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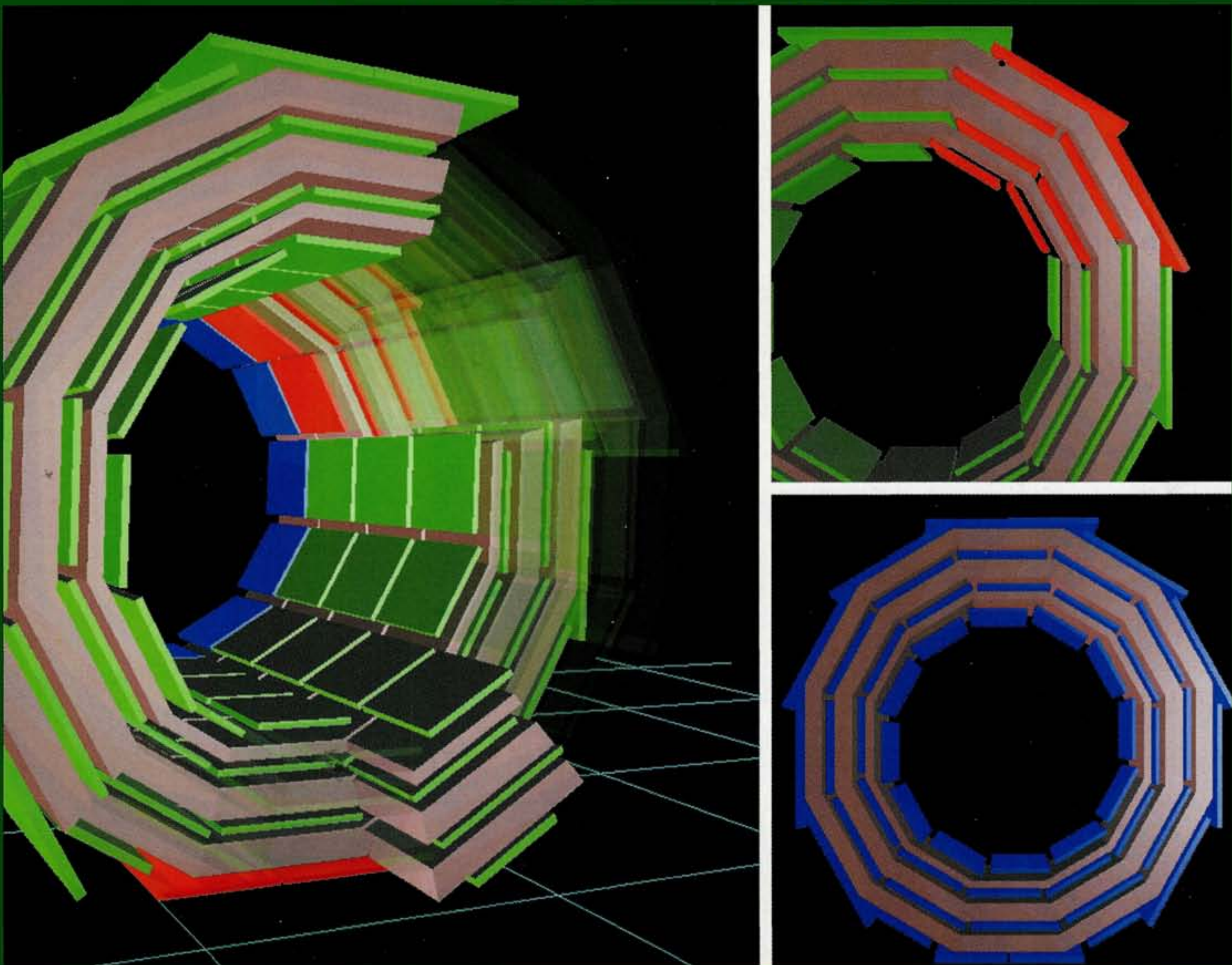

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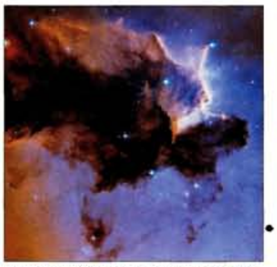
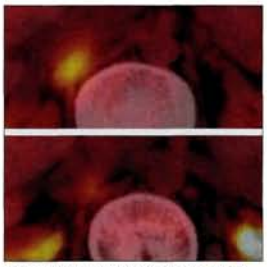
LHC cooling reaches milestone p5



Hubble revisits Eagle Nebula p12



PET and CT help fight cancer p23

Cover: Part of the control-system user interface prepared for one of the CMS sub-detectors (the muon drift tubes), where green indicates the correct operational state, blue indicates off and red indicates an error state. (Courtesy Robert Gomez-Reino.) Commercial solutions are being increasingly used for control systems at CERN (p19).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CERN

LHC cryogenic unit keeps its cool

The cryogenic system for the Large Hadron Collider (LHC) at CERN reached a major milestone on 7 April by achieving operation of the unit at Point 8 at its nominal temperature of 1.8 K. The LHC and its superconducting magnets are designed to operate at this very low temperature, making the 27 km accelerator the coldest large-scale installation in the world. Although acceptance tests performed on the surface had already reached the required temperature in 2002, this is the first time that the nominal temperature has been achieved *in situ*.

The LHC cryogenics system is hugely complex, with 31 kt of material (compressor stations, cold boxes with expansion turbines and heat exchangers, and interconnecting lines) requiring 700 kl of liquid helium passing through 40 000 pipe junctions.

Although normal liquid helium at 4.5 K would be able to cool the magnets so that they became superconducting, the LHC will use superfluid helium at the lower temperature of 1.8 K. Superfluid helium has unusually efficient heat-transfer properties, allowing kilowatts of refrigeration to be transported over more than 1 km with a temperature drop of less than 0.1 K.

Eight cryogenic installations distributed around the LHC ring, with a total power exceeding 140 kW, will cool the helium in two stages, first to 4.5 K and then to the final 1.8 K. Four units built by the Japanese-Swiss consortium IHI-Linde have already been installed; the other four units, made by the French company Air Liquide, are currently being installed and will be tested in 2006.

Adrien Forgeas, of the Commissariat à l'Energie Atomique (CEA), Grenoble, one of the team responsible for supervising the installation and commissioning the cryogenic unit at Point 8.

B-DECAYS

Analysis method measures angle γ

Up to a few years ago, no significant measurement of the angle γ in the unitarity triangle of B-meson physics was expected to come out of the current B-factories. However, a recent proposal to measure γ in $B \rightarrow DK$ decays using a Dalitz plot analysis has revolutionized the field. Results are emerging from both the B-factories at KEK and at SLAC.

Determinations of the Cabibbo–Kobayashi–Maskawa (CKM) matrix elements provide important checks on the consistency of the Standard Model and ways to search for new physics. The CKM matrix parameterizes the mixing of different quarks as seen by the weak interaction and provides the Standard Model interpretation for charge–parity (CP) violation.

The nine complex elements of the matrix are related by unitarity constraints to a series of equations. One such relationship of specific interest to B-physics can be represented by a triangle, referred to as the "unitarity triangle". The angles of the unitarity triangle are referred to as α, β and γ (φ_2, φ_1 and φ_3 respectively in Japan). Although β has already been measured with an accuracy of a few degrees, it is more difficult to measure α and γ accurately.

The new analysis uses three-body decay of the neutral D, $D^0 \rightarrow K_s\pi^+\pi^-$ from the channels $B^\pm \rightarrow D^0K^\pm$, $B^\pm \rightarrow D^*K^\pm$ and $B^\pm \rightarrow DK^{*\pm}$. In the Dalitz plot analysis on the three-body decay of the D the invariant mass of the $K_s\pi^+$ system is plotted versus the $K_s\pi^-$ system in two dimensions, helping a measurement of an asymmetry when looking at B^+ compared with B^- decays. The method also utilizes more event information and is thus more sensitive compared with a 1D approach.

Using a data sample of 253 fb^{-1}, the Belle collaboration at KEK obtains 276 signal candidates for $B^\pm \rightarrow D^0K^\pm$, 69 candidates for $B^\pm \rightarrow D^*K^\pm$ and 56 candidates for $B^\pm \rightarrow DK^{*\pm}$ (Abe *et al.* 2004 and 2005). Combining the first two channels yields the result $\gamma = 68° \pm 14° \pm 13° \pm 11°$. The first error is statistical, the second is experimental systematics and the third is model uncertainty. The statistical significance of CP violation is 98%. This is not quite enough to claim observation of direct CP violation just yet, but it is getting close.

The BaBar collaboration at SLAC is also working on a similar analysis and their preliminary result stands at $\gamma = 70° \pm 26° \pm 10° \pm 10°$ (Aubert *et al.* 2004). Such values of γ agree with what is expected by the Standard Model and global fits of other information; moreover, the Dalitz plot method is fast becoming an established tool for measuring γ.

Further reading

K Abe *et al.* The Belle collaboration 2004 http://arxiv.org/abs/hep-ex/0411049
K Abe *et al.* The Belle collaboration 2005 http://arxiv.org/abs/hep-ex/0504013
B Aubert *et al.* The BaBar collaboration 2004 http://arxiv.org/abs/hep-ex/0408088

DETECTORS

CMS VPT production reaches 10 000 mark

Joolz Williams working on the vacuum phototriode testing system at the Rutherford Appleton Laboratory. CMS will ultimately use 15 500 VPTs. (Courtesy CCLRC RAL.)

The CMS experiment, under construction for the Large Hadron Collider (LHC) at CERN, recently took delivery of its 10 000th vacuum phototriode (VPT), to be used in the Electromagnetic Endcap Calorimeter. The occasion was marked by a seminar organised in St Petersburg by the VPT manufacturer, National Research Institute Electron. The manufacturing programme is scheduled for completion in early 2006, when a total of 15 500 devices will have been delivered.

The VPT is a single-stage photomultiplier, developed for CMS by groups at the Rutherford Appleton Laboratory, Brunel University and the Petersburg Nuclear Physics Institute, Gatchina. In CMS, each VPT will be bonded to a scintillating lead-tungstate crystal supplied by the Bogoroditsk Techno-Chemical Plant, also in Russia. Each CMS endcap will contain 7324 such crystals and VPTs.

The LHC will provide a very demanding environment for the detectors: they must operate for 10 years under intense gamma and neutron irradiation, and in a magnetic field of 4 T.

In addition, the beam-crossing rate of 40 MHz means that the VPTs must respond to light signals on a timescale of a few nanoseconds. Only a few manufacturers in the world are able to meet the technical requirements of the CMS experiment.

The seminar in St Petersburg was attended by representatives of CERN, the CMS experiment, NRI Electron, and OJSC Russian Electronics, the holding company of both NRI Electron and Bogoroditsk Techno-Chemical Plant. At the end of the seminar, the Russian Academy of Engineering Science gave a special award to Hans Rykaczewski, the CMS-ECAL resources manager, to recognize his contribution to the collaboration between CERN and Russian industry.

NUCLEAR PHYSICS

Double dose of magic proves key to element production

Researchers at Michigan State University's National Superconducting Cyclotron Laboratory (NSCL) have reported the first measurement of the half-life of nickel-78 (^{78}Ni). With completely filled proton and neutron shells, ^{78}Ni is doubly magic and also neutron-rich, and is an important element for understanding heavy-metal nucleosynthesis.

Doubly magic nuclei are of fundamental interest to nuclear physics, as their simplified structure makes it feasible for them to be modelled. In addition, neutron-rich nuclei play an important role in the astrophysical rapid neutron-capture process, or "*r* process". The *r* process is responsible for the origin of about half of the elements heavier than iron in the universe, yet its exact mechanism is still unknown. ^{78}Ni is the only doubly magic nucleus that provides an important "waiting point" in the path of the *r* process, where the reaction sequence halts to wait for the decay of the nucleus.

There are 10 doubly magic nuclei (excluding super-heavy ones), and only four of these are far from stability: ^{48}Ni, ^{78}Ni, ^{100}Sn and ^{132}Sn. Of these, (neutron-poor) ^{48}Ni and (neutron-rich) ^{78}Ni are the last ones with properties yet to be experimentally measured. Now the results from NSCL demonstrate that experiments with ^{78}Ni are finally feasible.

In this experiment, a secondary beam comprised of a mix of several neutron-rich nuclei near ^{78}Ni was produced by the fragmentation of a ^{86}Kr^{34+} primary beam with and energy of 140 MeV per nucleon on a beryllium target at the NSCL Coupled Cyclotron Facility. A total of 11 ^{78}Ni events were identified over a total beam-time of 104 h. The half-life obtained, $110 + 100 - 60$ ms, is lower than models predict. The measurement provides a first constraint for nuclear models and valuable experimental input to the understanding of the *r* process.

Further reading

P T Hosmer *et al.* 2005 *Phys. Rev. Lett.* **94** 112501.

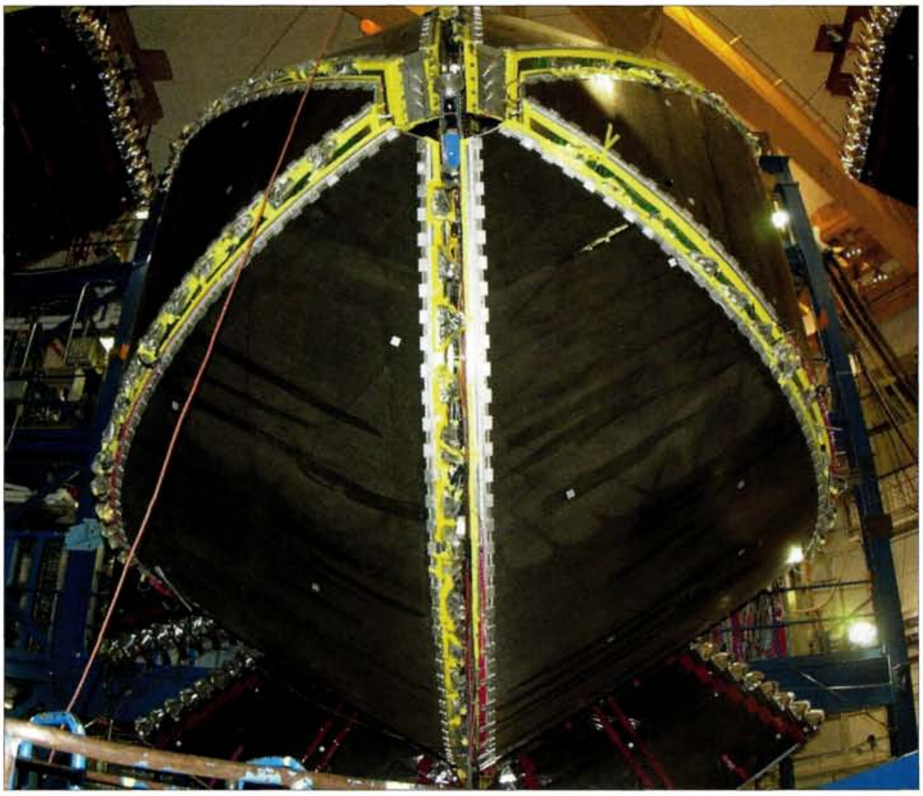
JLAB

Mystery deepens as pentaquarks refuse to make an appearance

Preliminary data on the hot topic of the search for pentaquarks were presented at the April Meeting of the American Physical Society by the Jefferson Laboratory's CEBAF Large Acceptance Spectrometer (CLAS) collaboration. Quantum chromodynamics (QCD) does not forbid exotic, pentaquark states comprising four quarks and an antiquark, but the jury is still out as to whether such a state has been observed. Several experiments have published positive results while an equal number of different experiments have found nothing. The new result adds to the negative evidence.

The g11 experiment at the CLAS detector is a fixed-target photoproduction experiment in which a tagged photon beam, with photon energies individually measured, at an energy of 1.6–3.8 GeV hits a proton target. Data-taking was completed in 2004 with 70 pb^{-1} of integrated luminosity. The collaboration searched for the $\Theta^+(1540)$ produced together with a neutral kaon in the reaction $\gamma p \rightarrow \Theta^+\overline{K}^0$, where the $\overline{K}^0$ is detected via its K^0_S component decaying into $\pi^+\pi^-$.

The Θ^+ is expected to decay into a neutron and a K^+, and the neutron is reconstructed from the missing mass in the reaction. No signal is seen in the nK^+ mass spectrum, putting a limit on the production cross-section for $\gamma p \rightarrow \Theta^+K^0$bar of less than 4 nb at a 95% confidence level.



New results from the g11 experiment at Jefferson Laboratory's CLAS detector, seen here with the "clam-shell" open, are adding to the pentaquark mystery. (Courtesy JLab.)

This result is at odds with a published analysis of CLAS, where a Θ^+ signal was seen with a 7.8 σ significance in the reaction $\gamma p \rightarrow \Theta^+\pi^+K^-$. The earlier study was performed on 5 pb^{-1} of data, where a couple of severe geometry cuts had to be applied to the original nK^+ distribution to reveal the Θ^+ signal. An experiment at higher energy to verify this result is planned.

POLICY

EU decides on the future of research

On 20 April Europe's seven major intergovernmental research organizations, working together in the EIROforum partnership, presented their comprehensive paper on science policy, "Towards a Europe of Knowledge and Innovation".

Five years ago, at the meeting of the European Council in Lisbon, the creation of a European Research Area (ERA) was proposed as a means to achieve the ambitious targets necessary to develop a leading, knowledge-based economy in Europe.

Two years later the EIROforum partnership was created between seven of Europe's major intergovernmental research organizations, the oldest of which is CERN. These organizations operate some of the largest research infrastructures in the world, with a combined budget comparable to that of the current Sixth Framework Programme (FP6) of the European Union (EU).

The EIROforum paper describes the partnership's collective vision for the future of European scientific research necessary to support the Lisbon Process by working for the implementation of the ERA. The partners support the creation of a climate in Europe in which competitive research is undertaken in an efficient, cost-effective and successful manner. The aim is to be able to recruit and retain world-leading scientists in Europe, and at the same time help European industry by promoting joint front-line research that can ▷

POLICY

generate important spin-offs. The paper presents many concrete ways in which the EIROforum organizations can participate effectively in the consolidation of the ERA.

A couple of weeks earlier, the European Commission adopted the proposal for the seventh Framework Programme (FP7). FPs are the EU's main instrument for funding research in Europe. They cover a period of five years with the last year of one FP and the first year of the following FP overlapping. FP6 has been operational since 2003 with a total budget of €17.5 billion. FP7 will cover the period 2007–2013 with a budget of €72.7 billion and a time span of seven instead of five years. The ambitious proposal calls for improved efficiencies and aims to build on the achievements of previous programmes.

A new element is the establishment of a "European Research Council", an independent, science-driven body that will fund European frontier research projects and ensure that European research is competitive at a global level. It will implement the peer review and selection process and will ensure the financial and scientific management of the grants. The EIROforum paper also supports this proposal.

In a third European initiative, on 8 April the European Strategy Forum on Research Infrastructures (ESFRI) presented the EU Commission with its paper "Towards New Research Infrastructures for Europe – the ESFRI 'List of Opportunities'". The forum was launched in April 2002 to support a coherent approach to policy-making on research infrastructures in Europe. Its horizon is the next 10–20 years.

The projects chosen had to be of pan-European interest, in an advanced state of maturity so that they can receive funds in FP7 and of international relevance. The forum wanted a "balanced" list that best corresponds to major needs of Europe's scientific community. Out of a total of 23 opportunities, there were four projects on physics and astronomy, four on multidisciplinary facilities and one in computing.

Of the physics and astronomy projects, two are in nuclear physics, one in astronomy and one in neutrino physics (KM3NeT, a future deep underwater experiment in the Mediterranean). Multidisciplinary facilities include a European X-ray free-electron laser (XFEL) facility. The report also mentions, without specific details, five global projects with strong European participation, including the International Space Station (ISS) and the International Linear Collider (ILC).

● The seven EIRO forum members are the European Organization for Nuclear Research (CERN), the European Fusion Development Agreement (EFDA), the European Molecular Biology Laboratory (EMBL), the European Space Agency (ESA), the European Southern Observatory (ESO), the European Synchrotron Radiation Facility (ESRF) and the Institut Laue–Langevin (ILL).

BETA DECAY

Neutral Atom Trap at TRIUMF places best limits on scalar bosons

"Table-top" experiments can still probe physics complementary to particle searches at high-energy accelerators. A beta-neutrino correlation experiment using TRIUMF's Neutral Atom Trap (TRINAT) has now set the best limits on general scalar interactions contributing to nuclear beta decay.

TRINAT uses the radiation pressure of laser light to capture radioactive atoms in a 1 mm-sized cloud. Laser light of a frequency slightly below an atomic resonance is shone from all sides of the trap. Atoms moving away from the trap then "see" along their direction of motion light that is blueshifted closer to the resonance, while away from their direction of motion they see light redshifted further away from resonance. The net effect is of radiation pressure opposite to the direction of motion, as the atom absorbs more light that is closer to its resonance.

The trapped atomic nuclei undergo beta decay, which produces three decay products: a positron (β+), a neutrino (ν) and the recoiling daughter nucleus. The daughter nucleus has a kinetic energy of 0–430 eV; while it would stop in 1 nm of material, it can escape the trap. By measuring the momentum of the nucleus in coincidence with that of the β+, the TRINAT team can deduce the momentum of the neutrino more accurately than in previous experiments (which did not measure the recoil energy).

The microchannel plate/electric-field assembly – the heart of the trap-detection apparatus in TRINAT. The electric-field rings (in black) accelerate the Ar ions produced by beta decay; they are then detected at the MPC (shown in the picture to the right of the white support).

These techniques have been pioneered at TRIUMF using potassium isotopes with 1 s half-lives produced at the Isotope Separation and Acceleration (ISAC) facility with the main TRIUMF cyclotron – this "table-top" experiment admittedly is driven by the world's largest cyclotron. Results are also becoming available from other experiments based on neutral-atom traps at Berkeley and Los Alamos.

In the Standard Model the weak interaction is mediated by spin-1 vector bosons, the W^+, W^- and Z. Measurements of the $\beta-\nu$ angular distribution in the decay of $^{38}K^m \rightarrow {}^{38}Ar + \beta + \nu$ where both parent and daughter have no nuclear spin allow the search for contributions from hypothetical spin-0 scalar bosons. The TRINAT result for the $\beta-\nu$ correlation parameter a is $0.9981 \pm 0.0030 \pm 0.0037$, consistent with the Standard Model value $a = 1$.

The previous best result, by a Seattle–Notre Dame collaboration using beta-delayed proton emission of ^{32}Ar produced at the ISOLDE facility at CERN, is in the process of being re-evaluated after new measurements of the mass of parent and daughter. Such results constrain the existence of spin-0 bosons with mass:coupling ratios as great as four times the W^+ mass, and are complementary to other measurements.

