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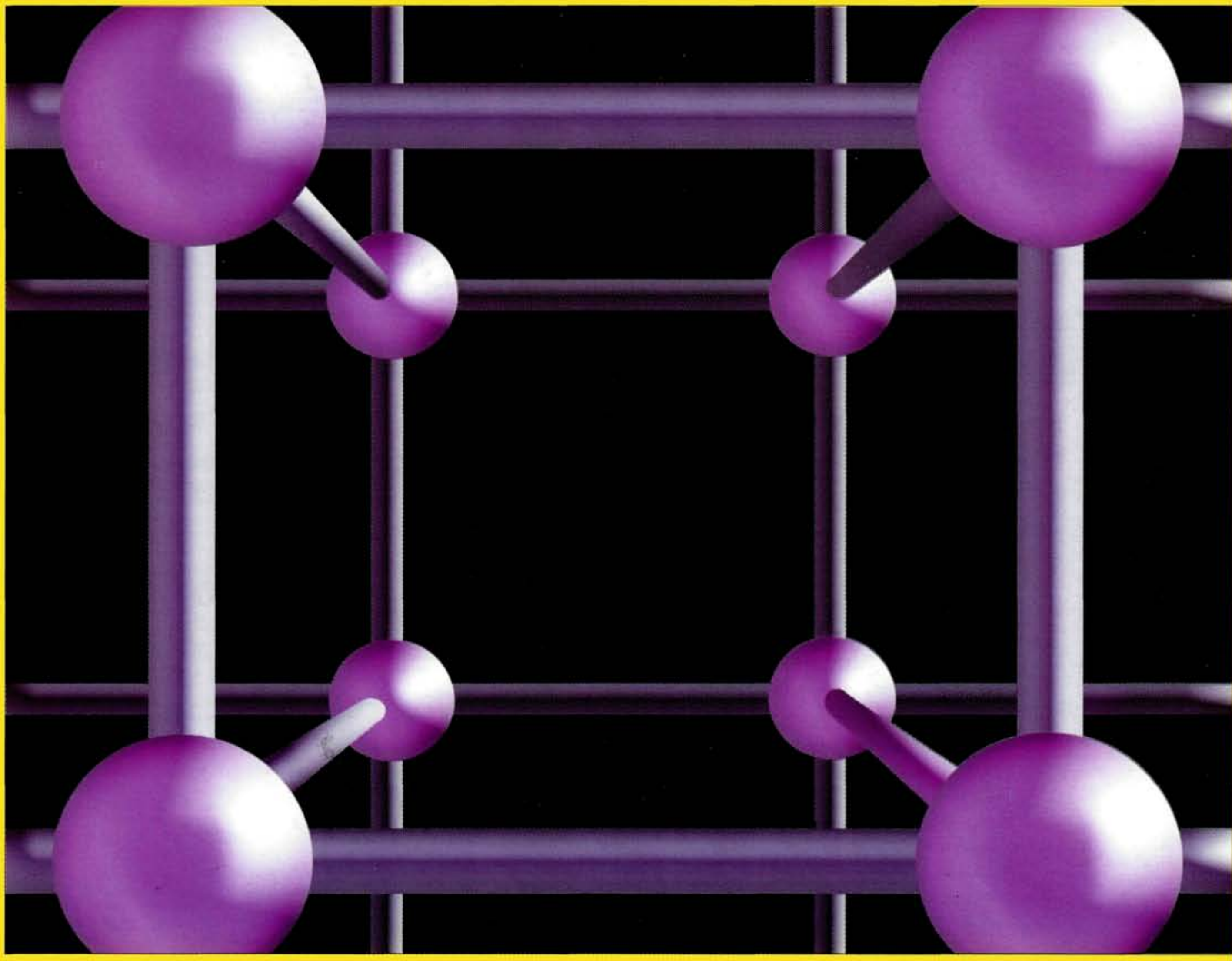

