INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

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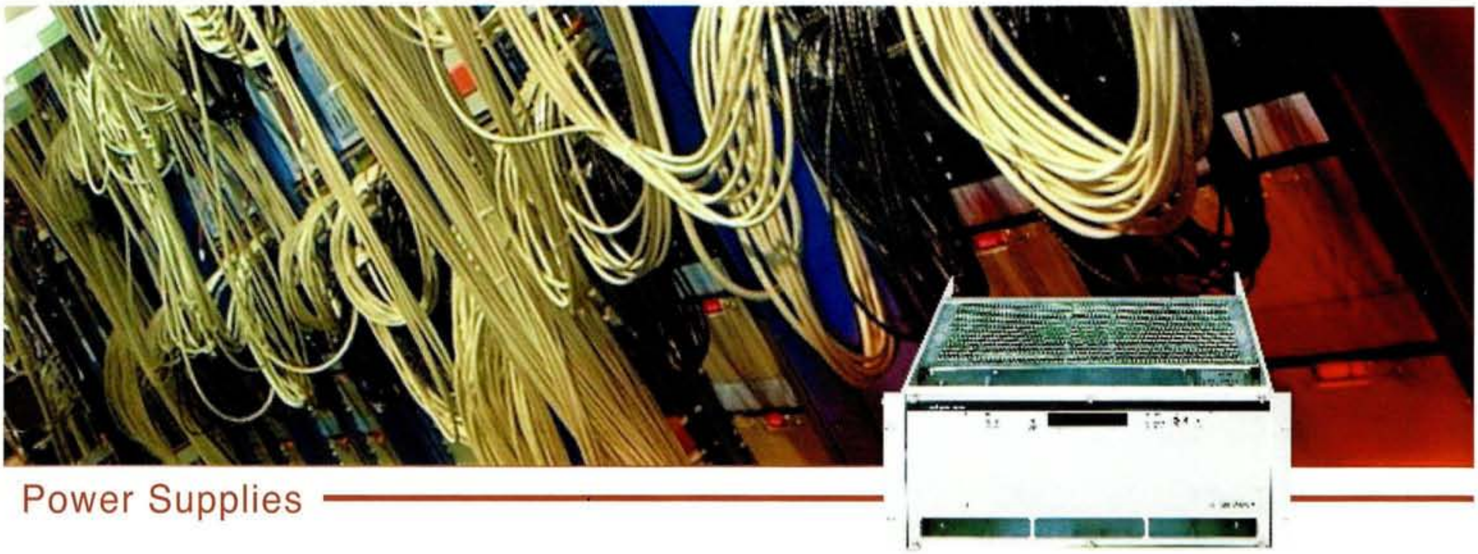

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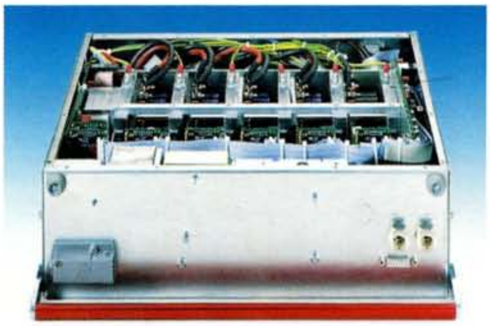

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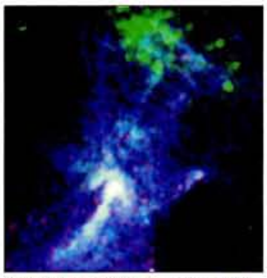

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Cover: An aerial view of the South Pole Station, where IceCube, a new neutrino observatory, is under construction (p17). (All images courtesy of the IceCube Collaboration.)

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

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August, in English and French editions. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by Institute of Physics Publishing Ltd
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Tel: +44 (0)117 929 7481; E-mail: jo.nicholas@iop.org; Web: iop.org

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Tel: +44 (0)117 930 1265 (for display advertising) or +44 (0)117 930 1196 (for recruitment advertising);
E-mail: sales@cerncourier.com; Fax: +44 (0)117 930 1178

General distribution Jacques Dallemagne, CERN, 1211 Geneva 23, Switzerland. E-mail: courrier-adressage@cern.ch
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UK Barrie Bunning, Library and Information Services Group, R61 Library, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX. E-mail: B.J.Bunning@rl.ac.uk
US/Canada Published by *Cern Courier*, 6N246 Willow Drive, St Charles, IL 60175. Periodical postage paid in St Charles, IL. Fax: 630 377 1569. E-mail: vosses@aol.com
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174

Published by European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland. Tel: +41 (0) 22 767 61 11
Telefax: +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

 ISSN 0304-288X

NEUTRINOS

MICE project gets the green light

On 21 March, the UK's science and innovation minister announced the approval and funding of the Muon Ionisation Cooling Experiment, MICE, at the Rutherford Appleton Laboratory (RAL). MICE will use a new, dedicated muon beam line at the laboratory's pulsed neutron and muon source, ISIS.

MICE is an essential step in accelerator R&D towards the realization of a neutrino factory, in which an intense neutrino beam is obtained from the decay of muons in a storage ring. The unique feature of such a facility is that it can produce intense and well defined beams of electron-(anti)neutrinos at high energies, well above the production threshold for tau particles. This should allow measurements of the "appearance" of both muon- and tau-neutrinos from electron-neutrinos. Neutrino factories are therefore the ultimate tool for precision studies of neutrino oscillations and of leptonic charge–parity (CP) violation, a measurement that might prove decisive in understanding the matter-antimatter asymmetry of the universe.

The largest novelty of a neutrino factory in terms of accelerator physics is probably muon ionization cooling, which improves performance by a factor of four to ten, depending on the design; it also represents a large fraction of the neutrino factory's estimated cost. Although proposed more than 20 years ago and generally considered as sound, the ionization cooling of muons has never been demonstrated.

Muons are born in a rather undisciplined state at a few hundred million electron-volts from interactions of proton beams, and need to be cooled before they can be accelerated – to about 20 GeV – and stored to produce neutrinos. Known beam-cooling techniques (electron, stochastic or laser cooling) are much too slow, considering that muons live only a few microseconds before they decay.

A method that is expected to work instead is to cool the transverse phase-space of the beam by passing it through energy-absorbing material and accelerating structures embedded within a focusing magnetic lattice. The muons lose energy in both the transverse and longitudinal direction when they pass though the absorbers, while the acceleration increases only their longitudinal momentum. This technique, based on a principle first described by Russian pioneers Gersh Budker and Alexander Skrinsky in the early 1970s, is known as ionization cooling.

Engineering drawing of the MICE experiment, which is 15 m long and 3 m high. The beam enters through the time-of-flight counters at the left, goes through the spectrometers for momentum and angle measurements, then enters the cooling channel made of a succession of liquid-hydrogen absorbers and RF cavities embedded in a magnetic field.

Custom-made beryllium RF cavity window, which leads to an improvement in the electromagnetic field by a factor of two.

Unfortunately, although its mathematics is simple on paper, ionization cooling is in practice a delicate mix of technologies involving liquid hydrogen (the best absorber material), strong radio-frequency (RF) electric fields (to re-accelerate the muons in an orderly fashion) and magnetic fields for containment. This combination is extremely challenging. The windows of the vessel for the liquid hydrogen need to be as thin as possible to prevent multiple scattering, while ensuring safety in the confined space between potential sources that could ignite the highly inflammable hydrogen. The operation of RF cavities at high gradient in high magnetic fields is still unproven. Finally, the precise study of cooling requires measuring the beam properties with unprecedented accuracy; each muon will be measured using techniques from high-energy physics rather than standard beam diagnostics.

The size and complexity of this undertaking require the close collaboration of the accelerator and experimental particle-physics communities. MICE comprises some 140 physicists and engineers from Belgium, Italy, the Netherlands, Japan, Russia, Switzerland, the US and the UK. The proposed schedule for MICE envisages that the technical feasibility of muon ionization cooling will be established by 2008/9. The path will then be clear for a detailed proposal for a neutrino factory.

Further reading

See www.mice.iit.edu/.

COSMOLOGY

Model suggests dark energy is an illusion

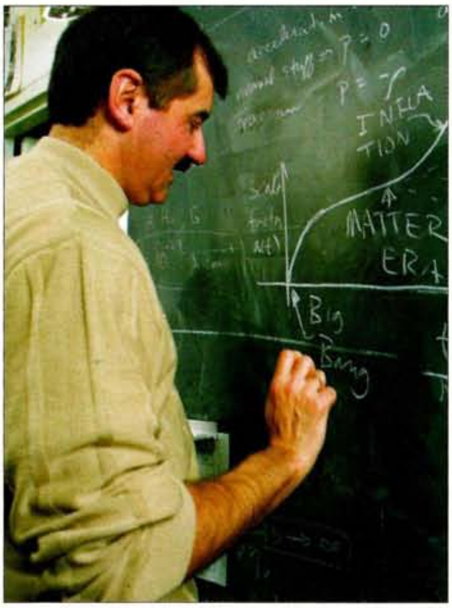
Arguably the most fascinating question in modern cosmology is why the universe is expanding at an accelerating rate. An original solution to this puzzle has been put forward by four theoretical physicists: Edward Kolb of Fermilab, Sabino Matarrese of the University of Padova, Alessio Notari of the University of Montreal, and Antonio Riotto of the Italian National Institute for Research in Nuclear and Subnuclear Physics (INFN)/Padova. Their study has been submitted to the journal *Physical Review Letters*.

In 1998, observations of distant supernovae provided detailed information about the expansion rate of the universe, demonstrating that it is accelerating. This can be interpreted as evidence of "dark energy", a new component of the universe, representing some 70% of its total mass. (Of the rest, about 25% appears to be another mysterious component, dark matter, while only about 5% consists of the ordinary "baryonic" matter.) Other explanations include a modification of gravity at large distances and more exotic ideas, such as the presence of a dynamic scalar field referred to as "quintessence".

Although the hypothesis of dark energy is fascinating and more appealing than the other explanations, it faces a serious problem. Attempts to calculate the amount of dark energy give answers much larger than its measured magnitude: more than 100 orders of magnitude larger, in fact.

Kolb and colleagues offer an alternative explanation, which they say is rather conservative. They propose no new ingredient for the universe; instead, their explanation is firmly rooted in inflation, an essential concept of modern cosmology, according to which the universe experienced an incredibly rapid expansion at a very early stage.

The new explanation, which the researchers refer to as the Super-Hubble Cold Dark Matter (SHCDM) model, considers what would happen if there were cosmological perturbations with very long wavelengths ("super-Hubble") larger than the size of the observable universe. They show that a local observer would infer an expansion history of the universe that would depend on the time evolution of the perturbations, which in certain cases would lead to the observation of accelerated expansion. The origin of the long-wavelength perturbations is inflation, as, effectively, the visible universe is only a tiny part of the pre-inflation-era universe. The accelerating universe is therefore simply an impression due to our inability to see the full picture.



Kolb ponders the early universe. (Fermilab.)

Of course, observation is the ultimate arbiter between theories. The SHCDM model predicts a different relationship between luminosity–distance and redshift than the dark-energy models do. While the two models are indistinguishable within current experimental precision, more precise cosmological observations in the future should be able to distinguish between them.

Further reading

See http://arxiv.org/abs/hep-th/0503117.

HEAVY IONS

RHIC groups serve up 'perfect' liquid

The four detector groups conducting research at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory have announced results indicating that they have observed a state of hot, dense matter that is more remarkable than had been predicted. In papers summarizing the first three years of RHIC findings, to be published simultaneously by the journal *Nuclear Physics A*, the four collaborations (BRAHMS, PHENIX, PHOBOS and STAR) say that instead of behaving like a gas of free quarks and gluons, as was expected, the matter created in RHIC's heavy-ion collisions appears to be more like a liquid.

The evidence comes from measurements of unexpected patterns in the trajectories of the thousands of particles produced in individual collisions. The primordial particles produced tend to move collectively in response to variations of pressure across the volume formed by the colliding nuclei – an effect known as "flow", since it is analogous to the properties of fluid motion.

However, unlike ordinary liquids, in which individual molecules move about randomly, the hot matter at RHIC seems to move in a pattern exhibiting a high degree of coordination among the particles.

This flow is consistent with that of a theoretically "perfect" fluid with extremely low viscosity and the ability to reach thermal equilibrium very rapidly because of the high degree of interaction among the particles. The physicists at RHIC do not have a direct measure of the viscosity, but they can infer from the flow pattern that, qualitatively, the viscosity is very low, approaching the quantum mechanical limit.

Correction

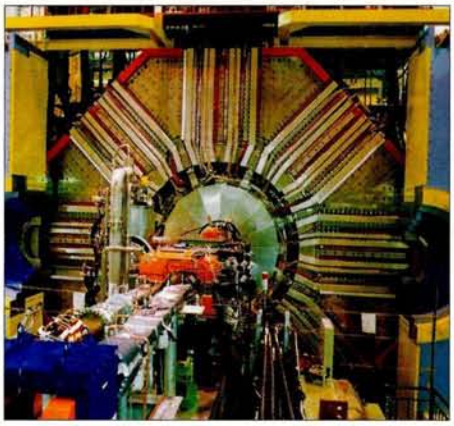
On page 6 of the April issue the article about the MDT chambers for the ATLAS experiment referred to the Institute for Theoretical and Experimental Physics (ITEP) in Protvino. The chambers are indeed being constructed in Protvino, at the Institute for High Energy Physics (IHEP), whereas ITEP is of course in Moscow. Apologies to all concerned.

KEK

Belle discovers yet more new particles

The record performance of the KEK B-factory is currently supplying Belle with about 1 million $B\bar{B}$ meson pairs per day (*CERN Courier* April 2005 p5). While data analyses on charge–parity (CP) violation and searches for new physics beyond the Standard Model continue, the vast amounts of accumulated data have helped another important aspect of Belle's physics programme: the discovery of new particle states in the charm sector.

Recent additions to Belle's new particle list are the Y(3940) and the strange charmed baryon $\Sigma_c(2800)$, to be added to the $\eta_c(2S)$, the $D_0^*(2308)$, the $D_1(2427)$ and the X(3872) already discovered (*CERN Courier* January/February 2004 p8). This brings Belle's total of new particles discovered to six.



The Belle experiment. (Courtesy KEK.)

Now it seems, however, that Belle's new-particle tally may be seven. Last summer the collaboration reported strong evidence for a mass peak in the spectrum of particles recoiling against a J/Ψ in electron–positron collisions with a similar mass to the Y(3940). Although the mass of this new peak is the same as that of the Y(3940) within errors (measurement errors are about 10 MeV for both observations), the Belle team is not yet convinced that these two states are the same and, for the time being at least, are referring to the new object as the X(3940).

The X(3940) mainly decays into D plus anti-D^* mesons, as expected for charmonium states with this mass. The Y(3940), on the other hand, does not seem to follow this pattern and its preference to decay into an ω and a J/Ψ is difficult to understand in the context of heavy quark potential models, which have explained the charmonium spectrum up to now. The Y(3940) may not therefore be an ordinary quark–antiquark meson, but rather a "hybrid state" – a meson comprising a charmed quark, an anti-charmed quark and a gluon.

Belle's particle hunters have their work cut out as they try to pin down the identity of the new particles they have already observed, while more data – and opportunities for more discoveries – pour in faster and faster.

TRIUMF

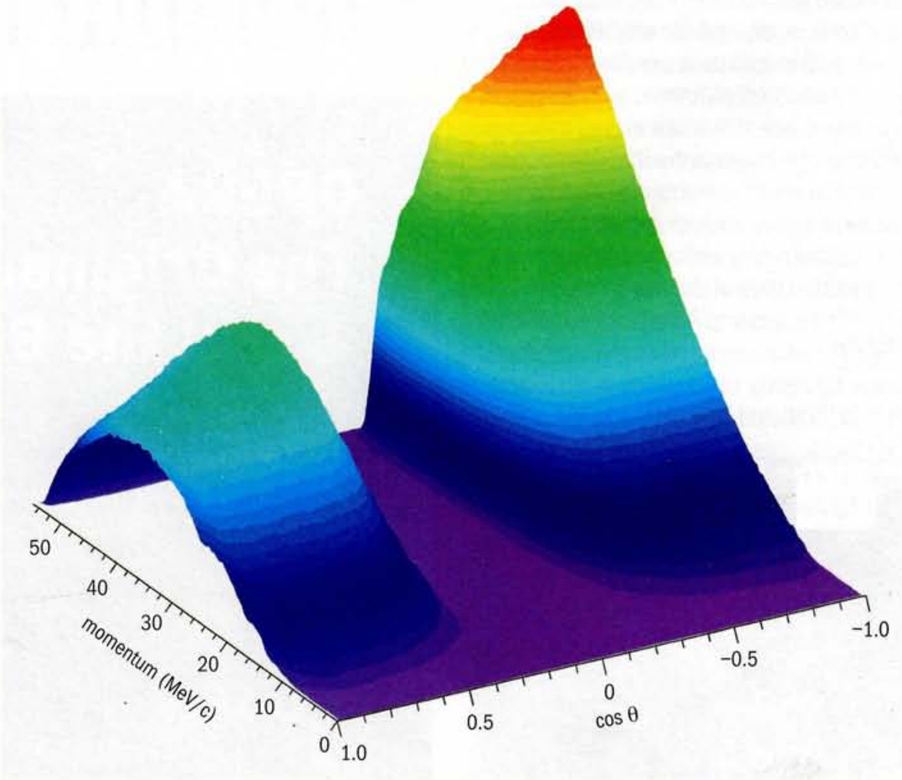
TWIST tests the Standard Model

Normal muon decay ($\mu^+ \rightarrow e^+ \nu_e \overline{\nu_\mu}$) is an ideal process to investigate the electroweak interaction in the Standard Model. The reaction involves only leptons, obviating the need for uncertain strong-interaction corrections, thus making it a clean probe of the theory's purely left-handed (V–A) structure. A high-precision determination of the parameters describing the muon-decay spectral shape explores physics possibilities beyond the Standard Model, for example involving right-handed interactions. The world's most precise determination of these parameters has been the goal of the TRIUMF Weak Interaction Symmetry Test (TWIST) experiment. The collaboration has recently completed its first phase by directly measuring the muon-decay parameters ρ and δ, improving the Particle Data Group (PDG) values by factors of 2.5 and 2.9 respectively.

The distribution in energy and angle of positrons from polarized muon decay is described by the four "Michel parameters". The spectrum's isotropic part has a momentum dependence determined by ρ plus an additional small term that is proportional to a second parameter, η. The asymmetry is proportional to a third parameter ξ multiplied by the muon polarization, P_μ, while a fourth parameter, δ, determines its momentum dependence. Within the Standard Model, these parameters are predicted to be $\rho = \frac{3}{4}$, $\delta = \frac{3}{4}$, $\xi = 1$ and $\eta = 0$.

TWIST uses beams of positive muons as they can be produced with high polarization. The high-intensity TRIUMF proton beam produces π^+, some of which decay at rest at the surface of a production target to create a highly polarized "surface" muon beam with momentum 29.6 MeV/c, which is subsequently transported into a 2 T superconducting solenoid.

Most of the muon beam stops in a thin target, located at the centre of a symmetric array of 56 low-mass, high-precision planar drift-chambers. Limitations on final errors are dominated by systematic effects since the statistical precision is very high. The measured momentum and angular distribution of the decay positrons are shown in the figure. The drop in acceptance near $|\cos(\theta)| = 0$ is because of the poor reconstruction efficiency in that region. To extract the muon-decay parameters, a 2D fit is made to a fiducial region where the detector acceptance is uniform, using a blind-analysis technique. The results are based on 6×10^9 muon decays, spread over 16 data sets. Four sets were analysed for both ρ and δ. A fifth set of low-polarized muons from pion decays in flight was also analysed for ρ. The remaining data sets, combined with further Monte Carlo simulations, were used to estimate the sensitivities to various systematic effects.