TRINAT can determine detector response functions *in situ* from the data itself. This is routinely done in high-energy experiments but never before for low-energy beta decay. The experiment has also used the equivalent of the missing-mass construction in high-energy physics to constrain the admixture of possible sterile neutrinos of million-electron-volt mass with the electron–neutrino.

TRINAT is also investigating other physics topics. These include measuring the neutrino asymmetry from polarized nuclei to search for evidence of non-Standard Model right-handed neutrinos (using a complementary measurement to the purely leptonic muon-decay studied at TRIUMF and PSI – *CERN Courier* May 2005 p8); measuring the spin asymmetry of the daughter nuclei in pure Gamow–Teller decays; and testing hints of a nonzero tensor interaction reported in $\pi \rightarrow \nu e \gamma$ by the PIBETA collaboration at PSI.

Further reading

A Gorelov *et al.* 2005 *Phys. Rev. Lett.* **94** 142501.

Compiled by Steve Reucroft and John Swain, Northeastern University

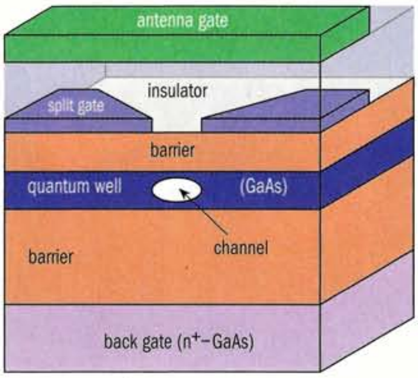
On-chip NMR could benefit quantum computing devices

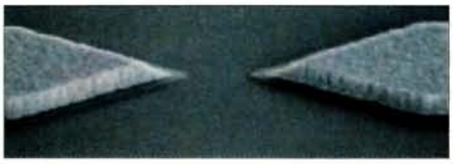
Nanoscale gallium arsenide resonators may be the key to a new approach to quantum computing. Go Yusa of NTT Basic Research Laboratories in Japan and colleagues have created a semiconductor device in which they can control nuclear spins in a region on the scale of a few nanometres.

The device is constructed in a tiny slab of gallium arsenide, 100 nm by 600 nm and 20 nm thick, which consists basically of a narrow constriction in which a 2D electron gas forms, and an antenna gate via which a radio-frequency field can be applied to the channel. This allows the researchers to polarize only the nuclear spins in this nanometre-scale region.

The researchers apply a static magnetic field to the device then pass a current through the structure, producing a large polarization in the nuclear spins in the narrow channel. The polarization can be determined by the effect that a second, oscillating magnetic field has on the resistance of the device.

The researchers are able to map out a wide range of NMR transitions, including ones that differ not only by one unit of $h/2\pi$, but also by two or three units, and they can also set up coherent superpositions that last as long as 1 ms. The work opens up the possibility of making quantum computing devices with completely electrical readouts, and it could also revolutionize chemical analysis. Biological molecules can, in principle, be placed on the device and, through interactions that couple their nuclear spins to it, have their NMR spectra determined for quantities as small as picomoles.





Top: schematic illustration of the structure of the NMR device, based on a 20 nm gallium arsenide quantum well. A pair of Schottky split gates defines the point contact channel, indicated by a white ellipse. Bottom: scanning electron microscope image of the split gates beneath the antenna gate. The gap between the gates is 600 nm.

Further reading

Go Yusa *et al.* 2005 *Nature* **434** 1001.

Polymer regains its shape under UV light

The "shape memory effect" occurs in materials that can be bent out of shape temporarily but that revert to their original shape in response to some stimulus. The best known such material is probably nitinol, which returns to its original form on heating.

Now Andreas Lendlien, of the GKSS Research Center Geesthacht GmbH in Teltow, Germany, and colleagues have reported a polymer that can be bent in a certain wavelength of UV light, maintains its bent shape on heating up to 50 °C, but flips back to its original form in response to a different wavelength of UV. This easily and remotely controllable shape memory material opens up countless possibilities in just about any field where movement at a distance is needed.

Further reading

A Lendlien *et al.* 2005 *Nature* **434** 879.

Neutrons measure shock temperature

How do you measure the temperature of a shocked piece of metal? It looks as though neutrons could provide the answer. V W Yuan and colleagues at Los Alamos National Laboratory in New Mexico used the 21.1 eV resonance in tungsten-182 to measure the temperature in molybdenum shocked to some 63 GPa. The tungsten was doped into the surface of the molybdenum and a 1 μs pulse of neutrons was used as a probe after a shock was delivered that made the metal move at 11 times the speed of sound.

The tungsten atoms thermally agitated in the shock absorbed neutrons of different speeds, depending on whether the atoms moved towards or away from the neutrons. By measuring the arrival times of neutrons that were not absorbed, the team could measure the speeds of the tungsten atoms and thus the temperature. The technique may allow scientists to determine experimentally equations of state for all kinds of materials under extreme conditions.

Further reading

V W Yuan *et al.* 2005 *Phys. Rev. Lett.* **94** 125504.

Lasers keep it cool

A novel way to obtain heat from material could lead to a refrigerator featuring photons and phonons among its moving parts. J Thiede and colleagues at Los Alamos National Laboratory in New Mexico have set a new record in cooling matter with a laser beam.

The key is to use a material that can absorb laser photons and re-emit them at higher energy by combining their energy with those of phonons – the quanta of vibrations that make up heat. Using a specially doped glass fibre and about 10 W of light at a wavelength of 1026 nm from a diode-pumped solid state Yb:YAG laser, Thiede's team achieved −65 °C, beating the previous record of −37 °C. This approaches useful cryogenic temperatures.

Further reading

J Thiede *et al.* 2005 *Appl. Phys. Lett.* **86** 154107.

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

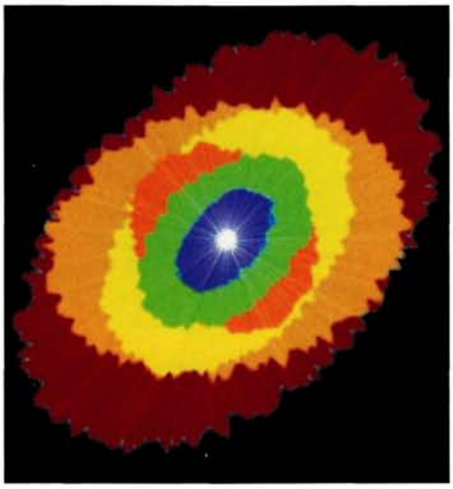
Giant flare illuminates the Earth

On 27 December 2004, one day after the devastating tsunami in the Indian Ocean, the Earth was illuminated by the biggest splash of light ever recorded from outside the solar system. For 0.2 s, the flare released as much energy as has been radiated by the Sun in 250 000 years. Five papers recently published in *Nature* describe this event.

The source of this giant flare was identified as the soft gamma repeater SGR 1806-20 located at some 50 000 light-years on the opposite side of the galaxy. Soft gamma repeaters flare up randomly and release gamma rays with a slightly softer spectrum than usual gamma-ray bursts. Only four such objects are known and a giant flare has now been detected for three of them.

The 2004 event is, however, more than an order of magnitude brighter than those recorded previously, on 5 March 1979 (SGR 0525-66) and 27 August 1998 (SGR 1900+14). Soft gamma repeaters are thought to be "magnetars" – isolated neutron stars with an extreme magnetic field that reaches 100 billion T at the surface of the star.

The most likely interpretation of this dramatic outburst is a magnetic reconnection, similar to – but much more powerful than – solar flares. Its unusual strength may be related to a quake in the crust at the surface of the neutron star. According to Kevin Hurley and collaborators, the opening of the magnetic field lines outward launched a hot fireball, a thermal pair plasma emitting the quasi-blackbody spectrum observed during the initial gamma-ray spike with a kT value of around 200 keV (Hurley *et al.*).



Graphic illustrating the expanding fireball from the giant flare of SGR 1806-20. Colours indicate the observed size and shape of the fireball at different times covering roughly three weeks of observations by the Very Large Array. (Courtesy G B Taylor NRAO/AUI/NSF.)

This prompt emission, first reported by ESA's INTEGRAL satellite, was followed by an exponential decay lasting about 400 s. On top of the general trend, very clear oscillations have been recorded with a period of 7.56 s, the previously known spin period of the magnetar SGR 1806-20.

On 3 January 2005, the Very Large Array (VLA) in New Mexico detected a radio source at the position of the giant flare (B M Gaensler *et al.*). Further observations over the following weeks showed that the radio-emitting fireball was expanding at roughly one-third the speed of light. The source is not spherical as suggested by polarization measures. Indeed, it seems to be elongated, with its shape changing from one observation to the other.

The extraordinary luminosity of the flare of December 2004 suggests that similar events could have been seen in nearby galaxies. Such an event would look like one of the many short gamma-ray bursts (GRBs) detected by the Burst And Transient Source Experiment (BATSE) in the 1990s. Hurley and collaborators therefore speculate that about 40% of the short GRBs detected by BATSE could be due to such giant flares from magnetars. However, the suggestion by P Cameron and colleagues that SGR 1806-20 is at only about half the distance assumed for this estimate makes it less likely that such events could explain a significant fraction of the still mysterious GRBs (Cameron *et al.*).

Further reading

P B Cameron *et al.* 2005 *Nature* **434** 1112.
B M Gaensler *et al.* 2005 *Nature* **434** 1104.
K Hurley *et al.* 2005 *Nature* **434** 1098.
D M Palmer *et al.* 2005 *Nature* **434** 1107.
T Terasawa *et al.* 2005 *Nature* **434** 1110.

Picture of the month

This very sharp image was taken by the Hubble Space Telescope in celebration of its 15th anniversary. Ten years after Hubble captured the fascinating "Pillars of Creation" in the heart of the Eagle Nebula (Messier 16), the telescope once again points its eye at this beautiful nebula to reveal another dust sculpture. The delicate dust column measures approximately 10 light-years and is eroded by the intense ultraviolet light from massive young stars outside the image. (Courtesy NASA, ESA and The Hubble Heritage Team [STScI/AURA].)

CERN COURIER ARCHIVE: 1962

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

JOB EVALUATION

Equal work deserves equal pay

What is being done?
With the growth of CERN it became necessary to work out a system of gradings – this was done in 1959 – and a method for finding out which grades to assign to which jobs. We believe that we have found such a method in "Job Evaluation".

While it cannot and does not pretend to be an exact system of measurement, Job Evaluation is an orderly approach, based on judgement, to determine the relative values of various jobs. It is not a study of individuals – although it is through the individual that the approach is made – but a study of the various jobs within the Organization.

Evaluation factors
Predominantly **"non-manual"** jobs are evaluated according to the following factors:
1. Nature and variety of the work: varied work involving certain difficulties should be better paid than simple routine work.
2. Nature of available guidelines for the performance of work: it is clear that an activity where the guidelines are well established involves less responsibility than one for which only very general instructions are given.
3. Nature of supervisory control exercised over the work: all other things being equal, a job which is subject to constant supervision is inferior to that of someone working more independently.
4. Originality: certain jobs call for originality and new ideas from their holders, and this of course is taken into account when making the evaluation.

"...subject to constant supervision". (The original article included several cartoons depicting aspects of working practices.)

5. Work relationships: these are professional contacts between one staff member and others, or with bodies outside CERN. These relationships, which may involve committal of CERN to certain action or policy, of course must have a bearing on the job grade.
6. Nature and scope of decisions taken and recommendations made by the staff member.
7. Supervision of other people's work: normally the supervisor is better paid than those who are supervised.

"Research" jobs. We are still at the discussion stage as to what factors could best be used in evaluating the jobs of physicists and engineers on research assignments.

Exclusions
The above factors in evaluation are usually accepted as reasonable. On the other hand, there are some factors which are often considered to have an influence on the grade, whereas reflection shows that this should not be so. Among the latter the most typical are:
1. Seniority. Often a staff member thinks that he should be promoted because he has been in the same grade for several years. If his duties have not changed, if his work is the same, and if we want to abide by the principle of equal pay for equal work, there is no reason to change his grade.
2. Age. One often hears: "X is so much older than the rest of the group". However, if X is doing the same work as his younger colleagues he cannot be promoted merely for reasons of age.
3. Quality and quantity of work. Of two people with the same functions, one may work very well and the other less well. Nevertheless, they have the same grade because the job is the same. However, there are rewards for outstanding staff members – Exceptional Performance Awards – and sanctions against poor performers, such as witholding the Annual Increment.
4. Special qualifications. The principle of equal pay for equal work means that staff members are graded for what they do and not for what they are capable of doing. Therefore, if a person is "overqualified" for his job, raising him one or two grades (which would arouse the indignation of his colleagues, and justifiably so) would be no solution; he should be found another post more in keeping with his qualifications.

• Extracted from the original two-page article.

ROYAL VISIT

Royal visit to CERN

On Thursday 24 May CERN was honoured by the visit of H M Baudouin I, King of the Belgians. Since this was a private occasion, rather than an official visit, not many people had more than a few hours' notice, and the King was able to see the Laboratory in its normal working state.

• Extracted from a three-page article.

P Lapostolle (director of the MSC Division) and the King inside the SC Machine hall discussing the machine, the coils for which were manufactured in Belgium.

EDITOR'S NOTE

The *CERN Courier* came into being in August 1959, and in 1962 it became a regular monthly publication, appearing in something like its present form.

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.

Compiled by Hannelore Hämmerle and Nicole Crémel

KNOWLEDGE TRANSFER

Inverted CERN School of Computing transforms students into teachers

At the end of February, CERN turned an established event on its head with the inverted CERN School of Computing (iCSC). Former students of the previous regular CERN School of Computing (CSC) organized and delivered a three-day series of lectures to pass on their knowledge and experience of data, software and distributed computing topics.

The CSC, which has been running since 1970, is an annual two-week event organized in one of CERN's 20 member states, in collaboration with a national institute, to deliver theoretical and hands-on training to up to 80 students from all over the world. Experience from past CSCs has shown that the sum of the students' knowledge often exceeds that of the lecturer. To make use of this knowledge, the idea for the iCSC was born, and received an enthusiastic response when it was presented to students at CSC 2004, which took place in Italy.

During CSC 2004, students discussed possible topics, which were further developed and formed into proposals for the iCSC using an electronic discussion forum. The CSC organizers received so many proposals that some of them had to be rejected – not because of their quality, but because they did not fit with the three main themes identified: database systems, advanced software development and engineering, and Web services in distributed computing.

The authors of three proposals were appointed as theme coordinators, and were then responsible for designing the content and inviting other students to act as lecturers. The school centred on practical sessions, sometimes including demonstrations, but also provided theoretical treatment of the topics. One focal issue of the school was new methods for developing and engineering advanced software tools, where generic concepts outside the academic circle such as enterprise computing were also shown.

"Where students turn into teachers" – CERN's first inverted school of computing.

Ioannis Baltopoulos gave a series of three lectures at the iCSC, on Web services in distributed computing.

"The students brought their experience to the school, and not only gave a catalogue of recipes, but also a structured approach on fields where no books exist so far," said Francois Fluckiger, director of the CSC. "For example, one student made a taxonomy of security issues that programmers should keep in mind during the process of writing code, which has never been done before. This then reached an even wider audience in the IT seminar at CERN."

A total of 16 hours of teaching were presented by 11 students from CERN, Imperial College London, and the universities of Heidelberg and Sienna. The students provided detailed descriptions of the sessions so that participants could judge in advance whether or not lectures were appropriate for them. Attendance was consistently above 50 throughout the three-day programme, with peaks of up to 100 listeners.

The iCSC also served as a platform for the students to meet and network, forming part of a programme to increase the active involvement of participants in the CSC, which already includes interactive sessions and contests for students to present personal topics, as well as opportunities for interacting with special visitors. An optional examination at the end of the CSC provided the students with a formal certificate of credits recognized by an increasing number of universities.

The guiding principle of the CSC is the transfer of knowledge, and the iCSC has shown that unlike in normal schools, this transfer can work both ways.

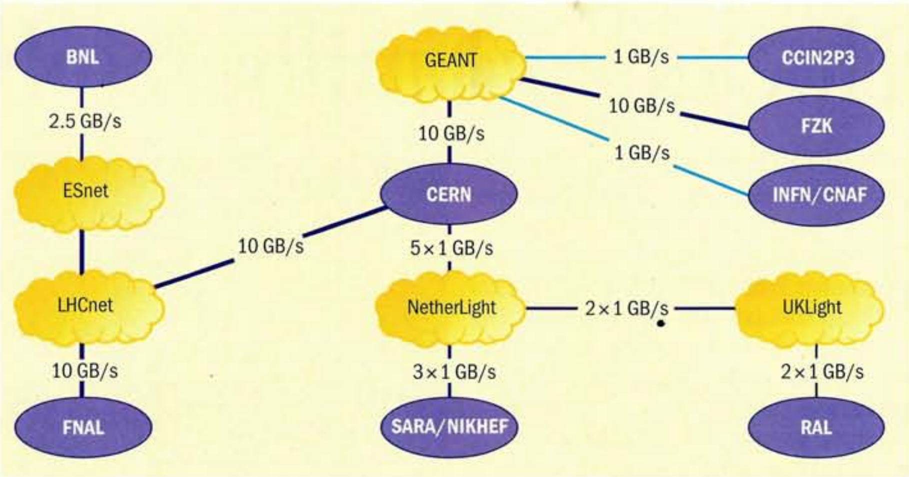
For more information about the iCSC, see http://cern.ch/CSC/.

GRID COMPUTING

LHC Grid tackles multiple service challenges

In April, eight major computing centres successfully completed a challenge to sustain a continuous data flow of 600 MB/s on average for 10 days from CERN to seven sites in Europe and the US. The total amount of data transmitted during this challenge – 500 TB – would take about 250 years to download using a typical 512 kbit/s household broadband connection.

This exercise in high-speed data transfer was part of a series of service challenges designed to test the global computing infrastructure for the Large Hadron Collider (LHC). The participants included Brookhaven National Laboratory and Fermilab in the US, Forschungszentrum Karlsruhe in Germany, CCIN2P3 in France, INFN-CNAF in Italy, SARA/NIKHEF in the Netherlands and the Rutherford Appleton Laboratory in the UK.



Network connections between CERN and the computing centres participating in the April service challenge, and the underlying high-speed networks that facilitated the challenge.

The service challenges are a recent addition to the data challenges being carried out in collaboration with the four LHC experiments (ALICE, ATLAS, CMS and LHCb) to simulate the computing conditions expected once the LHC is fully operational. Whereas previous data challenges tested the computing models of the experiments, the service challenges focus on the reliability of the underlying Grid infrastructure. The current service challenge is the second in a series of four leading up to LHC operations in 2007. It exceeded expectations by sustaining roughly one-third of the ultimate data rate from the LHC, and reaching peak rates of over 800 MB/s.

The eight computing centres involved in the service challenge are, in a sense, the tip of the Grid iceberg. In March, the LHC Computing Grid (LCG) project announced that it now has more than 100 participating sites in 31 countries, making it the world's largest international scientific Grid. The sites participating in the LCG project, primarily universities and research laboratories, contribute more than 10 000 central processor units and a total of nearly 10 million GB of storage capacity on disk and tape.

Yet despite the record-breaking scale of the LCG project today, the current processing capacity of this Grid is estimated to be just 5% of the long-term needs of the LHC. Therefore, the LCG project needs to continue to grow its capacity rapidly over the next two years by adding sites, increasing resources available at existing sites, and ensuring interoperation with other Grid projects such as Grid3/OSG and NorduGrid. In addition, the exponential increase in processor speed and disk storage capacity inherent to the IT industry will help to achieve the LHC's ambitious computing goals.

A further challenge facing this Grid infrastructure is the need to diversify its user base beyond high-energy physics. Already, other scientific applications from disciplines such as biomedicine are being tested on the LCG infrastructure, thanks largely to the support of the EU-funded Enabling Grids for E-sciencE (EGEE) project, which is a major contributor to the operations of the LCG project. This is proving to be a useful learning experience not just for academics, but also for industry. For example in March, the Compagnie Générale de Géophysique started to run seismic processing software on the Grid infrastructure, supported by EGEE (see p17).

A similar incentive lies behind the decision of Hewlett-Packard (HP) to allocate a substantial number of Intel Itanium-2 64-bit (IA64) processors to LCG from its Bristol and Puerto Rico computer centres. This year, the Poznan Supercomputing and Networking Center in Poland joined HP and CERN to become the third contributor of IA64 nodes to LCG. The CERN openlab for DataGrid applications, an industry partnership involving HP, IBM, Intel, Oracle and Enterasys, has ported the complete LCG middleware to IA64. Work is also under way to port common HEP libraries like SEAL and POOL to the new environment. 64-bit computing will be crucial to the future of scientific computing, and thanks to the CERN openlab initiative, the HEP community now has the chance to test its applications for 64-bit compatibility on the LCG infrastructure.

GRID TECHNOLOGY

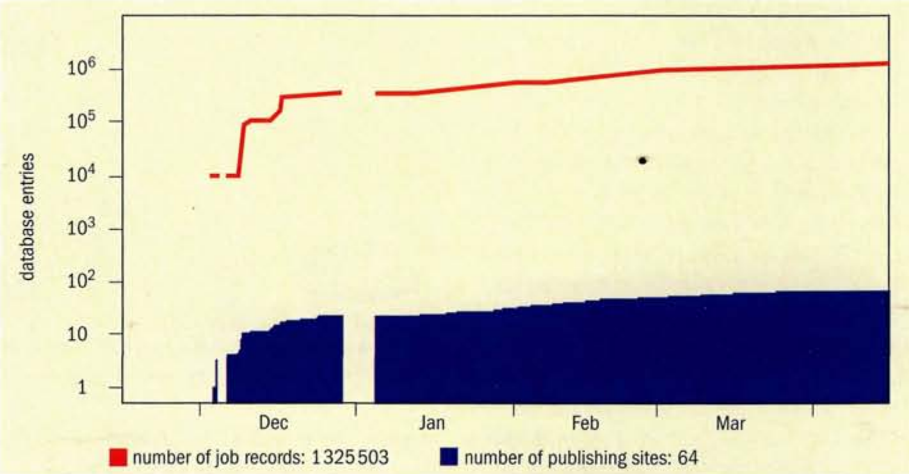
LHC Grid accounting package clocks up 1 million job records

By the end of March, more than 1 million job records had been published by sites participating in the Large Hadron Collider Computing Grid (LCG) using the APEL (Accounting Processor for Event Logs) package. APEL is a program that builds daily accounting records, based on information located in the log files of individual computing elements of the Grid.

In the LCG environment, the distributed computing resources, application data and grid users belong to virtual organizations (VOs). Jobs submitted by the users are sent either to computing resources close to the data to minimize network traffic or to remote sites with available job slots to reduce queuing times.

