana nature of the neutrino or push the relevant exclusion limits to the mass-scale indicated by neutrino oscillations. The experiment uses the novel approach of shielding crystals with a cryogenic liquid.

The Max-Planck-Institute is one of the leading institutes in the project. The institute is responsible for the design and construction of new germanium detectors, the detector suspension and insertion system and the corresponding infrastructure. It is also involved in the software to support simulation and analysis. The successful candidate is expected to contribute in both sectors.

Salary and benefits are commensurate with public service organizations (BAT IIa). The contract is initially limited to 2 years with the possibility of an extension. Candidates should have good knowledge and working experience in experimental particle, astroparticle or low background physics. The Max Planck Society wishes to increase the participation of women in its research activities. Therefore, applications from women are particularly welcome. The Max Planck Society is committed to employing more handicapped individuals and especially encourages them to apply.

Interested applicants should submit an application letter, a statement of research interests, a curriculum vitae, a list of publications, and arrange for three letters of support to be sent to

Max Planck Institute for Physics
Frau U. Grenzemann
Föhringer Ring 6
D-80805 München

Further information can be obtained from Prof. Allen Caldwell (EMail: caldwell@mppmu.mpg.de) or Dr. Iris Abt (EMail: isa@mppmu.mpg.de). Applications should be sent as soon as possible, at the latest 6 weeks after publication.

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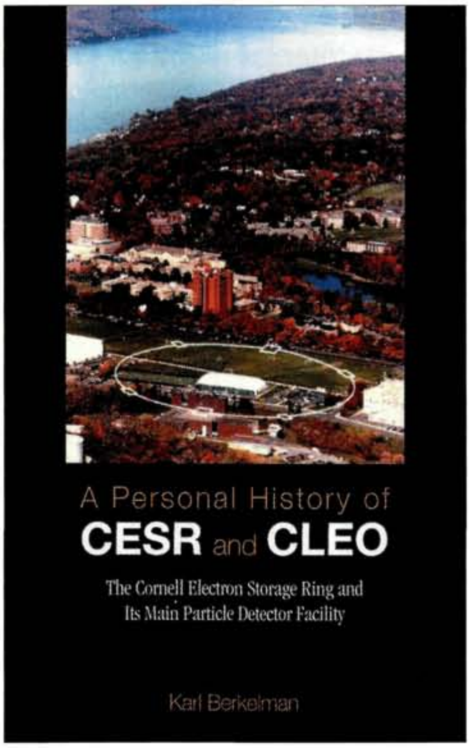
A Personal History of CESR and CLEO by Karl Berkelman, World Scientific. Hardback ISBN 9812386971, $52 (£38).

This slim volume relates in chronological order the main events in the story of the particle-physics laboratory at Cornell, from its foundation in the days when any major university would have the ambition and generally the means to found and run its own particle accelerator, to the present day, in which Cornell has the only front-rank accelerator not based in a national or international laboratory. The story of how Cornell survived and prospered as similar laboratories foundered is a fascinating one.

The Laboratory of Nuclear Studies was founded as faculty members of Cornell University, New York, returned from duties on the Manhattan Project in 1946. Shortly thereafter, the first director, Robert Bacher, left for the Atomic Energy Commission and Bob Wilson was hired from Harvard to replace him. The Cornell ethos that underpins the remarkable success of the laboratory emanates in large part from Wilson's "can do" mentality and determination to cut out all frills and many corners in order to get the biggest "bang for the buck" spent on an accelerator. The faculty pitched in enthusiastically and became experts in a wide variety of techniques in both accelerator physics and analysis. After Wilson left to found Fermilab, "Mac" McDaniel continued his tradition of inspiring leadership, although with a very different style.

Berkelman himself took over in 1985, bringing his own style of modest, calm but inspirational leadership to the still-juvenile CESR machine and detectors. The book is the story not only of some remarkable accelerators, but also of a remarkable experiment, CLEO, as well as its sister experiment for many years, CUSB. Perpetually renewing itself as it passed from CLEO-I through various integers and half-integers to CLEO-III, the collaboration grew but always retained the very democratic outlook that Berkelman considers the secret of its success. This success is impressive indeed; in 2001, over half the entries in the PDG tables for B mesons and charmed mesons and baryons were established by results from CESR.