Observed momentum and angular distribution of positrons from muon decay in TWIST.

TWIST's new measurement of $\rho = 0.75080 \pm 0.00032(\text{stat.}) \pm 0.00097(\text{syst.}) \pm 0.00023$ (last uncertainty due to the current PDG error in η) sets an upper limit on the mixing angle of a possible heavier right-handed partner to the W boson, $|\zeta| < 0.03$ at 90% confidence level (c.l.). Combining ρ with the new measurement of $\delta = 0.74964 \pm 0.00066(\text{stat.}) \pm 0.00112(\text{syst.})$, and the PDG value of $P_\mu \xi \delta/\rho$, an indirect limit is set on $P_\mu \xi$: $0.996 < P_\mu \xi < 1.004$ with 90% c.l. The lower limit slightly improves the limit on the mass of the possible right-handed boson, $W_R \geq 420$ GeV/c^2. Finally, an upper limit is found for the muon right-handed coupling probability, $Q_R^\mu < 0.00184$ at 90% c.l.

Muon decay, combined with measurements from experiments at higher energies and in nuclear beta decay, helps our understanding of the asymmetry in the weak interaction's handedness. In the future phases of the experiment, TWIST aims to produce a direct measurement of $P_\mu \xi$ with a precision of a few parts in 10^4 and to increase its sensitivity to ρ and δ by approximately another factor of five.

Further reading

A Gaponenko *et al.* 2005 (in press) *Phys. Rev. D* hep-ex/0410045.
J R Musser *et. al.* 2005 *Phys. Rev. Lett.* **94** 101805.
See also http://twist.triumf.ca.

JLAB

Electrons reveal secrets of neutrinos

The US Department of Energy's Thomas Jefferson National Accelerator Facility (JLab) is well known for its Continuous Electron Beam Accelerator Facility (CEBAF), where experiments with a 6 GeV electron beam probe nuclear structure. Now it turns out the same beam may also be helpful for neutrino research. Physicists from several neutrino projects around the world recently visited JLab to take electron-scattering data on carbon, hydrogen, deuterium and iron targets.

Precise knowledge of neutrino beams and neutrino interactions with atomic nuclei helps neutrino researchers analyse the results of their experiments. They gather this by participating in nuclear and high-energy physics experiments, a practice known as "neutrino engineering". Examples are the HARP experiment at CERN, which measures pion-production cross-sections of protons on nuclear targets, and experiment E04-001 at JLab, which measures electron-nucleus cross-sections.

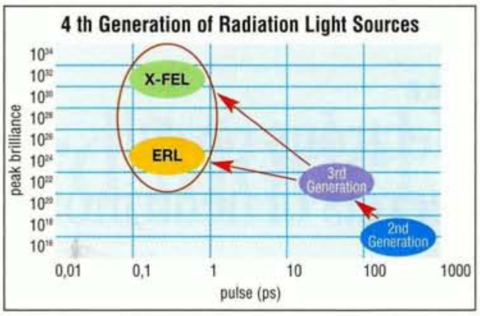
Electrons at CEBAF energies interact with nuclei predominantly via the electromagnetic force, while neutrinos interact via the weak force. However, precise information about the electron interaction provides information about the neutrino interaction, since the two forces are actually different aspects of the electroweak force. Electrons probe the vector structure of the nucleon, whereas neutrinos probe both the vector and axial-vector structure. So both probes are needed to understand the full electroweak structure of the nucleon and the nucleus.

The nuclear targets studied in the JLab experiment are the same as, or closely resemble, the production targets and detectors commonly used in neutrino experiments. Thus electron-scattering studies with nucleons and nuclei at low momentum-transfer-squared Q^2, such as the data taken at JLab in the Q^2 range of 0.01–2 $(\text{GeV}/c)^2$, can provide information about how neutrinos interact in neutrino experiments. For example, since experiments such as K2K (KEK to Kamioka) in Japan and MiniBooNE at Fermilab use 1 GeV neutrino beams to study neutrino oscillations, electroweak analysis of 1 GeV electron-scattering data from E04-001 can be used as a first step to provide constraints on neutrino cross-sections needed in the study of neutrino oscillations.

In the long term, JLab and JLab's own researchers are collaborating in a future experiment, MINERvA (Main Injector Experiment v-A), which is dedicated to measuring neutrino cross-sections in Fermilab's NuMI (Neutrinos at the Main Injector) beam line. Combining the high-precision electron cross-section data from E04-001 with precise data on neutrino cross-sections from MINERvA should allow the axial structure of the nucleon to be extracted.

A new approach to research-industry partnerships

Several billion euros will be invested in advanced particle accelerators in the next few years. The LHC and SNS will shortly be open for operation. Ten new synchrotrons will start operation in just five years, whereas it took three decades to construct the 30 facilities now in service worldwide.



Light source synchrotrons have become an indispensable research tool for materials sciences, biology, nanotechnologies and protenome. This new generation increases brilliance by a factor of 10^{10}, and cuts pulse time 100-fold

The level of performance that was previously available only to facilities such as Argonne or ESRF will become standard with the fourth generation of synchrotrons. These spectacular developments should lead to unprecedented scientific discoveries as well as revamping the approach to the design and operation of these systems.

These new facilities also involve heavy investments and risks, most notably due to the increase in the number of power sources and the superconducting systems that are necessary for higher performance. "*We are undoubtedly entering a new era of partnership between users and the power source manufacturers,* says Eric Margoto, scientific marketing at Thales ED. *"A more holistic system approach is being developed. Customers are increasingly asking us to supply a complete RF amplification function, integrating the factor of operating costs. In other words, not only do we have to master the critical technologies needed to deliver power source efficiency of 70 percent or even more, but we have to offer the expertise needed to integrate a large number of sources, and make sure they are synchronized, among other requirements.*"

The international scientific community expects higher performance and efficiency from equipment for their synchrotrons, as well as new-generation colliders such as the ILC. There are a number of points in common between these two sectors, in particular L-band as the standard frequency, and a number of power sources that goes way beyond today's conventional installations.

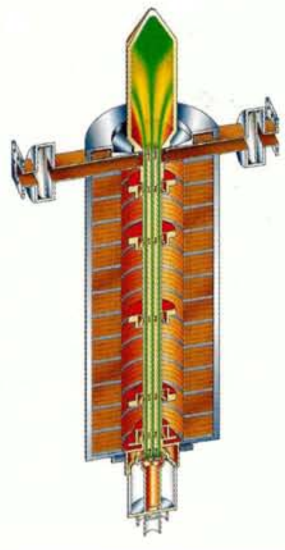
Two innovative solutions have already been tested and installed, namely the IOT (inductive output tube) and multibeam klystrons.

"*Thales is a recognized pioneer in the development and application of reliable high-tech solutions for scientific research,*" notes Eric Margoto. "*In fact, we offer unrivaled experience in this area. Our products have become the market benchmark, due to their performance and reliability. But today, users demand more than simply a power source offering exceptional performance. We have to provide a secure, long-term supply of significant quantities, to all of these laboratories while maintaining the same level of performance. That is of course Thales' business, as we have already shown in a number of professional markets. Furthermore, this approach is reflected in our proactive commitment to scientific research*".

Klystron product line

TH 2104, Developed about 30 years ago for Boeing, this klystron is still the only one to offer such high performance: 10 MW peak power, 250 kW average. Thales has built over 100 units of this type to date.

Thales ED is a pioneer in multibeam klystrons, a technology that has proven decisive in increasing efficiency. The first multibeam klystron, the **TH 1801** (67% at 10 MW peak, 150 kW average), has been integrated in TESLA. This demonstrator is the first step of the Euro X-FEL developed by the DESY research institute in Hamburg, with possible applications for the ILC.



THALES
and synchrotrons

Thales products are an integral part of more than 25 synchrotrons worldwide. A world leader in Linac and High power klystrons and IOT solutions, Thales has already provided turnkey RF amplification packages to Canada (CLS), China (SSRF), Switzerland (SLS) and the United Kingdom (DLS). Japan's J-Parc system will enter service in 2006, using Thales' 500 kW power tetrodes.

Thales is currently doubling its production capacity for these product lines.

www.thalesgroup.com/electrondevices

IOT product line

TH793
Installed for the Diamond Light Source and Australian National Synchrotron facilities, the TH 793 IOT, introduced in 2002, offers 69 percent efficiency at 80 kW. Used with the new generation of modular-design amplifiers, it helps increase system availability.

TH 713
Thales ED is now gearing up for production of the independently-developed TH 713.
The first prototypes have already met their initial performance objectives, of 1.3 GHz, 16 kW, 60% efficiency and 21 dB gain, and efficiency should exceed 65% in the coming months.

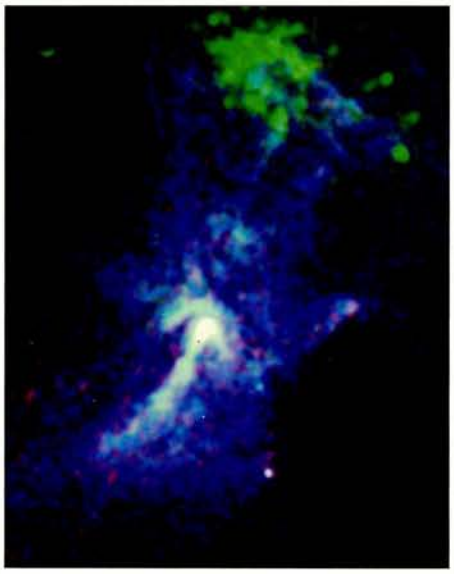
Compiled by Steve Reucroft and John Swain, Northeastern University

Black holes could act like cosmic particle accelerators

Usually we think of black holes pulling things in rather than hurling them out, but C Chicone and B Mashhoon of the University of Missouri would argue differently. While radially moving particles do get pulled towards the black hole, it turns out that our intuition is not so good when it comes to swarms of ultrarelativistic particles moving tangentially to it.

Tidal forces, the researchers argue, can accelerate the particles to almost the speed of light. The interactions of the charged particles with the ambient medium can then lead to the transfer of this tidal energy to particles in the ambient medium. These can escape from the system to appear far away as ultra-high-energy cosmic rays.

Chicone and Mashhoon say that this acceleration mechanism agrees with observations by the Chandra X-ray Observatory of accelerated motion normal to the radial jets in four neutron stars in our galaxy: the Crab Pulsar, the Vela Pulsar, PSR B1509-58 and SNR G54.1+0.3. The mechanism may also account for ultra-high-energy cosmic rays with energies above the Greisen–Kuzmin–Zatsepin cut-off for extra-galactic sources of 10^{20} eV. Microquasars or neutron stars in our galaxy could be sources of the highest-energy cosmic rays – an idea that the Pierre Auger Observatory may help to shed light on in the near future.



Neutron stars such as the pulsar PSR B1509-58, observed here by the Chandra X-ray Observatory, could be cosmic particle accelerators. (NASA/MIT/B Gaensler et al.*)*

Further reading

C Chicone and B Mashhoon 2005 http://arxiv.org/abs/astro-ph/0502560

Plastic electronics might benefit from memory technology

A new non-volatile rewritable memory device based on an unusual combination of technologies could provide an inexpensive and highly robust way to store information. A team from the University of Groningen and Philips Research in the Netherlands has demonstrated a ferroelectric field-effect transistor (FeFET) made with a ferroelectric fluoropolymer and a bisalkoxy-substituted poly (p-phenylene vinylene) semiconductor material.

The ferroelectric material provides an alternative means of band-bending in the FET, but at greater magnitude than in conventional devices, which are limited by breakdown of the gate insulator. This is the first demonstration of a non-volatile plastic-memory technology that meets the performance needs of commercial plastic electronics applications. It could enable new concepts, such as food packaging that alerts consumers when its contents are getting close to their "use by" date.

Further reading

Ronald C G Naber *et al.* 2005 *Nature Materials* **4** 243.

GIMPS finds largest prime number yet

On 18 February Martin Nowak, an eye surgeon and amateur mathematician from Germany, found the largest prime number yet, with an amazing 7 816 230 digits. He used more than 50 days of CPU time on a 2.4 GHz Pentium 4 computer – plus some additional help. Tens of thousands of participants in the Great Internet Mersenne Prime Search (GIMPS) lent spare cycles to the effort, demonstrating how a computational Grid can do big calculations.

The result was independently verified in five days by Tony Reix of Grenoble, using a 16 Itanium CPU Bull NovaScale 5000 HPC and again by Jeff Gilchrist of Elytra Enterprises in Ottawa, who used 15 days of time on 12 CPUs of a Compaq Alpha GS160 1.2 GHz CPU server at SHARCNET. The prime is a "Mersenne Prime", which is of the form 2^p-1, where p is a prime. In this case the power is 25 964 951.

There is no immediate application of such an enormous prime, but for those who like a challenge the Electronic Frontier Foundation is offering a prize of $100 000 for the first prime with 10 million digits and $250 000 for a prime with 1000 million digits. You can also obtain a poster containing the entire new prime number!

Further reading

www.mersenne.org/
www.eff.org/awards/coop.html

Role of air pressure in splashes revealed

Suppose that rain fell on the Moon? This is a question that Sidney Nagel of the University of Chicago in Illinois and colleagues have asked and to which they found a remarkable answer: the drops would not splash. It is common in fluid mechanics that things cannot be explained in detail because the Navier–Stokes equations are so complicated, but this finding really flies in the face of intuition. It turns out that splashing is reduced as air pressure drops, so the air plays an integral role in the formation of a splash. Below about 0.2 atm of pressure, drops of alcohol simply do not splash at all. So, suppose vodka spilled on the Moon...

Further reading

New Scientist 2 April 2005 p14.

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

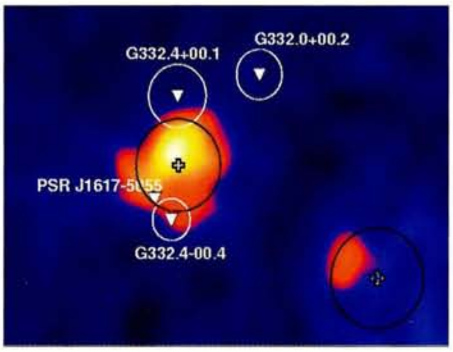
HESS detects mysterious high-energy sources in the Milky Way

The first detailed image of the central part of our galaxy at very-high-energy gamma rays shows several sources. Surprisingly, some of them do not have a known counterpart at radio, optical or X-ray wavelengths, so their nature is a complete mystery.

Gamma rays at tera-electron-volt energies are detected using the Earth's atmosphere as a detector. The passage of such a photon through the upper atmosphere triggers a shower of relativistic electrons and positrons moving faster than the speed of light in the air, thus emitting Cherenkov radiation. This faint bluish light-flash can be detected at night by dedicated ground-based telescopes.

Currently, the most sensitive Cherenkov telescope array is the European-African High Energy Stereoscopic System (HESS) located in the Namibian desert (*CERN Courier* January/February 2005 p30). It consists of four mirror telescopes 13 m in diameter placed at the corners of a square of side 120 m. Its image resolution of a few arc-minutes has enabled for the first time a map to be made at tera-electron-volt energies of the central part of our galaxy, the Milky Way.

The image published in the journal *Science* by Felix Aharonian and an international team of scientists reveals eight new sources of very-high-energy gamma rays in the central 60° of the disc of our galaxy. This essentially doubles the number of sources known at these energies. Three of the newly discovered sources could be associated with supernova remnants, two with giga-electron-volt gamma-ray sources discovered by the Energetic Gamma-Ray Experiment Telescope (EGRET) aboard the Compton Gamma-Ray Observatory, and in three cases an association with pulsar-powered nebulae such as the Crab Nebula is not excluded.



Detail of the map of the galaxy at very-high-energy gamma rays obtained by the HESS telescope array. Black crosses and circles show the position of the best fit and the extent of two newly discovered sources. Possible known counterparts are shown by white triangles and are labelled. The lower-right source cannot be associated with a known source at other wavelengths. (Courtesy the HESS collaboration.)

However, at least two of the sources discovered by HESS are not at a position where there is a possible counterpart. These could be members of a new class of "dark" particle accelerators.

Cosmic particle accelerators are believed to accelerate charged particles in strong shockwaves such as those produced when the gas expelled from a supernova hits the ambient interstellar medium. High-energy gamma rays are secondary products, which have probably been boosted to tera-electron-volt energies by ultra-relativistic electrons through the inverse Compton process. Gamma rays are easier to detect because they travel in straight lines from their source – unlike charged particles, which are deflected by magnetic fields in the galaxy. The discovery of new sources in the HESS survey of the galaxy therefore helps to solve the long-standing question of the origin of cosmic rays.

Further reading

F Aharonian *et al.* 2005 *Science* **307** 1938.

Picture of the month

Three years after the dramatic outburst of the star V838 Monocerotis, light continues to echo on surrounding dust. This latest image taken in October 2004 by the Hubble Space Telescope complements the previous sequence showing the propagation of the light-flash through the interstellar medium (*CERN Courier* June 2003 p12). Each time Hubble observes the event, different thin sections of the dust are seen as the pulse of illumination continues to expand away from the star at the speed of light, producing a constantly changing appearance. (Courtesy NASA, ESA and H E Bond [STScI].)

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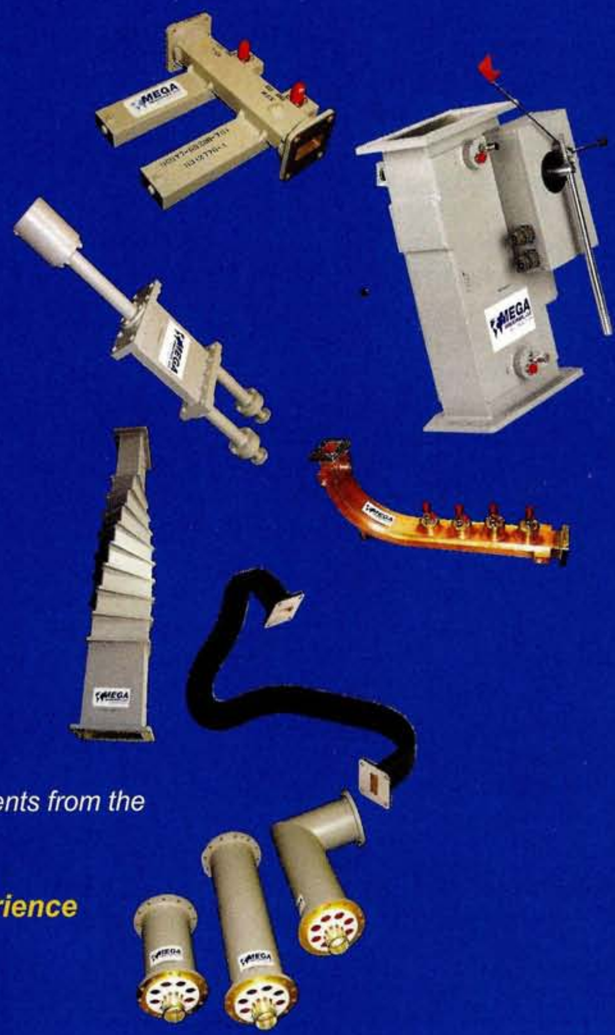

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A look back to *CERN Courier* vol. 2, May 1962

CHANGING TIMES

Team work and individual work in research

The vast expansion of research activities during the last few decades is due mainly to the rapid growth of the type of research which is more often than not "applied". Our knowledge of nature is also growing, but not quite so fast. Intuitively one is ready to grasp the need for putting a whole team to work when a difficult achievement is at stake, whereas it is preferable to be by oneself when it comes to putting a cunning question to nature or reflecting upon its secrets. It is, then, research for a practical purpose which tends to be done by teams, while research of the first type is more for the lone wolf. The present-day evolution, in which the acquisition of "know-how" is expanded more quickly than the quest for pure knowledge of nature, can thus be identified to a certain extent with the trend away from individual or solitary research towards research work by teams. This identity is not perfect, for, as we shall see later, even the purest research into the secrets of nature calls for an increasing amount of team work.