Accounting records are needed to determine the consumption by different VOs of resources such as central processor unit time and memory, as well as the provision of resources by the various sites. The data are assembled to form usage records that identify the Grid user, the VO and the resources used to execute a job. Each accounting record is unique, since there is only one record per Grid job.

The accounting records located at each site are consolidated using R-GMA, an implementation of the Grid Monitoring Architecture (GMA) proposed by the Global Grid Forum. GMA models the information infrastructure of a Grid as a set of consumers requesting information, a set of producers providing information, and a registry for the communication between producers and consumers.



In the three months since the release of the APEL package in LCG-2 middleware, more than 50% of sites have published accounting data comprising a total of over 1 million job records.

From an R-GMA viewpoint, the producers are sites containing a database of local accounting records for jobs that have been successfully executed, and the consumer is a "Grid operations centre" that archives accounting records across all sites and provides a Web interface with which to view the data.

The successful implementation of APEL in the LCG project paves the way for the next major step: to provide accounting for storage usage on the Grid.

● An extended version of this article can be found at www.cerncourier.com/articles/cnl.

DATA MANAGEMENT

Software achieves breakthrough in data challenge

On 30 March, IBM and CERN announced that IBM's storage virtualization software has achieved breakthrough performance results in an internal data challenge at CERN. The data challenge was part of ongoing tests to simulate the computing needs of the Large Hadron Collider (LHC) Computing Grid, the largest scientific computing Grid in the world. The LHC is expected to produce massive amounts of data – 15 million GB per year – once it is operational in 2007. The recent results represent a major milestone for CERN, which is testing cutting-edge data-management solutions in the context of the CERN openlab, an industrial partnership.

Using IBM's TotalStorage SAN File System storage virtualization software, the internal tests shattered performance records during a data challenge test by CERN by reading and writing data to disk at rates in excess of 1 GB/s for a total I/O of over 1 PB in a 13 day period. This result shows that IBM's pioneering virtualization solution has the ability to manage the anticipated needs of what will be the most data-intensive experiment in the world.

CERN openlab is a collaboration between CERN and leading industrial organizations – including Enterasys, HP, Intel and Oracle – that aims to implement and test data-intensive Grid-computing technologies that will aid the LHC scientists. As part of the CERN openlab work, IBM has involved several leading storage-management experts from IBM's Almaden Research Center in California, US, and the Zürich Research Lab in Switzerland in the work at CERN.

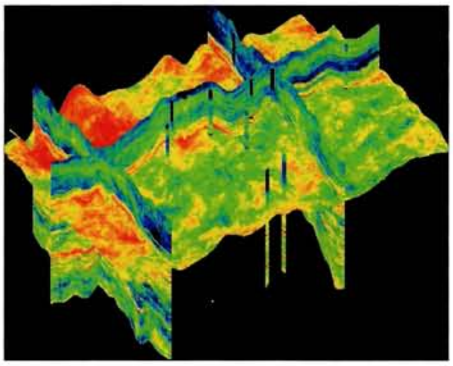
In addition, through its Shared University Research programme, IBM supplied CERN with 28 TB of iSCSI disk storage, a cluster of six eServer xSeries systems running Linux, and on-site engineering support and services by IBM Switzerland.

GEOSCIENCE

First industrial application runs on EGEE project infrastructure

The seismic processing software Geocluster is the first industrial application successfully running on the computing Grid infrastructure of the Enabling Grids for E-sciencE (EGEE) project. Geocluster is developed and marketed by the Compagnie Générale de Géophysique (CGG) in France, a leading supplier of geophysical products and services to the worldwide oil, gas, mining and environmental industries.

The Geocluster software, which includes several tools for signal processing, simulation and inversion, enables researchers to process seismic data and to explore the composition of the Earth's layers. In addition to Geocluster, which is used only for R&D, CGG develops, markets and supports a broad range of geoscience software systems covering seismic data acquisition and processing, as well as geoscience interpretation and data management.



The Geocluster software, which runs on the EGEE Grid infrastructure, produces 3D visualizations of the rock properties of the area under study.

The EGEE project is developing a Grid infrastructure to provide researchers in both academia and industry with access to major computing resources, independent of their location, 24 hours a day. To date, there are six different scientific disciplines running on the EGEE Grid infrastructure.

Dominique Thomas, CGG software development manager, pointed out: "There are numerous benefits in operating on the EGEE infrastructure, not least the fact that you can share IT resources and software. It frees the researcher from the additional burden of managing IT hardware and software complexity and limitations. Thanks to EGEE, providing the geosciences research community with easy access to comprehensive and commercial seismic processing software is now a reality."

GGF13

Global Grid gets an Asian dimension

Although the Grid concept was pioneered in the US, and the EU currently runs some of the most ambitious international programmes for scientific Grids, Asia is playing an increasingly active role in this emerging field. This was one of the main themes of the 13th Global Grid Forum (GGF13), which was held on 13–16 March in Seoul, South Korea.

The local organizer Jysoo Lee, director of the Korea Institute of Science and Technology Information (KISTI), estimated that there are now 10 national-scale Grid projects in seven countries in Asia, in addition to a large number of smaller initiatives.

While international collaboration in Asia has been slower to evolve than in Europe, partly due to the weaker political integration of the region, promising signs are appearing. For example, at the meeting, Singapore's National Grid Office and KISTI signed a memorandum of understanding to achieve closer collaboration in Grid development.

A highlight of the meeting was an update on Japan's National Research Grid Initiative (NAREGI) by the project deputy director, Satoshi Matsuoka. This initiative was launched two years ago and involves several major universities, national laboratories and leading Japanese IT vendors.

In contrast with Europe, where high-energy physics has been the scientific flagship for Grid development, NAREGI focuses on nanotechnology – in particular molecular simulation of nanosystems – as the pilot application. This is a strategically significant choice, given the high political profile and huge funding being poured into nanotechnology both in Japan and worldwide.

A technical breakthrough achieved recently by the NAREGI partners is a "super scheduler" for managing jobs on the Grid, which complies fully with the Open Grid Service Architecture (OGSA) – a first proof-of-principle that this architecture for Grid services actually works. NAREGI's strategy is to switch from UNICORE-based middleware to OGSA during the five-year lifetime of the project.

Sessions devoted to Enterprise Grids revealed that this is an area where Asia is still building momentum. This is perhaps surprising, given the region's reputation as an early adopter of advanced IT infrastructure. For example, Korea has been leading the world in deploying broadband Internet infrastructure, with more than 80% of Korean households now having a broadband connection.

As a result of a Grid Economy workshop during the forum, major Korean companies such as Korea Telecom and Samsung Networks are now reviewing their strategies for investing in Grids. The organizers also took advantage of the presence of senior GGF representatives to impress on the Korean minister of information and communications the importance of this emerging technology.

Meanwhile, delegates who ventured into the streets of Seoul could visit one of the countless 24 hour "PC *baangs*" – part Internet café, part gaming room. These burst at the seams with patrons playing online games, checking e-mail, watching video clips or even Internet TV. Onlookers might be forgiven for wondering whether they were seeing the real future of the Grid.

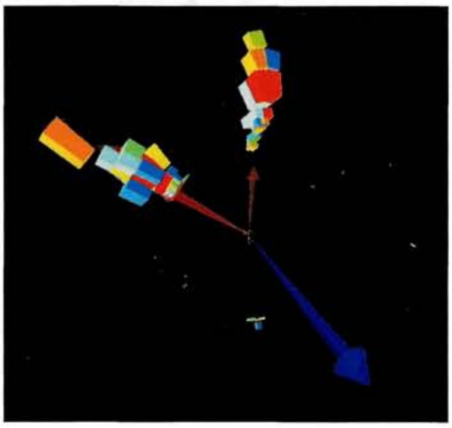
GRID COMPUTING

DO's data-processing record

Hundreds of scientists from the DO collaboration at Fermilab are using Grid computing to process particle physics data. Facilities in six countries around the globe have begun to provide computing power equivalent to 3000 1 GHz Pentium III processors to crunch more experimental data than ever before. In six months, the computers will churn through 250 TB of data – enough to fill a stack of CDs as high as the Eiffel Tower.

Reprocessing of stored data is necessary whenever physicists and computer scientists have made significant advances. Researchers are constantly trying to optimize the software to process each collision event faster, and the physicists' understanding of the complex DO detector is also steadily improving.

The researchers are using the Grid to reprocess three years' worth of data – 1000 million particle collisions – in six months. The DO computer farm can process about 4 million events per day, so even with no new data coming in it would take three years to reprocess three years' worth of data. To do it in six months the collaboration had to look for computing resources around the world. As each collision event is processed, the software pulls additional information from large databases, requiring several complex auxiliary systems to work well together at all times. This system then has to be adapted to run on computer systems in many different environments, with many different configurations. Researchers at Fermilab and the participating institutions have been working for almost a year to ensure that the current reprocessing runs smoothly.



The reprocessed data will improve the full physics programme, including searches for new phenomena such as supersymmetry. This DO event from 2003 is the highest-energy event in one of the DO searches for supersymmetry. (Courtesy of DO-Fermilab.)

Canada's WestGrid, the University of Texas at Arlington, US, CCIN2P3 France and Fyzikální Ústav in the Czech Republic are the first collaborating sites remotely reprocessing DO data. Computing centres and Grid projects at the University of Oklahoma in the US, GridKa in Germany, and GridPP and the Particle Physics and Astronomy Research Council in the UK will follow soon. Fermilab scientists also hope to add collaborating sites in Brazil, India, Korea and China.

● The DO experiment is a collaboration of about 650 scientists from more than 80 institutions in the US and 19 other countries (see www-d0.fnal.gov/).

HISTORY

The world's first home PC is here!

In the January 1975 edition of *Popular Electronics* magazine, the Altair 8800 was heralded as "the world's first minicomputer kit to rival commercial models". It is considered to have been the first mass-produced personal computer (PC), and could be built for under $400. Announced in the *Popular Electronics* editorial as a "home computer", the Altair 8800 was offered as a kit, and so had to be assembled before it could be used.

Without a screen or keyboard, the Altair 8800 could be programmed in machine language using toggle switches and LEDs on the front panel. The first programming language, Altair BASIC, was also the first product of Microsoft, written by Bill Gates, Paul Allen and Monte Davidoff.

Although the Altair 8800 had its fans among DIY hobbyists, the real breakthrough for PCs came in the 1980s, when IBM introduced the IBM PC. It is estimated that 1000 million PCs will be in use by the end of 2005.

Calendar of events

June

14–17 The 2005 International Conference on Parallel Processing (ICPP-05) Oslo, Norway, www2.dnd.no/icpp2005/

20–24 Second International IEEE Symposium Sardinia, Italy, www.globalstor.org/

21–24 International Supercomputer Conference (ISC2005) Heidelberg, Germany, www.supercomp.de/index.php?s=default

26–29 GGF14 Chicago, Illinois, US, www.ggf.org

July

24–27 The 14th IEEE International Symposium on High Performance Distributed Computing (HPDC-14) Research Triangle Park, North Carolina, US, www.caip.rutgers.edu/hpdc2005/

24–27 3rd International Conference on Computing, Communication and Control Technologies (CCCT '05) Austin, Texas, US, www.iiisconfer.org/ccct05/website/default.asp

August

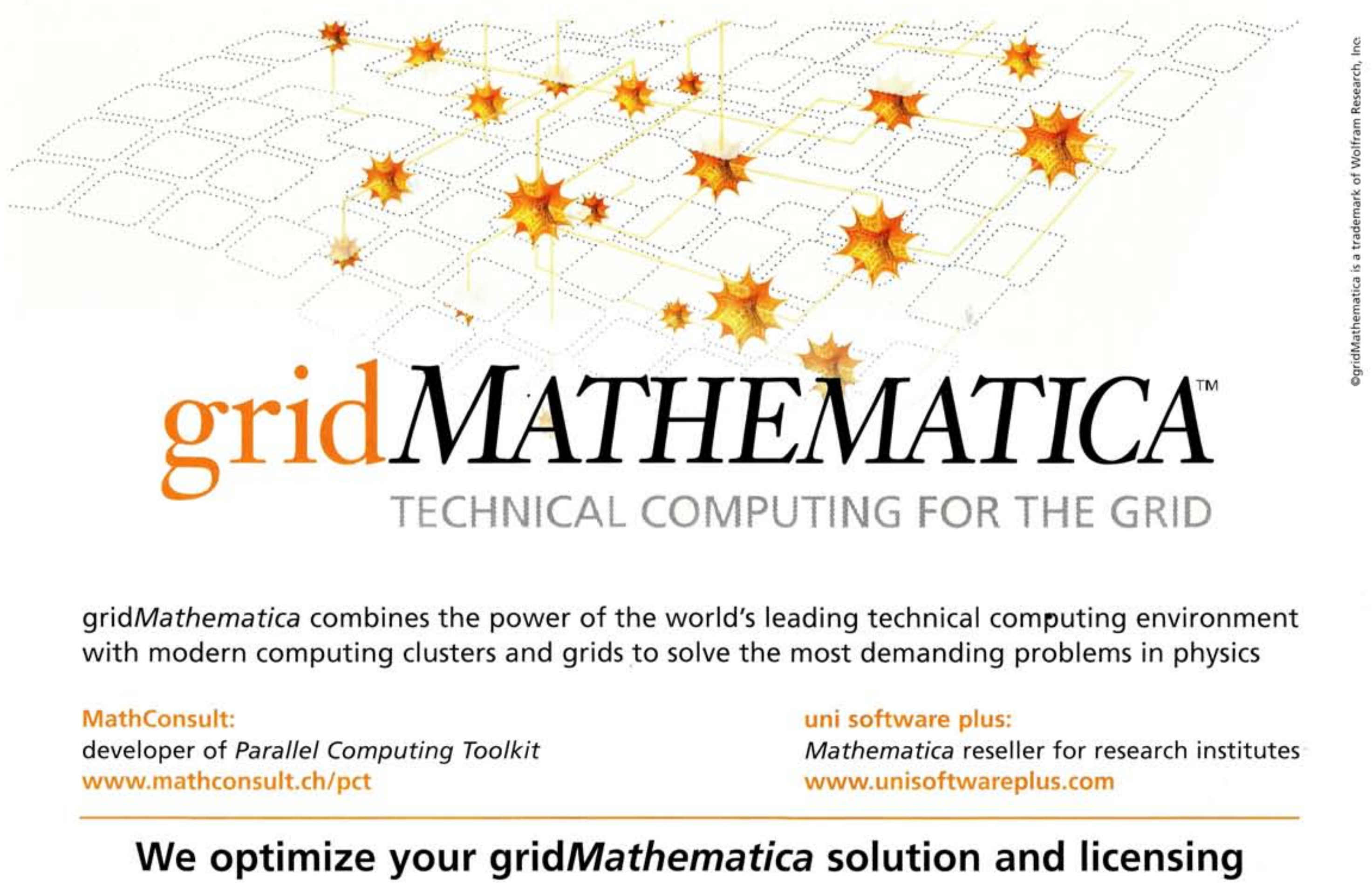
17–19 1st WSEAS International Symposium on Grid Computing Corfu, Greece, www.worldses.org/conferences/2005/corfu/smo/grid/index.html

September

5–9 Parallel Computing Technologies (PaCT-2005) Krasnoyarsk, Russia, http://ssd.sscc.ru/conference/pact2005/

12–18 XX International Symposium on Nuclear Electronics and Computing (NEC '2005) Varna, Bulgaria, http://sunct2.jinr.ru/NEC-2005/first_an.html

18–21 12th European Parallel Virtual Machine and Message Passing Interface Conference Sorrento, Italy, www.pvmmpi05.jeanmonnet.unina2.it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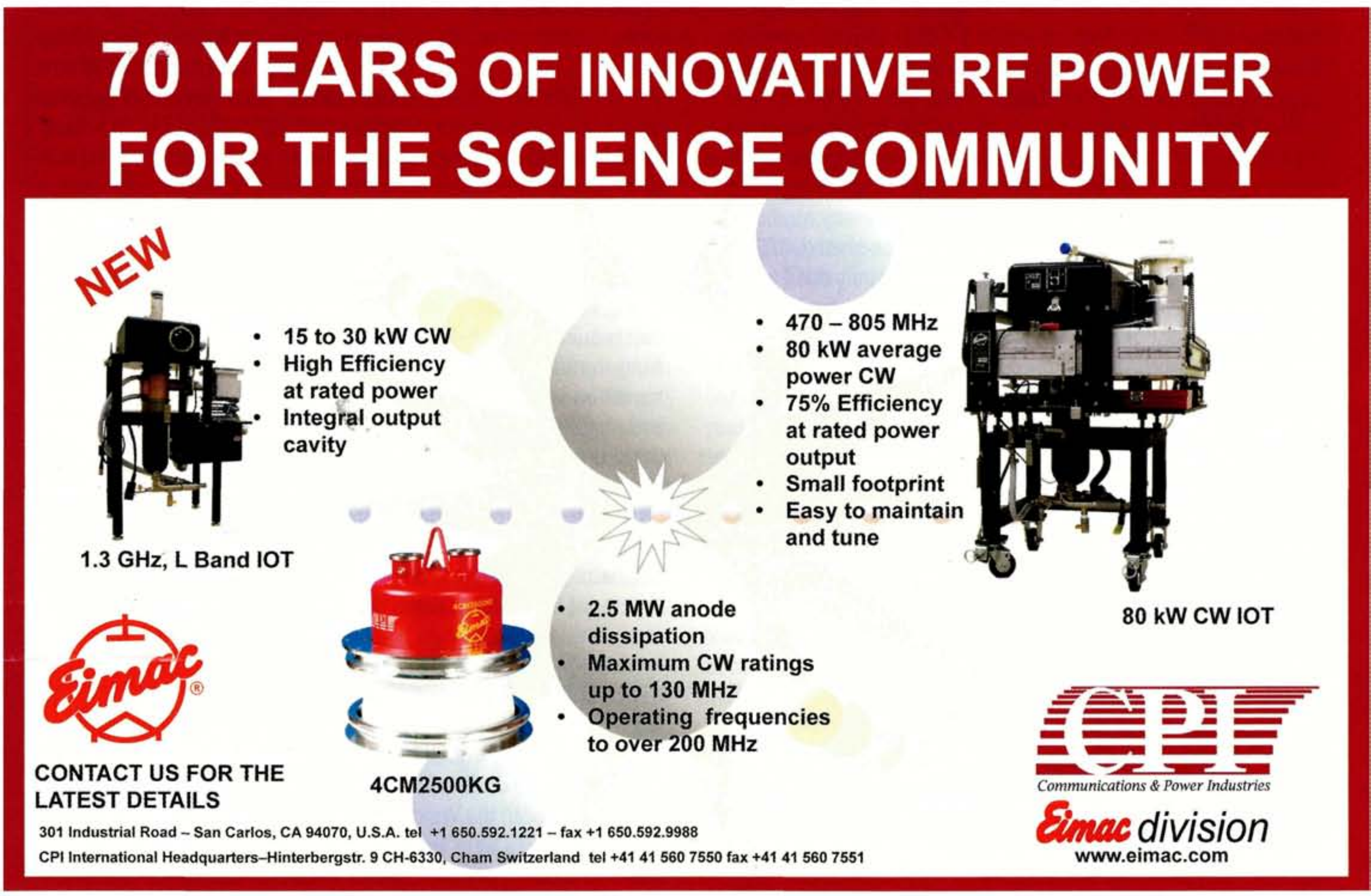
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Industrial solutions find a place at CERN

David Myers and **Wayne Salter** describe the increasing use of commercial solutions in control systems at CERN and the recent formation of a users' group.

Historically at CERN the control of equipment not used directly for data acquisition has been called "slow control", presumably because of the much lower bandwidth required and response times measured in tens of milliseconds, if not tens of seconds. It has also often been a subject addressed as an afterthought. However, with the size of the experiments for the Large Hadron Collider (LHC), or even those currently operating with fixed targets, so much equipment has to be monitored and operated that running the experiments would be difficult, if not impossible, without an efficient slow-control system.

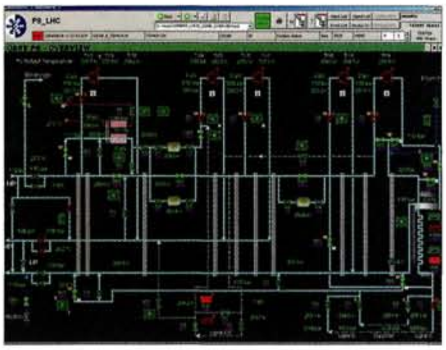

Fig. 1. An overview panel from one of the LHC cryogenics applications.

The difference between control in high-energy physics experiments (excluding data acquisition) and most industrial systems is now mainly one of size, and herein lies the benefit of not being required to push the technological frontiers too much. In many applications it has become possible to use commercial off-the-shelf (COTS) solutions, with the advantage that the physics community does not need to develop or maintain them (the latter is perhaps more important). However, nothing comes without a price, and in this case it is the need to follow industrial standards.

Control systems

For the controls of the LHC experiments, the Joint Controls Project (JCOP) was set up in 1998 as a collaboration between the four experiments (ATLAS, ALICE, CMS and LHCb) and CERN to provide common control solutions. In the early phases of the project it was decided to evaluate COTS solutions for their suitability for the LHC experiments. Programmable logic controllers (PLCs), which were already widely used in more standard industrial applications at CERN (such as cooling and ventilation, vacuum, etc), but less so for experiment controls, were investigated for suitability. Following an evaluation, it was felt that these could indeed be used in many areas within experiment controls where reliable process control was required, but where there was no need for latencies lower than a few tens of milliseconds, and no need for highly sophisticated software processing. PLCs are now used extensively, but still perhaps less than they could be.

A second area where industrial solutions looked promising was supervisory process control and hardware interfacing. A *de facto* industry standard called OPC (object linking and embedding [OLE] for process control) was emerging and promised to reduce substantially the number of interface protocols that a controls system needed to support. In the past, each different PLC type to be connected meant another proprietary protocol to support. However, with OPC, a single interfacing standard was defined by manufacturers of PLCs and other kinds of hardware equipment. Thus, each hardware supplier provides a software interface called an OPC server. Similarly, providers of supervisory control and data acquisition (SCADA) software provide the corresponding OPC client capability. After evaluation it was decided that OPC would be a good choice to standardize the interfacing of COTS equipment.

A third area where COTS solutions were felt to be worth investigating was supervision systems. This was a far more complex area that required a more detailed evaluation, one that lasted two years from the initial survey of the market until the completion of the hands-on evaluation of a shortlist of products. The experiments eventually concluded that SCADA technology could be suitable for their controls systems, provided the chosen product:

- allowed very large scalable control systems to be built with the order of several million data items;
- was sufficiently open to allow all internal SCADA data to be accessible from external applications;
- allowed an object-oriented development approach – because an experiment-control system has a large number of similar devices, it is essential to be able to develop a class definition for each type of device once, then instantiate it easily many times;
- supported distributed development – the control systems of the LHC experiments would be developed in many distributed locations around the world;
- ran under both the Windows and Linux operating systems.