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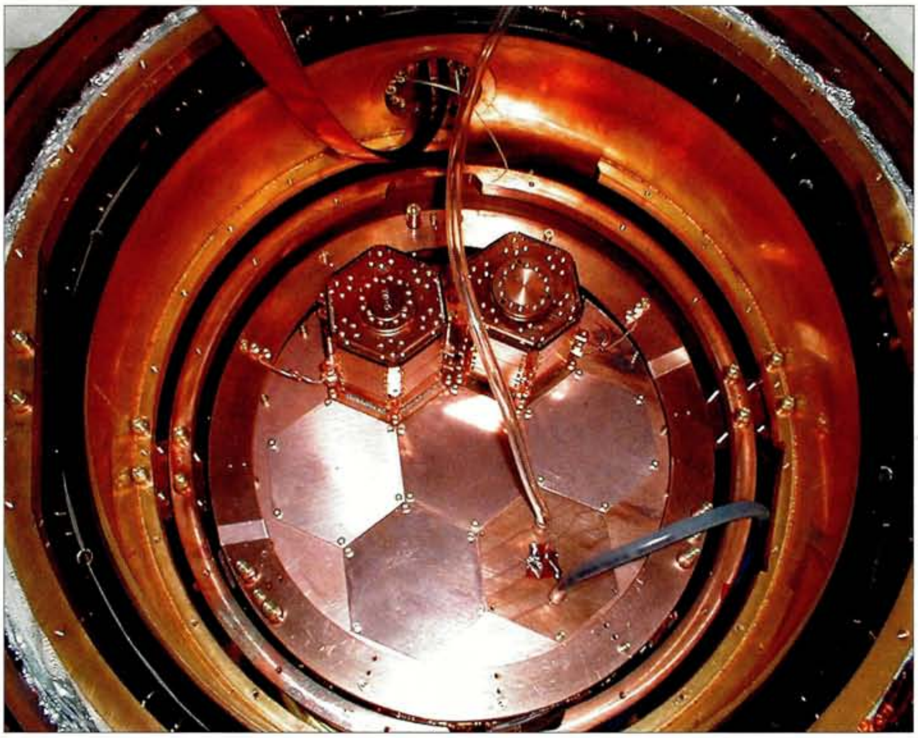
Cover: New calculations in lattice QCD are yielding the most precise results so far (p23). (Image courtesy of Ian McVicar, University of Glasgow.)

DARK MATTER

CDMS II narrows search for WIMPs



A WIMP trap. A view of the inner layers of the CDMS cryostat with two detector "towers" mounted in the holes covered by hexagonal plates. The coldest part of the cryostat remains at 10 mK during operation. The surrounding layers are higher temperature stages of the cryostat, which is constructed from copper with very low radioactivity in order to reduce the background in the extremely sensitive detectors. (Fermilab.)

With the first data from their underground observatory in northern Minnesota, the scientists of the Cryogenic Dark Matter Search (CDMS) have peered with greater sensitivity than ever before into the suspected realm of WIMPs, or weakly interacting massive particles. The results show, however, that if they do exist WIMPs are still staying out of sight.

WIMPs are of interest for the two extremes of the very large and the very small. There is strong evidence for large amounts of non-luminous dark matter in the universe, which cannot consist of normal matter (baryons) but seems likely to consist of WIMPs. At the opposite end of the scale supersymmetry yields a range of massive new particles, but the lightest – such as the neutralino – could be stable and therefore a good candidate to be a WIMP.

The CDMS II experiment, which is run by a collaboration of 48 scientists from 13 institutions, plus 28 engineering, technical and administrative staff, is located nearly 780 m below ground in a former iron mine in Soudan, Minnesota. The experiment uses four 250 g germanium detectors and two 100 g silicon detectors, which are cooled to less than 50 mK so that molecular motion becomes negligible. Substantial shielding and the 780 m of rock together reduce the background due to cosmic rays and radioactivity.

The detectors simultaneously measure the ionization and vibration (phonons) produced by particle interactions within the crystals. WIMPs should reveal their presence by creating less ionization than other particles for the same amount of vibration. This is because the WIMPs will scatter from nuclei in the detectors while other particles are more likely to scatter from electrons, and recoiling electrons create more ionization than recoiling nuclei. The timing of the phonons also provides a means of distinguishing between WIMPs and other particles.