Let us consider, then, the state of affairs in physics, and especially nuclear physics, a few years before the last war. We find there such greatly renowned names as Mme Curie and Rutherford, Einstein and Bohr. Apart from a few exceptions, they are all lone workers or else leaders who tower above their colleagues to such an extent that they cannot be regarded as members of a team. As a first exception to this rule, there were even at that time cases where two partners appeared instead of a solitary leader. There are so few instances when there were more, that they can be almost ignored, whereas duets are fairly frequent, for example in the list of Nobel prize-winners.

Shortly before the war, a new style was beginning to appear, where several equals worked together. Why? Because in most of the sciences, and certainly in nuclear science, increasingly powerful tools were being introduced. The assistance of engineers had to be sought for building and operating the big machines. These machines have to operate at the limit of their possibilities; they could not accordingly be put in the hands of routine engineers; the engineers themselves had to have a creative turn of mind. It was already being asked whether an engineer could be the equal of a scientist. Did the two really make a team and work together on an equal footing? Was there sufficient mutual respect to hold the team together and share the fruits of the work? To these questions, which began to arise before the war, no entirely satisfactory answer has yet been found.

In these new teams, the leader is no longer necessarily the source of all the ideas and inspiration. He should rather have the ability to take a broad view, without entering into too much detail, and display some diplomatic gifts, for care has to be taken of both internal and public relations. The leader must be able to coordinate, and the financial responsibilities are becoming increasingly heavy. Are those in power always ready to put lots of money in the hands of absentminded professors? Among the members of the team, a specialized idea-monger will sometimes be found, alongside other specialists such as chemists or electrical engineers. Team work is beginning to be the general rule and is developing a style of its own.

On the other hand, it should also be said that, with the great increase in the number of scientific posts which has occurred in the last 20 years, an evergrowing number of young people have a chance of doing pure scientific work. This has brought about a certain levelling up of temperaments and a certain bureaucratic outlook, especially in the very big establishments. The proportion of individual creative minds goes down, but that of research workers willing to accept the constraints of team work goes up, and it is admittedly easier to do science in this way now than it was 30 years ago, since it suits better the common run of people.

• Extracted from an article by Lew Kowarski, leader of the Data Handling Division, based on a talk he gave in Zurich on 6 March 1962. The article also included two boxes detailing the scale of CERN in 1962.

1962: THE STATISTICS

Thirty years ago, the number of people in a nuclear-physics laboratory could be reckoned in tens. Now, the staff of CERN, for instance, is some 1150, sub-divided approximately as follows:

- **scientists and engineers: 200**
- **technicians: 625**
- **administrative and secretarial: 175**
- **others: 150**

Fellows, visiting scientists, and supernumeraries, together with experimental teams from various universities, bring the total number to over 1700.

1962: THE STRUCTURE

The CERN "orchestra" is conducted by the director-general, assisted by a Directorate of three: a member for research, one for applied physics, and one for administration.

There are 12 Divisions, each with its own leader, and each Division is itself divided into a number of sections. Three of the Divisions include experimental teams, each with some five or six physicists.

Experiments are approved by the Nuclear Physics Research Committee, after preliminary selection by the Electronic Experiments Committee, the Emulsion Experiments Committee, or the Track Chambers Committee.

Major policy is decided by the Council, following recommendations by the Committee of Council. The Council is advised by the Scientific Policy Committee and the Finance Committee.

EDITOR'S NOTE

The *CERN Courier* came into being in August 1959, and in 1962 it became a regular monthly publication.

Following on from the extracts published in 2004, CERN's 50th anniversary year, this regular archive feature will tell the story of particle physics through the pages of the *CERN Courier* from 1962 onwards.

The ice cube at the end of the world

What do you get when you take 1 Gt of water, cool it to −40 °C and add 4800 phototubes? The answer is IceCube, a 1 km^3 neutrino telescope now being deployed at the South Pole.

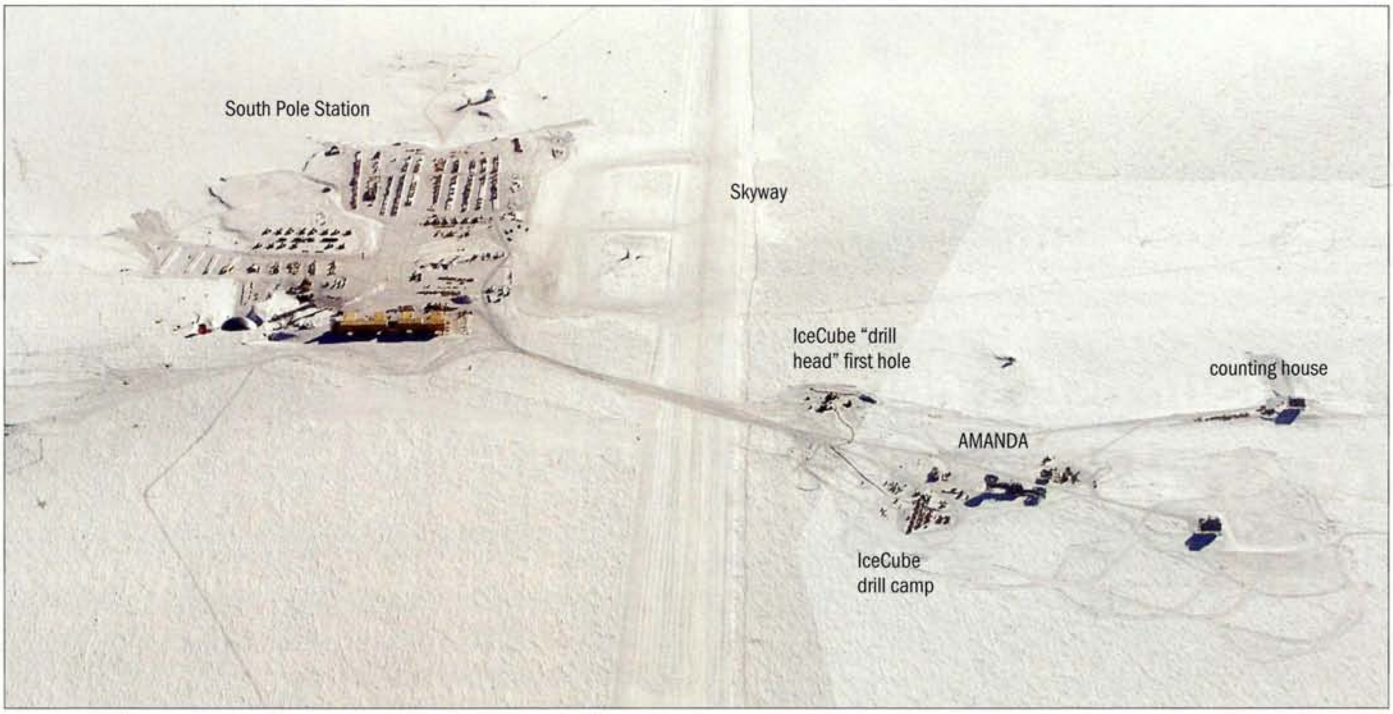


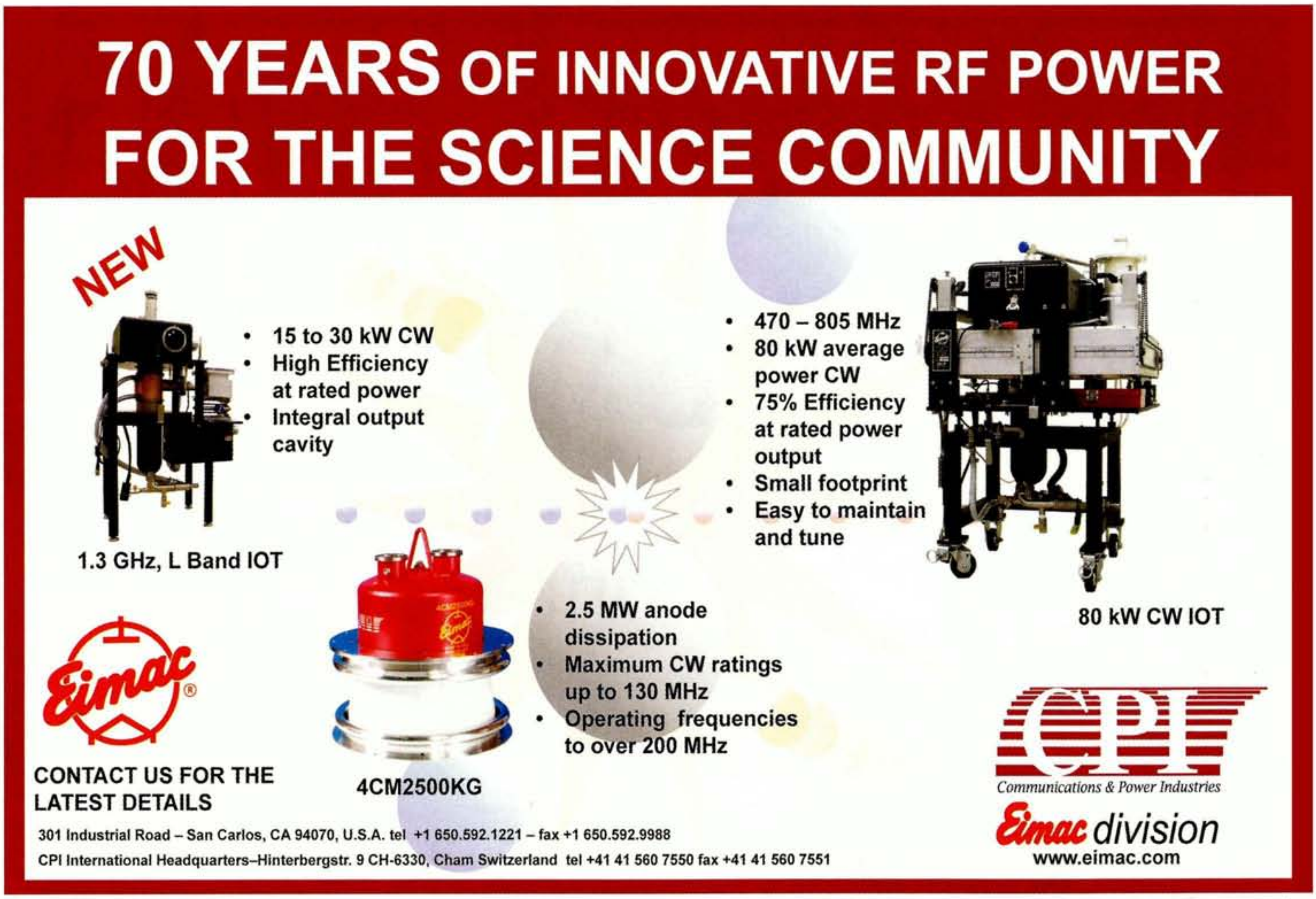
Fig. 1. An aerial view of the US South Pole Station, indicating the locations of the drill camp for the IceCube experiment and the first hole to be drilled. The detector will be deployed across a hexagonal region, part of which is indicated by the lighter shaded area.

The IceCube observatory is being built to detect extraterrestrial neutrinos with energies above 100 GeV. Neutrinos are attractive for high-energy astronomy because they are not absorbed in dense sources like other probe particles, and they travel in straight lines from their source. Protons or nuclear cosmic rays are also bent by interstellar magnetic fields, and while photons fly straight, at energies above 10 TeV, their interactions (by e^+e^- pair creation) with interstellar background photons limit their range.

The interaction cross-sections of neutrinos are tiny, so a huge detector is required. Calculations of neutrino production in many different types of sources show that a 1 km^3 (1 Gt) detector is required to observe astrophysical signals. IceCube will observe neutrinos that interact in Antarctic ice at the South Pole, producing muons, electrons or tau particles. These leptons interact with the ice (and the tau also decays), producing additional charged particles. High-energy (peta-electron-volts) muons travel many kilometres in the ice, and IceCube will observe muons that traverse the detector. The charged particles emit optical Cherenkov radiation, which can travel hundreds of metres before being detected by IceCube's digital optical modules (DOMs). The type of neutrino, its direction and its energy can then be reconstructed by measuring the intensity and arrival time of the light at many DOMs.

Work at the South Pole

The South Pole might seem like an unusual place to build a huge detector, but the Antarctic ice is very clear and very stable. Deep below the surface, the light-absorption length can exceed 250 m. Compared with seawater, which is another active medium, the ice has much lower levels of background radiation and a longer attenuation length, but more light is scattered. ▷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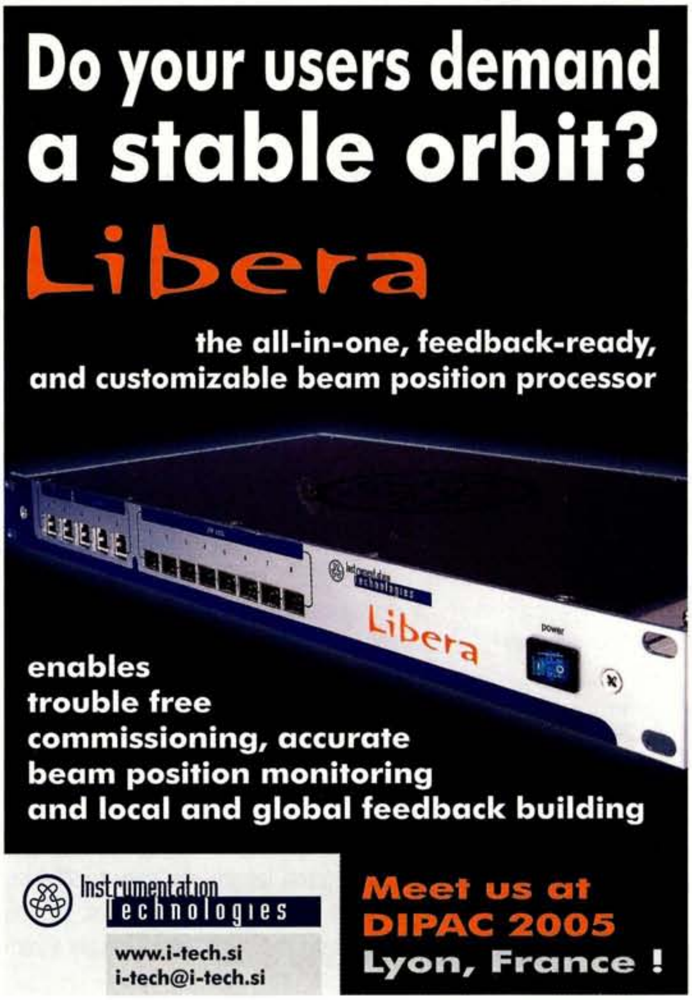
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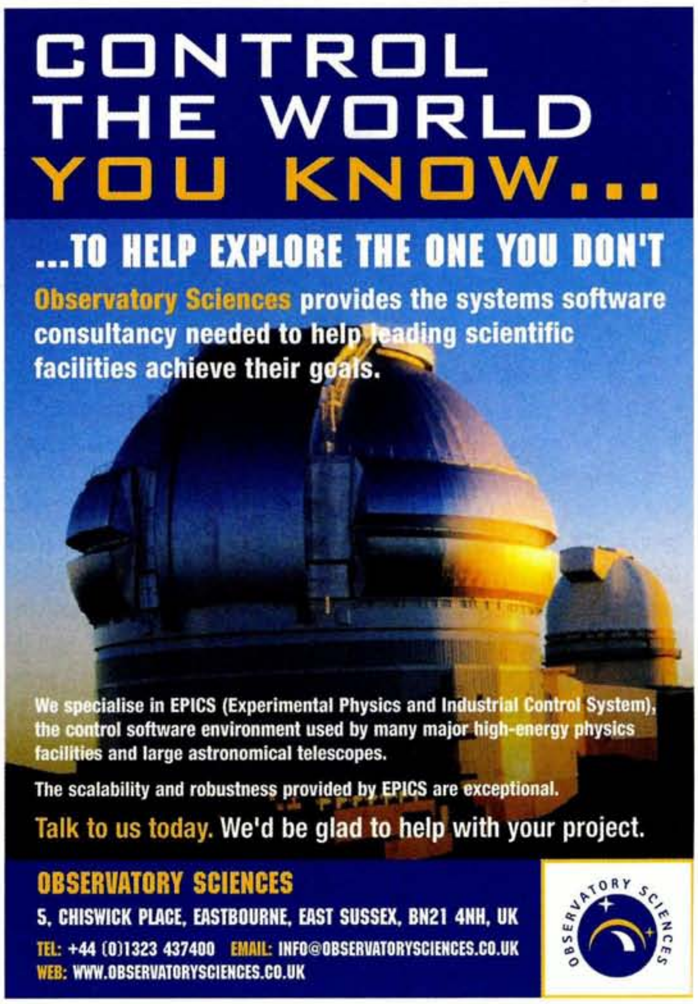
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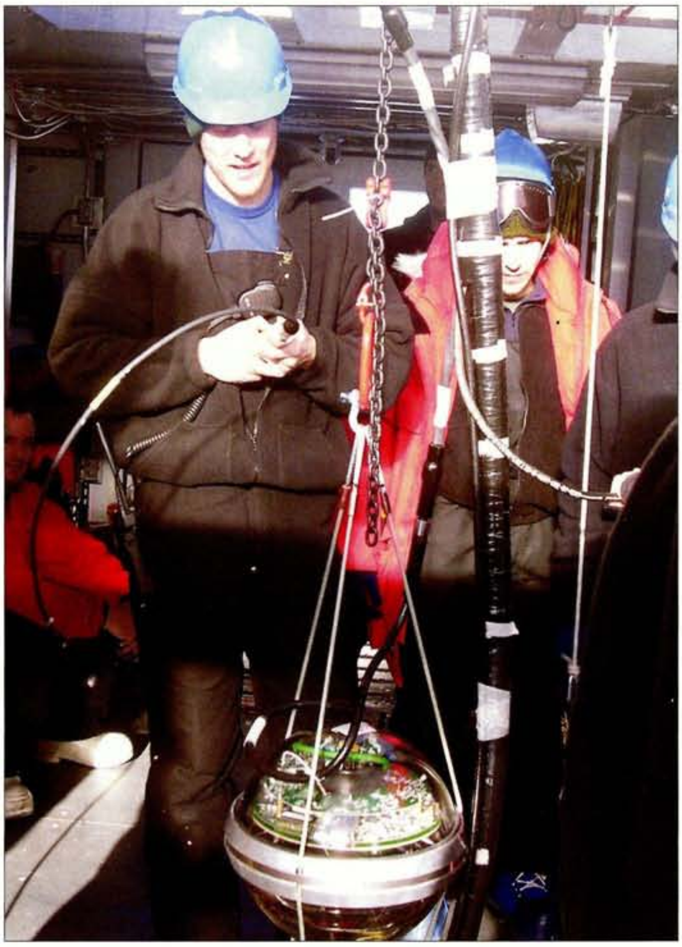

Fig. 2. The first digital optical modules are lowered into the hole.