Although there were very many SCADA products on the market at that time (more than 100), only a small number were found to support all these requirements. PVSS (Prozeßvisualisierungs- und Steuerungssystem), from the Austrian company ETM, was one of these and was selected after a formal tender process in 1999 for use in the control systems of the four LHC experiments. Since then, members of the four experiment collaborations in approximately 100 institutes in 26 countries have started working with PVSS to build their part of the overall control systems for these experiments. In addition, during 2000, after a study of the use of SCADA systems at CERN, a recommendation was made by the CERN Controls Board to minimize the number of SCADA systems used and to standardize on PVSS for all new CERN projects requiring SCADA functionality.

To enable efficient use of PVSS for these projects, the existing contract with ETM was extended to cover essentially all projects at CERN. As a result, PVSS has been used for many other systems at CERN, including several fixed-target experiments (COMPASS, NA60 and HARP), the gas and magnet control systems for the LHC experiments, the LHC cryogenics and vacuum-control systems, and the supervision of several safety systems for the LHC machine and experiments.

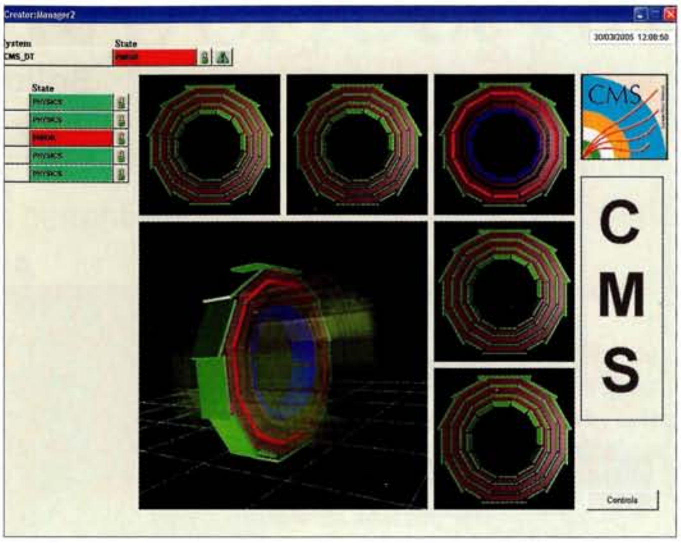

Fig. 2. The main panel for one of the CMS sub-detectors, providing a 3D representation of the detector elements.

PVSS Users' Group

Because PVSS offers extensive functionality, its correct use needs experience and therefore a support service is provided to help users get started. The service, housed in the Controls Group of the Information Technology (IT) Department, also provides expert advice and technical support for more advanced users. Furthermore, a framework layer specific to high-energy physics has been developed to deal with common physics hardware components and to provide additional specific functionality.

The IT Controls Group has also maintained good contacts with users of PVSS outside CERN, and after discussions it became clear that having a forum in which to exchange ideas, solutions and experience on the use of PVSS would be potentially beneficial. Thus, in collaboration with ETM, it was decided to form a PVSS Users' Group. The first meeting of this group took place at CERN on 5–6 April 2005.

Nearly 150 participants attended the meeting, from a wide range of different application domains including high-energy physics, radio astronomy, air-traffic control, traffic monitoring, gas production and distribution, water distribution and purification, maritime navigation systems and many others. Approximately three-quarters of the participants were from outside of CERN and the majority of these from industry. The meeting programme included 14 interesting and diverse presentations on experience in the use of PVSS and special developments done with it, and there was a presentation on the foreseen future evolution of PVSS from ETM's point of view. Three lively discussion sessions were held, on "Design Aspects in Sophisticated PVSS Applications", "How to Develop Successfully Company Standards with PVSS" and "User Evolution Wishes for PVSS". The participants were also given the opportunity to visit the ATLAS cavern and the CMS installation hall, allowing them to see for themselves the size and complexity of the experiments that PVSS will be used to control.

The meeting concluded with a discussion on the future role of the Users' Group, and the outcome was that it would indeed be beneficial. It was decided that it should allow users of PVSS to meet and establish contacts for future collaborations, and provide a forum to:
- discuss each others' experiences, problems and solutions;
- discuss missing functionality and enhancements to the product;
- discuss and prioritize requests to ETM;
- discuss topics of relevance to the PVSS users' community, such as control-system security, emerging standards and the development of new technologies;
- allow ETM to communicate its development strategy for PVSS.

The consensus was that the meeting had been an excellent forum for users to meet and exchange ideas, and it brought together an interesting mix of people from research and industry. Although the industrial approach was sometimes quite different from that of the research domains, there were many similarities in the type of problems encountered and the solutions chosen. The seeds of new collaborations were sown at the meeting and it will be interesting to watch these develop in the weeks and months to come.

- For a conference report on the first PVSS Users Meeting at CERN see www.cerncourier.com/articles/cnl.

David Myers *and* **Wayne Salter**, *CERN.*

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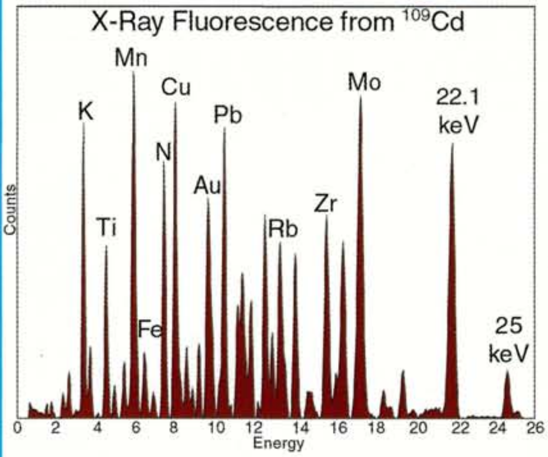

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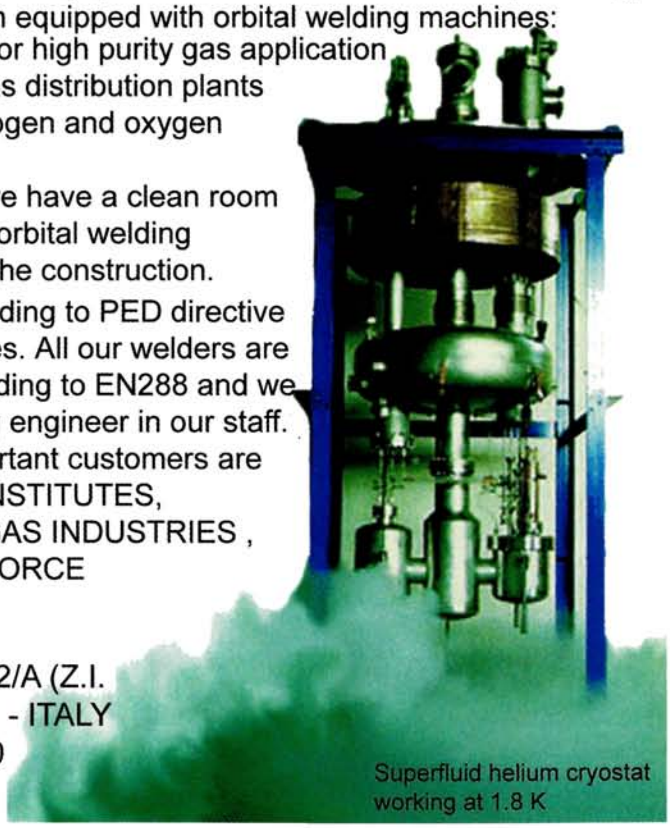

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PET and CT: a perfect fit

David Townsend began his pioneering work in PET imaging 30 years ago while at CERN. Here he talks to **Beatrice Bressan** about his current work and how the field developed.

David Townsend is a professor in the Department of Medicine, University of Tennessee Medical Center in Knoxville, Tennessee (TN). The winner of the 2004 Clinical Scientist of the Year Award from the Academy of Molecular Imaging, he is an internationally renowned researcher with 30 years' experience as a physicist working in the field of positron emission tomography (PET). Townsend began his eight years at CERN in 1970. While working at the Cantonal Hospital in Geneva from 1979 to 1993, he recognised the importance of combining the functionality of PET with that of computed tomography (CT). During that same period, Townsend also worked with Georges Charpak, CERN physicist and 1992 Nobel laureate in physics, on medical applications of Charpak's multi-wire chambers.

Video-capture of David Townsend giving his "Advances in PET Imaging" seminar at CERN on 9 February 2005.

After Townsend moved to Pittsburgh in 1993, his group in the US helped to develop the first combined PET/CT scanner; more than 1000 are now used worldwide to image human cancer. In 1999, Townsend received the Image of the Year Award from the Society of Nuclear Medicine in the US, for an image he produced using the first prototype scanner combining state-of-the art PET with true diagnostic-quality CT.

Current research objectives in instrumentation for PET include advances in PET/CT methodology and the assessment of the role of combined PET/CT imaging for a range of different cancers. The PET/CT combination, pioneered by Townsend and Ron Nutt, CEO and president of CTI Molecular Imaging in Knoxville, TN, is a milestone in these developments, revealing in particular the role of the physicist and engineer in bringing such developments into clinical practice and exploring how they affect patient care.

The past 20 years have seen significant advances in the development of imaging instrumentation for PET. Current high-performance clinical PET scanners comprise more than 20 000 individual detector elements, with an axial coverage of 16 cm and around 15% energy resolution. Can you identify the most important factors that have contributed to this remarkable development in PET?

This impressive progress is due essentially to developments in detector construction, new scintillators, better scanner designs, improved reconstruction algorithms, high-performance electronics and, of course, the vast increase in computer power, all of which have been achieved without an appreciable increase in the selling price of the scanners.

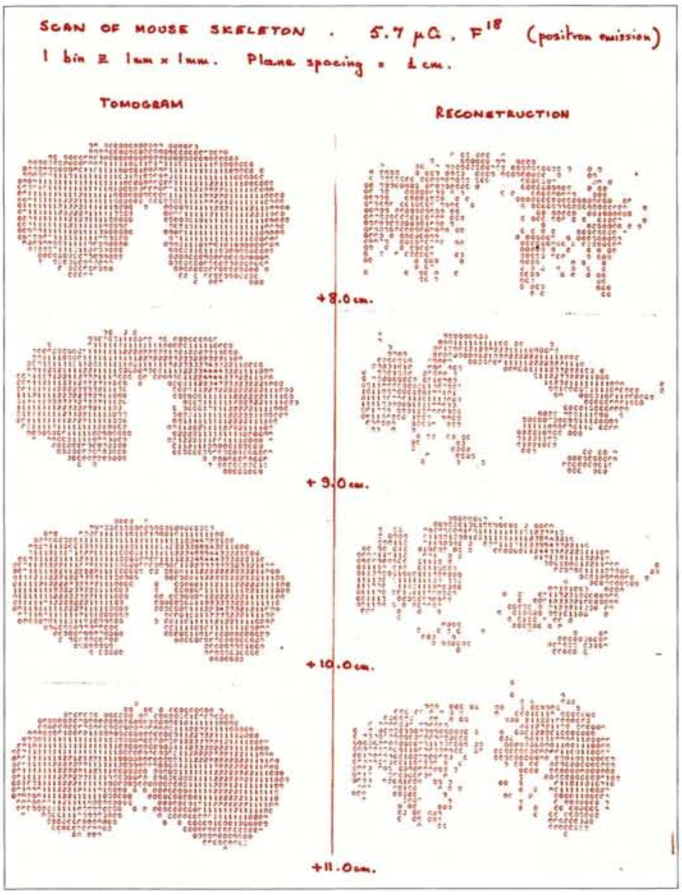
The PET/CT image is one of the most exciting developments in nuclear medicine and radiology, its significance being the merging not simply of images but of the imaging technology. Why is the recent appearance of combined PET and CT scanners that can simultaneously image both anatomy and function of particular importance?

Initial diagnosis and staging of tumours are commonly based on morphological changes seen on CT scans. However, PET can differentiate malignant tissue from benign tissue and is a more effective tool than CT in the search for metastases. Clearly, valuable information can be found in both, and by merging the two it is possible now to view morphological and physiological information in one fused image. To acquire the PET/CT image, a patient passes through the CT portion of the scanner first and then through the PET scanner where the metabolic information is acquired. When the patient has passed through both portions, a merged or fused image can be created.

Let's take a step back. The history of PET is rich, dynamic and marked by many significant technological achievements. Volumes of books would be required to record the history of PET developments and its birth still remains quite controversial. Could you identify the most important events that have shaped modern PET?

You are indeed correct that the birth of PET is somewhat controversial. One of the first suggestions to use positron-emitting tracers for medical applications was made in 1951 by W H Sweet and G Brownell at Massachusetts General Hospital, and some attempts were made to explore the use of positron-emitting tracers for medical applications in the 1950s. During the late 1950s and 1960s, attempts were made to build a positron scanner, although these attempts were not very successful. After the invention of the CT scanner in 1972, tomography in nuclear medicine received more attention, and during the 1970s a number of different groups attempted to design and construct a positron scanner.

S Rankowitz and J S Robertson of Brookhaven National Laboratory built the first ring tomograph in 1962. In 1975, M Ter-Pogossian, M E Phelps and E Hoffman at Washington University in St Louis presented their first PET tomograph, known as Positron Emission Transaxial Tomograph I (PETT I). Later the name was changed to PET, because the transaxial plane was not the only plane in which images could be reconstructed. In 1979, G N Hounsfield and ▷



The first mouse image taken in 1977, when PET began at CERN.

A M Cormack were awarded the Nobel Prize for Physiology and Medicine in recognition of their development of X-ray CT.

Since the very early development of nuclear-medicine instrumentation, scintillators such as sodium iodide (NaI) have formed the basis for the detector systems. The detector material used in PET is the determining factor in the sensitivity, the image resolution and the count-rate capability.

The only detector of choice in the mid-1970s was thallium-activated NaI – NaI(Tl) – which requires care when manufactured because of its hygroscopic nature. More importantly, it also has a low density and a low effective atomic number that limits the stopping power and efficiency to detect the 511 keV gamma rays from positron annihilation. Which other scintillators have contributed to modern PET tomography?

Thanks to its characteristics, bismuth germanate, or BGO, is the crystal that has served the PET community well since the late 1970s, and it has been used in the fabrication of most PET tomographs for the past two decades. The first actual tomograph constructed that employed BGO was designed and built by Chris Thompson and co-workers at the Neurological Institute in Montreal in 1978.

Although the characteristics of BGO are good, a new scintillator, lutetium oxyorthosilicate (LSO) (discovered by C Melcher, now at CTI Molecular Imaging in Knoxville, TN), is a significant advance for PET imaging. BGO is very dense but has only 15% of the light output of NaI(Tl). LSO has a slightly greater density and a slightly lower effective atomic number, but has five times more light output and is seven times faster than BGO. The first LSO PET tomograph, the MicroPET for small animal imaging, was designed at the University of California in Los Angeles (UCLA) by Simon Cherry and co-workers. The first human LSO tomograph, designed for high-resolution brain imaging, was built by CPS Innovations in Knoxville, TN, and delivered to the Max Planck Institute in February 1999.

What were your key achievements in PET during your career at CERN? Did CERN play a role in its birth?

In 1975, I was working at CERN when Alan Jeavons, a CERN physicist, asked me to look at the problem of reconstructing images from PET data acquired on the small high-density avalanche chambers (HIDACs) he had built for another application with the University of Geneva. We got the idea for using the HIDACs for PET because a group in Berkeley and University of California, San Francisco (UCSF) was using wire chambers for PET. I developed some software to reconstruct the data from Jeavons' detectors, and we took the first mouse image with the participation of radiobiologist Marilena Streit-Bianchi in 1977 at CERN.

The reconstruction methods I developed at CERN were further extended mathematically by Benno Schorr (a CERN mathematician), Rolf Clackdoyle and myself from 1980 to 1982. We used those, and other algorithms developed by Michel Defrise in Brussels and Paul Kinahan in Vancouver, in 1987 and 1988 to reconstruct PET data from the first CTI [Computer Technology and Imaging Inc, renamed CTI Molecular Imaging in June 2002] multi-ring PET scanner installed in London at Hammersmith Hospital. PET was not invented at CERN, but some essential and early work at CERN contributed significantly to the development of 3D PET, and then to a new scanner design, the Advanced Rotating Tomograph (ART).

The prototype of the ART scanner, the Partial Ring Tomograph (PRT), was developed at CERN from 1989 to 1990 by Martin Wensveen, Henri Tochon-Danguy and myself, and evaluated clinically at the Cantonal Hospital within the Department of Nuclear Medicine under Alfred Donath. The ART was a forerunner of the PET part of the combined PET/CT scanner, which has now had a major impact on medical imaging.

What has to happen for us to reach a more highly performing PET/CT combination?

The sensitivity of the PET components must be improved in order to acquire more photons in a given time. That is still a challenge, because the axial coverage of current scanners is only 16 cm, whereas after injection of the radiopharmaceutical, radiation is emitted from everywhere in the patient's body where the radiopharmaceutical localizes. So, if the detector covered the whole body, the patient could be imaged in one step. However, building such a system would be very expensive.

Do you think it is still possible to have other combinations with other imaging techniques?

Yes, absolutely, but only if there is a medical reason to do it – such a development won't be driven by advances in technology alone. When we looked at building a PET/CT scanner, we found that most whole-body anatomical imaging for oncology is still performed with CT, whereas in brain and spinal malignancies, anatomical imaging is performed with magnetic resonance (MR).

PET/CT is less technologically challenging than combining PET with MR. PET and CT modalities basically do not interfere with each other, except maybe when they are operated simultaneously within the same gantry. The combined PET/CT scanner provides physicians with a highly powerful tool to diagnose and stage disease, monitor the effects of treatment, and potentially design much better, patient-specific therapies.

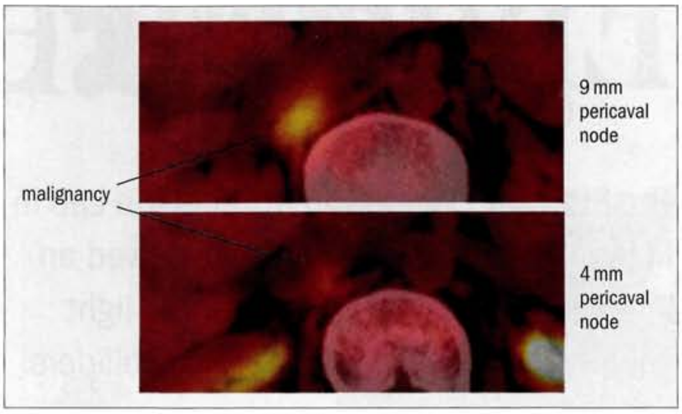
What is the actual cost of a PET/CT scanner?

The cost of the highest-performing system is about $2.5 million [€1.98 million], but it may be significantly less if a lower-performance design is adequate for the envisaged application.

Further reading

R Nutt 2002 The History of Positron Emission Tomography *Molecular Imaging and Biology* **4** 11.

D W Townsend 2004 From 3-D Positron Emission Tomography to 3-D Positron Emission Tomography/Computed Tomography: What Did We Learn? *Molecular Imaging and Biology* **6** 275.



A 48-year-old patient with a history of stage IIIA ovarian cancer. The PET/CT scan reveals malignancy in two pericaval nodes. The ability to identify radiotracer uptake in such small lymph nodes is a strength of the new HI-REZ, 16-slice biograph PET/CT scanner (Siemens Medical Solutions).

Beatrice Bressan, *CERN, interviewed David Townsend when he visited CERN to give the seminar "Advances in PET Imaging: from Physics to Physician" on 9 February, organized by the Technology Transfer Group and the Physics Department. For a video of the seminar, see http://agenda.cern.ch/fullAgenda.php?ida=a05760.*

Energy-recovering lin

The ERL2005 Workshop at Jefferson Lab in March – the first of its kind – reviewed an innovative use of electron linacs in light sources and, potentially, particle colliders.

In March, 159 scientists from around the world gathered at the US Department of Energy's (DOE's) Jefferson Lab (JLab) in Newport News, Virginia, for ERL2005, the first international workshop dedicated to energy-recovering linear accelerators (ERLs). The workshop was conceived during accelerator discussions preceding the publication in 2003 of the DOE's *Facilities for the Future of Science: A Twenty-Year Outlook* (*CERN Courier* January/February 2004 p13).

Those discussions initially focused on the need to develop high-brightness, high-current injectors, but soon expanded to include the ERLs then beginning to be implemented on three continents. Planning ensued for ERL2005, which was approved by the International Committee for Future Accelerators (ICFA) as an Advanced ICFA Beam Dynamics Workshop, and interest quickly grew. Other sponsors included three institutions building or planning to build superconducting radio-frequency (SRF) ERLs: Cornell University and Brookhaven National Laboratory in the US and the Council for the Central Laboratory of the Research Councils' (CCLRC's) Daresbury Laboratory in the UK.

The growth of ERLs

ERLs began to come of age in 1999 at a light source at JLab – the SRF ERL-driven free-electron laser (FEL). At present, several ERL projects around the world are under design or construction, and test facilities at several laboratories have been funded. Unlike the recycling of electrons in a synchrotron or a storage ring, an ERL uses a conceptually simple phasing technique to recycle the electrons' energy. On a path measuring exactly an integer multiple of the linac RF wavelength plus a half-wavelength, an ERL's accelerated beam travels through an experiment and re-enters the linac to yield back its energy, via the RF field, to the beam being accelerated. The decelerated beam is then dumped at low energy.

An obvious advantage of ERLs is economic. Consider, for example, the ERL-driven 4th Generation Light Source (4GLS) facility planned for Daresbury, where a prototype ERL is under construction. In its May 2003 issue (p7), *Physics World* reported that without energy recovery, "4GLS would consume roughly the output of a large commercial power station". Energy recovery also simplifies spent-beam disposal.