The success of a lab depends greatly on the personality of charismatic leaders, and in many ways this book is the story of three of them: Wilson, McDaniel and Maury Tigner.



Tigner rides to the rescue at several moments of crisis in his predecessors' reigns with a typically inspired technical solution or idea, and it is in his capable hands that the future of the laboratory now lies. Naturally, the book downplays the influence of Berkelman himself, which was large, but it makes clear the other important factor in Cornell's success – the strength in depth in the faculty and the dedication of all the staff.

Perhaps another visible thread throughout the narrative is the long-standing rivalry between SLAC and Cornell, always simmering below the surface and occasionally erupting in open contests such as the competition with the PEP machine and the discussions on the site for a US B-factory. Berkelman is illuminating on some of the factors he believes played a part in these decisions and the role of the National Science Foundation in steadfastly supporting the laboratory while perforce leaving it substantially free to run its own affairs.

Berkelman has a straightforward and clear style, and there are several interesting and enlightening illustrations. However, despite the claim in the preface that he tried "to broaden its accessibility to a wider audience" than particle physicists, it is difficult to believe that any such readers will be able to make much progress through the host of technicalities in both machine physics and particle physics that are inevitable in a book of this kind, and which indeed give it much of its value. On the other hand, physicists who either know and/or love the Cornell that is the real hero of this book, or who wish to discover the reasons behind its remarkable and in many ways unique success, will find much food for thought in this interesting and valuable exposition.

Brian Foster, Oxford.

Books received

The Future of Theoretical Physics and Cosmology: Celebrating Stephen Hawking's 60th Birthday by G W Gibbons, E P S Shellard and S J Rankin (eds), Cambridge University Press. Hardback ISBN 0521820812, £40 ($60).

Stephen Hawking's 60th birthday was celebrated in Cambridge, UK, with a meeting attended by many well-known theoretical physicists. This volume is based on lectures given at the meeting. It begins with talks by Martin Rees, James Hartle, Roger Penrose, Kip Thorne and Hawking himself given at a public symposium that formed part of the conference. Subsequent chapters cover advanced presentations on space–time singularities, black holes, Hawking radiation, quantum gravity, M-theory, cosmology and quantum cosmology.

Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets by Hagen Kleinert, World Scientific. Hardback ISBN 9812381066, £84 ($138). Paperback ISBN 9812381074, £29 ($48).

This third edition is a significantly expanded version of the original textbook published in 1990. It includes, for the first time, explicit solutions of nontrivial quantum-mechanical systems, in particular the hydrogen atom.

Introduction to Nuclear Reactions by C Bertulani and P Danielewicz, Institute of Physics Publishing. Paperback ISBN 0750309326, £40 ($60).

This graduate textbook is based on lectures given at Michigan State University. It leads the reader from basic laws to the final formulae used to calculate measurable quantities, and examines in detail different models of the nucleus and discusses their inter-relations. It combines a thorough theoretical approach with applications to recent experimental results.

SUPPLIER INFORMATION

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The Janis model HE-3-TLSV is a top-loading sample in vacuum He-3 cryostat. A load lock chamber allows users to conveniently exchange samples without warming the cryostat. The system offers sample temperatures below 400 mK and holding time of 24 hours or longer. Originally designed for neutron diffraction experiments, other configurations are also available.

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ICTP: the next 40 years

The director of the Abdus Salam International Centre for Theoretical Physics (ICTP) looks to future challenges as the institution celebrates its 40th anniversary.

CERN is 50 years old this year, just as ICTP turns 40. Both are international institutions of advanced scientific research with similar aspirations and, understandably, their histories are intertwined. Two members of the CERN theory division, Jacques Prentki and Léon Van Hove, took part in panels of experts that encouraged the setting up of an international centre for theoretical physics. After the formation of ICTP in Trieste, its scientific council has been served, at various times, by Van Hove, Victor Weisskopf and Herwig Schopper, all at one time director-generals of CERN; Alvaro De Rújula, a young researcher at ICTP during its early years who later became director of CERN's theory division; and Abdus Salam, founding director of ICTP who served for several years on CERN's scientific policy committee.