The CDMS II results show with 90% certainty that the interaction cross-section for a WIMP with a mass of 60 GeV must be less than 4×10^{-43} cm^2, or about one interaction every 25 days per kilogram of germanium (Akerib *et al.* 2004). This measurement is at least four times more sensitive than the best previous measurement offered by the EDELWEISS experiment in the Fréjus Underground Laboratory in France.

The results, which are described in a paper submitted to *Physical Review Letters*, were presented at the April Meeting of the American Physical Society on 1–4 May in Denver. The data set the world's lowest exclusion limits on the cross-section for coherent WIMP–nucleon scalar interactions for all WIMP masses above 15 GeV. They thereby rule out a significant range of neutralino supersymmetric models.

Further reading

D S Akerib *et al.* (CDMS collaboration) 2004 http://arxiv.org/abs/astro-ph/0405033.

COLLIDERS

BEPC stops running and begins major upgrade programme

With the blow of a whistle at 8 a.m. on 30 April, the Beijing Electron Positron Collider (BEPC) finished running and the installation of its major upgrade, BEPCII, began. By the end of October the first stage, including the upgrade of the linac injector and the removal of the Beijing Spectrometer (BES) from the interaction region, will have been carried out. The upgrade will be finished by the end of 2006 and physics running should be resumed by the spring of 2007. To minimize interruption to the users of the Beijing Synchrotron Radiation Facility, the upgrade is planned in three stages, with synchrotron radiation runs in between.

BEPC has been running in the energy region of the tau and charm for more than 15 years, with many notable experimental results. However, to meet the challenges in the precision measurements of the charm energy region, a thorough upgrade is necessary if the facility is to continue productive studies and to lead the world in this research. The Chinese government approved the BEPCII programme, which has a budget of 640 million Chinese yuan ($77 million) and a construction period of three years.

The Institute of High Energy Physics in Beijing, China, has begun a major upgrade of its Electron Positron Collider, BEPC. The upgrade is due to be completed by the end of 2006.

To meet the challenging goal of continuing world-leading studies of charm physics, a double-ring design has been chosen. A storage ring will be added in the existing tunnel so that the electrons and positrons can travel separately in their own rings. The number of positron and electron bunches will be increased from 1 to 93 in each ring, with a large horizontal collision angle of ±11 mrad. In addition, other new technologies have been adopted – such as a superconducting radiofrequency system, superconducting micro-beta quadrupoles and a low-impedance vacuum chamber – so that the performance of BEPCII will be improved by a factor of 100, for a design luminosity of 10^{33} $cm^{-2}s^{-1}$ at a centre-of-mass energy of 3.77 GeV. As the circumference of BEPCII is only 240 m and the straight section of the interaction region is rather short, many technical challenges will have to be overcome to meet the design goals.

At the same time, the Beijing Spectrometer is being upgraded to improve its measurement precision and reduce systematic errors, as well as to adapt to the high event rate of BEPCII. The upgraded BESIII includes a CsI calorimeter, a superconducting solenoid magnet and a main drift chamber with small cells and helium-based gas.

The removal of BES and the upgrade of the linac mark the beginning of the BEPCII installation. After the upgrade, the positron injection rate of the linac will reach 50 mA per minute, an improvement of a factor of 10, with full energy injection up to 1.89 GeV. Further milestones will involve the dismantling of the old storage ring and the installation of the new double ring, from April 2005 to January 2006, followed by the moving of BESIII into the interaction region in October 2006.

The upgraded BEPC should be able to maintain its leading role in charm-physics research, with new results in the search for glueballs, quark–gluon hybrids and exotic particles, precision measurements of the R-value, precision measurements of the Cabibbo–Kobayashi–Maskawa matrix element, the study of the charmonium spectrum and charmonium decay properties, and so on. The hope is that BEPCII will provide a new platform for productive and fruitful physics, not only for Chinese physicists but also those from around the world.