The overall promise of ERLs has been distilled in a paper by JLab's Lia Merminga, who chaired ERL2005 with Swapan Chattopadhyay, also from JLab. Together with co-authors D R Douglas and G A Krafft, Merminga wrote: "At the most fundamental level, beam-energy

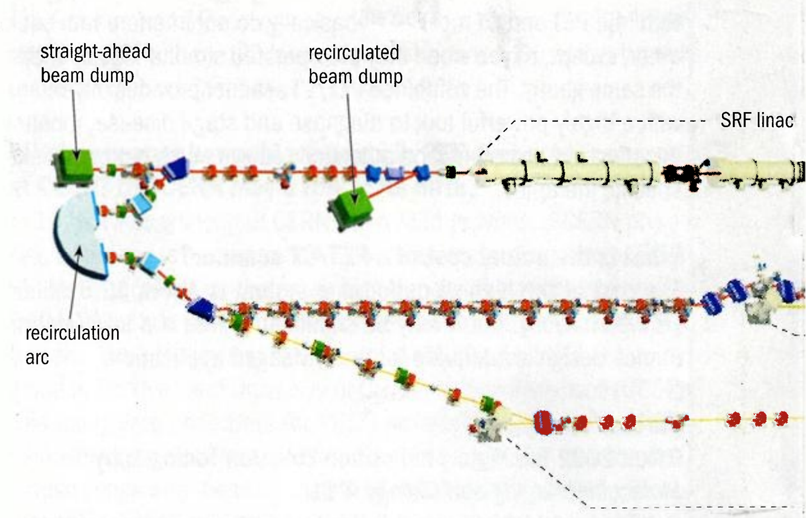


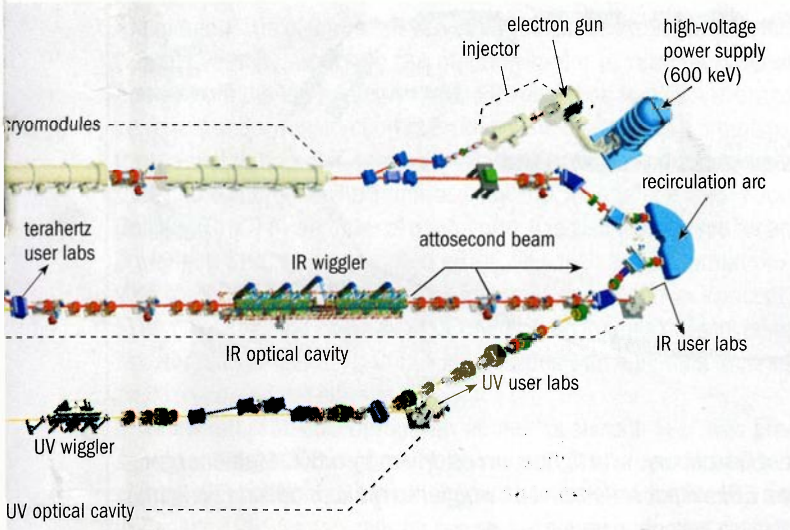
Fig. 1. A 160 MeV, 10 mA energy-recovering linac (ERL) drives JLab's upgrade beam slaloms through the array of magnets in the infrared wiggler (or up to 1 2005). The electron beam re-circulates through the linac and is decelerated f electrons. The beam itself is dumped. Besides driving the IR and UV wigglers,

recovery allows the construction of electron linear accelerators that can accelerate average beam currents similar to those provided by storage rings, but with the superior beam quality typical of linacs. Such an ability to simultaneously provide both high current and high beam quality can be broadly utilized in, for example, high-average-power free-electron laser sources designed to yield unprecedented optical beam power; light sources extending the available photon brilliance beyond the limits imposed by present-day synchrotron light sources; electron cooling devices which would benefit from both high average current and good beam quality to ensure a high cooling rate of the circulating particles in a storage ring collider; or, possibly, as the electron accelerator in an electron-ion collider intended to achieve operating luminosity beyond that provided by existing, storage-ring-based colliders" (Merminga *et al.* 2003).

Realizing these prospects will require overcoming the technical challenges that the workshop was convened to discuss. These include polarized and unpolarized photoinjectors with high average current and low emittance; optimized lattice design and longitudinal gymnastics; beam stability and multibunch/multipass instabilities; beam-halo formation and control of beam loss; SRF optimization for continuous-wave, high-current applications; higher-order-mode (HOM) damping and efficient extraction of HOM power; RF control and stability; synchronization; and high-current diagnostics and instrumentation.

Neither the energy-recovery idea nor its close association with SRF is new. In 1965, Cornell's Maury Tigner suggested a possible collider combining the then-novel concept of the superconducting linear accelerator with what he called "energy recovery" – an "artifice", he

acs begin maturing



d free-electron laser. The FEL produces up to 10 kW of light as the electron kW when directed through the ultraviolet wiggler being installed in mid- or energy recovery, recycling the beam's energy for accelerating new the ERL yields terahertz light directly via a bending magnet.

From ERL performance to piano performance: physicist Stefan Simrock of DESY plays at ERL2005. (Courtesy Greg Adams.)

wrote, that "might also be useful in experiments other than the clashing-beam type" (Tigner 1965). Energy recovery was demonstrated as early as the mid-1970s, but the first ERL with high average current drove the first kilowatt-scale FEL from 1999 to 2001 at JLab.

That FEL, which was later substantially upgraded, gave users infrared light at 3–6 µm for 1800 hours – the most achievable with available funding – and led to publications by some 30 groups. Research topics included nanotube production, hydrogen-defect dynamics in silicon, and protein energy transport. The experimentation influenced thinking about linear and nonlinear dynamical processes. Moreover, the ERL itself directly produced broadband light in the terahertz region between electronics and photonics, at over four orders of magnitude higher average power than anywhere before (*CERN Courier* January/February 2003 p6 and September 2003 p6). In *Nature*, Mark Sherwin of the University of California, Santa Barbara (UCSB) predicted "new investigations and applications in a wide range of disciplines" (Sherwin 2002).

At 5 mA and 42 MeV, JLab's original SRF ERL was a small but much-higher-current cousin of CEBAF, the five-pass, 6 GeV recirculating linac that enables the laboratory's main mission of research in nuclear physics (*CERN Courier* December 2004 p22). The ERL/FEL has now been upgraded to produce light at 10 kW in the infrared, with a 1 kW capability imminent in the ultraviolet (figure 1). For infrared operation, the average beam current has been doubled to 10 mA. In the further evolution of ERLs, high average current will be crucial. Optimal performance, in fact, is a trade-off between that and beam degradation. Envisaged ERL projects involve average currents about an order of magnitude higher than those demonstrated so far.

In his plenary speech at the workshop, Todd I Smith of Stanford University summarized the status and outlook for ERL-based FELs. After mentioning electrostatic machines at UCSB, the College of Judea and Samaria in Israel, the Korea Atomic Energy Research Institute (KAERI) in South Korea, and FOM Nieuwegein in the Netherlands, he moved on to JLab and the other two operational RF linac FELs – an SRF machine at the Japan Atomic Energy Research Institute (JAERI) and a room-temperature ERL at the Budker Institute for Nuclear Physics (BINP), Novosibirsk. Smith said that energy-recovering RF-linac-based FELs are proliferating at a rate both "astonishing" and "satisfying". Among those being planned are machines at KAERI, at Saclay in France and 4GLS at Daresbury. In Florida, in partnership with JLab and UCSB, the National High-Field Magnetic Laboratory has proposed initial steps toward a 60 MeV SRF ERL to drive a kilowatt FEL spanning a wavelength range of 2–1000 µm.

Let there be light

All existing hard X-ray synchrotron radiation facilities are based on storage rings. A half-century ago, first-generation synchrotron-light devices tapped particle accelerators parasitically. Then came a second generation of light sources that were based on dedicated storage rings, followed, in the 1990s, by third-generation machines with high brightness. Third-generation facilities include short-wavelength hard X-ray sources (such as the European Synchrotron Radiation Facility in Grenoble, the Advanced Photon Source at Argonne, and SPring-8 in Japan) and long-wavelength soft X-ray sources (such as the Advanced Light Source at Berkeley, the Synchrotrone Trieste ▷

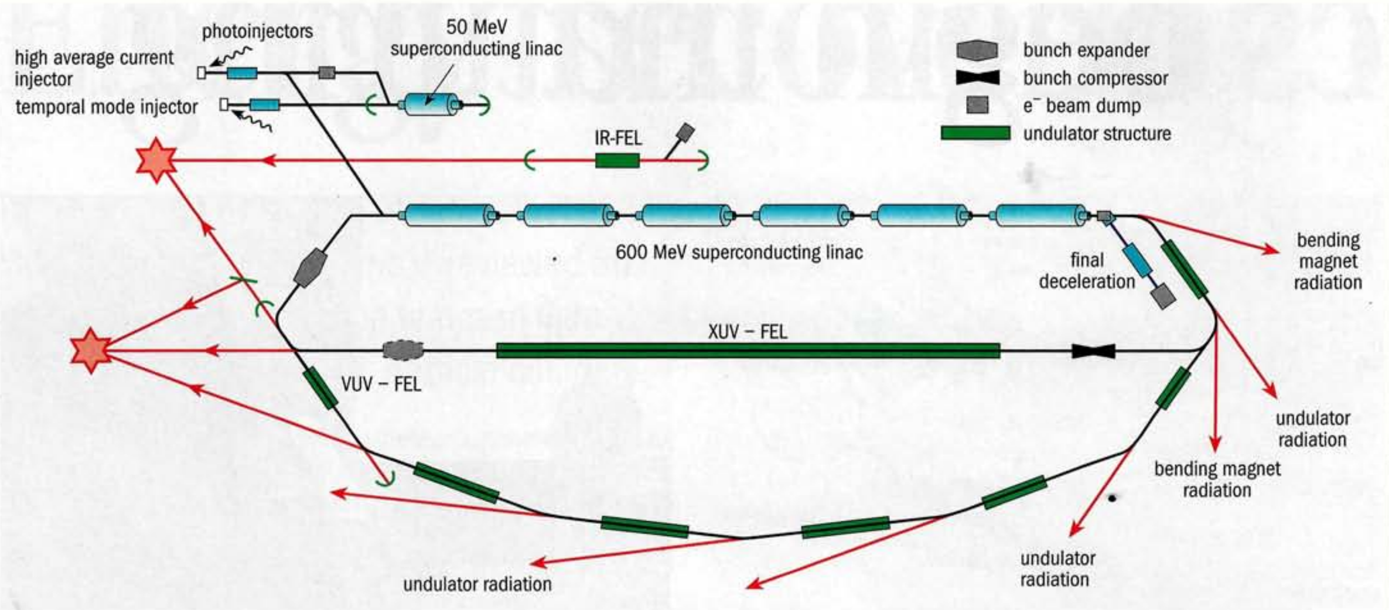


Fig. 2. Conceptual schematic of the planned ERL-based 4GLS project at Daresbury, with light sources driven by a 600 MeV energy-recovering linear accelerator. Daresbury is building a 50 MeV prototype ERL with a Jefferson Lab wiggler to make infrared FEL light.

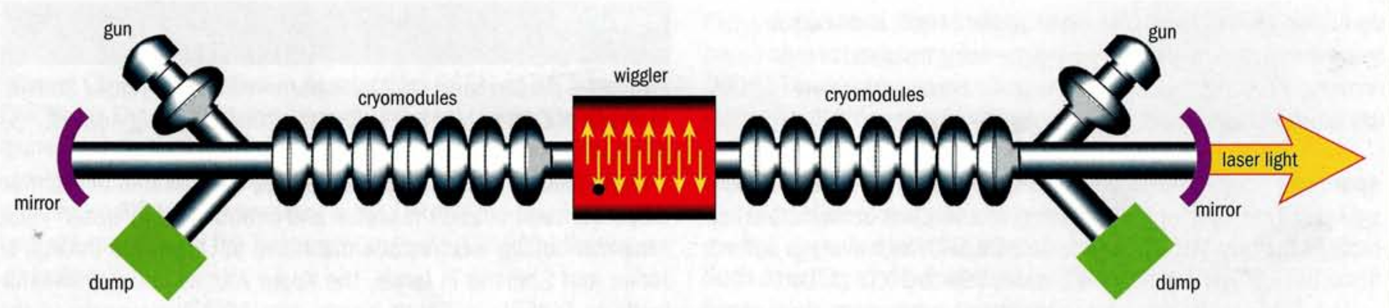


Fig. 3. Schematic of the "push–pull" concept for the free-electron laser, presented at ERL2005. (Courtesy Andrew Hutton.)

in Italy, the Synchrotron Research Center in Taiwan, and the Pohang Light Source in South Korea). Fourth-generation X-ray light sources based on FELs driven by linacs are under development at DESY, SLAC and RIKEN's Harima Institute in Japan. The idea of an X-ray synchrotron light source based on ERLs was advocated in 1998 by G Kulipanov, N Vinokurov and A N Skrinsky at BINP, with their pioneering MARS proposal, and later by JLab's Geoffrey Krafft.

Serious pursuit of a design for an ERL light source by Cornell has recently yielded funding from the US National Science Foundation (NSF) to begin developing a major ERL-based upgrade of the Cornell High Energy Synchrotron Source at the Cornell Electron Storage Ring (*CERN Courier* April 2005 p9). ERLs also constitute "a natural and cost-effective upgrade path" for storage-ring light sources, according to Charles K Sinclair of Cornell. At the workshop, Sinclair characterized the potential improvements in ERLs in brightness, coherence and pulse brevity as "transformational". In one of his examples of applications, he noted that on the timescale of hundreds of femtoseconds, an ERL can enable experimenters to follow the structure of ultrafast chemical reactions. With the NSF funding, Cornell is developing an injector to deliver low-emittance beams at 100 mA.

At JLab – Cornell's partner in preparing the NSF proposal – collaborative experiments are being conducted concerning other issues in ERL development: beam break-up in the ERL/FEL and RF control in both the ERL/FEL and CEBAF. To complement the FEL's demonstration of high average current, CEBAF was specially configured briefly during 2003 for a single-pass proof-of-principle study of energy recovery at the giga-electron-volt scale. JLab's assets for developing SRF-driven ERLs also include the Center for Advanced Studies of Accelerators (CASA) and the Institute for SRF Science and Technology, housed in a test laboratory with a substantial complement of SRF R&D facilities.

As a first step in the 4GLS project, Daresbury is building a 50 MeV prototype ERL that will supply electron beams to a test FEL using an infrared wiggler on loan from JLab. Eventually, with a 600 MeV ERL, 4GLS would complement the UK's higher-energy X-ray light source, Diamond, which is under construction at the CCLRC's Rutherford Appleton Laboratory. The 4GLS facility is planned to exploit the sub-picosecond regime and to combine exceptionally high transverse and longitudinal brightness. Central to the plan are a variety of opportunities for pump-probe experiments and the combining of spontaneous and stimulated sources at a single centre. Two photocathode guns are planned, one for high average current, the other for high peak current (figure 2).

For physics research conducted at colliders, ERLs offer the promise of providing electron cooling for hadron storage rings and high-current, low-emittance electron beams for high-luminosity electron-ion colliders. In the cooling process, which brings higher luminosity to ion-beam collisions, an ion beam and an electron beam are merged. The electron beam's energy is chosen to match the ion beam's velocity, enabling the electron beam to remove thermal energy from the ion beam. An R&D ERL designed for 0.5 A average current is under construction at Brookhaven. It serves as a prototype for the electron cooler designed for RHICII, the proposed upgrade that could increase the luminosity of the Relativistic Heavy Ion Collider (RHIC) by an order of magnitude. It is also a prototype for an envisaged RHIC upgrade called eRHIC, in which an ERL would provide electron beams for electron–ion collisions. A similar concept, ELIC, envisages the upgrade of CEBAF at JLab for energy-recovering acceleration of electrons to use in collisions with light ions from an electron-cooled ion-storage ring.

A new ERL/FEL concept known as the "push–pull FEL" was presented at ERL2005 by Andrew Hutton of JLab. This proposal, which in some ways resembles a high-energy collider configuration mentioned in Tigner's 1965 paper, calls for two sets of superconducting cavities with two identical electron beams travelling in opposite directions. Each set of cavities accelerates one electron beam and decelerates the other. This arrangement allows the energy used to accelerate one beam to be recovered and used again for the other. The difference compared with other energy-recovery proposals is that each electron beam is decelerated by a different structure from the one that accelerated it, so this is energy exchange rather than energy recovery. The push–pull approach can lead to a compact layout (figure 3, p28).

The continued success of ERLs would most likely accelerate interest in Chattopadhyay's call for "practical, affordable yet unique and exciting new accelerator facilities" at the "mezzo scale" (*CERN Courier* October 2002 p46). Such successes would also, as Merminga and colleagues concluded, "set the stage for high-energy machines at the gigawatt scale, providing intense, high-quality beams for investigation of fundamental processes as well as the generation of photon beams at wavelengths spanning large portions of the electromagnetic spectrum". Toward such ends, said Chattopadhyay, "Jefferson Lab is advancing the ERL field at the fastest pace possible and is committed to working in partnership with the international community to promote the development of ERLs further as the next-generation instrument of science wherever it is feasible". He added that "the successful emergence of the Cornell and Daresbury facilities, both collaborators with Jefferson Lab, signals a bright future ahead".

Further reading

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M Sherwin 2002 *Nature* **420** 131.
M Tigner 1965 *Nuovo Cimento* **37** 1228.
For presentations made at ERL2005 see http://conferences.jlab.org/ERL/.

Steven Corneliussen, *Jefferson Laboratory.*

HERA and LHC workshops help prepare for the future

A series of workshops has given scientists the opportunity to discover how the studies currently being carried out at HERA will influence future physics at the LHC.


Rolf-Dieter Heuer, research director at DESY, is seen here (left) with Joël Feltesse of CEA Saclay during a coffee break.

After the major luminosity upgrade of DESY's electron–proton collider HERA in 2001 (*CERN Courier* March 2005 p17), experiments at the accelerator are now producing data for Run II, which will last until the end of HERA operation in 2007. The results obtained by the two collider experiments H1 and ZEUS will have a profound impact on the physics to be explored at CERN's Large Hadron Collider (LHC). Since March 2004, members of the communities working at HERA and preparing for the LHC have been meeting regularly at CERN and DESY in a series of workshops intended to promote cooperation between the two communities. The aim of the six "HERA and the LHC" workshops, the final meeting of which was held at DESY during the week before Easter 2005, was to investigate the exact implication of HERA results on the physics at the LHC.

The goals of the series of workshops, which had more than 200 registered participants, were as follows:

- to identify and prioritize those measurements to be made at HERA that have an impact on the physics reach of the LHC;
- to encourage and stimulate the transfer of knowledge between both communities and establish an ongoing interaction;
- to encourage and stimulate theoretical and phenomenological efforts;
- to examine and improve theoretical and experimental tools;
- to increase the quantitative understanding of the implication of HERA measurements on LHC physics.

At the final meeting of the series, the speakers summarized the results and presented the conclusions from studies and discussions carried out during the past year by working groups on parton density functions, multijet final states and energy flows, heavy quarks, diffraction and Monte Carlo tools. In general it was made very clear that there is a strong interest from the LHC physics community in detailed studies at HERA. Several general talks on physics at the LHC and HERA outlined the importance of the results obtained at HERA, with special emphasis on the measurements that have still to be done and that will have a significant impact on the physics reach of the LHC. "Clearly, to calculate properly the production rates of Higgs and supersymmetry we absolutely need to understand quantum chromodynamics [QCD] as well as possible," said John Ellis from CERN. It also became evident that much more theoretical, phenomenological and experimental investigations would be desirable, and to this end several projects were launched during the workshop.

Speakers repeatedly stressed the importance for LHC physics of precise measurements of the parton densities, i.e. the densities of the various types of quarks and the gluons within the proton. In particular, the whole issue of parton density functions (PDFs), from the standard integrated ones to unintegrated and generalized PDFs and eventually to diffractive PDFs, is a rich field for theoretical and experimental studies. These include not only a precise experimental determination of the PDFs, but also address the more fundamental question of the universality of the PDFs and in particular whether those obtained at HERA can be applied to the LHC without further modification beyond evolution effects in QCD.

In the multijet working group, one of the main topics was the issue of multiple scatterings and underlying events. The understanding of these effects has an impact on, for example, the Higgs cross-section measurements in the boson-fusion channel at the LHC. A major step towards a deeper understanding of multiple scatterings is their relation to diffractive scattering: they are simply different facets of the large density of partons at high energies. The dynamics of these high-density systems require extensions of the concept of parton densities from transverse-momentum dependent (unintegrated) to generalized and diffractive parton densities, which can be measured precisely at HERA. These parton densities will be essential for analysing diffractive Higgs production at the LHC, a very clean and promising channel. However, to study this process and also problems of parton dynamics at low x that are still unsolved, the forward region of the LHC detectors needs further instrumentation. This is a task for which the experiments at HERA have accumulated both technical and physics experience over recent years.

Heavy quark production at the LHC is also interesting in terms of QCD. The densities of heavy quarks will play an important role at the LHC, for example in Higgs production channels, and they will be accurately measured at HERA in the high-luminosity programme. In the forward production of heavy quarks, as will be the case in the LHCb experiment, effects coming from high parton densities and the saturation of the cross-section might be observed directly.

All of these studies require adequate tools and simulation programs. The working groups made measurements from HERA, the Tevatron at Fermilab and the SPS at CERN available in the form of easy-to-use computer codes. These will be useful for any tuning of Monte Carlo generators. New concepts were also investigated and user-friendly interfaces to simulation programs were developed.

A unique machine

During the year of the workshops, co-operation between experimenters at HERA and the LHC and the interest from the theoretical and phenomenological side have continuously increased. It has become clear that not only can the LHC profit from HERA (i.e. with exact measurements of parton densities), but also that HERA will profit from investigations carried out for the LHC, such as the application of next-to-leading (NLO) calculations in Monte Carlo event generators (MC@NLO).

HERA is a unique machine; it is the only high-energy electron–proton collider in the world. During the workshop meetings, it became obvious that for many topics, it is the only place today where many of the necessary measurements and studies can be performed. HERA is a machine for precision QCD measurements, just as the Large Electron–Positron collider was for the electroweak sector, with the difference that QCD is richer but also more difficult. Many questions are still unanswered, for example those concerned with the understanding of diffraction and issues in parton evolution with all its consequences for the LHC.

The workshops have critically assessed the physics programme of HERA and made suggestions for further measurements and investigations, in particular those that will be important for the physics reach of the LHC and that cannot be performed anywhere other than at HERA. One example is the precise measurement of the gluon density using the longitudinal structure function F_L, which is important for clarifying uncertainties in the present knowledge of the gluon density and the formulation of QCD at high parton densities.

In view of the prospects for further progress emerging from the high-statistics HERA Run II data, a continuation of the workshop series is now planned on an annual basis. The next meeting will be held at CERN in March 2006.

Further reading

For more information on the workshops, see www.desy.de/~heralhc/.

Hannes Jung, *DESY, and* **Albert De Roeck**, *CERN.*

Records fall at Cornell

Experiments at Cornell are breaking records for accelerating gradients and Q values in superconducting radio-frequency cavities, reports **Hasan Padamsee**.

Improvements in our understanding of the mechanisms that limit accelerating gradients or electric fields, together with technological advances from worldwide R&D, have steadily increased the performance of superconducting cavities over the past decade.