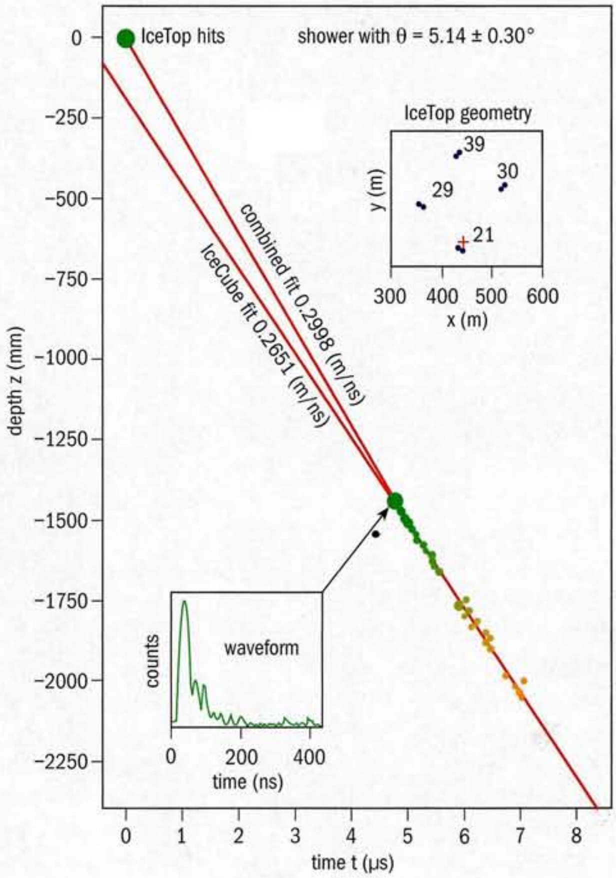

Fig. 3. An analysed IceTop–IceCube coincidence event from 7 February. The main graph shows the optical module depth in metres versus the arrival time of the first photon. The insets show the hits in the IceTop tanks and the waveform observed at the top optical module. The two fitted lines show the fit dz/dt for the muon, both for the in-ice digital optical modules only ("IceCube") and including the IceTop hits ("combined").

Using the US South Pole station as a base for operations, deployment of the IceCube detector in the ice began on 15 January, when the first hole was started (figure 1 on p17). A jet of water heated to 90 °C was used to melt the hole. The drill pumped 750 l/min of water from a 5 MW heater to reach a drilling speed of slightly over 1 m/min. Drilling this first hole, 2450 m deep and 60 cm in diameter, took about 52 h. Once the drilling was complete, a string of 60 DOMs was lowered into the hole, which took another 20 h (figure 2). The DOMs are attached to the string every 17 m, between depths of 1450 and 2450 m. The water that remained in the hole took about two weeks to freeze.

The South Pole is very different from an accelerator laboratory, and logistics is a key issue for IceCube. Environmental conditions are rough, and manpower and working time are limited, so everything must be carefully engineered and tested before being shipped to the Pole. Everything must be flown in from the Antarctic coast on LC-130 turboprop aeroplanes equipped with skis. The drilling rig alone filled 30 flights, about an eighth of the annual capacity; fuel for the drill required another 25 flights. Many of the components were transported in pieces to the Pole. The reassembly time limited this inaugural drilling campaign to about 10 days.

Figure 3 shows an early result of this hard work, a cosmic-ray muon in IceCube, in coincidence with an air shower observed by eight surface tanks that form part of the IceTop array above IceCube (see below). These data were taken less than two weeks after deployment, showing that everything works "right out of the box". At the time, many of the DOMs were not yet turned on. More recent tests have verified that all 60 DOMs are working.

This success owed much to the Antarctic Muon and Neutrino Detector Array (AMANDA), which preceded IceCube and had more than 650 modules. The AMANDA optical modules contained only a photomultiplier tube (PMT) and analogue signals were transmitted to the surface on the power cable; later versions used fibre-optic cables to transmit analogue signals. These schemes worked in AMANDA, which observed several thousand atmospheric neutrinos, but the approach required manpower-intensive calibrations and could not be scaled up for the much larger IceCube. The solution was "String 18", a string of DOMs that, in addition to the AMANDA fibre readout, included electronics for locally digitizing the signals, and sending digital signals to the surface. The digital readout worked, and the DOM approach was adopted by IceCube. This advance was a key to reaching the 1 km^3 scale.

Each DOM functions independently. Data collection starts when a photon is detected. The PMT output is collected with a custom ▷

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Fig. 4. Two IceTop tanks being installed in a shallow trench.

waveform-digitizer chip, which samples the signal 128 times at 300 megasamples per second. Three parallel 10 bit digitizers combine to provide a dynamic range of 16 bits. Late-arriving light is recorded with a 40 MHz, 10 bit analogue-to-digital converter, which stores 256 samples (6.4 μs). These waveforms enable IceCube to reconstruct the arrival time of most detected photons. A large field-programmable gate array with an embedded processor controls the system, compresses the data and forms it into packets.

The entire DOM uses only 5 W of power. Adjacent DOMs communicate via local-coincidence cables, allowing for possible coincidence triggers. Data are transmitted to the surface over the DOM power cables, and at the surface trigger conditions for the strings and array-wide are applied. The data are stored locally and selected samples transmitted to the Northern Hemisphere via satellite link.

A surface cosmic-ray air-shower detector array, IceTop, forms part of IceCube. IceTop will eventually consist of 160 ice-filled tanks 2 m in diameter, distributed over 1 km^2 (figure 4). The tanks are similar to the water tanks used in other air-shower arrays – such as at Haverah Park in the UK, the Milagro Gamma Ray Observatory in the US and the Pierre Auger Observatory in Argentina. Each tank contains two DOMs frozen in the ice. DOMs in each pair of tanks are connected via local coincidence signals, providing a simple local trigger. Part of IceTop was the first piece of IceCube to be deployed, with eight tanks installed in December 2004.

IceTop will serve several functions: tagging IceCube events that are accompanied by cosmic-ray air showers; studying the cosmic-ray composition up to around 10^{18} eV (correlating IceTop showers with IceCube muons); and as a calibration source to tag directionally the cosmic-ray muons that reach IceCube.

One big problem in large arrays is measuring the relative timing between separated detector elements. IceCube solved this with "RapCal", a timing calibration whereby signals are sent down the cables from the surface then retransmitted to the surface. Accuracy is maintained by using identical electronics at the two ends of the cables. In IceCube, laboratory measurements and early data show that the local DOM clocks are kept calibrated to about 2 ns.

The environment at the South Pole motivated extensive reliability engineering and pre-deployment testing. The extended temperature range – down to −55 °C – was a challenge for the selection of parts

Fig. 5. IceCube should detect several neutrinos from a single gamma-ray burst, of the kind that probably occurred in the supernova remnant W49B, located about 35 000 light-years from Earth and shown here in a composite image from NASA's Chandra X-ray Observatory and infrared observations with the Palomar 200 inch telescope. (X-ray: NASA/CXC/SSC/J Keohane et al.; Infrared: Caltech/SSC/J Rho and T Jarrett.)

and for design verification. Indeed, IceTop may reach temperatures below −55 °C, beyond the design range of any electronic components. Reliability estimates were also challenging. Conventional models predict that the failure rate halves for each 10 °C drop in temperature; according to these models, IceCube will last forever.

The physics of IceCube

IceCube will study many physics topics, but the major objective is high-energy neutrino astronomy. Any source that accelerates protons or heavier ions (cosmic rays) also produces neutrinos. The accelerated particles will collide with other nuclei, producing hadronic showers. Pions and kaons in the shower will decay, emitting neutrinos. Cosmic rays have been observed with energies up to 3×10^{20} eV and the neutrino spectrum should extend to a few per cent of this energy. The neutrino flux is model-dependent, but most calculations predict that a 1 km^3 detector should see at least a handful of events each year.

There are several likely astrophysical sources of neutrinos. These include active galactic nuclei (AGNs), gamma-ray bursters (GRBs) and supernova remnants. AGNs are galaxies with massive black holes at their centres, which can power a jet of relativistic particles. Calculations based on the observed flux of photons at energies of tera-electron-volts show that IceCube should observe neutrinos from AGNs. GRBs are mysterious objects that produce bursts of high-energy gamma rays (figure 5). They are associated with objects in galaxies, including hypernovae (very large supernovae) and colliding neutron stars. Some calculations suggest that IceCube should see a handful of neutrinos from a single GRB, which would be a striking result. Supernova remnants such as the Crab Nebula are the likely source of most cosmic rays of moderate energy in our galaxy. If this is correct, they must also produce neutrinos.

Neutrinos also probe cosmic rays more directly. Ultra-high- ▷

energy (above 5×10^{19} eV) protons interact with relic microwave photons from the big bang. These protons are excited into Δ resonances, which decay to lower-energy nucleons and pions. Subsequent pion and neutron decays then produce neutrinos. The proton energy-loss limits the range of very energetic protons; this is known as the Greisen–Kuzmin–Zatsepin cutoff. Photo-dissociation plays a similar role for heavier ions, limiting their range and producing neutrinos. By measuring the ultra-high-energy neutrino spectrum, IceCube will probe the cosmic-ray composition and possible evolution (with redshift) of energetic cosmic-ray sources.

Besides being two orders of magnitude larger, IceCube has several advantages over experiments such as AMANDA and the array in Lake Baikal. IceCube is optimized for higher-energy neutrinos (especially above 1 TeV), where the atmospheric neutrino background is lower. The high detector granularity will allow IceCube to study electron-neutrinos and tau-neutrinos as well as muon-neutrinos. The electron-neutrinos produce blob-like electromagnetic showers, which contrast strongly with long muon tracks; the latter can extend for many kilometres. Above 10^{15} eV, tau-neutrinos are identifiable through their distinctive "double-bang" signature – an initial shower from the tau-neutrino interaction and the single track of a tau particle, which eventually decays, producing a second shower.

IceCube will study many other physics topics. Over a decade, it will observe about 1 million atmospheric neutrinos, enough to search for deviations from the standard three-flavour scenario for neutrino oscillations. The IceCube collaboration will also look for violations of the Lorentz and equivalence principles, and will search for neutrinos produced by the annihilation of weakly interacting massive particles that have been gravitationally captured by the Earth or the Sun. Because of the very low dark-noise rates (about 800 Hz per DOM), IceCube can detect bursts of low-energy neutrinos from collapsing supernovae. The detector will also contribute to glaciology, studying the dust layers that record the Earth's weather over the past 200 000 years.

• The IceCube collaboration consists of more than 150 scientists, engineers and computer scientists from the US, Belgium, Germany, Japan, the Netherlands, New Zealand, Sweden and the UK. IceCube is funded by a \$242 million Major Research Equipment Grant from the US National Science Foundation, plus approximately \$30 million from European funding agencies.

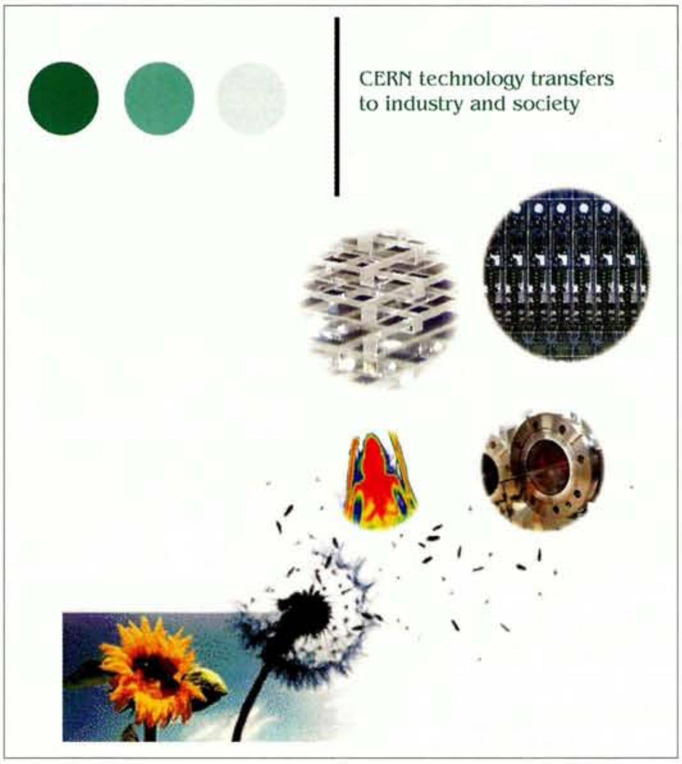
Further reading

J Ahrens *et al.* 2004 *Astropart. Phys.* **20** 507.
E Andres *et al.* 2001 *Nature* **410** 6827.
See also www.icecube.wisc.edu.

Spencer Klein, *Lawrence Berkeley National Laboratory and*
Francis Halzen, *University of Wisconsin.*

CERN's innovations mean real benefits for industry

The ever-increasing high-technology requirements of particle-physics research provide a fertile ground for CERN's Technology Transfer Group, as **Beatrice Bressan** describes.



The new report from CERN's Technology Transfer Group.

Advances in ultra-high vacuum technology

SAES Getters pioneered getter technology with the invention of a technique for producing stable getter alloys in 1950. CERN's collaboration with the company began in the late 1970s when the vacuum system for the Large Electron Positron (LEP) collider was designed. A non-evaporable getter (NEG) strip based on the SAES Getters getter alloy St101 was selected as the main pumping system for the storage ring. As a result, SAES Getters supplied about 23 km of the strip to CERN. Later, in the 1990s, CERN developed and patented the thin-film NEG coating that delivers both *in situ* gas pumping and reduced out-gassing in a vacuum chamber. This involved CERN combining its expertise and knowledge of NEG and sputtering, which had matured in the development of radio-frequency cavities for LEP2, and was a breakthrough in pumping technology for particle accelerators.

Ten years later, SAES Getters signed a licensing agreement with CERN for the transfer of this technology, which the company now markets under the tradename of "IntegraTorr". This technology represents a revolutionary way to integrate NEG pumping into a particle-accelerator vacuum chamber and also has applications in heavy-ion rings, synchrotron radiation facilities, insertion devices and beam lines.

Technology transfer promotes the injection of science into all levels of daily life in many different ways. For example, nobody would ever have thought that a phenomenon based on quantum theory – quantum entanglement – would find practical applications in cryptography, computing and teleportation, and lead to the creation of companies to safeguard the sharing of information. High-energy particle physics stimulates innovative technological developments. In the quest to find out what matter is made of and how its different components interact, high-energy physics needs highly sophisticated instruments in which the technology and required performance often exceed the available industrial know-how. Thanks to the technologies developed for its research activities, CERN has produced improvements in a variety of fields, many of which are described in a new publication that illustrates the effectiveness of technology transfer between the organization and industry.

Since its creation in 1954 CERN has had a tradition of partnership with industry and making its technologies available to third parties. Many of CERN's users come from distant locations and would like as much as possible to analyse data from their experiments in their home institutions. This led to the development of data networks between CERN and these institutes. As a result CERN became one of the major hubs of the European scientific data network, and with hindsight it is in a way natural that it was the birthplace of the World Wide Web. Furthermore, the major technology conferences and exhibitions that CERN has often organized – the first took place in 1974 – have been important occasions for establishing relationships between CERN and industry. However, up to the 1980s, except for the protection of computer software through a copyright statement, there was no structure in the laboratory to support an innovation policy.

During the first 30 years of its life, CERN did not use intellectual-property protection, such as patents. Its policy was "publish or perish", rather than "protect, publish and flourish". Furthermore, the ▷

Pixel detector aids the materials industry

Semiconductor pixel technology is the first in a new generation of energy-sensitive systems that enable the counting of single photons. It has various imaging applications and derives from developments in particle-physics experiments. Particle trackers consisting of layers of pixel detectors record the position and time of particles when they pass through. This enables single events to be selected and particle tracks to be reconstructed.

Panalytical (formerly Philips Analytical) is producing X-ray diffraction equipment for advanced-materials studies in which the prototype uses a technology developed at CERN: the Medipix2, a single-photon-counting pixel-detector readout chip. The information contained in the energy of the incoming photons is used to reject noise from detector leakage current or background light and to count only those photons that deposit energy within a given energy window. The resulting images are practically noise-free. In addition, because a linear response is obtained at up to 1 million photons per second per pixel, it is possible to use the technology in applications that involve a large number of photons.

In vivo PET scanner has clear benefits

The ClearPET small-animal system is a second-generation high-performance positron emission tomography (PET) scanner, which for the first time combines high resolution and high sensitivity by using new technologies in crystals and electronics. This system is a project of the Crystal Clear Collaboration, an interdisciplinary network of 11 institutes including CERN and 92 world experts in different aspects of material science. The German company Raytest, experienced in the design and development of new scientific instrumentation, is the commercial partner in this collaboration.

ClearPET applies the non-invasive PET technique to the *in vivo* imaging of small animals (rodents and small primates). Recently developed systems have a high spatial resolution of about 2 mm. A direct application of this technology is in small-animal PET for *in vivo* whole-body investigations under physiological conditions, including functional and diagnostic studies, as well as the study of new tracers and of new drugs for applications in therapy, and testing treatments and new drugs in brain and cancer research.

conventional model of technology transfer was via purchasing contracts, which required frequent interaction between industry and CERN owing to the highly innovative equipment concerned. The contracts and the financial rules required competitive bidding, with the award going to the lowest offer – a process that is not well adapted to collaborative agreements aimed at technology transfer. Then in 1984, when planning for the Large Hadron Collider (LHC) began, CERN recognized the need for strong involvement of industry even at the initial R&D stage, given the magnitude and technical complexity of the project.

In 1986 the relations between CERN and industry were analysed and two years later its member states encouraged the organization to take a more proactive attitude towards technology transfer. This was formalized with the establishment of the Industrial Technology Liaison Office – the beginning of a technology-transfer strategy at CERN. The call for technology for the development of the LHC detectors, launched in 1991, was another opportunity to reinforce the relationships between CERN and industry. At the same time value was given to the protection of intellectual property generated by the laboratory's activities and endorsed by the creation of a Technology Transfer Group.

This means that CERN now has another way to fuel technical innovations in the industries of its member states, beyond the conventional method of procurement. The proactive model, facilitated by the endorsement of a technology-transfer policy in 2000, enables CERN to identify, protect, promote, transfer and disseminate innovative technologies in the European scientific and industrial environment. Once the technology and intellectual property have been properly identified and adequately channelled (that is to say, protected by the appropriate means), they enter a promotional step intended to attract external interest and to prepare the ground for targeted dissemination and implementation.

The dissemination and exploitation of CERN's technologies are at the heart of the technology-transfer process. In addition to the conventional licensing model for transferring the technology, there is a policy of R&D partnership, which aims to promote CERN's technology more quickly and to further its dissemination outside particle physics. This type of transfer requires a large investment for the development of a specific product, so tangible financial results are uncertain.

Further reading

Many examples from the 160 CERN technologies managed by CERN Technology Transfer are illustrated in the new publication *CERN Technology Transfers to Industry and Society*, ISBN 9290832401 See also www.cern.ch/technologytransfer.

Beatrice Bressan, *Technology Transfer Group, CERN.*

VENUS reveals the futur

VENUS, the latest superconducting ECR ion source, is blazing the trail for the next generation of heavy-ion accelerators, as **Daniela Leitner** of LBNL explains.

A key technology for the next generation of heavy-ion accelerators will be a powerful, high-charge-state heavy-ion injector that provides an ion-beam intensity an order of magnitude higher than is currently achievable. In addition, future facilities – such as the proposed Rare Isotope Accelerator (RIA) in the US, the Radioactive Ion Beam Factory at RIKEN in Japan, and the project to upgrade the facility at the Gesellschaft für Schwerionenforschung (GSI) in Germany – will demand a high flexibility in the species of ions available for experiments that may last several weeks. High-performance electron cyclotron resonance (ECR) ion sources routinely produce beams of ions ranging from hydrogen to uranium, thereby providing the necessary reliability and flexibility. However, to meet the requirements for high currents, a new generation of ECR ion source will be needed.