TRIUMF

Canadian lab proposes new five-year plan

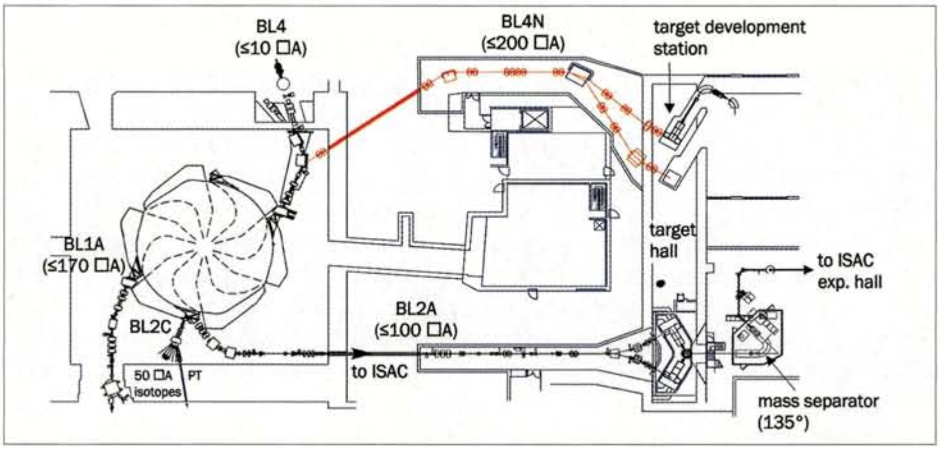
Canada's national laboratory for particle and nuclear physics, TRIUMF, has proposed a new five-year plan to take it through to the end of the decade. The plan is ambitious, but realistic, and builds on the laboratory's past and present accomplishments. It aims to deliver first-rate science in a timely and efficient manner and will ensure that TRIUMF remains competitive at the highest international level.

TRIUMF is funded by the Canadian government on a five-year cycle; the current one running from 2000 to 2005. Over the past two years scientists and staff at TRIUMF and its associated universities have been discussing the plan to be forwarded to the government for funding in 2005–2010. The plan was peer-reviewed by two international committees in the latter part of 2003 and presented to the National Research Council of Canada in February 2004. Council recommendations will be transmitted to the higher levels of government for funding decisions later this year.

The underlying theme is to provide Canadian scientists with access to world-class subatomic facilities at TRIUMF, and to provide scientific and engineering support to enable Canadian particle-physics groups to lead or significantly contribute to various experiments worldwide. For facilities at TRIUMF, which are freely open to the global community, the plan includes:

- completion of the ISAC-II radioactive beam post-accelerator, which will extend the maximum ion mass from 30 to 150 and the beam energy from 1.5 to 6.5 MeV/u;
- a new proton line and targetry for the development of new radioactive beams;
- major upgrades to the muon beam lines for materials science and chemistry research;
- greater throughput of radioisotopes for research in the life sciences.

To support external experiments, the plan includes the development of a data hub at TRIUMF for data analysis for the ATLAS experiment at CERN's Large Hadron Collider; contributions to the T2K long-baseline neutrino experiment in Japan; and to the KOPIO ($K^0 \rightarrow \pi^0 + \nu + \bar{\nu}$) kaon rare-decay experiment at Brookhaven; and research and development for the Next Linear Collider. The plan also identifies the importance of transferring the technical knowledge developed at TRIUMF to the commercial sector, and that of educational outreach to the general public and students.



The beams delivered by the TRIUMF cyclotron, showing the location of the proposed radioactive beam development line (in red), which is dependent on the new funding plan.

GRID COMPUTING

SweGrid gets set for future challenges

SweGrid, the first national Grid test-bed in Sweden, was inaugurated on 18 March in Uppsala. The Grid nodes, each consisting of a cluster of 100 PCs and 2 Tbyte of disk storage, are located at the six national computer centres in Umeå, Uppsala, Stockholm, Linköping, Göteborg and Lund, and are linked together through the 10 Gbit/s national network SUNET. An additional 60 Tbyte disk storage will be delivered in May and eventually the test-bed will comprise 120 Tbyte disk storage plus 120 Tbyte robotic tape storage in total.