The TESLA collaboration is now achieving accelerating gradients of 35 MV/m in 1 m-long superconducting structures suitable for the proposed 500 GeV International Linear Collider. The best single-cell cavities at many laboratories reach 40–42 MV/m. At these gradients, energy losses from the superconducting microwave cavity resonators are still miniscule, with "intrinsic Q" values exceeding 10^{10}, i.e. it takes 10^{10} oscillations for the stored energy in the resonator to die out. If Galileo's original pendulum oscillator had possessed a similar Q value, it would still be oscillating now, 400 years later.

Fig. 1. Comparison of the TESLA cavity shape (left) and the new cavity shape.

One goal of future R&D programmes is to push accelerating gradients and Q values even higher either to reach tera-electron-volt energies or to save on costs. However, above 40 MV/m the magnetic field at the surface of the resonator approaches the fundamental limit where superconductivity breaks down. One way to circumvent this limit is to modify the shape of the cavity to reduce the ratio between the peak magnetic field and the accelerating field.

About two years ago, Valery Shemelin, Rongli Geng and Hasan Padamsee at the Cornell University Laboratory for Elementary-Particle Physics (LEPP) introduced a "re-entrant" shape, which lowers the surface magnetic field by 10%. Figure 1 compares the re-entrant cavity shape and the shape of the TESLA cavity. The downside of the new shape is the higher accompanying surface electric fields, which enhance "field emission" of electrons from the regions of high electric field. Field emission does not present a "brick wall" limit, however, because techniques such as high-pressure rinsing with high-purity water at pressures of about 100 bar eliminate the microparticle contaminants that cause field emission.

Another important aspect of cavity shape is beam aperture. When a bunch of charge passes through an accelerating cavity it leaves behind a wakefield, which disrupts oncoming bunches. Smaller apertures produce stronger wakefields. The re-entrant shape has the same aperture as the TESLA shape; nevertheless, reducing the aperture, say from 70 to 60 mm, would yield higher accelerating gradients because it would allow a surface magnetic field 16% lower. Further studies are in progress to evaluate the trade-off between higher wakefields and higher potential accelerating gradients.

New ideas are usually proved in single-cell cavities before the technical challenges of multi-cell accelerating units are addressed. The first 70 mm-aperture re-entrant single-cell cavity fabricated at Cornell reached a world record accelerating field of 46 MV/m at a Q value of 10^{10}, and 47 MV/m in the pulsed mode, which is suitable for a linear collider. Figure 2 on p33 shows how Q varies with accelerating field for the cavity. To reach these record performance levels, the cavity was made from high-purity, high-thermal-conductivity niobium (with residual resistivity ratio of 500) to avoid thermal breakdown of the superconductivity. Electropolishing provided an ultra-smooth surface. High-pressure rinsing at 100 bar thoroughly scrubbed the surface free of the microparticles that cause field emission. Final assembly took place in a Class-100 clean-room environment. All these are now standard techniques for the best superconducting cavity preparation. In addition, baking at 100 °C for 50 h promoted a redistribution of the oxygen in the radio-frequency (RF) layer, which is known to avoid premature RF losses.

Record operating Qs

When operating an accelerating cavity with beam, another important Q value is the "operating" or "loaded" Q. This is determined by the power lost to the beam, whereas the "intrinsic Q" is determined by the ohmic power loss in the cavity walls. Intrinsic Q values are 10^{10} or higher as discussed above. For applications with minimal beam loading, the closer loaded Q is to intrinsic Q, the smaller the overall RF power investment and operating costs.

The state of the art for structures designed to accelerate velocity-of-light particles is operation at a loaded Q of 2×10^7. Higher loaded Qs are extremely challenging because the resulting bandwidth of the cavity resonance is only a few hertz (out of a typical 1.5 GHz), making the field in the cavity extremely sensitive to any perturbation of the resonance frequency due to microphonics or detuning of Lorentz forces. However, Qs above 10^8 are highly desirable for future applications, in particular for energy-recovery linacs (ERLs) for future high-flux, high-brilliance light sources (p26). These are being pursued by many laboratories around the world, including Cornell. No control system has ever met the amplitude and phase-stability requirements of the RF field at a loaded Q of 10^8.

Building on techniques developed at DESY for the Tesla Test Facility, researchers at Cornell, under the direction of Matthias Liepe, have developed a new digital RF control system that provides great flexibility, high computational power and low latency

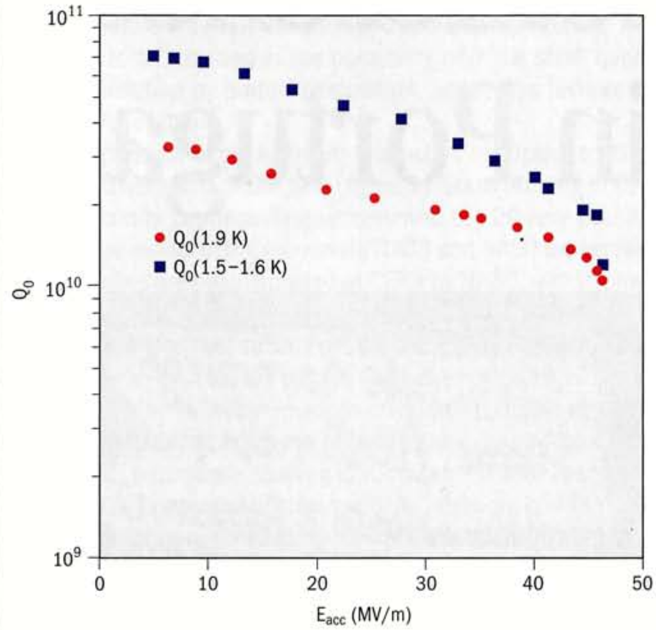


Fig. 2. Experimental results for measurements of unloaded Q values versus accelerating electric fields E_{acc}. The Q values remain above 10^{10} until the accelerating field hits 46 MV/m.

for a wide range of control and data-acquisition applications. Recently Cornell tested this system in two extreme regimes of loaded Q. First, in the Cornell Electron Storage Ring (CESR), the system stabilized the vector-sum field of two of the ring's superconducting 500 MHz cavities at a loaded Q of 2×10^5 with a beam current of several hundred milliamps. Several months of continuous operation proved the system's high reliability and the field stability surpassed design requirements.

In a more crucial and demanding test, a team from Cornell and Jefferson Laboratory (JLab) connected the system to a cavity with a loaded Q greater than 10^8 at JLab's infrared free-electron laser and tested it with beam in the energy-recovery mode, in which the effective beam current is practically zero. In continuous operation, excellent field stability – about 2×10^{-4} rms in relative amplitude and 0.03 degrees rms in phase – was achieved at a loaded Q of 1.4×10^8 in full energy-recovery mode. This sets a new record for loaded Q operation of linac cavities. At the highest loaded Q, less than 500 W of klystron power was required to operate the cavity at a field of 12 MV/m in energy-recovery mode with a beam current of 5 mA. At the more usual loaded Q of 2×10^7, about 2 kW is required.

The control system used includes digital and RF hardware developed in-house; very fast feedback and feed-forward controls; automatic start-up and trip recovery; continuous and pulsed-mode operation; fast quench-detection; and cavity-frequency control. The cavity-frequency control relied on a fast tuner based on a piezoelectric tuning element, which proved effective in keeping the cavity on resonance. As an added bonus, the ramp-up time to high gradients was less than 1 s, instead of the more usual minutes.

Hasan Padamsee, *LEPP, Cornell University.*

SUPPLIER INFORMATION

Hard probes conference finds success in Portugal

In November, more than 100 enthusiasts headed to a fishing village near Lisbon for the first international conference on hard probes of heavy-ion collisions, Hard Probes 2004.

The town of Ericeira on the Atlantic coast faces Cabo da Roca, the western limit of the European continent. It proved an inspiring setting for Hard Probes 2004, the first International Conference on Hard and Electromagnetic Probes of High Energy Nuclear Collisions.

The conference grew out of a series of Hard Probe Café meetings, the first of which was held in 1994 at CERN. The idea then was to form a collaboration of theorists and experimentalists interested in the interface between hard perturbative quantum chromodynamics (QCD) and relativistic heavy-ion physics. CERN's Super Proton Synchrotron (SPS), with a beam energy of up to 200 GeV/nucleon, was the highest-energy heavy-ion facility at the time and hard processes were rare. But it was becoming clear that the use of penetrating hard probes – for example, high-mass lepton pairs and high-momentum photons – held promise for understanding the strongly interacting hot medium formed in heavy-ion collisions.

Subsequent experimental results from the SPS, and the commissioning of the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory, put hard processes in the focus of physicists' attention. After meetings in Europe and the US, when the first published proceedings helped in planning experiments at RHIC and the Large Hadron Collider (LHC) at CERN, the Hard Probe Café could no longer accommodate all the enthusiasts. So Hard Probes 2004 was born, organized by Carlos Lourenço, Helmut Satz, João Seixas and Jorge Dias de Deus, and held on 3–10 November 2004 in the beautiful resort of Ericeira. The 120 or so participants did not have much free time to enjoy the sea breeze; the programme was intense as well as interesting, and local maritime advice underlined the importance of keeping the aim in mind (figure 1).

After a first day of lectures that were more pedagogically oriented, Krishna Rajagopal of MIT opened the conference by surveying what is known about the QCD phase diagram and its new states of matter, from quark–gluon plasma (QGP) to colour superconductors. Jochen Bartels of DESY recalled the parton formulation of high-energy interactions, addressing parton evolution and saturation. These aspects have led to major progress in the understanding of the initial conditions in heavy-ion collisions, forming a new approach to the physics of high-energy hadron and nuclear collisions: the colour glass condensate, reviewed by Edmond Iancu of Saclay and Raju Venugopalan of Brookhaven. Related percolation studies were presented by Carlos Pajares of Santiago de Compostela. It is becoming evident that QCD at high parton density can provide a common framework for describing different high-energy interactions, from deep inelastic scattering to relativistic nuclear collisions.

Fig. 1. This motto can be seen on a mural near the beach at Ericeira, and reads: "If you sail without aim, no wind is right."

Probes with charm

One of the main topics discussed at the Hard Probe Café was the fate of heavy quarkonia – bound states of heavy quarks and anti-quarks – in hot quark–gluon matter. Around 20 years ago, Tetsuo Matsui and Helmut Satz predicted that at sufficiently high temperatures Debye screening in the quark–gluon plasma would lead to the dissociation of quarkonia. At the conference, Frithjof Karsch of Bielefeld surveyed the status of theoretical quarkonium studies; our understanding of the topic has progressed significantly following recent lattice QCD calculations, which were discussed by Tetsuo Hatsuda of Tsukuba, Peter Petreczky of Brookhaven and others.

The different binding energies and bound-state radii of the various quarkonia lead to different dissociation temperatures; while the higher excited charmonium states melt near the deconfinement point, the J/ψ (the $\bar{c}c$ ground state) can survive up to higher temperatures. Such behaviour had been previously obtained from potential model studies, and had shown that the in-medium dissociation pattern of quarkonia constitutes a very effective tool for the study of quark–gluon plasma. It can now provide a direct way to relate QCD calculations to data collected from heavy-ion collisions.

The use of heavy quarks for the diagnostics of QCD matter depends of course on reliable computations of their yields in perturbative QCD; the status of these calculations was reviewed by Stefano Frixione of Genova and Ramona Vogt of Lawrence Berkeley National Laboratory (LBNL). The increase of heavy-quark production at high energies could in fact even lead to enhanced quarkonium yields, as Ralf Rapp of Texas A&M and Bob Thews of Arizona showed for different recombination and coalescence models. A further issue to be resolved is the possibility of initial state quarkonium dissociation by parton percolation, which was reviewed by Marzia Nardi of Torino.

The suppression of charmonium production in nuclear collisions was indeed observed at the SPS (figure 2). Louis Kluberg of CERN and Laboratoire Leprince-Ringuet reviewed the 20 year evolution and the final results of the pioneering NA38 and NA50 experiments. Further studies are being pursued at CERN by NA60, with improved detector capabilities, and at RHIC by PHENIX, where the much lower integrated luminosities, so far, limit the usefulness of the higher collider energies. The HERA-B collaboration presented recent results on χ_c production in proton–nucleus collisions at HERA, while Mike Leitch of Los Alamos reviewed several issues in quarkonium production. It is particularly puzzling that the ground state resonances J/ψ and Υ show complete absence of polarization, contrary to the expectations of non-relativistic QCD, while the excited states $\Upsilon(2S)$ and $\Upsilon(3S)$ show maximum transverse polarization.

The meeting also discussed measurements of heavy-flavour production. The STAR collaboration reported on open-charm measurements made by reconstructing the $D^\circ \rightarrow K^-\pi^+$ hadronic decay in d–Au collisions at RHIC. The reconstruction of such hadronic decay modes is difficult to perform in heavy-ion collisions, owing to the high particle multiplicities. The single-electron transverse momentum spectrum provides an alternative, albeit indirect, measurement of charm production at RHIC energies. The charm production cross-sections currently derived from the PHENIX and STAR data differ by a factor of two. Effects that might cause this discrepancy are being investigated and improved results should be available soon.

Another promising direction is the use of electromagnetic probes – leptons and photons; their production has for a long time been considered one of the basic pieces of evidence for the formation of a quark–gluon plasma. There is great interest in these probes because they escape from the medium almost without any interactions, and thus carry valuable information about the early stages in the evolution of dense matter. Moreover, their emission rates can be calculated in lattice QCD as well as in perturbation theory, as discussed by Jean-Paul Blaizot of Saclay, Charles Gale of McGill and others. Rolf Baier of Bielefeld showed that parton-saturation effects also play a crucial role here.

New experimental information on dilepton production was presented by the NA60 experiment at CERN, which took proton–nucleus and In–In data in 2002 and 2003, respectively, with better statistics and mass resolution than previous measurements. Such "second-generation" data should answer some of the questions raised by results previously obtained by CERES at the SPS and lower-energy experiments (such as DLS at LBNL's BEVALAC and KEK's E235), reviewed by Itzhak Tserruya of the Weizmann Institute. Currently, PHENIX at RHIC cannot explore the physics of the low-mass dilepton continuum, given the overwhelming combinatorial background levels. This should be solved by a "hadron blind detector", based on a proximity focus Cherenkov detector, soon to be added to PHENIX.

Jets are another classic hard probe. Colliding beams of protons or heavy nuclei produce jets when partons from the incoming projectiles undergo hard scattering off each other and emerge from the reaction at large angles. In the early 1980s, James Bjorken proposed that jets would interact with the material generated by high-energy nuclear collisions in a way analogous to the more familiar interaction of charged particles in detector material. He suggested that this interaction would lead to energy loss in a quark–gluon plasma (jet quenching). Further theoretical analysis showed that gluon bremsstrahlung is an efficient way of dissipating jet energy to the medium, generating large and potentially observable differences between hot and cold strongly interacting matter.

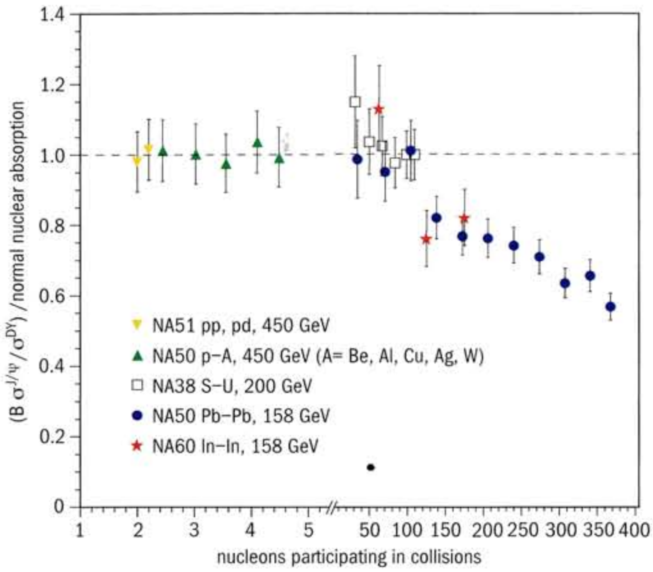


Fig. 2. Several experiments at the SPS studied the production of J/ψ mesons in proton and ion-induced collisions. The most "head-on" collisions between indium or lead nuclei show a significantly suppressed J/ψ yield when compared with the baseline defined by proton–nucleus interactions, as expected if deconfined QCD matter is formed in those collisions.

Jets and RHIC

Jets are the hard probe *par excellence* at RHIC, where the collision energy is high enough to produce them in vast numbers. The first runs with gold beams at RHIC did indeed reveal strong modifications to jet structure, agreeing with the predictions of jet quenching in matter many times denser than cold nuclear matter. Heavy-ion physicists are now looking more deeply into jet-related measurements and interesting nuclear effects continue to emerge. The diversity and quality of the high-momentum-transfer data from the four RHIC experiments justified eight detailed talks. Data were presented from pp, d–Au and Au–Au collisions at the top RHIC centre-of-mass energy of 200 GeV, together with Au–Au measurements at 62.4 GeV, chosen to match the energy of CERN's Intersecting Storage Rings (for which extensive pp collision data are available for comparison).

One of the key pieces of evidence for jet quenching is the strong suppression of high-momentum inclusive pion and charged particle production in the most central nuclear collisions, seen by all RHIC experiments and now provided by PHENIX for transverse ▷

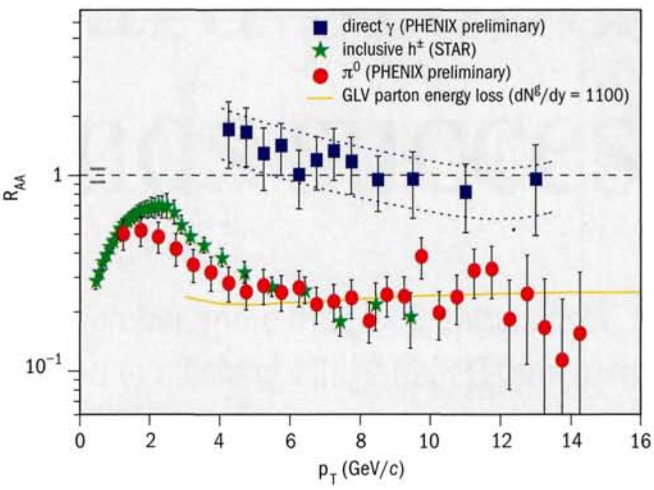


Fig. 3. In the high-energy Au–Au collisions probed at RHIC, the high-transverse-momentum hadrons are suppressed with respect to the "expected" scaling with the number of binary nucleon–nucleon collisions, contrary to what happens with the photons, which can penetrate through the dense matter produced in these interactions.

momenta up to 14 GeV/c. It is crucial to crosscheck such measurements and theoretical calculations in simpler systems. Inclusive particle spectra at high transverse momentum in pp collisions are described well by perturbative QCD calculations, so that the reference spectra for measuring nuclear effects are well understood. Jets and hard photons at high momentum are generated by similar mechanisms, but direct photons should not lose energy in the nuclear medium, since they have no colour charge. Klaus Reygers of Münster showed that, at RHIC, direct photons are indeed produced at the rate expected from QCD calculations, while high-momentum pions are suppressed by a factor of five (figure 3).

On the theory side, Xin-Nian Wang of LBNL and Urs Wiedemann of CERN discussed partonic energy loss in matter, and showed that perturbative QCD calculations incorporating medium-induced bremsstrahlung can describe the main jet-related measurements. A key test is the variation of energy loss with collision energies. Jet quenching generates strong effects at the top RHIC energy of 200 GeV, but does it diminish at lower collision energy? Recently analysed Au–Au data from RHIC at 62.4 GeV found a hadron suppression similar to that at 200 GeV. Model calculations of jet quenching had predicted this, as the result of smaller overall energy loss convoluted with a softer underlying initial partonic spectrum.

It is therefore natural to look at the extensive data amassed by the fixed-target experiments at the SPS, with centre-of-mass energies of 17–20 GeV. Though jet production at SPS energies is rare, high-statistics data sets can probe the lower reaches of the hard-scattering regime. Until recently it was thought that in Pb–Pb collisions at the SPS, production of hadrons with high transfer momentum was enhanced, not suppressed. David D'Enterria of Columbia has re-examined the pp reference data used to measure the hadron production at the SPS, and concludes that its uncertainties were previously underestimated and that signs of jet quenching may indeed also be present at the SPS. This has spurred the SPS heavy-ion collaborations to re-analyse their old data, with more news to be expected by the summer of 2005.

Future prospects

Most of the Au–Au data from RHIC presented at the conference are from the 2002 run, with an integrated luminosity of 250 μb^{-1}. The RHIC collaborations are still analysing the 2004 data set, with a much higher integrated luminosity (3.7 nb^{-1}), and new results on jet physics and other rare probes are expected within a few months.

John Harris of Yale discussed the long-term future of RHIC, including upgrades to the major detectors and the addition of electron cooling to the accelerator which will increase its luminosity for Au–Au by a factor of 10 (RHIC–II). The theoretical interest in low x forward physics was emphasized by Al Mueller of Columbia; this topic should also be high on RHIC's agenda, as noted by Les Bland of Brookhaven. In 2008, the high-energy frontier in heavy-ion collisions will move to the LHC; Bolek Wyslouch of MIT, Andreas Morsch of CERN and Philippe Crochet of Clermont-Ferrand previewed the possibilities this will open up.

Further heavy-ion runs at the SPS could occur in parallel with operation of the LHC, as advocated by Hans Specht of Heidelberg, to profit from what seems to be an ideal collision energy for the studies of the transition to the QGP phase, associated with the high luminosities offered by fixed target running. High-precision data from such runs could be available several years before the start of GSI's Facility for Antiproton and Ion Research (FAIR), where heavy-ion collisions will be studied at up to 35 GeV/nucleon (data sets have been taken at the SPS at 20–200 GeV/nucleon).

The wealth of information presented at the meeting was summarized in three talks: on quarkonia and heavy flavours, by Enrico Scomparin of Torino; on jets and high-transverse-momentum physics, by Peter Jacobs of LBNL; and on electromagnetic probes, by Axel Drees of Stony Brook. Dmitri Kharzeev of Brookhaven summarized the theory presentations at the meeting, inspired by the venue's history. When the Pope divided the unknown world between Portugal and Spain in the 1494 treaty of Tordesillas, he drew a line in what he thought was an empty ocean; 10 years later, South America had been discovered and was being explored. Similarly, the boundaries of 10 years ago, between the old hadronic and the new partonic worlds in the phase diagram of strongly interacting matter, are now more complex and less sharp, thanks to impressive recent progress.

The focused programme, good attendance, spectacular location and extracurricular activities (including a concert of 18th-century popular music in the majestic Convento de Mafra) made this a memorable and successful meeting – one in a new conference series. The second will be held in the spring of 2006 in the San Francisco Bay Area, convened by physicists from Berkeley and Brookhaven. A third is already on the horizon, as Santiago de Compostela in northern Spain would like to welcome a pilgrimage of hard probe physicists.