The Versatile ECR Ion Source for Nuclear Science (VENUS), designed and built at the Lawrence Berkeley National Laboratory (LBNL), is the most advanced superconducting ECR ion source and the first "next-generation" source in operation (figure 1). It is the first fully superconducting ECR ion source that reaches magnetic-confinement fields sufficient for optimum operation at 28 GHz. Recently the project passed a major milestone with the successful coupling of 28 GHz microwaves into the plasma of the ion source. Preliminary tests at this frequency have already resulted in record intensities for beams of medium and highly charged ions. The results indicate for the first time that the high demands of the next generation of heavy-ion accelerators can be met.

The development of ECR ion sources has its roots in fusion plasma research in the late 1960s. The principle is to use magnetic confinement and ECR heating to produce a plasma made up of energetic electrons and relatively cold ions. Figure 2 shows the main ingredients of an ECR ion source: magnets for plasma confinement, microwaves for ECR heating, and gas to create and sustain the plasma. For high-charge-state sources the magnetic confinement consists of an axial magnetic-mirror field superimposed by a radially increasing sextupole (also called hexapole) or other multipole magnetic field. The combination of the axial mirror field and the radial multipole field produces a "minimum-B" configuration, in which the magnetic field is at a minimum at the centre of the device and increases in every direction away from the centre, providing stable plasma confinement.

The electrons, which are heated resonantly by microwaves, produce the high-charge-state ions primarily by sequential impact ionization of atoms and ions in the plasma. The ions and electrons must be confined for long enough for this sequential ionization to take place. In a typical ECR ion source, ions need to be confined for about 10^{-2} s to produce high-charge-state ions. The ionization rate depends on the plasma density, which typically ranges from about 10^{11} cm^{-3} for low-frequency sources to more than 10^{12} cm^{-3} for the highest-frequency sources. Charge exchange with neutral atoms must be minimized, so operating pressures are typically 10^{-6} mbar or less. The plasma chamber is biased positively so that the ions can be extracted from the plasma and accelerated into the beam-transport system.

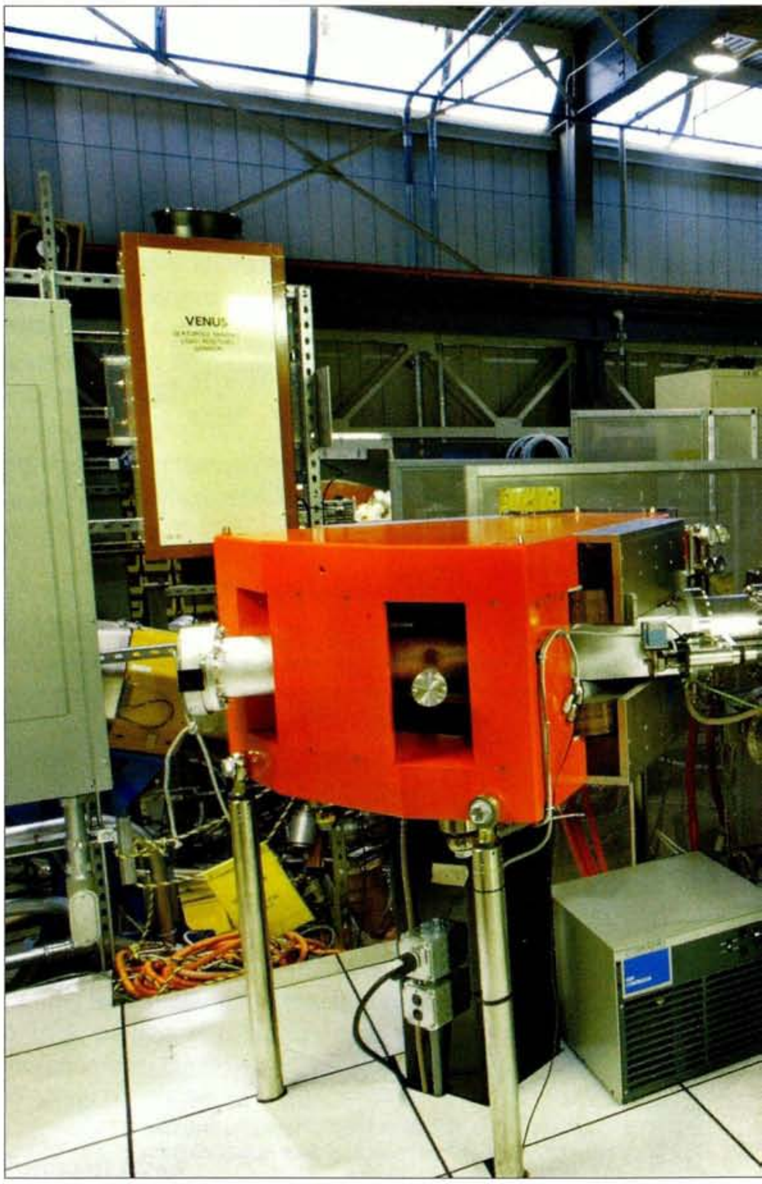


Fig. 1. The VENUS electron cyclotron resonance ion source and analys

The first sources using ECR heating to produce multiply-charged ions were reported in 1972 in France by Richard Geller. Since then

e of heavy-ion sources

agnet of LBNL, installed on the roof of the 88 inch cyclotron.

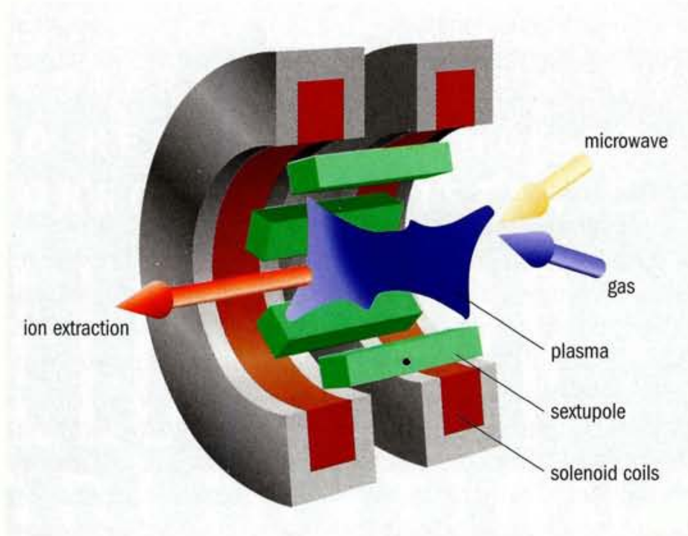


Fig. 2. Schematic of an ECR ion source. The magnetic-confinement structure consists of an axial magnetic-mirror field superimposed by a radially increasing sextupole field.

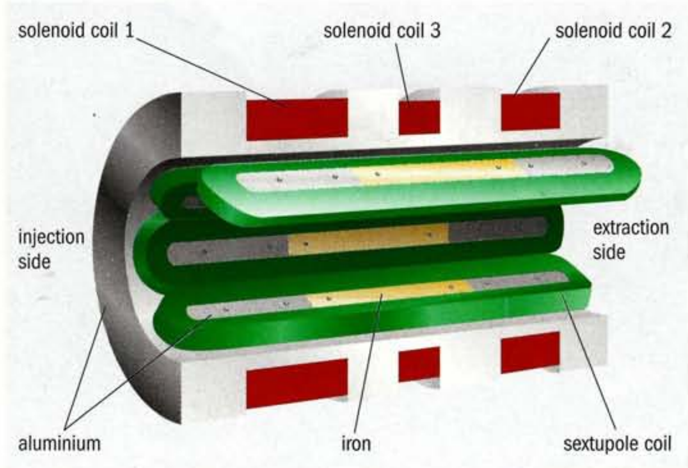


Fig. 3. Conceptual design of the superconducting magnet structure for the ECR ion source VENUS.

the development and refinement of ECR ion sources have improved performance dramatically. For example, in 1980 the Micromafios source at the Centre d'Etudes Nucléaires de Grenoble produced 20 eμA of Ar^{8+} and 10 eμA of Ar^{9+}. Later the 18 GHz source at RIKEN produced 2000 eμA of Ar^{8+} and 1000 eμA of Ar^{9+} in 2003.

The main drivers for improving the performance of ECR ion sources were formulated in Geller's famous ECR scaling laws, which predicted that higher magnetic fields and higher frequencies would increase both plasma density and ion-confinement times, which would improve performance. Following these guidelines and using other experimental data, the ambitious design for the VENUS ECR ion source was developed with magnetic-confinement fields much greater than those of previous sources. The strong forces between the superconducting sextupole and the solenoid coils were the main technical challenges of building such a source. Indeed, VENUS was the first source to build such a strong confinement structure, and it holds the world record for the highest ECR confinement field ever achieved, with an axial field of 4 T at injection, 3 T at extraction and a radial field at the plasma chamber wall of 2.4 T.

The technology that made this high field-strength possible was the careful design of the magnet-clamping structure, utilizing bladders filled with liquid metal and a split-pole structure made from iron and aluminium for the sextupole coils. The iron increases the radial field-strength by about 10%, and the aluminium pieces ▷

were used to match the thermal expansion of the superconducting wire and the pole. Figure 3 on p29 shows the conceptual design of the magnet structure.

Originally VENUS was designed to produce high-current, high-charge-state ions for the 88 inch cyclotron at LBNL, but it has evolved to serve also as the prototype injector ion source for the driver linac of the proposed RIA facility. In the latter application VENUS has become a highly visible project. Similar injector sources are proposed or under construction in RIKEN, GSI and the Laboratori Nazionali del Sud, Catania, in Italy.

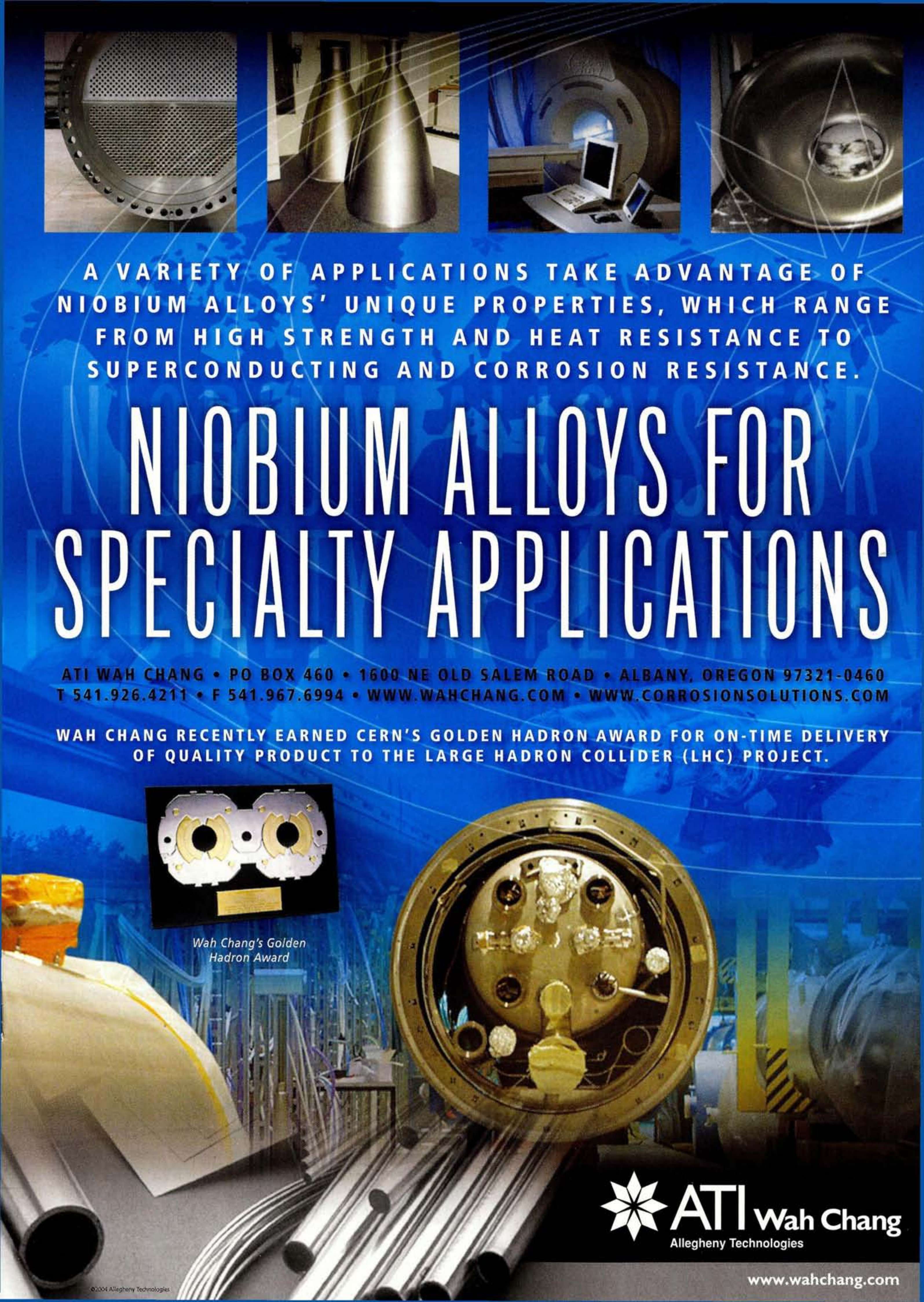
Testing, testing...

The operational experience with VENUS has been excellent in terms of stability, reproducibility and reliability during the commissioning period with power at 18 and 28 GHz. During initial operation at 28 GHz, record intensities of medium-charge-state beams such as 245 eμA of Bi^{29+}, and high-charge-state beams such as 16 eμA of Bi^{41+}, were extracted easily. The testing programme has initially focused on bismuth, since its mass is close to that of uranium, which will be the most challenging ion beam for RIA and also for the radioactive ion-beam factory in RIKEN. Bismuth is an ideal test beam since it is less reactive than uranium, not radioactive and evaporates at modest temperatures. However, the processes of extraction and ion-beam formation, as well as the transport characteristics, are very similar to those for uranium. Moreover, bismuth is also very similar to lead, so the results could also be of interest for a future intensity upgrade for the Large Hadron Collider at CERN.

The preliminary performance data measured at 28 GHz in 2004 with VENUS confirmed the scaling laws for intensity, and were the first evidence that meeting the high-intensity requirements is feasible. Nevertheless, these high-intensity beams present a new challenge for the beam-transport lines of ECR ion sources, which are traditionally designed for low-current ion beams. In addition, the high magnetic field at the extraction region greatly affects ion-beam formation and quality (i.e. emittance). This could appear to limit a further increase in the confinement fields and heating frequencies. However, experiments have found that higher-charge-state beams have much higher beam quality than lower-charge-state beams.

This can be explained by a model where the high-charge-state ions are extracted closer to the magnetic-field axis than the low-charge-state ions, leading to less angular momentum and a smaller transverse beam emittance. VENUS's widely variable magnetic field at extraction will enable us to explore this model experimentally. Later this year the VENUS source will be tested with uranium ions – one of the key ion beams for RIA and for the RIKEN radioactive ion-beam factory – which will be a major milestone for the project.

Daniela Leitner, *Lawrence Berkeley National Laboratory.*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RICH meeting provides a wealth of information

RICH2004, held in the Yucatan Peninsula in Mexico, presented a snapshot of the lively field of Cherenkov light imaging.

The well established ring imaging Cherenkov (RICH) technique measures the Cherenkov angle via direct imaging of photons emitted through the Cherenkov effect. It is mainly used in high-energy and astroparticle physics experiments to identify charged particles over an impressive range in momentum, from a few hundred mega-electron-volts/c up to several hundred giga-electron-volts/c. The performance of the technique has yet to be matched by competing technologies, especially when the physics objectives require excellent particle identification.

In 1993, Eugenio Nappi of Bari and Tom Ypsilantis of Collège de France began a series of international workshops to provide a forum for reviewing the most significant developments and new perspectives on this powerful technique. From 30 November to 5 December 2004, the beautiful resort of Playa del Carmen on the Yucatan Peninsula in Mexico hosted the fifth in the series. Following on from the first workshop in Bari, Italy, and subsequent meetings in Uppsala, Ein Gedi and Pylos, this was the first foray to the other side of the Atlantic.

RICH2004 was dedicated to the centenary of the birth of Pavel Cherenkov in July 1904, who discovered the effect through which charged particles travelling faster than light in a medium emit a characteristic radiation. To honour him, the local organizing committee – headed by two seasoned RICH practitioners in Mexico, Jurgen Engelfried from the University in San Luis Potosi (UASLP) and Guy Paic from the Instituto de Ciencias Nucleares of the National University in Mexico City (UNAM) – invited Cherenkov's daughter, Elena Cherenkova, to the meeting. A physicist herself, she captured the attention of the audience by recollecting her father through unpublished photographs and anecdotes. Boris Govorkov, a long-time collaborator of Cherenkov, was also invited to talk about the history of the discovery of Cherenkov radiation.

The workshop itself consisted of topical sessions on Cherenkov-light imaging applications and related technological issues. It attracted some 100 participants from around the world and the large number of abstracts received proved that this field is still very fertile and open to innovative ideas, about both the basic configuration of detectors and the technology used in their construction. While all the submitted contributions were very interesting, the organizers had to make a selection to allow time for extensive discussions between talks. In addition to the 10 invited talks, 55 other papers were accepted for oral presentations, while the remainder were conveyed in the poster session.

RICH2004's organizers: Guy Paic (far left) and Jurgen Engelfried (far right), talking with Boris Govorkov and Elena Cherenkova.

The main advances of the past few years played a central role in the workshop. These include the imaging of Cherenkov photons totally reflected in quartz bars (the basic principle of the Detection of Internally Reflected Cherenkov light [DIRC] technique adopted in the BaBar experiment at the Stanford Linear Accelerator Center [SLAC]); the development and applications of photocathodes made of thin films of caesium iodide (CsI); and the current availability of multi-anode photomultipliers (MAPMTs) and large-area hybrid photon detectors (HPDs).

Jochen Schwiening of SLAC gave an overview of the current DIRC layout for BaBar, while in a contribution to the poster session Jerry Va'vra, also from SLAC, described the possibility of enhancing the detector's performance by adding a focusing system. The design and construction of gaseous photodetectors based on large-area CsI photocathodes, which work in reflective mode with electron extraction in CH_4 at atmospheric pressure, have been mastered. This was shown by Abraham Gallas of CERN, Silvia Dalla Torre of Trieste and Mauro Iodice of Rome, who reported on applications in the ALICE and COMPASS detectors at CERN and in experiments in Hall A at the Jefferson Laboratory, respectively. Herbert Hoedlmoser of CERN also reviewed preliminary results from irradiation tests on CsI photocathodes.

Although gaseous photon detectors remain the most effective ▷

Elena Cherenkova, right, in discussion with Silvia Dalla Torre, the organizer of the next RICH conference; in the background is the image of Pavel Cherenkov from Elena's talk about her father.

solution for large detector areas in relatively low-rate experiments, the improvements in the technology of multichannel vacuum-based photon detectors have created the possibility of using the Cherenkov-light imaging technique in applications that were unthinkable only a few years ago. One example is measuring how long Cherenkov photons take to propagate in long quartz bars (the time-of-propagation or TOP counter), as Toru Iijima from Nagoya discussed. The two RICHs being constructed for the LHCb experiment at CERN are the most exacting examples of this "new generation" and several talks covered their challenging design.