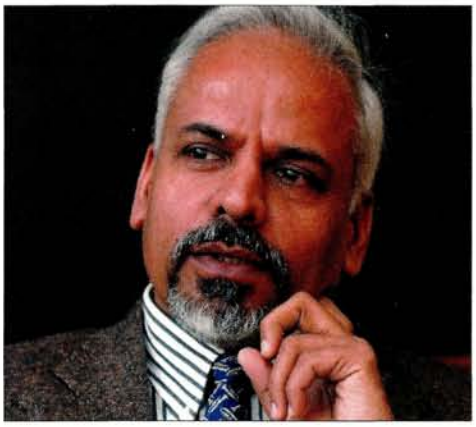
ICTP's creators intended to raise the level of science in developing countries by reducing scientific isolation through any means possible. The centre has been an institution run by a few scientists for the benefit of many. It operates on the principle that it can make a difference to the levels of science of individual scientists independent of the level of their home institutions.

These principles have remained unchanged, though it has become necessary for ICTP to adapt itself to changing circumstances. In particular, the unevenness of the progress made by developing countries has made it necessary to adopt different types of programmes for different regions of the world.

Forty years on, what exactly has ICTP accomplished? A brief list includes:

- Around 2000 scientific activities – from introductory schools to advanced workshops – organized on ICTP's premises.
- Around 100 000 scientific visitors – about half of whom come from developing countries and many of whom regard ICTP as a scientific home away from home.
- Thousands of research papers that have been published by the ICTP community in scholarly international journals.

Some of ICTP's scientific staff and many of its visitors are among the best in the world. During



the Cold War years ICTP was where the best scientists from both sides of the iron curtain met. It has also spun off intellectual centres elsewhere in the world, where they were needed most, and nurtured bright young scientists when their careers needed a boost. It has helped create new scientific institutions in Trieste, adding substance to the city's claims of caring for global science, and has rightly earned itself a high standing as a unique institution. We are indeed proud of our accomplishments.

But the magnitude of what remains to be done is immense. If we assume that a viable ratio of scientists to the overall population is a modest 1 in 1000, and that a third of these belong to physical sciences – which is ICTP's domain, despite the name – we ought to be connected to about two million scientists. By this measure, we fall short by a factor of 20, even on a cumulative count.