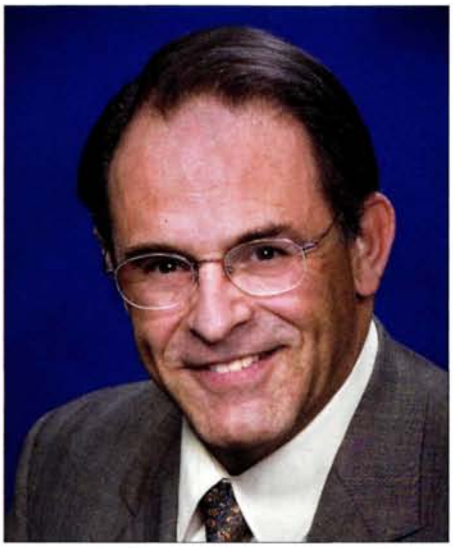
Peter Jacobs, *Lawrence Berkeley National Laboratory*, **Dmitri Kharzeev**, *Brookhaven National Laboratory*, **Carlos Lourenço**, *CERN, and* **Helmut Satz**, *Bielefeld University and IST-Lisbon.*

APPOINTMENTS

Aronson selected to take charge of particle physics at Brookhaven

Samuel Aronson has become the associate laboratory director for high energy and nuclear physics at the US Department of Energy's Brookhaven National Laboratory, as from 1 April. Previously the chair of the laboratory's Physics Department, Aronson succeeds Thomas Kirk, who has become a special assistant to the director.

In his new position, Aronson is responsible for overseeing a $190 million (€150 million) annual budget and about 750 employees. The directorate encompasses the Collider-Accelerator Department, the Physics Department, the Center for Accelerator Physics, the Instrumentation Division and the Superconducting Magnet Division. The operation of the Relativistic Heavy Ion Collider (RHIC) is currently the biggest project in the directorate, at which about 1000 scientists from around the world perform research. Other large projects include the management of the US participation in building the ATLAS detector at the Large Hadron Collider now under construction at CERN, and participation in the Rare Symmetry Violating Processes project proposed at Brookhaven.



Aronson: ready for the challenges ahead.

Aronson joined Brookhaven in 1978. He became head of the PHENIX detector project in 1991 during the construction of RHIC, then became chair of the Physics Department in 2001. He faces some difficult challenges in maintaining the high calibre of Brookhaven's physics programme. He said, "We're seeing some of the worst budgets and budget forecasts in a very long time. The challenge is to maintain and advance a compelling science programme at Brookhaven Lab in the face of these decreased budgets."

UK names Peach and Blair as first directors of John Adams Institute

Ken Peach and Grahame Blair have been appointed the director and deputy director respectively of the UK's new John Adams Institute for Accelerator Science. The institute, based in Oxford University and Royal Holloway, University of London, is one of two university centres created in 2004 by the Particle Physics and Astronomy Research Council (PPARC).

Together with the Cockcroft Institute, comprising the universities of Liverpool, Lancaster and Manchester, the John Adams Institute is participating in a £21 million (€31 million) programme of research and development in accelerator technology for future facilities, including an International Linear Collider and a neutrino factory.

Peach is currently director of the Particle Physics Department and director of the eScience Centre of the Council for the Central Laboratory of the Research Councils based at the Rutherford Appleton Laboratory. He is one of the leaders in the UK in emphasizing the importance of accelerator physics. Peach played a significant role in establishing the feasibility of a neutrino factory and in the recent approval by PPARC and the UK's Office of Science and Technology of the Muon Ionisation Cooling Experiment (MICE) project (*CERN Courier* May 2005 p5). He also chairs CERN's Scientific Policy Committee.

The new institute is named after John Adams, pioneer of accelerators at CERN.

Blair is at present professor of physics at Royal Holloway, University of London. He has played a leading role in the revival of accelerator-physics research in particle physics in UK universities, and is the principal investigator of the LC-ABD research programme of PPARC, which aims to develop the beam-delivery system for the proposed International Linear Collider.

AWARDS

CMS rewards industrial excellence

The CMS collaboration's sixth annual supplier-award ceremony took place at CERN on 5 April. This year nine firms received the experiment's Gold Award for demonstrating excellence by providing components within specification, on schedule and within budget.

Two of the firms also received the prestigious Crystal Award, given to companies that have taken efforts above their contractual obligations to develop new designs, explore novel technologies, and collaborate in research and development programmes with CERN. Of the nine firms to receive awards this year, five are involved in the construction of the CMS tracker.

The Crystal Awards went to two Japanese firms. Hamamatsu Photonics supplies the silicon-strip sensors for the tracker of CMS and was rewarded for optimizing its manufacturing process and for the quality of its components. The CMS tracker uses more than 200 sq. m of silicon-strip sensors – two orders of magnitude greater than in previous CERN experiments – and Hamamatsu became a crucial partner in the project.

The second Crystal Award went to NGK Insulators, involved in the optical-link project for the tracker's electronics system. The firm is responsible for manufacturing the 3900 12-channel analogue receiver modules and also produces the four-channel transceivers for the control system, unique components that are used not only in the tracker, but also in several other sub-detectors in CMS.

NGK is also supplying the 12-channel digital receiver modules for the CMS electromagnetic calorimeter project.

Representatives of the firms that received CMS best supplier awards. Left to right: C Fulvia (Plyform), K Sato and K Yamamura (Hamamatsu Photonics), G Roveta (Criotec Impianti), M Fornari (Telema), H P Reinhardt (Reinhardt Microtech), M Sonninen (Planar Systems), E Dyakov (Lutch), M Mottier (NGK Insulators) and J Vital (Chipidea Microelectronics).

Three other firms contributing to the tracker received the CMS Gold Award. Finnish firm Planar Systems and Swiss firm Reinhard Microtech were presented with the award for producing more than 15 000 aluminium-on-glass pitch adapters, fulfilling the stringent quality requirements. Plyform received an award for supplying most of the composite carbon-fibre material for the tracker, demonstrating excellent technical competence and great flexibility.

Three companies taking part in the CMS superconducting coil project received Gold Awards. The Italian firm Criotec Impianti was presented with an award for manufacturing the thermal shields. These are cooled to liquid-nitrogen temperatures (77 K) and form a thermal radiation shield for the solenoid's cold mass, which is cooled to 4.2 K. The Russian firm Lutch received an award for manufacturing the suspension tie rods that will be used to support the 225 t of the cold mass. They have to withstand the forces generated when the magnet is on, as well as deal with temperature differences of 270° between their two extremities.

The Italian firm Telema received its award for manufacturing the dump resistor for the protection of the magnet. The precision achieved is remarkable for this type of component, as the resistor must very rapidly absorb two-thirds of the 2.6 GJ of energy stored in the magnet.

The final award went to a Portuguese firm. Chipidea Microelectronics has developed and designed analogue-to-digital converters meeting very demanding specifications regarding precision, noise levels and energy consumption. These devices are crucial to the operation of the CMS electromagnetic calorimeter.

Hands-on-CERN receives a Webby

Hands-on-CERN (http://hands-on-cern.physto.se), the particle-physics educational website developed by Erik Johansson of Stockholm University, has been awarded the 9th Webby Award for Science. It beat off competition from three sites from NASA that were nominated for the science category. A fourth nominee, the *National Geographic* Forces of Nature site, was the People's Voice winner in this category.

The annual "Webbys" – which have been called the "online Oscars" – are widely regarded as the leading international honour for websites and the people behind them. They are awarded by the International Academy of Digital Arts and Sciences in more than 60 categories, from fashion to politics. In addition, the public around the world cast votes for the People's Voice winners.

Hands-on-CERN uses events from the DELPHI experiment at the Large Electron–Positron collider to explore the smallest components of matter (*CERN Courier* March 2002 p18). It uses the "WWW interactive remote event display", WIRED, which was adapted for Hands-on-CERN in particular by Mark Dönszelmann of CERN's WIRED development team. The interactive event displays are backed up with pages describing how detectors and accelerators work. The site also contains various animations.

AWARDS

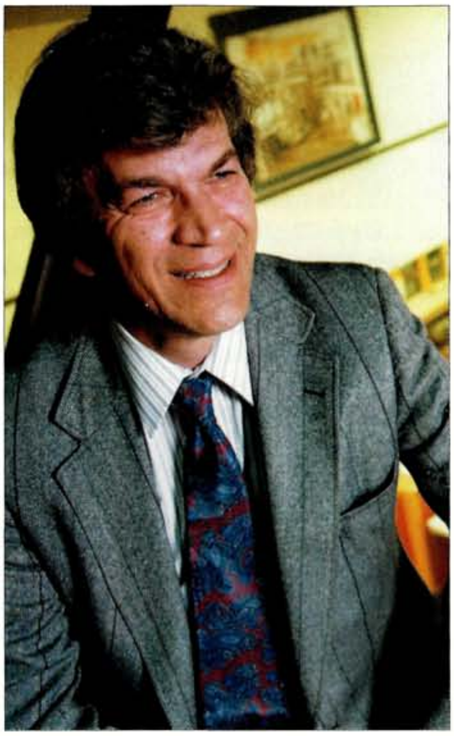
Davidson and Roser share prize for pioneering accelerator science

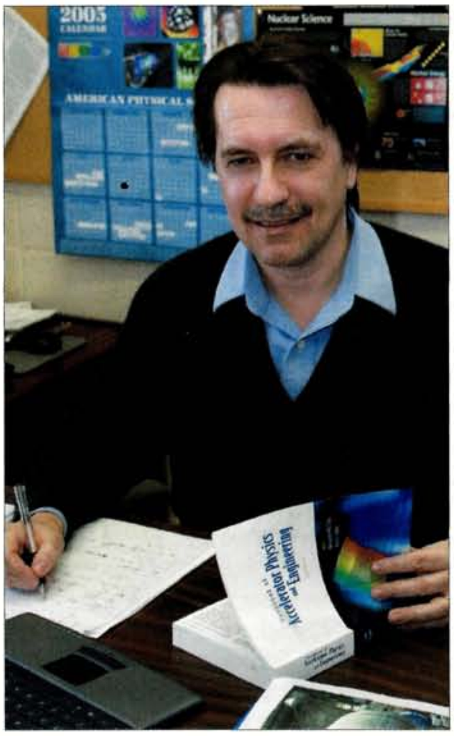
Ronald Davidson of Princeton University and Thomas Roser of the US Department of Energy's Brookhaven National Laboratory have been awarded the 2005 Particle Accelerator Science and Technology Award by the Nuclear and Plasma Science Society of the Institute of Electrical and Electronics Engineers. The award was presented on 18 May at the Particle Accelerator Conference, PAC05, held in Knoxville, Tennessee.

Davidson, who is deputy head of the Theory Department and head of the Beam Dynamics and Non-neutral Plasma Division at the Princeton Plasma Physics Laboratory, receives the award for "pioneering contributions to the theory of charged particle beams with intense self fields, including fundamental studies of nonlinear dynamics and collective processes".

Davidson has made numerous fundamental theoretical contributions to several areas of pure and applied plasma physics, including intense charged particle beams and advanced accelerator concepts.

Roser, who is associate chair for accelerators and Accelerator Division head at Brookhaven, receives the award "for pioneering scientific work and introduction of new technology in the acceleration, storage and collision of polarized protons" at the Relativistic Heavy Ion Collider (RHIC). He has made significant contributions to the design and construction of the magnets known as Siberian snakes for RHIC and for the Alternating Gradient Synchrotron, which feeds polarized protons into RHIC.





Left to right: Ronald Davidson of Princeton University and Thomas Roser of Brookhaven.

CORRECTIONS

- In "Electrons jump atoms to dispose of excess energy" on p13 of the December 2004 issue, the distance of "about six atomic radii apart" should be 0.34 nm, rather than 34 nm.
- In the issue of May 2005, p38 refers to the "error from CDF from 200 fb^{-1} of data"; here, "200 fb^{-1}" should read "0.2 fb^{-1}".
- Also in May 2005 on p33, the correct name of the prize awarded to Alain Blondel by the Société Française de Physique is the Jean Ricard Prize. Apologies to all concerned.
- Also in May 2005, on p35 the building shown is identified as the main building of ICTP in Trieste; it is of course ICTP's Adriatico guest house.

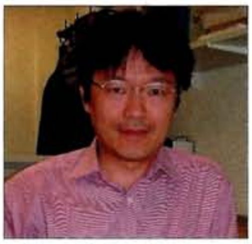
MEETINGS

The traditional Crimean Summer School and Conference **New Trends in High-Energy Physics** will be held in Yalta, Ukraine, on 10–17 September. Topics will include elastic and diffractive scattering of hadrons and nuclei; deep inelastic scattering; multiparticle dynamics; spin and polarization; collective properties of strongly interacting matter; astroparticle physics and cosmology; heavy flavours and hadron spectroscopy; duality, strings and confinement; the Standard Model and beyond; advances in quantum-field theory; integrable systems; and new physics at future colliders. For further details see http://crimea2005.bitp.kiev.ua. Send applications to Laszlo Jenkovszky, BITP, Kiev-143, Ukraine. Alternatively e-mail crimea2005@bitp.kiev.ua or jenk@bitp.kiev.ua, or fax +38 044 5265998.

A **Symposium in Memory of George Placzek** will be held at Brno University of Technology on 21–24 September. Organized by Masaryk University in Brno, in co-operation with several other scientific institutions, the conference will honour the 100th anniversary of Placzek's birth and 50th anniversary of his death. A call for papers related to Placzek's life and fields of his scientific activities has been announced. For further details see http://dumbell.physics.muni.cz/placzek/.

PHOTOS

Sweden's **Anders Palm** (left) and his class visited CERN on 25–26 April. Palm is the winner of the 2005 Ingvar Lindqvist Award for teaching physics. The award, instituted in 1991 by the Royal Swedish Academy of Sciences, is also made to teachers in mathematics, chemistry and biology. The location is the cavern of the LHCb experiment.



Left to right: **Katsuyu Kasami**, **Tom Haruyama**, **Hitoshi Inoue** of KEK, and **Satoshi Mihara**, University of Tokyo, have received the Commendation for Science and Technology from the minister of education, culture, sports, science and technology in Japan. The award is in recognition of their "research on a pulse tube cryocooler for a liquid xenon calorimeters" , developed at KEK originally for the MEG experiment at PSI and now at CERN for cooling in the TOTEM experiment.

Representatives of the **Fundamenteel Onderzoek der Materie** (FOM), the Foundation for Fundamental Research on Matter, which funds research in the Netherlands, came to CERN on 22 April. Their visit took in the ATLAS assembly hall, the test facilities for the superconducting magnets for the LHC, and the ATLAS experimental cavern, where they paused for a group photo.

On 28 April, CERN welcomed **Jean-Claude Petit**, director of programmes of the Commissariat à l'Energie Atomique (CEA) in France, and **Olivier Pagezy**, finance director of the CEA. They visited the assembly hall for the CMS experiment, the COMPASS experiment and the test facilities for the LHC magnets. Left to right in the ATLAS cavern are Petit, **Peter Jenni**, ATLAS spokesman, Pagezy and **Gabriele Fioni**, CEA deputy director of programmes.

Marc Verwilghen (left), Belgian minister of economy, energy, foreign trade and science policy, came to CERN on 8 April. He visited the assembly hall and underground cavern for the CMS experiment, as well as the hall where the superconducting magnets for the LHC are being tested. Here he is seen with CERN's director-general, **Robert Aymar**.

On 21 April, **Maria van der Hoeven**, the Netherlands minister for education, culture and science, visited CERN. She toured the underground cavern where the ATLAS detector is being installed, the LHC tunnel, and the magnet assembly and test halls before meeting a group of young scientists from the Netherlands. Here she talks with, from left to right, **Jos Engelen**, CERN's chief scientific officer, **Peter Jenni**, the ATLAS spokesman, **Herman Ten Kate**, head of the ATLAS magnet project, and **Frank Linde**, director of the Netherlands National Institute for Nuclear Physics and High Energy Physics (NIKHEF).

NEW PRODUCTS

Acqiris is now offering dual- and single-channel 6U CompactPCI streamer analysers featuring an optical data link. The new high-speed SC240 and SC210 are designed for use with mass-storage devices or post-processing engines. Both provide on-board data-handling through an FPGA data-processing unit. The standard optical link offers two birectional links operating at up to 2.5 Gbit/s. For further information see www.acqiris.com.

CeramTec North America, a manufacturer of custom-engineered, high-tech ceramics, has redesigned and expanded its website to provide a better showcase for its product range. The new site consolidates information previously held on three sites, features animation and video clips, and allows customers to request quotes as well as to order online. See www2.ceramtec.com.

FuG Elektronik GmbH has completely redesigned its medium- and high-voltage range of power-supply units. The new MCP (125–2000 V) and HCP (3500 V to 150 kV) series offer many new features, such as lower weight and separate digital displays for current and voltage. A new range of computer interfaces is also available, including Profibus, USB and Ethernet. For further information call +49 8031 28510, e-mail info@fuh-elektronik.de or see www.fug-elektronik.de.

Hiden Analytical has expanded the Hiden QIC series of gas analysers, which analyse gas and vapour species in real time. The company has also extended its range of UHV surface analysers with the addition of MAXIM, a high-performance quadrupole secondary ion monitor featuring a tenfold increase in detection capability. For further information tel +44 1925 445225, e-mail info@hiden.co.uk or see www.hidenanalytical.com.

Microwave Amplifiers has released the AM84, a solid-state five-stage pulsed amplifier delivering nominally 1 kW of output power, for use in particle-accelerator applications. The unit is available in pulsed mode at operating frequencies of 1.1–3.1 GHz in modular form or for mounting in a 19 inch 3U rack. CW units are also available in modular form with an integral forced air-cooled heatsink assembly, or in 19 inch 9U rack mount units. For further information tel +44 1275 853196, e-mail sales@maltd.com or see www.maltd.com.

NEXCOM International has announced a series of blade servers with Oracle 9i/10g RAC (Real Application Cluster), which will improve the manageability, expandability and efficiency of Oracle in Linux. Coupled with the features of Oracle 9i/10g RAC, the NEXCOM HS416 blade server is ideal for data centres. To find out more, see http://bladeserver.nexcom.com.tw/index.jsp.

OBITUARIES

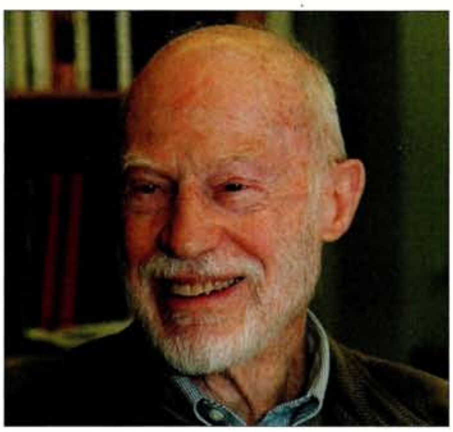
Bryce DeWitt 1923–2004

Bryce DeWitt passed away on 23 September 2004. His life, long dedicated to physics, has left a profound legacy in the theory of gravity (classical and quantum) and in quantum-field theory. He was often far ahead of his time.

DeWitt graduated from Harvard in 1943 and joined the war effort as a navy pilot. He returned to Harvard after the war to do his PhD thesis under the supervision of Julian Schwinger. The subject was nothing less than quantum gravity, and DeWitt's degree was awarded in 1950. He then pursued postdoctoral activities at the Institute for Advanced Study in Princeton, the Swiss Federal Institute of Technology (ETH) in Zurich and a year at the Tata Institute in Bombay.

From 1952 to 1955 he was a senior physicist at Livermore Laboratory in the US. He became an expert in numerical hydrodynamics, which he later applied with his students to the first numerical studies of black-hole collisions, thus inaugurating the field of numerical relativity.

In 1956 DeWitt became director of the Institute of Field Physics at the University of North Carolina. At the university he discovered the properties of Green's functions in curved space–time, which



played a major role in his studies of the heat kernel in curved spaces. This had wide-ranging applications in quantum-field theory, general relativity and even mathematics.

In the 1960s DeWitt wrote some monumental works on the analysis of quantum gravity and quantum-gauge theories. He extended the rules that Feynman had found at one-loop in 1961 to all orders, as well as the correct inclusion of the ghosts (also known as Faddeev–Popov ghosts). He also formulated carefully the Wheeler–DeWitt equation that has played an important role in the Hamiltonian understanding of quantum gravity and quantum cosmology.

He was the first also to study the mini-superspace approach to the Friedmann–Robertson–Walker (FRW) cosmology in order to analyse to what extent quantum mechanics can tame the initial singularity. In 1973 DeWitt and his wife, Cecile DeWitt-Morette, moved to the University of Texas.

DeWitt published numerous books and papers, but perhaps the most comprehensive account of his vision is *The Global Approach to Quantum Field Theory* (*CERN Courier* April 2004 p40). He was a member of the American Physical Society, the US National Academy of Sciences, and the American Academy of Arts and Sciences. He was awarded the 1987 Dirac Medal of the International Centre for Theoretical Physics, Trieste, jointly with Bruno Zumino, the Marcel Grossmann Prize (with Cecile DeWitt-Morette) in 2000, the Pomeranchuk Prize in 2002, and the Einstein Prize of the American Physical Society in 2004.

Based on an appreciation by Luis Alvarez-Gaume of CERN at the ceremony for the posthumous award of the Einstein Prize in Tampa, Florida, on 17 April 2005.

OBITUARIES

Hans A Bethe 1906–2005

Hans Bethe, who died on 6 March 2005, was the last of the brilliant young theorists who entered physics right after quantum mechanics was discovered. In 1926, at the age of 20, he joined Arnold Sommerfeld's seminar in Munich just as Erwin Schrödinger's papers began to appear. He quickly demonstrated exceptional power and ingenuity. By 1931 his publication list included three classics: the spectrum of an atom embedded in a lattice, one of the first applications of group theory to quantum mechanics; a complete solution of the 1D Heisenberg ferromagnet using the famous Bethe Ansatz; and the first detailed quantum theory of energy loss suffered by charged particles traversing matter.

Because his mother was Jewish at birth, Bethe was dismissed from his post at Tübingen when the Nazis came to power. After two highly productive years in England, he moved to Cornell University in 1935, where he was to remain for the rest of his life.

Bethe had an unequalled ability to synthesize and elucidate complex newly developed knowledge. This was first demonstrated in the 1933 *Handbuch der Physik* by a long article on solid-state physics, and another on one- and two-electron atoms; and a few years later in three issues of *Reviews of Modern Physics*, which became known as the Bethe Bible on nuclear physics.

This mastery of nuclear physics had two remarkable consequences. In 1938, Bethe discovered the carbon cycle, the intricate catalytic mechanism that turns hydrogen into helium in massive stars. In 1967, this work won the Nobel Prize for Physics – the first one to be awarded for a topic in astronomy.