In parallel with the industrial production of HPDs and MAPMTs, the development of custom designs has recently evolved considerably. A partnership with one major industrial manufacturer has been established to develop multi-anode hybrid avalanche photodiodes and photodevices based on the combination of a micro-channel plate and micromegas, as reported by Takayuki Sumiyoshi of KEK and Va'vra, respectively.

Besides the CsI-based RICHs mentioned above, Vladimir Peskov from Paris also discussed novel gaseous detectors. In the same vein, Fabio Sauli of CERN reviewed advances in the gas electron-multiplier (GEM) technique, which enables high-performance detectors to be built that are essentially discharge-free and have very high gains. Amos Breskin of the Weizmann Institute reviewed the important results obtained in detecting single photons with a multi-GEM counter, filled with CF_4 or Ar/CH_4, which operates smoothly up to a gain as high as 10^5. These studies were the basis for the development of the "hadron-blind" Cherenkov detector under construction for the Pioneering High-Energy Nuclear Interaction Experiment (PHENIX) at the Brookhaven National Laboratory (BNL), as reported by Itzak Tserruya, also of the Weizmann Institute.

The trend of operating RICH detectors in the visible range improves performance because the chromatic aberration is less than with detectors working in the far-ultraviolet region; it also implies a larger choice of materials for the radiator, such as silica aerogel. Several speakers discussed the outstanding improvement of the optical characteristics of this amazing material, made possible by the work of the group of Alexander Danyliuk and Alexei Onuchin in Novosibirsk and of the Japanese company Matsushita.

The high transparency of aerogel nowadays and the possibility of producing tiles made of layers with different refractive indices enable more compact detector designs based on proximity focusing geometry. Such a design is envisaged for the upgrade of the Belle experiment at KEK and, in threshold mode, for heavy-ion experiments, as reported by Peter Krizan of Ljubliana and Paic, respectively. On technological aspects, Veljko Radeka of BNL reported on perspectives for front-end and read-out electronics, and Olav Ullaland of CERN discussed the design of fluid systems.

A discussion about the performance of operating detection systems included overviews of the RICH for the HERA-B experiment at DESY, from Marko Staric of Ljubljana; the triethylamine RICH in the CLEO III experiment at Cornell, from Radia Sia of Syracuse; and the dual-radiator RICH of the HERMES detector at DESY, from Harold Jackson of Argonne. Forthcoming RICH detectors in fixed-target and collider experiments took centre stage halfway through the workshop with reports on RICH2 for COMPASS at CERN from Fulvio Tessarotto of Trieste, and the RICHs for the Charged Kaons at the Main Injector (CKM) and B Physics at the Tevatron (BTeV) experiments at Fermilab from Peter Cooper of Fermilab and Tomasz Skwarnicki of Syracuse, respectively. The impressive results obtained with RICH detectors, especially in charge–parity violation in B-physics experiments, were reviewed by Blair Ratcliff of SLAC.

A full day of the workshop was devoted to astroparticle physics applications, beginning with overviews from Greg Hallewell of Marseille and Alan Watson of Leeds. They made it clear that the new generation of experiments under construction in astrophysics will be the most challenging designs ever attempted.

The consensus of the workshop is that nowadays, with the exception of the next generation of experiments at linear colliders, all experiments need and plan for particle identification at ever-higher momenta and therefore, for the most part, rely on RICH detectors. This was the key message of the talk by Nappi at the end of the meeting. The high quality of the talks and the enjoyable location made this event a great success and RICH practitioners are very much looking forward to the sixth in the series, which will be held in Trieste in autumn 2007.

• RICH2004 was sponsored by several Mexican institutions including the Centro de Investigación y de Estudios Avanzados (CINVESTAV), the Consejo Nacional de Ciencia y Tecnología (CONACyT), UNAM and UASLP; CERN; the National Science Foundation (NSF); the Centro LatinoAmericano de Fisica (CLAF); SLAC; and Fermilab.

Further reading

Presentation slides of all the talks can be downloaded from the conference website at www.ifisica.uaslp.mx/rich2004/.
The proceedings of the workshop will be published by Elsevier in the journal *Nuclear Instruments and Methods in Physics Research*.

Eugenio Nappi, *INFN-Bari, and* **Guy Paic**, *ICN-UNAM.*

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Physics in the Italian Alps

In February, 120 physicists travelled to the mountain village of La Thuile in Italy to discuss results and perspectives in particle physics. **Michael Koratzinos** reports.

Now in its 19th year, the Rencontres de Physique de la Vallée d'Aoste is known for being a vibrant winter conference, where presentations of new results and in-depth discussions are interlaced with time for skiing. Taking place in La Thuile, a village on the Italian side of Mont Blanc, it consistently attracts a balanced mix of young researchers and seasoned regulars from both theoretical and experimental high-energy physics. The 2005 meeting, which took place from 27 February to 5 March, was no exception.

One of the 10 sessions in full swing at the Panibel Hotel.

As well as the standard sessions on particle physics, cosmology and astrophysics typical for such a conference, the organizers always try to include a round-table session on a topical subject, as well as a session on a wider-interest topic that tackles the impact of science on society. This year, the first of these sessions was Physics and the Feasibility of High-Intensity, Medium-Energy Accelerators, and the second was The Energy Problem.

Dark energy, WIMPs and cannon balls

An increasing number of experiments are trying to answer questions in high-energy physics by taking to the skies, making the distinction between particle physics and astronomy more fuzzy. The first session of the conference presented an impressive array of experiments and results, ranging from gravitational-wave detection to gamma-ray astronomy. The team working on the Laser Interferometer Gravitational-Wave Observatory (LIGO), with two fully functioning antennas 3000 km apart, now understands the systematics and has begun the fourth period of data-taking with improved sensitivity.

In gamma-ray astronomy, ground-based detectors – which detect the Cherenkov light emitted when gamma-ray-induced particle showers traverse the atmosphere – are constantly improving. The High Energy Stereoscopic System (HESS) in Namibia became fully operational in 2004 with a threshold of 100 GeV, while new detectors with thresholds as low as 20 GeV are in the pipeline. Satellite-based gamma-ray detectors have also provided some excitement, with the Energetic Gamma Ray Experiment Telescope (EGRET) observing an excess of diffuse gamma rays above 1 GeV, uniformly distributed over all directions in the sky.

This excess could be interpreted as due to the annihilation of neutralinos. The neutralino is the supersymmetric candidate of choice as a weakly interacting massive particle (WIMP) – a popular option for the dark matter of the universe. This prompted Dmitri Kajakov of the Institute for Theoretical and Experimental Physics (ITEP), Moscow, to state that "dark matter is the supersymmetric partner of the cosmic microwave background", since neutralinos can be thought of as spin-$\frac{1}{2}$ photons.

The Gamma-Ray Large Area Space Telescope (GLAST) satellite, launching in 2007, will offer an important improvement in gamma-ray astronomy, with sensitivity to 10 000 gamma-ray sources compared with EGRET's 200.

The DAMA/NaI collaboration raised some eyebrows. It reported an annual modulation of 6.3σ significance in data observed over seven years in its nuclear-recoil experiment at the Gran Sasso National Laboratory, which stopped taking data in 2002. This modulation could be interpreted as due to a WIMP component in the galactic halo, which is seen from Earth as a "wind" with different speeds, depending on the annual cycle. The collaboration's study of possible backgrounds has not identified any process that could mimic such a signal, but other experiments have not observed a similar effect. The new set-up, DAMA/LIBRA, which is more than twice as big and started taking data in 2003, might shed some light.

Another way of looking for WIMPs is through their annihilations that produce antimatter. Antimatter in the universe is not produced in large quantities in standard processes, therefore any excess of antimatter seen would be exciting news for WIMP searchers. The Payload for Antimatter Matter Exploration and Light-Nuclei Astrophysics (PAMELA) satellite due to be launched later this year will provide valuable data on antiproton and positron spectra.

Alvaro De Rújula of CERN, using traditional (and increasingly rare) coloured transparencies written by hand, gave an account of his theory of gamma-ray bursts (GRBs), which has now developed into a theory of cosmic rays. Central to the theory are the cosmic "cannon balls", objects ejected from supernovae with a density of one particle per cubic centimetre, and with a mass similar to that of the planet Mercury but a radius similar to that of the orbit of Mars (*CERN Courier* June 2003 p5). These cannon balls, moving through the interstellar medium at high speeds (with initial γ factors of the order of 1000), not only explain GRBs and their afterglows in a simple way, but also explain all features of cosmic-ray spectra and ▷

Participants at the meeting find time to pick up their e-mails.

composition, at least semi-quantitatively, without the need to resort to fanciful new physics. What the theory does not attempt to explain, however, is how cannon balls are accelerated in the first place.

Dark energy was reviewed by Antonio Masiero of the University of Padova. Masiero pointed out that theories that do not associate dark energy with the cosmological constant do exist. One can assume, for instance, that general relativity does not hold over very long distances, or that there is some dynamical explanation, like an evolving scalar field that has not yet reached its state of minimum energy (known as a quintessence scalar field), or even that dark energy is tracking neutrinos. With the latter assumption, he came to the interesting conclusion that the mass of the neutrinos depends on their density, and therefore that neutrino mass changes with time. The cosmological constant or vacuum-energy approach, however, offers the less exotic explanation of dark energy.

Finally, Andreas Eckart of the University of Cologne reviewed our knowledge of black holes, with emphasis on the massive black hole at the centre of our own galaxy, Sagittarius A*. He played an impressive time sequence of observations taken over 10 years of the vicinity of this black hole, showing star orbits curving around it.

The golden age of neutrino experiments

The neutrino session began with Guido Altarelli of CERN, who reviewed the subject in some depth. Although impressive progress has been made during the past decade, there are unmeasured parameters that the new generation of experiments must address. The Antarctic Muon and Neutrino Detector Array (AMANDA), which uses the clean ice of the South Pole for neutrino detection, reported no signal from its search for neutrino point-sources in the sky, but the collaboration is already excited about its sequel, IceCube (see p17).

The Sudbury Neutrino Observatory (SNO) collaboration has added salt to its apparatus, to increase the detection efficiency by nearly a factor of three compared with the earlier runs. Analysis yields slightly smaller errors on Δm_{13} than K2K (KEK to Kamiokande), the long-baseline experiment in Japan, which reported on the end of data-taking. K2K is now handing over to the Main Injector Neutrino Oscillation Search (MINOS) in the US, which had recorded the first events in its near detector just in time for the conference. MINOS is similar in conception to K2K, but has a magnetic field in its fiducial volume – the first time in such an underground detector – and it will need three years of data-taking to provide competitive results.

The director of the Gran Sasso National Laboratory, Eugenio Coccia, gave a status report of the activities of the laboratory, which is undergoing an important safety and infrastructure upgrade following a chemical leak (*CERN Courier* September 2003 p6). The laboratory is the host of a multitude of experiments on neutrino and dark-matter physics. These include the Imaging Cosmic And Rare Underground Signals (ICARUS) and Oscillation Project With Emulsion Tracking Apparatus (OPERA) experiments for the future CERN Neutrinos to Gran Sasso (CNGS) project and Borexino, which is the only experiment other than KamLAND in Japan that can measure low-energy solar neutrinos. The laboratory also houses neutrinoless double-beta-decay experiments.

Strong, weak and electroweak matters

In the session on quantum chromodynamics, Michael Danilov of ITEP had the unenviable task of reviewing the numerous experiments that have looked for pentaquarks. In recent years, there have been 17 reports of a pentaquark signal and 17 null results. Danilov justified his sceptical approach by pointing out various problems with the observed signals. The small width of the Θ^+ is very unusual for strong decays. Moreover, this state has not been seen at the Large Electron Positron (LEP) collider, although this fact can be circumvented by assuming that the production cross-section falls with energy. However, the Belle experiment at KEK does not see the signal either, weakening the cross-section argument. The Θ_c is seen by the H1 experiment at HERA, but not by ZEUS or by the Collision Detector at Fermilab (CDF). Finally, many experiments have not seen the Ξ^{--} signal. Although Danilov thinks that the statistical significance of the reported signals has been overestimated, it is still too large to be a statistical fluctuation. The question will only be settled by high-statistics experiments coming soon.

Amarjit Soni of Brookhaven summarized our knowledge of charge–parity (CP) violation by emphasizing the success of the B-factories, the fact that the Cabibbo–Kobayashi–Maskawa paradigm is confirmed, and that we now know how to determine the unitarity triangle angles α and γ, as well as the previously known angle β.

The electroweak session began with a report on new results from LEP, with LEP showing no signs that it has said its final word yet. The running of α_{QED} has been the subject of a new analysis of Bhabha events at LEP. The results from the OPAL experiment, recently submitted for publication, give the strongest direct evidence for the running of α_{QED} ever achieved in a single experiment, with a significance above 5σ. Regarding the W mass, the combined data error for LEP now stands at 42 MeV, whereas at the Tevatron, Run II is being analysed and the error from CDF from 200 fb^{-1} of data (a third of the collected data) is already less than their published result for Run I. The Tevatron collaborations expect to achieve a 30–40 MeV error on the W mass with 2 fb^{-1} of data. The search is on for the Higgs particle at Fermilab with a new evaluation of the Tevatron's reach. For a low-mass Standard Model Higgs, the integrated luminosity needed for discovery (5σ) is 8 fb^{-1}; evidence (3σ) needs 3 fb^{-1}, while exclusion up to 130 GeV needs 4 fb^{-1}.

From high intensity to future physics

The round-table discussion on physics and the feasibility of high-intensity, medium-energy accelerators was chaired by Giorgio Chiarelli of the University of Pisa, and after a short introduction he asked the panel members for their views. Pantaleo Raimondi of

Frascati gave an overview of B and ϕ factories and Gino Isidori, also of Frascati, pointed to a series of interesting measurements that can be performed by a possible upgrade to the Double Annular Ring For Nice Experiments (DAFNE) set-up at Frascati, where the time schedule would be a key point.

Francesco Forti of Pisa discussed the possibility of a "super B-factory". He noted that by 2009, 1 ab^{-1}-worth of B-physics data will be available around the world, and to have a real impact any new machine would need to provide integrated luminosities of the order of 50 ab^{-1}. Roland Garoby of CERN talked about a future high-intensity proton beam at CERN, where the need for a powerful proton driver, a necessary building block of future projects, has been identified. Finally, Franco Cervelli of Pisa reviewed the high-intensity frontier, including prospects for the physics of quantum chromodynamics, kaons, the muon dipole-moment and neutrinos. A lively debate followed.

In the interesting science and society session on alternative energy sources, Durante Borda of the Instituto Superior Tecnico of Lisbon gave a detailed account of ITER, the prototype nuclear-fusion reactor that is expected to be the first of its kind to generate more energy than it consumes. ITER is designed to fuse deuterium (obtained from water) with tritium obtained *in situ* from lithium bombarded with neutrons, thereby creating helium and releasing heat (in the form of neutrons) captured through heat exchangers. It is hoped that this ambitious project, with its many engineering challenges, will pave the way for commercial fusion-power plants.

This talk was followed by presentations on geothermal, solar, hydroelectric and wind energy, covering a wide spectrum of renewable energy resources. It was clear from the presentations that the problem of future energy production is complicated, and a clear winner has yet to emerge from these alternative energy sources.

In the session on physics beyond the Standard Model, Andrea Romanino of CERN did not make many friends among the community working towards the Large Hadron Collider (LHC) at CERN. He stated that "split supersymmetry" – a variation of supersymmetry (SUSY) that ignores the naturalness criterion – pushes the SUSY scale (and any SUSY particles) beyond reach of the LHC, although within reach of a future multi-tera-electron-volt collider.

Fabiola Gianotti of CERN appeared undeterred. She closed the session and the conference by giving a taste of the first data-taking period of the LHC to come. She reminded the audience that for Standard Model processes at least, one typical day at the LHC (at a luminosity of 10^{33}) is equivalent to 10 years at previous machines.

• The conference series is organized by Giorgio Bellettini and Giorgio Chiarelli of the University of Pisa and Mario Greco of the University of Rome.

Michael Koratzinos, *CERN.*

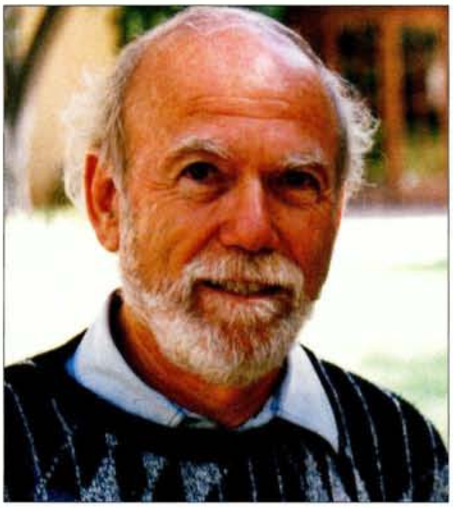
APPOINTMENTS

Barry Barish to lead design project for International Linear Collider

Barry Barish from the California Institute of Technology (Caltech) has been named the director of the Global Design Effort for the proposed International Linear Collider (ILC).

The announcement was made by the International Committee for Future Accelerators (ICFA) at the Linear Collider Workshop, which was held at Stanford University on 18 March. Barish is Linde Professor of Physics at Caltech and director of the Laser Interferometer Gravitational-Wave Observatory (LIGO) laboratory.

The ILC Global Design Effort will be the focal point for coordinating the interests and involvement of accelerator scientists and particle physicists in North America, Europe and Asia. Barish will lead the hundreds of scientists worldwide who are currently working on the research and development projects required for preparing a final Technical Design Report for the ILC (*CERN Courier* October 2004 p5). When this report is completed, the project will be able to move towards obtaining formal approval from funding agencies.



Barry Barish, newly appointed director of the Global Design Effort for the ILC.

The proposed collider has a vast set of goals. It would create high-energy particle collisions between electrons and positrons, and provide a tool to address many of the most compelling questions of the 21st century about dark matter, extra dimensions, and the fundamental nature of matter, energy, space and time.

From its inception, the ILC would be designed, funded, managed and operated as an international scientific project.

Sissakian is named the new director of JINR

Alexei Sissakian has been elected the new director of the Joint Institute for Nuclear Research (JINR) in Russia. Well known in the fields of elementary particle physics, theoretical physics and mathematical physics, and a full member of the Russian Academy of Natural Sciences and the National Academy of Sciences of Armenia, Sissakian is the fifth JINR director. He succeeds Vladimir Kadyshevsky, who headed the institute from 1992.

Sissakian, who has been laboratory director and vice-director at JINR, is a specialist in the field of multi-particle production. He has been an active participant in the preparation of scientific programmes and experiments at the U-70 accelerator at the Institute of High Energy Physics and at the JINR Nuclotron, as well as at CERN and Fermilab. Sissakian is also a professor at Moscow State University.

Left to right: JINR director Vladimir Kadyshevsky, head of the Federal Agency for Science and Innovation Sergey Mazurenko, and the newly elected JINR director Alexei Sissakian.

The election was held at the session of the Committee of Plenipotentiaries (CP) of the governments of the institute's member states, under the chairmanship of the head of the Russian Federation's Federal Agency for Science and Innovation, Sergey Mazurenko.

As well as appointing Sissakian as its new director, the CP also recommended the introduction of the honourary post of JINR scientific supervisor for Kadyshevsky.

INTERNATIONAL COLLABORATION

Vietnam targets fundamental science

Participants from the Fifth Rencontres du Vietnam on their visit to the Presidential Palace.