The initiative for this national Grid has come from the Swedish high-energy physics community and was driven by the future requirements

for large computing capacity to analyse data from the Large Hadron Collider (LHC). One-third of SweGrid's full computer resources are currently being used for the execution of the "ATLAS Data Challenge 2" in May and June 2004. In addition, many other applications in other branches of science, such as genome research, climate research, solid-state physics, quantum chemistry and space science, are also being launched on SweGrid.

The equipment for SweGrid has been financed by the Wallenberg Foundation in Sweden. The personnel costs for seven SweGrid technicians and three doctoral students are being covered by the Swedish Research Council through its Swedish National Infrastructure for Computing (SNIC). The Strategic Technical Advisory Committee in SNIC, composed of the directors of Sweden's six national computer centres, is acting as SweGrid's executive board.

A Nordic Grid development project, NorduGrid, began in 2000 as a collaboration between high-energy physicists. It set up the first small Nordic Grid test-bed in 2001 and used this to develop the NorduGrid middleware, which has become one of the first Grid middlewares to be used in production internationally, as during the "ATLAS Data Challenge 1" in 2003. ▷

GRID COMPUTING

▷ Stimulated by this progress, the Nordic Science Research Councils (NOS-N) took a common initiative to study how the computer resources in the Nordic countries could be organized in a common Grid facility, called the Nordic Data Grid Facility (NDGF). SweGrid constitutes a Swedish contribution to this common effort. The NDGF study group is scheduled to forward a detailed proposal for such a facility to the NOS-N committee within a year from now.

Several interesting presentations were given at the SweGrid inauguration seminar. Mario Campolargo, head of the Information Society Research Infrastructure Unit of the European Commission, described the pan-European GEANT computer network and the potential this represents for Grid development in Europe. He also discussed the significance of the current European Grid development initiatives sponsored by the EC 6th Framework Programme, such as Enabling Grids for e-Science in Europe, a CERN-led initiative in which Sweden has an active role.

Erik Elmroth from the Swedish National Computer Center in Umeå discussed current activities for making Grid services more accessible, such as developing tools for resource brokering and Grid-wide accounting, and establishing Grid portals as common easy-to-use interfaces to the Grid. Niclas Andersson, the leader of the six technicians who have set up and are now running SweGrid, described the deployment and operations of the test-bed and presented its technical specifications.

John Ellis from CERN gave an overview of the physics at the LHC and illustrated the large computer resources required if the new physics phenomena were to be discovered at the LHC. He demonstrated that finding a heavy particle of mass 1 TeV/c^2 at the LHC would be the equivalent of finding a needle in all of Sweden's haystacks, which he estimated to be 100 m^3 each in volume and to total 100 000. Gilbert Poulard, also from CERN, described the reconstruction and analysis of events in ATLAS and how the software and access to data will be exercised with Grid tools during the forthcoming Data Challenge 2.

There were also reports on Grid applications in other disciplines. Gunnar Norstedt from the Karolinska Institutet in Stockholm described the use of SweGrid for the analysis of gene promoters; a gene promoter is a portion of DNA that regulates the genes and their expression. A general computer code for such analysis has been set up and will be made available at SweGrid through a Grid portal. Roland Lindh from the quantum chemistry group at Lund University described MOLCAS, which is a code for electronic structure calculations in large molecules and which will be accessible on SweGrid.

The final part of the ceremony was conducted by Anders Ynnerman, the leader of SNIC. After Janne Carlsson from the Wallenberg Foundation and Jan Martinsson from the Swedish Research Council had expressed their great satisfaction with the project, Sverker Holmgren, head of the Uppsala National Computer Center, gave a successful first demonstration of how to operate SweGrid.