The second could not be more different: Bethe's leadership of the Theory Division at wartime Los Alamos. The phenomena relevant to nuclear explosions were so inaccessible to experiment that theory of all sorts was indispensable, and Bethe's intellectual powers and calm persona were needed to coordinate the stellar team that Robert Oppenheimer had assembled, consisting of people who had previously worked on whatever interested them, and usually alone.

After the war, Bethe worked intensely and simultaneously in two entirely different settings: at Cornell on pure academic physics, and as a senior advisor to – and critic of – the US government.

Hans Bethe and Boyce McDaniel, then director of Cornell's Laboratory of Nuclear Studies, in the tunnel of the 10 GeV synchrotron in 1968. (Photo by Sol Goldberg, Cornell University Photography.)

To an extent that was unique among the former leaders of the Manhattan Project, Bethe devoted great effort to what might appear to be contradictory ends: as a consultant to further weapons work and an opponent of such work, and as an advisor on US security policy and an opponent of central themes in this policy. This was because he held deep moral convictions and a strong pragmatic inclination.

From the start he was an outspoken advocate of arms control, and played a key part in establishing the atmospheric test ban. He publicly opposed developing the hydrogen bomb, but when it became known that such a device was possible he worked on it because he decided that the Soviets would soon have it. He worked on missile defence inside the government, concluded it would be both futile and counterproductive, and thereafter publicly opposed all attempts to deploy such systems. In a ceremony at Los Alamos on the 50th anniversary of Hiroshima, he called on scientists everywhere to desist from developing new nuclear weapons.

After the war, and thanks largely to Bethe, Cornell attracted some of the most talented physicists at Los Alamos – Richard Feynman and Robert Wilson, to name only the most famous. But Bethe always kept his own hands in front-line research until well over the age of 90. His first major post-war paper was his famous, rough-and-ready calculation of the Lamb shift, done on the train ride from the conference where Willis Lamb first announced that the Dirac equation did not account fully for the hydrogen spectrum. He then participated in virtuoso QED calculations with Feynman and their students.

During the 1950s and 1960s, he focused on nuclear matter, including the equation of state at high densities, which is important in astrophysics. After his retirement, he collaborated extensively with Gerald Brown at SUNY Stony Brook, calling himself "Gerry's postdoc", and worked for nearly two decades on type II supernovae. After he became convinced that the solar-neutrino problem was not a fault of solar models, he wrote a landmark paper on the implications of neutrino oscillations, and important follow-on articles with John Bahcall.

Bethe was not only a truly outstanding scientist, but also a man of legendary candour and honesty. He was a teacher and mentor to generations of young physicists. It was instructive to see him handling reporters from the Cornell undergraduate newspaper as respectfully as the Washington press corps. And he had a great sense of humour. In 1931 he published a spoof of Arthur Eddington's claim that he had calculated the fine structure constant from first principles. Bethe and two other youngsters published a "calculation" of the absolute zero (in Centigrade units!) from the fine structure constant in *Naturwissenschaften*, and caused a scandal. In 1997, when World Scientific published a massive volume of selected papers, Bethe made sure this spoof was included.

When his death was announced on the front page of *The New York Times*, someone not at Cornell or in physics, but who knew him, wrote and asked, "Do they make them like that anymore?".

Kurt Gottfried, Laboratory for Elementary-Particle Physics, Cornell University.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Rates per single column centimetre: standard $94/€75/£52, academic $88/€71/£49, courses and calls for proposals $85/€68/£47.
Please contact us for more information about colour options, publication dates and deadlines.

W. M. KECK OBSERVATORY

The University of California and the California Institute of Technology formed the California Association for Research in Astronomy (CARA) to construct and operate the W.M. Keck Observatory. CARA provides oversight of the observatory operations, and its related equipment, instrumentation, support facilities and infrastructure through its Board of Directors.

DIRECTOR

The CARA Board seeks a Director for the Observatory to succeed Fred Chaffee, who is retiring. The Director reports to the CARA Board and is responsible for managing observatory operations within budget, to maximize its readiness and effectiveness for scientific research. The Director is responsible for recruiting and maintaining high quality technical and administrative staff, developing an annual budget for review and approval, and developing with the Science Steering Committee the short-range and long-range development plans for the observatory. The Director oversees telescope scheduling for science and engineering and acts as the primary interface with the astronomical user community. The Director maintains effective liaison with the CARA Board, the Science Steering Committee, the University of Hawaii, the local Hawaiian community and other external organizations, in each case ensuring that the Observatory is aware and responsive to their respective needs and desires. The Director is also responsible for maintaining a public outreach office and pursuing and managing public and private fund-raising activities, with guidance from the Board.

REQUIREMENTS: Ph.D. in astronomy or related field or equivalent relevant experience. Experience and demonstrated capabilities in managing a scientific research facility and working in a team-oriented environment are essential. The Director must also be skilled in written and oral communications and have the ability to work collaboratively among varied constituencies to achieve consensus.

SALARY RANGE: Dependent on background and experience and to be negotiated.

STARTING DATE: July 1, 2006

GENERAL INFORMATION: The Director will be resident at the W.M. Keck Headquarters in Waimea, Hawaii. The initial appointment term will be from three to five years with the possibility of renewal. Further particulars of the appointment are available on request.

APPLICATIONS: Review of applications will begin on August 1, 2005, and the recruitment will remain open until the position is filled. Applications together with names of three referees should be submitted in confidence to the following address:

Dr Richard S Ellis, Chair, Search Committee, Astronomy 105-24, Caltech, Pasadena CA 91125

Email submission to jlm@astro.caltech.edu is also acceptable.

GSI Darmstadt the National Laboratory for Heavy-Ion Research, a member institute of the Helmholtz-Society of German Research Centers, is seeking an outstanding

Experimental Physicist

Ref. 1200-05.21

for a permanent staff position in experimental nuclear astrophysics.

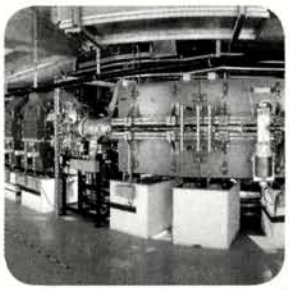
The successful candidate will participate in developing and pursuing the GSI experimental program in nuclear astrophysics using reactions with exotic fragment beams at the present SIS/FRS facility and at the future FAIR facility. While experiments at GSI will be the main focus of the work, scientific contacts with the worldwide nuclear astrophysics community will be encouraged.

Candidates should hold a Ph.D. in experimental nuclear physics and should have a broad astrophysical knowledge as well as a thorough training and several years of research experience in experimental nuclear astrophysics, in particular in the field of nuclear reactions.

Women are especially encouraged to apply for the position. Handicapped applicants will be given preference to other applicants with the same qualification.

Applications containing a curriculum vitae, a list of publications, the names and e-mail addresses of three referees, and the above reference number should be sent by postal mail until **July 31, 2005**, to:

GSI Darmstadt



Gesellschaft für Schwerionenforschung mbH
Personalabteilung
Ref. 1200-05.21
Planckstraße 1
D-64291 Darmstadt

Royal Holloway
University of London

John Adams Institute at Royal Holloway

Lecturer in Accelerator Science

Department of Physics

The John Adams Institute (JAI) for Accelerator Science was founded by PPARC in 2004 and is a joint initiative between Royal Holloway, University of London and Oxford University. Within the JAI, you will lead a major research initiative in the field of accelerator science and contribute to the departmental teaching programme.

The JAI at RHUL is currently very active in the field of laser-based beam diagnostics for the International Linear Collider, as well as in a programme of advanced accelerator simulation and design. You would be welcome to extend this programme into related areas, or to open up an entirely new field of accelerator research. This is a remarkable opportunity to direct the future direction of the JAI research programme at an early stage in its development. Further details about the post, the Institute and the work of the Royal Holloway Particle Physics Group can be found on our website at http://www.pp.rhul.ac.uk

Royal Holloway is one of the larger colleges of the University of London, situated on a pleasant campus about 25km west of central London, close to the town of Windsor and to Heathrow Airport.

Initial salary will be in the range £29,250 (Lecturer Grade A) and £30,123 - £38,017 (Lecturer Grade B) including London Allowance, depending on experience.

Informal enquiries about the posts can be made to g.blair@rhul.ac.uk

Further details and an application form are available from the Personnel Department, Royal Holloway, University of London, Egham, Surrey TW20 0EX; fax: 01784 473527; tel: 01784 414241; website: http://www.rhul.ac.uk/Personnel/JobVacancies.htm

Please quote reference KB/004384.

The closing date for the receipt of applications is 1st July 2005. Interviews to be held within the first two weeks of September.

We positively welcome applications from all sections of the community.

POST-DOCTORAL POSITION, EXPERIMENTAL PARTICLE ASTROPHYSICS WITH GLAST AT THE STANFORD LINEAR ACCELERATOR CENTER

The Stanford Linear Accelerator Center (SLAC) is one of the world's leading laboratories supporting research in high-energy physics. The laboratory's program includes the physics of high-energy electron-positron collisions, high luminosity storage rings, high-energy linear colliders, and particle astrophysics and cosmology.

SLAC invites applications for a Post-doctoral Research Associate position to work with the **Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT) instrument team.** The LAT is the major payload of the GLAST DoE/NASA mission and is currently under construction at SLAC/Stanford University. GLAST will be launched by NASA in late summer 2007. For details of the LAT instrument, science program, and collaboration see **http://www-glast.stanford.edu/index.html.**

These positions are highly competitive and require a background of research in high-energy physics and/or particle astrophysics. Applicants should hold a recent Ph. D. in physics, or in astronomy with a strong physics background. He/she is expected to play a significant role in understanding the calibration and performance of the LAT from integration and test to flight operations, and to participate in the preparations for and in the analysis of the flight science data. Experience in high-energy astrophysics is desirable. The tenure of the position is two years, with the potential for subsequent annual renewals subject to satisfactory performance.

To receive full consideration, all application material should be received by July 31, 2005; past that date, the applications will be considered until the position is filled. Applicants should send a letter stating their physics research interests along with a CV and three references to:

Professor Persis Drell
Director of Research
Stanford Linear Accelerator Center
2575 Sand Hill Road
Menlo Park, CA 94025

Equal opportunity through affirmative action.

Max Planck Institute for Physics
(Werner Heisenberg Institute)

MAX-PLANCK-GESELLSCHAFT

Senior Scientist in Experimental Neutrino Physics (GERDA experiment)

The Max-Planck-Institut für Physik is one of the world's leading research institutes, focused on particle and astroparticle physics from both an experimental and a theoretical perspective.

We invite applications for a senior staff position for the GERDA project, a new experiment to be located at the Gran Sasso National Laboratory, Italy.

The GERDA experiment is designed to investigate the nature of the neutrino and its absolute mass-scale by searching for the neutrinoless double-beta decay of ^{76}Ge. The goal is to either establish the Majorana nature of the neutrino or push the relevant exclusion limits to the mass-scale indicated by neutrino oscillations. The experiment uses the novel approach of shielding crystals with a cryogenic liquid. The Max Planck Institute is one of the leading institutes in the project. We are responsible for the design and construction of new germanium detectors, the detector suspension and insertion system and the corresponding infrastructure. We are also involved in the simulation and analysis software .

The successful candidate is expected to take leadership responsibility in one or more of these efforts. Candidates should have a good knowledge and working experience in experimental particle, astroparticle or low background physics.

Salary and benefits are in accordance with the German public service pay scale (BAT Ib). The position is tenure track with the tenure review date depending on the level of experience of the candidate. The Max Planck Society wishes to increase the participation of women in its research activities. Therefore, applications from women are particularly welcome. Following its commitment to an equal opportunities policy, the Max Planck Society especially encourages handicapped persons to apply.

Further information can be obtained from Prof. Allen Caldwell (Email: caldwell@mppmu.mpg.de) or Dr. Iris Abt (Email: isa@mppmu.mpg.de). Interested applicants should submit an application letter, a statement of research interests, a curriculum vitae, a list of publications, by June 30, 2005, and arrange for three letters of support to be sent by the same date to

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)
Prof. Allen Caldwell
Föhringer Ring 6
D-80805 München
Germany

For more information on the institute and its research visit our homepage at www.mppmu.mpg.de

The Cockcroft Institute

An International Centre for Research in Accelerator Science and Technology

Two Faculty Positions and Three Fixed Term Research Positions

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

www.lancs.ac.uk/cockcroft-institute

LANCASTER UNIVERSITY

Lecturer in Engineering

Quote ref: A477

Salary: £23,643 - £35,883 p.a. **Closing date: 30th June 2005**

The University of Lancaster intends to make an appointment to a position of Lecturer in the Engineering Department.

The successful candidate will join the Microwave Research Group, which has an international reputation for its work in the fields of vacuum electronics and high power radio-frequency (RF) engineering, and (s)he will be expected to initiate and lead innovative R&D in RF engineering and technology concerned with particle acceleration and beam handling as part of the programme of the Cockcroft Institute. Close collaboration is established with the High Energy Physics and Mathematical Physics groups in the Department of Physics at Lancaster University and with CCLRC ASTeC.

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

The position is available immediately from appointment.

Candidates may contact **Professor Richard Carter** for informal discussions. **(r.carter@lancaster.ac.uk, phone +44 1524 593086)**

Research Position in Accelerator Engineering

Quote ref: A482

Starting salary up to £24,820 p.a. **Closing date: 30th June 2005**

Applications are invited from highly motivated scientists and engineers to join the Accelerator Technology R&D programme of the Microwave Research Group of the Department of Engineering at Lancaster University in collaboration with the CCLRC ASTeC group at the Daresbury Laboratory.

A new position is available in the Crab Cavity collaboration immediately following appointment initially for a period of three years. The collaboration is concerned with the development of crab cavities and their RF system for the International Linear Collider (ILC). The achievement of the very difficult phase stability requirements, especially phase jitter between the two crab cavities, will require detailed understanding of the properties of the RF system including the klystron(s). The Crab Cavity collaboration is currently funded through the EU EuroTeV initiative and the PPARC LC-ABD consortium which is concerned primarily with the design and proof-of-principle of a beam delivery system for the ILC.

Informal enquiries can be addressed to **Professor Richard Carter (r.carter@lancaster.ac.uk, tel: +44 1524 593086)** and to **Dr Amos Dexter (Project Leader, a.dexter@lancaster.ac.uk, tel: +44 1524 593085) Engineering Department, Lancaster University, Lancaster LA14YR, UK.**

Further particulars and details of the application procedure for both positions are available from the **Director of Personnel, Lancaster University, Lancaster LA14YW**
Applications should be made on the form available at **http://www.lancs.ac.uk/users/personnel/apply.htm**.

THE UNIVERSITY of LIVERPOOL

Lecturer in Accelerator Physics

Quote ref: B495

Salary: £23,643 - £35,883 p.a. **Closing date: 30th June 2005**

An appointment is to be made to a position of Lecturer in the Department of Physics. The successful candidate will initiate and lead innovative R&D in the science and technology of particle acceleration and beam handling as part of the programme of the Cockcroft Institute. The successful applicant will also be a member of the new Accelerator Science group in the Physics Department, which will consist of five academic staff members. The Department has strong research groups in High Energy Physics, Nuclear Physics, and Condensed matter and Surface Physics. Close collaboration is already well established with the 4GLS and ERLP projects at Daresbury Laboratory and with CCLRC ASTeC. The infrastructure available both in the Liverpool Physics Department and at CCLRC Daresbury Laboratory constitutes a comprehensive resource in support of this position.

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

The position is available immediately from appointment.

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

Research Position in Accelerator Physics

Quote ref: B475

Starting salary up to £24,820 p.a. **Closing date: 30th June 2005**

Applications from highly motivated scientists and engineers are invited for a new position in the Accelerator Science R&D programme of the High Energy Physics Group in the University of Liverpools Department of Physics.

The position is available immediately following appointment and for a fixed term of initially 3 years.

The successful applicant will join the heLiCal project which is concerned with the development of an intense positron source primarily for the International Linear Collider (ILC) using a helical undulator insertion device, its optimisation for both luminosity and polarisation, and the robust delivery of its polarisation to the ILC interaction region.

The group includes ASTeC at the Daresbury and Rutherford Appleton Laboratories, DESY Hamburg and Zeuthen, and Liverpool and Durham Universities, and works in close collaboration with groups concerned with the ILC positron source in the US and in Europe (EuroTeV).

The position is funded through the EU EuroTeV initiative. The heLiCal group is also funded through the PPARC LC-ABD consortium, which is concerned primarily with the design and proof-of-principle of a beam delivery system for the ILC, and through CCLRC.

Informal enquiries can be addressed to **Professor John Dainton (jbd@hep.ph.liv.ac.uk, tel: +44 151 794 7769, fax: +44 151 794 3444), Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE**, to **Dr Ian Bailey (i.r.bailey@liverpool.ac.uk, tel: +44 151 794 2137)**, and to the **Project Leader, Dr Jim Clarke (j.a.clarke@dl.ac.uk, tel: +44 1925 603267), ASTeC, CCLRC Daresbury Laboratory, Warrington WA4 4AD**.

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

MANCHESTER 1824 The University of Manchester

Research Position in Linear Collider Accelerator Physics

Quote ref: EPS/127/05

Starting salary up to £24,820 p.a. **Closing date: 30th June 2005**

Manchester University intends to appoint a Post Doctoral Research Associate to join the Accelerator Physics programme in the School of Physics, part of the Cockcroft Institute.

The position is available immediately following appointment for a period of three years in the first instance.

The team is concerned with the design of collimation systems for the ILC: the technical challenges involved in design and fabrication, the effects on the beam bunch structure through wake fields, the production and removal of halo backgrounds, and the survival of the collimator elements themselves. The work includes computer simulation using codes such as ANSYS and MERLIN, and experimental measurements in a test beam programme.

These collimation studies are carried out in collaboration with groups in the EuroTeV initiative, the LC-ABD consortium, and CCLRC.

For informal inquiries contact **Professor Roger Barlow (Roger.Barlow@manchester.ac.uk), +44 161 275 4178**. Further particulars and an application form are available from the **EPS HR Office, Manchester University, Sackville St, Manchester M60 1QD** or on **http://www.man.ac.uk/news/vacancies/research.html**

INDEX TO DISPLAY ADVERTISERS

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Join the open-access revolution

Ken Peach argues that particle physicists can lead the way in a paradigm shift in scientific publishing to give everyone free access to research results.

There is a quiet revolution under way in academic publishing that will change how we publish and access scientific knowledge. "Open access", made possible by new electronic tools, will give enormous benefits to all readers by providing free access to research results.

The scientific articles published in journals under the traditional publishing paradigm are paid for through subscriptions by libraries and individuals, creating barriers for those unable to pay. The ever-increasing cost of the traditional publishing methods means that many libraries in Europe and the US – even the CERN Library, which is supposed to serve international researchers at a centre of excellence – are unable to offer complete coverage of their core subjects.

In 2003 the Berlin Declaration on open access to knowledge in the sciences and the humanities was launched at a meeting organized by the Max Planck Society. Six months later, the first practical actions towards implementing the recommendations of the declaration on an international level were formulated at a meeting held at CERN in May 2004. So far the declaration has been signed by 61 organizations throughout the world, which are now taking concrete measures for its implementation.

An obvious prerequisite for open access is that institutions implement a policy requiring their researchers to deposit a copy of all their published works in an open-access repository. The Council for the Central Laboratory of the Research Councils' library committee in the UK sponsored such a project, ePubs, with the aim of achieving an archive of the scientific output of CCLRC in the form of journal articles, conference papers, technical reports, e-prints, theses and books, containing the full text where possible (*CERN Courier* May 2005 p44).

The feasibility study, carried out from January to March 2003, demonstrated the business need for this service within the organization. The data, going back to the mid-1960s, can be retrieved using the search interface or the many browse indices, which include year, author and journal title. In addition the ePubs system is today indexed by Google and Google Scholar. The scientific content of the system has further led Thomson ISI (the provider of information resources including Web of Knowledge and Science Citation Index) to classify ePubs as a high-quality resource.

The next step is to encourage the researchers – while of course fully respecting their academic freedom – to publish their research articles in open-access journals where a suitable journal exists.

In recent years new journals applying alternative publishing models have appeared in the arena. The problem so far is that none of these journals have a long-term business model. They are sponsored either by a research organization or by other titles in the publisher's portfolio, or enjoy sponsorship that will not last forever.

Scientific publishing has a price and will continue to have a price, currently mainly covered by academic libraries through subscriptions. Moving to an open-access publishing model should dramatically reduce the global cost for the whole of the academic community. The publication costs should be considered a part of the research cost and the research administrators should budget for these when the research budgets are allocated. However, a change must not take place without safeguarding the peer-review system, which is the guarantor of scientific quality and integrity.

Outside biology and medicine, few journals that support open access are given the same academic credits as the traditional journals. This situation is further reinforced if there is a direct coupling between research funding and the "impact factors" of journals where results are published. However, by taking the risk and publishing important work in new journals that implement the open-access paradigm, the impact factor will automatically be enhanced.

The example of the *Journal of High Energy Physics* (JHEP) is striking. This relatively new journal was launched by the International School for Advanced Studies (SISSA) in Trieste in 1997. Today some studies give it an impact factor close to that of *Physical Review Letters* in publishing papers on high-energy physics. JHEP was launched ahead of its time and was forced, because of the lack of financial support, to become a subscription journal. However, with the support of the main physics laboratories, it would be possible in the present climate for this successful journal to enter the open-access arena once again.

If a change is wanted, it is up to us. Particle physics cannot change the world alone, but a clear position among our authors and our members of editorial boards will have a strong synergy with our colleagues pulling in the same direction in other fields.

- For more about the Berlin Declaration see www.zim.mpg.de/openaccess-berlin/berlindeclaration.html.

Ken Peach, director of particle physics, CCLRC Rutherford Appleton Laboratory.

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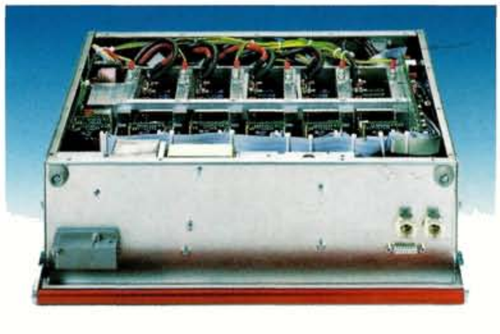

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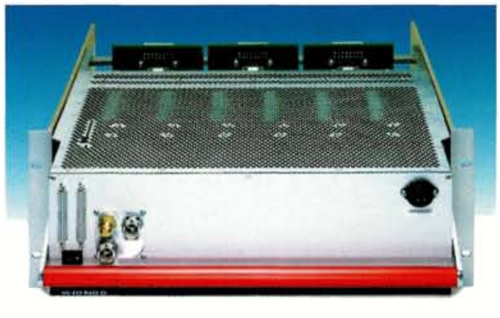

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