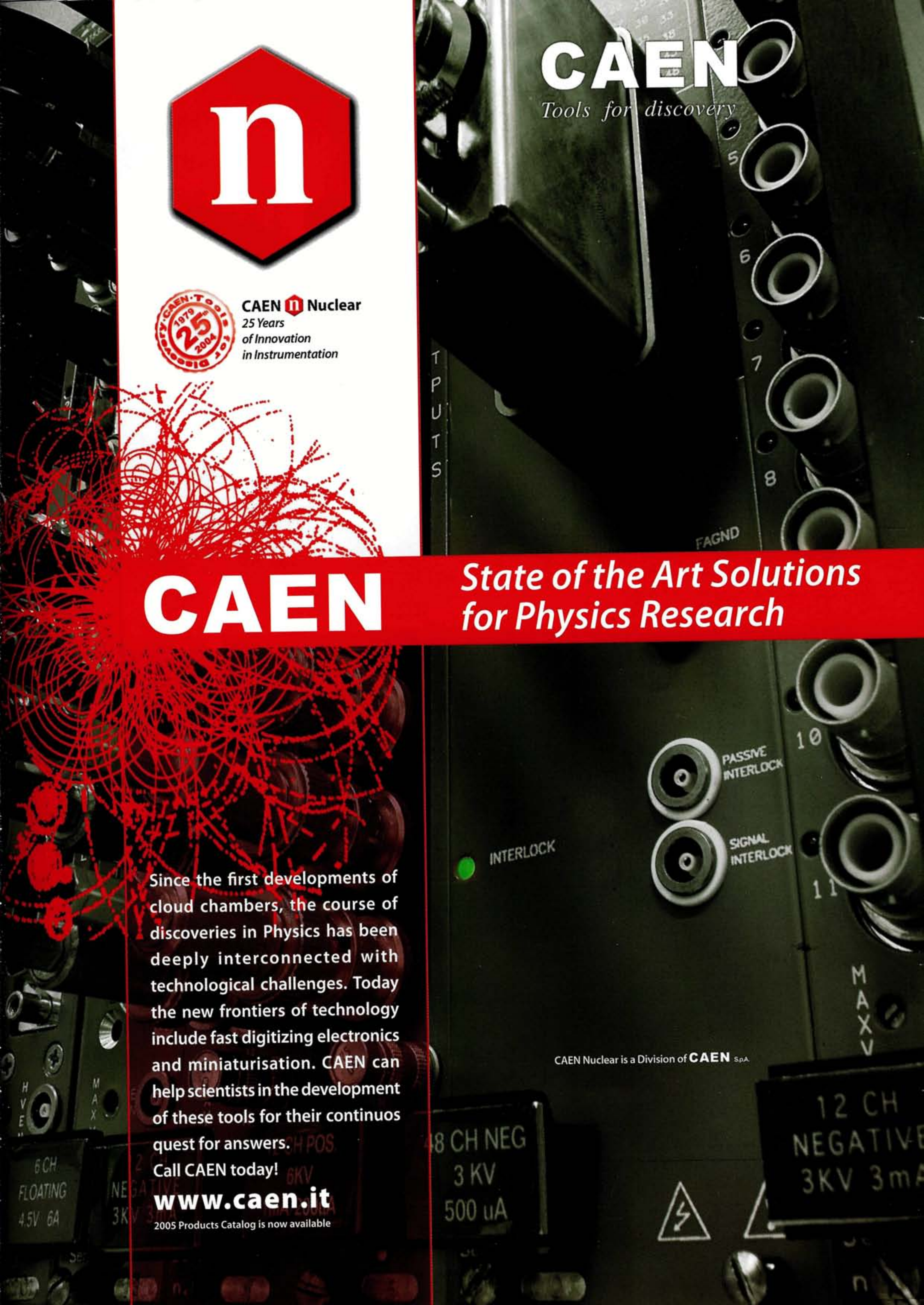
How do we motivate well-meaning scientists to be engaged in their work if they have to wait several days to download a four-page article in *Physical Review Letters*, or see the library in their university burn down in political conflict? Without working at some point at an institutional level how do we help create a cadre of adequate scientific capacity in countries where it's needed most? If scientists aren't suitably engaged, who shall advise governments across the world about the opportunities and responsibilities science affords in shaping the economic and physical well-being of their populations?

We must be involved in these issues, not simply as a moral imperative but because no part of the world today can prosper in exclusion, and if we leave some parts too far behind the consequences can be both adverse and unforeseen. This is the lesson forcefully inflicted upon us in the 21st century.

As ICTP celebrates its 40th anniversary (see p30), these concerns weigh on our minds. While we shall continue, as now, to support first-rate scientists individually, we have to develop several new avenues. Despite the continuing and generous support of the Italian government, we have neither the physical facilities nor the financial resources to arrange for every needy scientist to visit ICTP, or to support them in their own countries. So we have to work with the few outstanding and like-minded institutions to raise regional levels of science, in part through "South–South" co-operation. Where scientific traditions are great but resources scant, new centres must be created by raising money from all countries. We have to go beyond our support of individuals to groups of scientists who can be mutually supportive and multiply ICTP's effect. Taking advantage of our sponsoring institutions, namely UNESCO and the International Atomic Energy Agency, and others such as the International Telecommunication Union, we should strive to provide fast access at least to major research institutions throughout the world. At the same time we should work with scientific publishers to provide access to electronic publications and encourage distance learning.

The spirit of what we do is to spread the notion of scientific excellence. Obviously what we don't have ourselves we cannot impart to others. To support diversity without losing sight of quality is not easy: we cannot demand the same accomplishments from all those we support, but there can be no compromise on personal excellence and commitment to learning. In the end this is what matters most and will be most telling of ICTP's effectiveness.

Katepalli Sreenivasan, Abdus Salam honorary professor and director, ICTP.



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