NEUTRON PHYSICS

Russian neutron complex looks to future research programme

The future possibilities for research at the neutron complex of the Institute for Nuclear Research (INR) of the Russian Academy of Sciences (RAS) was the topic of a workshop that took place in Moscow on 12 March.

The operation of the INR RAS neutron complex located in Troitsk, Moscow, is based on a beam provided by the high-current proton linac of the Moscow Meson Facility. The complex includes a spallation or "impulse" neutron source (IN-0.6) with neutron guides and installations for condensed-matter investigations, a 100 tonne spectrometer for neutrons slowing down in lead (LNS-100) and an irradiation facility, called RADEX, at the beam-stop of the experimental area.

LNS-100 started operation in 2000, and now is to be joined by a time-of-flight facility that will allow complementary experiments in nuclear physics. The beam-stop is being modified to provide a time-of-flight neutron spectrometer, which should provide additional opportunities for neutron–nucleus studies by the beginning of 2005. The first measurements of neutron fluxes with a working model of the time-of-flight neutron spectrometer were taken in 2003.

Approximately 60 representatives from research groups in leading institutes in St Petersburg and the Moscow region participated in the workshop, where discussions revealed a strong interest among the nuclear physicists for co-operation in experiments at the neutron complex. It may also prove to be a suitable place for international experiments on accelerator-driven systems and studies of nuclear transmutation problems.

An accelerator-driven system facility developed around the linac in the INR RAS neutron complex, including a target and a 5 MW subcritical core, could be suitable for studies of the nuclear transmutation of minor actinides and long-lived fission products. Discussions between specialists from the Russian Research Centre Kurchatov Institute, based in Moscow, the Research and Development Institute of Power Engineering, also in Moscow, the Pôle Universitaire Léonard de Vinci La Défense, in Paris, the Institute for Nuclear Research and a number of other centres are now underway.

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CERN COURIER ARCHIVE: 1963

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

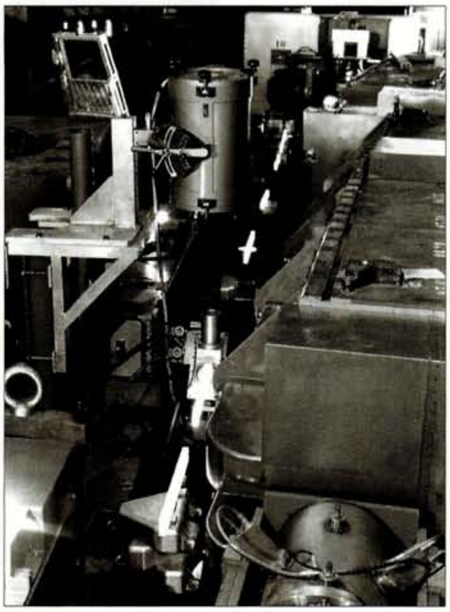
THE PS

Knocking out the Proton Synchrotron beam

On 12 May 1963, at thirty-five minutes past four in the afternoon, history was made again at the CERN Proton Synchrotron (PS). The first accelerating machine in the world to produce 25 GeV protons then became the source of the world's first beam of 25 GeV protons to travel freely in air. The story of events in the accelerator's main control room on that day is told here by **Berend Kuiper**, one of those chiefly responsible.

The mood of the ejection team in the PS main control room on Sunday morning, 12 May, was one of moderate confidence, since several operations of the ejection magnets together with the proton beam had already been rehearsed before and results had proved reasonably close to the predictions.

After patching up the high-voltage feeds, which had recently led to some trouble, the kicker magnet had been reinstalled in its vacuum box in straight-section 97 the previous Friday night. On Saturday morning the box had been reopened for a final check and the electrical connections verified by pulsing the magnet in air for an hour. The lid had just been replaced on the tank when suddenly the mechanics of the Nuclear Physics Apparatus (NPA) division, Albert Bertuol, Yves Favereau, Anton King and Pierre Pugin produced a baby pine tree with a beautiful yellow lace, which they solemnly mounted on top of the hydraulic accumulator by means of that indispensable tool of the physicist, "Scotch tape". Saturday afternoon had been spent on rehearsing some of the gymnastics of the magnet movement and the beam displacement, so as to study the correct positioning of one to the other. Also, the two magnets were for the first time electrically pulsed in the presence of a proton beam. The leakage field of the bending magnet proved not to disturb the unkicked beam appreciably, and the kicker magnet produced the expected deflection of the protons. All these preliminary results were the basis for the good hopes on Sunday morning when, between 8 and 9 a.m., Hugh Hereward with his Machine Proton Synchrotron operating team were setting up the 3 second 25 GeV synchrotron cycle and the NPA ejection men warmed up their equipment...