On 5–11 August 2004 Hanoi hosted the Fifth Rencontres du Vietnam, organized by Jean Trân Thanh Vân of Orsay. Two scientific communities – high-energy physicists and astrophysicists – gathered for two conferences: New Views in Particle Physics, and New Views on the Universe.

"Twinning" the conferences in this way was particularly fruitful; the conferences ran in parallel, yet there were common sessions for the presentation of new results of mutual interest. Researchers who are rarely able to be in the same place at the same time were thus able to meet, exchange ideas and launch new cross-disciplinary activities.

The keynote talks, given in a common opening session by Angela Olinto of Chicago and Albrecht Wagner of DESY, were informative overviews of the present state of astrophysics and high-energy physics, highlighting the bridges and tunnels between the two disciplines.

A special session, devoted to the physics of future accelerators and in particular to the difficult question of the next-generation accelerator, was followed by a round-table discussion featuring the directors and representatives of the major accelerator institutes: Michael Danilov (Russia's Institute for Theoretical and Experimental Physics, or ITEP), Yoji Totsuka (KEK), Albrecht Wagner (DESY), Michael Witherell (Fermilab), Stanley Wojcicki (Stanford) and Yongsheng Zhu (the Beijing Spectrometer, or BES).

The 300 participants from many countries included a significant number from Vietnam and the Pacific Rim. Nguyen van Hiêu, on behalf of the Vietnamese Academy of Science and Technology, gave an interesting overview of the current state of research in Vietnam. Vietnamese researchers are active participants in international collaborations for two major experiments, D0 at Fermilab and the Pierre Auger Observatory in Argentina. (The Vietnamese contribution to the latter is headed by Pierre Darriulat, formerly of CERN.)

During the meeting, the President of Vietnam, Trân Duc Luong, received a small group of participants from many countries at the Presidential Palace in the presence of Nguyen van Hiêu and Dang Vu Minh of the Academy of Science and Technology.

In his welcome speech, Luong – himself a geophysicist trained in the Soviet Union – emphasized that the development of science and technology is one of Vietnam's major priorities for the coming years. Trân Thanh Vân thanked the President and the Vietnamese people for their warm welcome and support. Danilov, a former director of ITEP, reiterated on behalf of the participants that research in fundamental science is vital for the healthy development of society.

Vietnamese society is rapidly entering a new technological era. Participants who had also attended the Second Rencontres du Vietnam 10 years ago were struck by the changes they saw.

NEW PRODUCTS

CEDIP Infrared Systems has announced a new toolkit for use with its range of cameras, which enables simple setting up and control via the LabVIEW programming environment. The toolkit enables users to acquire, store, retrieve, display and process still images and video using CEDIP's infrared cameras, and is provided on a CD-ROM. For further information, call +33 1 60 37 0100, e-mail cedip@cedip-infrared.com or visit the website www.cedip-infrared.com.

Fujikura Europe has released the SpliceMate, which it claims is the world's smallest laser fusion splicer for fibre optics, measuring 110 × 100 × 80 mm and weighing 640 g. The splicer is designed to be highly portable, so can be used in areas of limited access. For further details, call Neil Bessant on +44 20 8240 2027.

Lambert Instruments has developed an intensified charge-coupled device camera, the LI^{2}CAM, for industrial and scientific applications. It offers high sensitivity down to the single-photon level combined with speeds of up to 15 fps at a full resolution of 1392 x 1040 pixels. Other features are fast gating down to 40 ns (5 and 2 ns are optional) and external triggering. Computer control is via a USB2.0 interface. For further details, call +31 50 501 8461, e-mail info@lambert-instruments.com or see www.lambert-instruments.com.

Pfeiffer Vacuum has issued its 2005–2007 catalogue, covering the complete range of vacuum technology, including equipment for producing, controlling and measuring vacuum, as well as accessories and components. It contains information on the field of application of each product, as well as technical data and part numbers. For an online version see www.pfeiffer-vacuum.com.

Photonic Products has added Panasonic's range of aspherical glass lenses to its portfolio of optoelectronic components. The compact, lightweight lenses, with focal lengths from 0.69 mm to 20 mm, enable devices to be smaller and lighter but with higher performance. Data sheets are available from www.photonic-products.com/products/optics/panasonic_lens.htm.

AWARDS

Art McDonald wins 2004 Bruno Pontecorvo Prize for SNO results

The director of the Sudbury Neutrino Observatory (SNO), Arthur McDonald of Queen's University, Kingston, Canada, has been awarded the Bruno Pontecorvo Prize for 2004 by the Joint Institute for Nuclear Research in Dubna. McDonald receives the prize "for the demonstration of solar neutrino oscillations in the SNO experiment".

SNO has observed neutrinos from boron-8 decay in the Sun via two types of neutrino reactions – one sensitive only to electron neutrinos and others sensitive to all active neutrino flavours – and has found clear evidence of neutrino-flavour change. This confirms the hypothesis of Pontecorvo and Vladimir Gribov that the neutrino-flavour change is responsible for the deficit of solar neutrinos observed in other experiments, thereby solving the long-standing "solar-neutrino problem". SNO's measurements combined with other solar experiments and the reactor neutrino measurements of the KamLAND experiment determine that the oscillation of massive neutrinos is the dominant mechanism for the flavour change.

In his report at the session of the JINR Scientific Council, McDonald not only clearly demonstrated the achievements of the SNO Collaboration but also vividly depicted the Canadian period of Pontecorvo's activities in 1943–1948, in particular his proposals concerning neutrino sources and methods for detecting them.

Left to right: pictured at the award ceremony are Janet McDonald, Arthur McDonald with the 2004 prize, JINR director Vladimir Kadyshevsky and jury chairman Nikolay Russakovich. On the screen is a 1948 photograph of Pontecorvo, who was a Chalk River tennis champion.

A special seminar "The Sudbury Neutrino Observatory: confirming Pontecorvo's neutrino theories" was held at the Dzhelepov Laboratory of Nuclear Problems where Pontecorvo worked from 1950 until the end of his life. The seminar was devoted both to the latest results obtained by SNO and the future neutrino investigations at the SNOLAB underground laboratory; Pontecorvo's role in the development of massive neutrino physics and oscillation theory as a founder of this field of research was also discussed.

Max Planck award goes to particle physics and radio astronomy

The Max Planck Research Award 2005 has been awarded to the German particle physicist Christof Wetterich and the US radio astronomer Christopher Carilli. The award for international co-operation is made to one scientist working in Germany and one working abroad, both recognized at the international level and from whom continued high-calibre scientific work can be expected in the context of international co-operation.

Wetterich, from Heidelberg University, receives the prize in recognition of his work on cosmology, in particular dark energy. With his proposal of a dynamical dark energy, "quintessence", he has provided one of the most popular explanations for the accelerated expansion of the universe. He is also well known as an outstanding expert at bringing forward co-operation between theoretical physics, astronomical observations and numerical simulations.

Carilli works at the National Radio Astronomy Observatory in Socorro, New Mexico, and is an expert in radio astronomy. He observes traces of the most distant galaxies at early times in the universe and promotes the development of observation devices and measuring techniques. Carilli is also heavily involved in the development of the next generation of radio telescopes.

SCIENTIFIC PUBLISHING

CERN reaffirms commitment to open access

At a meeting on 20 March, CERN's Executive Committee endorsed a policy of open access to all of the laboratory's results, as expressed in the document "Continuing CERN Action on Open Access" released by its Scientific Information Policy Board (SIPB) earlier in the month. Today open access to scientific knowledge is the goal of an increasingly large component of the scientific community worldwide. Made possible by new electronic tools, it is a concept that would bring enormous benefits to all scientists by giving them free access to research results.

CERN has implicitly supported this principle from the very beginning. The organization's Convention, adopted in 1953 by the 12 founding member states, stipulates that "...the results of its experimental and theoretical work shall be published or otherwise made generally available". However, it is only in recent years that the technology has been developed to enable this aim to be achieved in practice.

The recent endorsement by the Executive Board follows earlier steps CERN has taken – signing the Berlin Declaration on open access in May 2004 at a meeting at CERN (Berlin 2), and, most recently, presenting its plan at a meeting in Southampton in February (Berlin 3). This meeting passed a resolution that closely matches the steps advocated by CERN, calling on research institutions to adopt the two essential features of the open-access movement. These are implementing policies requiring their researchers to deposit each published article in a freely accessible electronic repository, and encouraging their researchers to publish their research in open-access journals, including providing the support so this changeover can take place.

The ever-increasing cost of traditional scientific publishing is another incentive towards changing the publishing model. The CERN Library is currently unable to offer complete coverage of even its core subjects.

● For the document "Continuing CERN Action on Open Access" see http://doc.cern.ch/archive/electronic/cern/preprints/open/open-2005-006.pdf. For more about the Berlin Declaration see www.zim.mpg.de/openaccess-berlin/berlindeclaration.html.

CCLRC sets up e-publishing archive

The UK's Council for the Central Laboratory of the Research Councils (CCLRC) has introduced an electronic-publications archive, which currently contains bibliographic entries for 21 000 publications produced by CCLRC in its various historical forms since 1965.

The e-pubs archive is not intended to replace or duplicate the 500 000 records in the well known SPIRES database of high-energy physics literature, but to complement it by providing access to publications from the CCLRC laboratories at Daresbury, Rutherford-Appleton and Chilbolton. These publications cross a range of disciplines related to particle physics.

At present only a test sample of 400 eprints has been included. However, there are plans to include eprints in the archive of past reports produced by CCLRC, as well as future publications where copyright agreements with publishers permit it. Where eprints cannot be placed in the archive, but the publisher of an article has placed it online elsewhere, e-pubs stores digital-object identifiers that point to the online article, making it a gateway to the online libraries of many publishers.

Unlike many online bibliographies and digital libraries, the CCLRC e-pubs system takes advantage of the generic Web search engines as well as tools directed at academics and researchers. It presents its contents to be harvested either as text or through the protocols of the Open Archive Initiatives (OAI). Eprints thus enjoy far greater visibility than they might otherwise have had.

● CCLRC's e-pubs system can be found at http://epubs.cclrc.ac.uk/index. To find out more information about the OAI see www.openarchives.org/.

LETTERS

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

Sergio Fubini, MESC and SESAME

I read with sadness the obituary of Sergio Fubini (*CERN Courier* March 2005 p39) and would like to add that he played a crucial role in bringing international science to the troubled region of the Middle East. A considerably significant point in this respect was the Sinai Physics Meeting, held at the Egyptian resort of Dahab, on the Gulf of Aqaba, in November 1995. This historic meeting, which brought together Arab, Israeli and Western physicists, was conceived by Fubini, and led directly to the formation of the Middle East Scientific Cooperation (MESC), a network of scientists promoting research co-operation between Europe, the US and the Middle East.

The very idea of an international synchrotron radiation facility in the Middle East emerged from the MESC workshop in 1997. During this workshop Herman Winick of SLAC and Gustav-Adolf Voss, a former director of DESY, suggested using the components of Berlin's BESSY-I machine, scheduled to be closed down in 1999, as the core facility for a new laboratory in the Middle East. The brilliant idea of relocating BESSY-I was taken further through MESC in a series of meetings held under the auspices of UNESCO, CERN and the Abdus Salam ICTP. With the persuasion of Fubini and Herwig Schopper (former director-general of CERN) the German government finally agreed to donate the decommissioned BESSY-I to Middle East (the only region other than Africa without a synchrotron).

The rest is all history: BESSY-I was relocated to Jordan and the synchrotron laboratory with the name of SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East) was put under the auspices of UNESCO. SESAME, now in the advanced stages of completion, has evolved from a vision to a system.

Sameen Ahmed Khan, Middle East College of Information Technology, Oman.

RECRUITMENT

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Information on this project can be found at http://p-therapie.web.psi.ch/proscan.html and in Z. Med. Phys. 14 (2004) 25-34.
For further questions please contact Dr Eros Pedroni, Tel. +41 56 310 35 18.

Please send your application to: Paul Scherrer Institut, Human Resources, Mrs. Elke Baumann, ref. code 2104, 5232 Villigen PSI, Switzerland, e-mail: elke.baumann@psi.ch.

Further job opportunities: www.psi.ch

Deutsches Elektronen-Synchrotron
Neutrino Astrophysics

DESY

DESY is one of the worldwide 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.

The neutrino astrophysics group of DESY assumes central responsibility for development, operation and data analysis of the neutrino telescopes at Antarctica. We have an immediate opening for our branch in Zeuthen for a position as a

Postdoc

Your field of work is the data analysis of the AMANDA and IceCube neutrino telescopes. You will participate in the construction of the IceCube experiment and you might have to work during antarctic summer months at the South Pole.

The job requires a university degree in physics with PhD. Knowledge of the analysis methods and the software frameworks of high-energy and astro-particle physics are prerequisites, as are experience in building and operating experiments. If you want to work in a team of committed physicists and technicians and have a good knowledge of English, please send your application and CV to our personnel department at the address below. For further information email Dr. Stefan Schlenstedt at stefan.schlenstedt@desy.de

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The European Gravitational Observatory, a French-Italian consortium dedicated to the research on gravitational waves, operates the 3 km-long **VIRGO** detector, located in Pisa-Italy.

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UHH

Universität Hamburg

The Institute for Experimental Physics of the Hamburg University invites applications for a

Postdoctoral Position (BAT 2a) in Accelerator Physics

to start July 1st, 2005. The position is limited to a duration of max. 3 years. The salary will be according to the German civil services BAT IIa. There are 40 working hours per week. The limited duration is in accordance with § 57b Hochschulrahmengesetz in its version from 27.12.2004. The opening and its duration depends on final approval of funding for the project "self-seeding at the VUV-FEL at DESY" by the funding agency.

The University of Hamburg is an equal opportunity/affirmative action employer and welcomes applications from qualified women. Equally qualified handicapped applicants will be given preference.

Duties:
The duties consist of scientific work in the project. Within the job framework there will be opportunity to conduct independent research, to gain scientific qualification and to collect teaching experience.

Job profile:
The accelerator physics group of the Institute for Experimental Physics plans to contribute to the Work Package "Seeding and Harmonic Generation", supported by the EU within the EUROFEL collaboration. The successful applicant will work on accelerator physics issues of the "free-electron laser self-seeding scheme" which will be installed in the VUV-FEL at DESY. This requires control of the electron position at the 10 Micrometer level in all three spatial dimensions. Most demanding will be the control of the longitudinal position (i.e. timing) of the electron bunch relative to the photon pulse. The work will include an analysis of sources and mechanisms for the relative jitter of both the electron beam and the photon beam and the development of a technique to stabilize the required overlap.

Candidates must hold a university degree and have a PhD in physics or electrical engineering.

Interested applicants should send a curriculum vitae, a list of publications, a brief statement of research interests and skills and names of three potential referees, **before May 22nd, 2005** to: Prof. Dr. Jörg Rossbach, Institut für Experimentalphysik, Luruper Chaussee 149, D-22761 Hamburg, Germany.

Please don't send originals. For further information please contact: joerg.rossbach@desy.de

TOR ZUR WELT DER WISSENSCHAFT

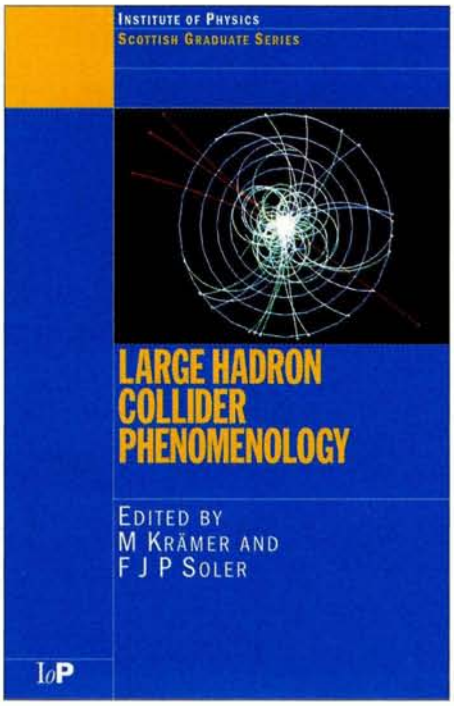
Large Hadron Collider Phenomenology by M Krämer and F J P Soler (eds), Institute of Physics Publishing. Hardback ISBN 0750309865, £75 ($125).

The Large Hadron Collider (LHC) is often described as the machine needed by the worldwide community of high-energy particle physics experimentalists and theorists to search for and, it is hoped, discover physics signals beyond those expected from the Standard Model of particle interactions. The general-purpose experiments now completing construction (ATLAS and CMS) are often described as huge facilities optimized for the search for the elusive Higgs boson, the one key element missing in the Standard Model. About three years from now, the whole community in our field will focus on new and, we hope, unexpected physics results. These will cover a wide range of topics, extending over all possible theoretical conjectures published to date, that are relevant to experiments at the scale of tera-electron-volts.

Given the dearth of guidance from experiments (aside from the beautiful but maddening agreement of even the most precise measurements with the predictions of the Standard Model), the driving goal of all theoretical developments beyond this very same Standard Model is that of solving the many fundamental issues in particle physics, which today are also relevant to cosmology, a science that has become much more mature experimentally over the past 10 years or so.

This book presents a series of lectures attempting to cover LHC phenomenology in the broadest possible sense. They range on one side from the intricacies of scalar fields, string theory and extra dimensions, to the basics of detector physics, which for more than 10 years has guided R&D in our field. This has led to the optimized design of the huge and complex detectors needed to extract minute signals from the huge backgrounds, involving today's exciting physics (electroweak gauge-boson production, quantum chromodynamic multi-jet events, and heavy flavour production). But the lectures also range from accelerator science to modern e-science (the birth of the computing Grid) and from the less well known intricacies of heavy-ion physics to those of forward physics, where diffractive and quasi-elastic phenomena dominate.

These lectures were meant for today's young physicists, many of whom will surely be the driving force behind the physics analyses and publications of the LHC experiments over the coming years. They were delivered on the occasion of the 57th Scottish Universities Summer School in Physics in summer 2003, by a well balanced mix of experienced theorists (D Ross, K Ellis and J Ellis) and seasoned experimentalists (V Gibson, H Hoffmann, B Müller, M A Parker, A de Roeck, R Schmidt and T S Virdee).



The emphasis in most of the lectures was on giving a snapshot of the current status of understanding in theory, phenomenology and accelerator and detector performance. The inevitable fate of such snapshots is to become fairly quickly obsolete, given the huge ongoing development of both the hardware and the software (should one add the middleware?) needed to operate the experiments, to simulate their performance accurately, to analyse their data quickly but unerringly, and to give a fair chance to all participants on all continents to join in the fun in the summer of 2007. Another drawback of such attempts is that, unavoidably, certain topics are treated superficially. However, I believe upon reading large sections of the book that this is largely outweighed by the benefit, for the young and less young reader, of finding in one volume a really complete coverage of all aspects relevant to LHC physics with a sufficiently rich bibliography to pursue in-depth reading.

For example, the reader interested in the phenomenology of quantum chromodynamic (QCD) beyond its direct application to LHC physics is referred to the book *QCD and Collider Physics* (by K Ellis, J Stirling and B Webber, 1996), the reader interested in more in-depth studies of accelerator physics and technology is referred to the *Handbook of Accelerator Physics and Engineering* (by A Chao and M Tigner, 2002), and the reader interested in the design and optimization of the general-purpose ATLAS and CMS detectors is referred to "Experimental challenges in high luminosity collider physics" (by N Ellis and T S Virdee, *Ann. Rev. Nucl. Part. Sci.* **44** 609, 1994) and to all the Technical Design Reports published from these experiments between 1996 and 2005.