A proton beam extracted from the PS lights up a series of scintillator blocks in its path.

[During the day the small crowd in the control room, consisting of the ejection team, the machine operators and engineers, and some "passers-by" followed the progress via a television camera arranged to view fluorescent screens at various key points in the beam line. There were problems with the delay between the kicker magnet and the bending magnet, which Hendrick Dijkhuizen and Javier Goñi tried hard to fix, and to make things worse the PS itself began to behave badly. (Ed.)]

EDITOR'S NOTE

One of the most remarkable photographs used on the cover of the *CERN Courier* was the image shown here, from the May 1963 issue. On 12 May, for the first time ever, a 25 GeV proton beam was extracted from the PS to travel in air. The following day G Bertin and F Juillard from the Public Information Office set up their camera to record the glow as the beam passed through scintillators along its path. Berend Kuiper's article in the same issue described the scenes leading up to this historic event.

...Meanwhile the clock had reached 4 p.m. and time was quickly running out, as the machine shifts allocated to ejection studies were due to end an hour later. To make a final attempt before closing time, Dijkhuizen and Goñi locked the kicker and the bending magnet over entirely separate timing units onto the PS cycle. This permitted their proper phasing without mutual interference. The magnets were now pulsed again, but the PS still didn't function any better than before. Each time the PS accelerated a few pulses the mob dashed to the TV screen, but over and over again the PS fell out before anything could be seen. Then, finally, at 4.35 p.m., the "beam on" signal stayed alight rather longer than usual and the TV reproduced the picture of the beam being kicked into the bending magnet window. As Horst Wachsmuth again switched the receiver to camera two, a piercing light flash near the cross mark on the fluorescent screen proved that the world's first 25 GeV proton beam had been successfully ejected – very close to the theoretical trajectory.

- Taken from *CERN Courier* May 1963 p63.

NEWS FROM ABROAD

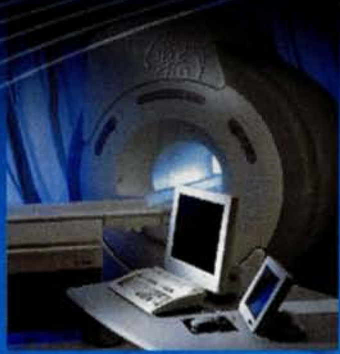
NASA to copy CERN's synchrocyclotron

The Langley Research Center of NASA, the US National Aeronautics and Space Administration, is to be equipped with a synchrocyclotron that will be used especially for the simulation of all the different kinds of ionizing radiation that will be encountered in space flights. This cyclotron will be an almost exact copy of the accelerator at CERN.

The synchrocyclotron will form the nucleus of the Space Radiation Effects Laboratory, which will probably be operated for NASA jointly by the College of William and Mary, the University of Virginia and the Virginia Polytechnic Institute.

- Taken from *CERN Courier* May 1963 p70.






Wah Chang's Golden Hadron Award

Compiled by Steve Reucroft and John Swain

Electron beam reveals lower speed for magnetic switching

Researchers at the Stanford Synchrotron Radiation Laboratory (SSRL) have found that the ultimate speed of magnetic switching is at least 1000 times slower than previously expected – a result that has implications for future hard-disk computer-drive technologies.