In summary, this book is an excellent introduction to LHC physics for any person entering the field now, at a moment when a huge effort from the whole community is still ongoing to meet the difficult challenge of assembling the various jigsaws needed to observe the first proton–proton collisions at the tera-electron-volt scale in summer 2007.

The reader has to be aware though that, apart from the foundations of the Standard Model, of supersymmetric and string theories, and of particle interactions in matter, many of the details provided in the lectures to illustrate the wonderful and exciting potential of the LHC and its associated detectors are to be considered as examples only. These will most likely bear little resemblance to the results published in the final publications a few (or many) years from now. I believe that most experimentalists, who have devoted a large fraction of their professional lives to make the LHC dream come true, hope that reality at the tera-electron-volt scale is something quite different from what has been envisaged to date by our theory colleagues. It is indeed the fulfilment of such a hope that can give a new and much needed impetus to our field, thereby surely opening up rich and thrilling prospects for the generations of theorists and experimentalists to come.
Daniel Froidevaux, CERN.

In Conclusion: A Collection of Summary Talks in High Energy Physics by James D Bjorken, World Scientific. Hardback ISBN 981023869X, £86 ($116). Paperback 9812384650, £40 ($54).

Few people have been asked to give as ▷

many conference summary talks as James D Bjorken; no-one has given them better. It is therefore an interesting idea to collect "Bj's" summaries into a single volume; to some extent, the idea works.

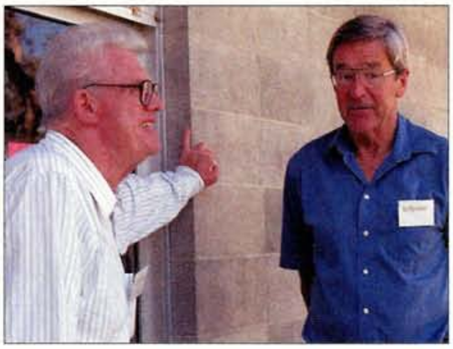
This book is divided into four sections, covering major areas of interest and activity in the author's career. Each section contains around five to seven talks stretching over the 40 or so years of Bj's activity at the forefront of theoretical physics. Each section is preceded by perhaps the most valuable element in the book: a preface in which the author puts each talk in its historical context, explains his thought processes and often delights the reader with a typical piece of self-deprecatory wit.

It must be admitted that many of the talks emit a musty air of controversies long stilled and ideas long forgotten; in particular, the first section, "From Current Algebra to Partons", is at times arcane and difficult unless one is familiar with the subject.

Nevertheless, there are moments of real pleasure in the elegance of Bj's thinking about deep inelastic scattering before the experiments at SLAC made the subject topical. An example is the idea that the known locality of the lepton electromagnetic and weak currents, and their great phenomenological similarity to the hadron currents, strongly implies that the weak and electromagnetic charges in the proton are also point-like. Other gems include the fortunate demise of the US proposal to name the quark colours red, white and blue!

Another fascinating section lays out the background to the discovery of the J/psi; some of the plots clearly show the J/psi enhancement, albeit with poor resolution, while theorists were trying to fit the data with various exotic parton densities and wondering why they got poor fits. Another theme throughout the book, illuminated with Bj's mordant wit, is the wonderful nature of hindsight.

The second half of the book is significantly more interesting to the experimentalist than the first, particularly the talks relating to the interpretation of electron–positron annihilation. A particular joy is the inclusion on page 233 of Bob Gould's immortal cartoon of the J/psi discovery. The final section deals with futurology. Many of the ideas contained therein are remarkably prescient and of value even today. Typically, Bj draws attention to areas in which he went spectacularly wrong:



Bjorken (right) at the symposium Bj's Day in the Sun, held at SLAC in 2000. On the left is his SLAC colleague and 1990 Nobel laureate Dick Taylor. (Courtesy Harvey Lynch.)

first opposing the Superconducting Super Collider (SSC) as too ambitious, he became a convert and just before its demise gave a talk saying how wrong he had been and that the SSC was clearly politically secure. Well, this reviewer made the same mistake and is proud to be in such illustrious company.

There is much pure gold in this book. As a primer on many of the major ideas of modern particle physics explained by one of its foremost architects, it is a work of lasting value. Sadly, it is littered with misprints and typographical errors, but presumably these are propagated unchanged from the original articles. Reading it from cover to cover is not to be recommended; dipping into it and benefiting from Bj's unique combination of wisdom and wit most certainly is.
Brian Foster, Oxford.

Fermi Remembered by James W Cronin (ed.), University of Chicago Press. Hardback ISBN 0226121119, $45.00.

Enrico Fermi is one of the great physicists of the 20th century. He died relatively young at the age of 53, so many of us (where "us" means even retired physicists) never had the opportunity to have direct contact with him, and the younger generation had no chance to meet him anyway. This is one reason why it is so important to collect testimonies about Fermi to try to get a picture of his work and of his personality. So the enterprise undertaken by Jim Cronin is certainly extremely useful. It also comes at the right time, before all those who were in contact with Fermi disappear (some, such as Herb Anderson, are no longer with us).

I never had the occasion to meet Fermi despite the fact that I am old enough to have known many of the participants in the Manhattan Project. I did not have the luck to attend, as Georges Charpak and Michel Gourdin did, the lectures given at Les Houches during his last summer in 1954. (Curiously, nobody, not even Segrè, in the biography that is included in the book, mentions these lectures.) At that time, my only contact with Fermi was through his magnificent lecture course, the notes of which were written by Orear, Rosenfeld and Schluter.

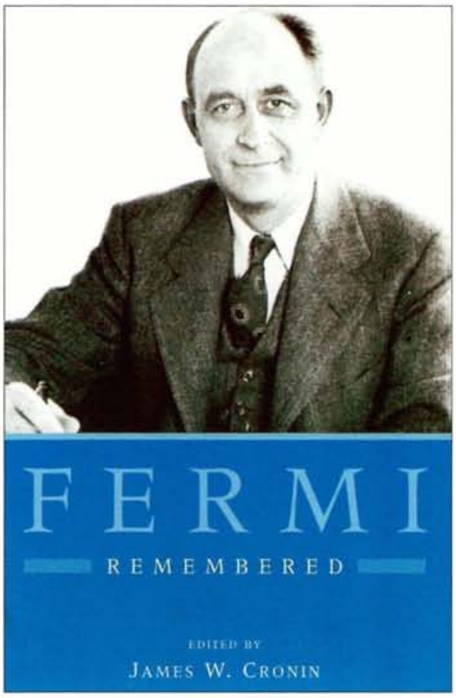
Before reading this book, I had heard many testimonies from Fermi's Italian and US colleagues or students. All admired his genius and all liked him very much as a man. All except one – my late friend Boris Jacobsohn, who had a better relationship with Teller (which was strange because Boris was a liberal). One gets a somewhat better idea of who Fermi was after reading the 26 testimonies in this book.

It is no accident that among these accounts we find seven Nobel laureates and one winner of the Wolf prize, plus a few exceptional individuals such as Dick Garwin. It proves the quality of Fermi's teaching, and the fact that he attracted very gifted people. He was of course extremely intelligent. He was able to simplify any problem, solve it and make it appear simple, to a point that sometimes people could not reconstruct his arguments afterwards. And he never made mistakes. On these two points Murray Gell-Mann commented that sometimes he preferred the not well prepared lectures of Vicky Weisskopf as well as his mistakes, which were more educative.

Fermi disliked generalities and preferred concrete things, in theory preferring to work examples until the end (a point of view with which I have a great sympathy), in experiments going as far as inventing and constructing his own instruments, such as the cart for moving a target inside the Chicago cyclotron. He was very careful, very precise, and this may be the key to his success in producing the first fission chain reaction in natural uranium, where criticality was, after all, rather marginal.

Fermi's contacts with politics and politicians were rather minimal. Yet he wrote to Benito Mussolini asking him to search for the missing Ettore Majorana and to Dean Acheson asking him to let Linus Pauling trave outside the US. However, he never tried to influence the decision to drop the bomb.

Fermi was very nice with young people, inviting them to parties and organising game



which he liked to win. He liked to win at sports too, whether swimming in Lake Michigan, rock climbing or playing tennis (although he lost against Leprince Ringuet, who, it must be said, was trained by the French champion Jean Borotra). He also liked to compete in physics. He once said to Jack Steinberger with some regret but great honesty: "I missed fission." Yet he was also extremely fair, referring to "Fermi statistics" as "Pauli statistics". Curiously he was not interested in art, while most scientists are at least attracted by music.

Among the testimonies, I would say that the most objective, the most balanced, is that of "Murph" Goldberger. In others one feels sometimes a kind of "cult of the personality". A very amusing chapter is that of Nina Byers, in which she compares two very different individuals, Fermi and Leo Szilard, who both did pioneering work on nuclear reactors, but whose paths separated completely. In this way, Byers, a well known opponent of the use of nuclear weapons, manages not to criticize Fermi explicitly for not opposing the use of the bomb. Also of great interest are the review of Fermi's theoretical achievements by Frank Wilczek, who received the Nobel prize probably after writing his article; Fermi's talk on the genesis of the nuclear-energy project, which is more complete than in his 1947 review in *Science*; and the reconstruction by Jim Cronin of Fermi's far sighted talk on the future of accelerator research.

I can only very strongly recommend reading this book. Just a detail: if you have my eyesight use a "Fresnel lens" to read the reproductions of the letters, which have been unnecessarily reduced. Regarding Fermi's Italian time, there is other material besides the biography by Segrè, mentioned above, in particular the article by Edoardo Amaldi in *History of Twentieth Century Physics*, Academic Press, New York, 1977, pp295–351. There are also the videotapes of the lectures of Gian-Carlo Wick in the Academic Training programme at CERN.
André Martin, CERN.

Enrico Fermi: His Work and Legacy by Carlo Bernardini and Luisa Bonolis (eds), Springer. Hardback ISBN 3540221417, €35.95 ($49.95).

In 2001, the centenary of Enrico Fermi's birth, the Italian Physical Society commissioned a series of articles to pay tribute to the man who was probably the most famous Italian scientist of the 20th century. Written by close colleagues as well as scientists whose fields Fermi influenced profoundly, the papers were published originally in Italian in *Conoscere Fermi nel centenario della nascita 29 settembre 1901–2001* (SIF 2001). Now they have been translated into English and are available in this volume, which bears witness to the originality and breadth of Fermi's scientific work. They confirm that Fermi was a rare combination of theorist, experimentalist, teacher and inspiring colleague.

The book begins with three biographical overviews written by close colleagues after Fermi's death and ends with a year-by-year chronology of his scientific endeavours. In between are 14 chapters by a variety of distinguished scientists, which span the breadth of Fermi's achievements in physics. With an extensive bibliography and many illustrations, the book is written for a general scientific audience.

Books received

Superconductivity by V L Ginzburg and E A Andryushin, World Scientific. Hardback ISBN 981238913X, £10 ($16).

First written in 1989, this non-technical introduction to superconductivity has now been published as a revised edition. Written in a lively style, the book provides an excellent background for students at school or college, without recourse to mathematics. One of the authors, Ginzburg, received the Nobel Prize for Physics in 2003.

Gravitation: from the Hubble Length to the Planck Length by I Ciufolini *et al.* (eds), Institute of Physics Publishing. Hardback ISBN 0750309482, £80 ($125).

This volume in the series *High Energy Physics, Cosmology and Gravitation* provides a summary of modern research in experimental gravity, cosmology and the quantum theory of gravitation. Based on lectures at the Villa Mondragone International School on Gravitation and Cosmology, it brings together leading experts who present an up-to-date review of their field.

A Modern Introduction to Quantum Field Theory by Michele Maggiore, Oxford University Press. Hardback ISBN 0198520735, £47.95 ($99.50). Paperback 0198520743, £23.95 ($44.50).
This book is a welcome addition to the *Oxford Master Series in Statistical, Computational, and Theoretical Physics*, aimed at final-year-undergraduate and beginning-graduate level. Assuming no previous knowledge of quantum-field theory, it introduces modern developments in the field. The inclusion of more advanced topics will also make this a useful book for graduate students and researchers.

VIEWPOINT

When research meets commerce

Bart Van de Vyver relates his experience of technology transfer when he left CERN to create a start-up company exploiting biotechnology research.

A dynamic technology-transfer department is only one of many factors determining how often and how successfully start-up companies will be created. This belief is not based on any solid evidence, but on a single example with, at best, anecdotal value. The example is from my own experience over the past three years in helping to create SpinX Technologies, a start-up company developing instruments for pharmaceutical research and clinical diagnostics.

The SpinX story started around Christmas 2001 in a branch of IKEA. Following a casual conversation with a stranger sharing his table at the cafeteria, Piero Zucchelli from CERN could not let go of one thought. Of the myriad technologies used or developed at CERN, there had to be some just waiting to be exploited outside of particle physics. Since my summer-student days when Piero had been my supervisor, we frequently worked together and I had become interested in business as well as in molecular biology. Over the next few weeks, we spent countless hours brainstorming how technology at CERN could be applied to biotechnology.

Gradually, we zoomed in on a field where many advances had been the work of physicists: microfluidics. The idea behind microfluidic devices, often called lab-on-a-chip systems, is to perform biochemical experiments using sub-microlitre volumes rather than millilitre volumes. Liquids are manipulated by running them through channels no wider than a human hair laid out on a silicon or plastic substrate. The applications are mostly biochemical and range from food testing to drug discovery.

What struck us most is that all microfluidic devices were specialized for a specific type of biochemical experiment characterized by a well defined but fixed sequence of operations. There were none where different protocols could be "programmed" on the same chip by setting a series of valves. Before long, Piero had come up with a valve implementation using an infrared laser. With this Virtual Laser Valve, everything started to fall into place and we soon had all the elements for a programmable microfluidics platform.

At some point a friend at CERN suggested that, if we were serious about this idea and believed it had commercial value, we should take it to serious investors. He would make the introductions. With nothing but an idea, we crossed the doorstep at Index Ventures, a venture-capital fund managing €750 million. It took us half a year to build their interest. For us, this was a turning point. Leaving the comfort of stable, well paid positions in research, we had to devote all our time and energy to SpinX with no guarantee of success.

Our case illustrates where a technology-transfer department can make a very real contribution, but also where it is essentially powerless. Contacts with venture-capital funds, law firms, business consultants and so on are obviously helpful to any aspiring entrepreneur, and a technology-transfer department is ideally placed to build this kind of network. But the key factor in attracting high-quality capital is commitment. Francesco de Rubertis, a partner at Index Ventures, says, "We do not invest in technologies, but in the teams that can make them happen." Venture capitalists expect the people behind an idea to be entirely devoted to their start-up. Anything less is a sure deal-breaker.

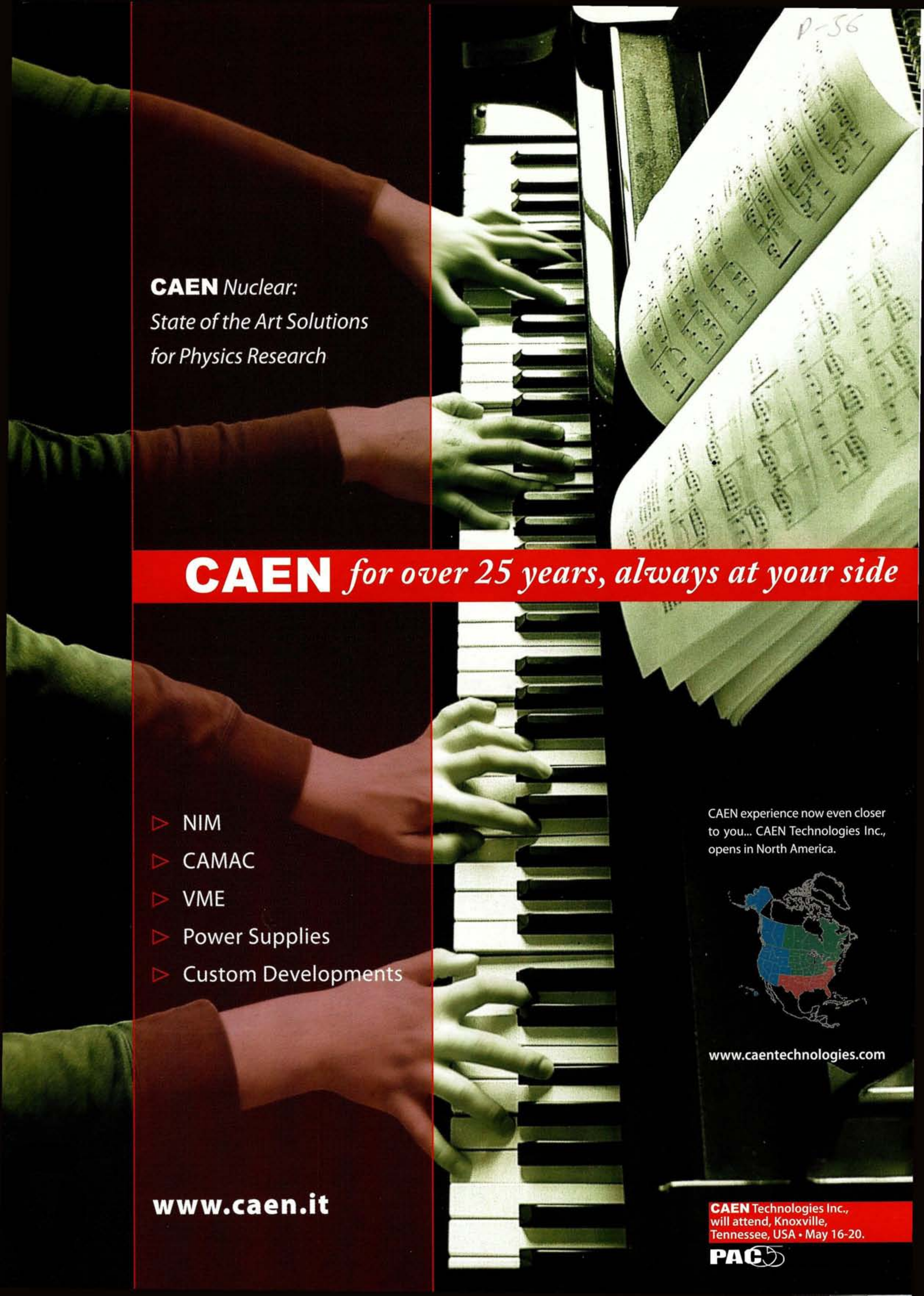
Throughout the process, the interaction with CERN in general and technology transfer at CERN in particular could not have been more productive. Both of us were offered leave from the moment we started to work full time until the moment the investors committed. During the due-diligence process, the technology-transfer department provided us in record time with a legal statement clarifying the ownership of the intellectual property.

We did convince Index Ventures of our business concept, SpinX was created and the experience has been extremely rewarding. Today we are a company of 10 people, we have identified the first application of our technology, we have built a working system for that application and we are talking with several pharmaceutical companies interested in evaluating the system.

Would SpinX exist if it hadn't been for CERN? I doubt it. We may not have started from any specific technology at CERN, but we could not have done it without the experience built there. It was at CERN that we learned the importance and benefits for international, multi-disciplinary teams to "try the impossible". With 10 people, SpinX has seven nationalities and six doctorates, with backgrounds ranging from physics and engineering to biochemistry and enzymology. Like particle detectors at CERN, the instrument we developed uses a host of off-the-shelf components from widely varying industries. Finally, there is the undeniable value of the CERN brand. Recently, following a conference presentation of the technology to a senior executive at Eli Lilly, he commented that if former CERN physicists could not get it to work, then nobody could!

• To find out more about CERN's Technology Transfer Group, see p25.

Bart Van de Vyver, founder, SpinX Technologies.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