"Smaller and faster" are the standard goals in computing, and magnetic recording is no exception. However, a physical speed limit has always been expected – a threshold above which the magnetic domains defining the "1"s and "0"s become unstable. In "precessional switching" these logical bits are recorded when the magnetic field associated with the "write" pulse current reaches a certain value. At the SSRL the linac's electron beam creates some of the world's briefest magnetic pulses, only 2 ps long, which have been used to investigate whether switching remains stable with such short pulses and, hence, at fast recording times.

The team fired up to seven electron bunches in a row through samples of magnetic recording media. They expected to see dark and light concentric rings around the focus point of the beam, corresponding to grains magnetized in the two possible directions. Instead, the pictures showed all shades of grey, indicating that some grains had switched while others had not. With the help of theoretical physicist Alexander Kashuba of the Landau Institute for Theoretical Physics in Moscow, the team realized their data bore the signature of a chaotic system.

The pulse length of 2 ps suggests a speed limit of about 1 bit per picosecond, or 10^{12} bits per second, some 500 times faster than in modern computers (Tudosa *et al.* 2004). The challenge now is to understand why the maximum speed limit seems to be at least 1000 times lower than expected.

Further reading

I Tudosa *et al.* 2004 *Nature* **428** 831.

Positrons show new kind of chemistry

A long-standing puzzle in positron physics has been why positrons sometimes seem to annihilate faster in matter than naive calculations would predict. Now Cliff Surko at the University of San Diego has found that the increase in annihilation cross-section for very-low-energy positrons may be linked to their forming bound states with neutral atoms – and the consequence could be a whole new kind of chemistry.

In 1997 calculations by Jim Mitroy and Gregory Ryzhikh of what is now Charles Darwin University in Australia had already predicted a bound state of neutral lithium and a positron. Other calculations suggest that the fact the Pauli principle is avoided for systems of an electron and a positron might make hydrogen–antihydrogen molecules lower in energy than hydrogen–hydrogen ones. Of course, none of these exotic molecules exist for long before the positrons annihilate, but the effect could make significant contributions to the low-energy positron annihilation rate in space.

Further reading

G Ryzhikh and J Mitroy 1997 *Phys. Rev. Lett.* **79** 4124.
E Samuel Reich 2004 *New Sci.* **182** 2444 p34.

The physics of cacti

Physics, as every physicist knows, is what ultimately determines the forms that living things take. Patrick Shipman and Alan Newell of the University of Arizona in Tucson have shown that some simple hypotheses about stresses in a growing cactus can lead to the spiral structures seen in plants such as cacti, sunflowers and in pine cones. The main observation centres on minimization of strain energy by triplets of almost periodic deformations, which lead to the natural-looking plant shapes and even the Fibonacci numbers (1,2,3,5,8,...) you can count on the spirals of a pineapple.

Further reading

P Shipman and A Newell 2004 *Phys. Rev. Lett.* **92** 168102.

Spacecraft takes off for relativity tests

The long-awaited launch of Gravity Probe B, a satellite designed to provide two new tests of general relativity, took place on 20 April. Carrying four ultra-precise gyroscopes, the satellite should provide the first direct measurements of the geodetic effect and the frame-dragging effect. The geodetic effect is a change in the direction of the spin axis that occurs as the gyroscope follows the curvature of space–time near any massive object. The frame-dragging, or Lense–Thirring effect, first predicted in 1918, is caused by the Earth's rotation effectively pulling space–time along with it as it turns.

The flight dewar for the Gravity Probe B satellite will maintain the experiment with its four ultra-precise gyroscopes at an operating temperature of 1.8 K.

During its mission, Gravity Probe B will monitor any drift in the gyroscopes' spin axes alignment in relation to a guide star. The size of the frame-dragging effect is miniscule. In a polar orbit of 640 km, it should make the spin axis change by just over 40 milliarcseconds in one year; in the same time period, the geodetic effect will produce a relatively huge change of more than 6600 milliarcseconds. Gravity Probe B will measure the minute frame-dragging effect to a precision of 1% or better and the geodetic effect to one part in 10 000.

Further reading

www.gravityprobeb.com.

Compiled by Marc Türler

Closest view of active galactic nucleus

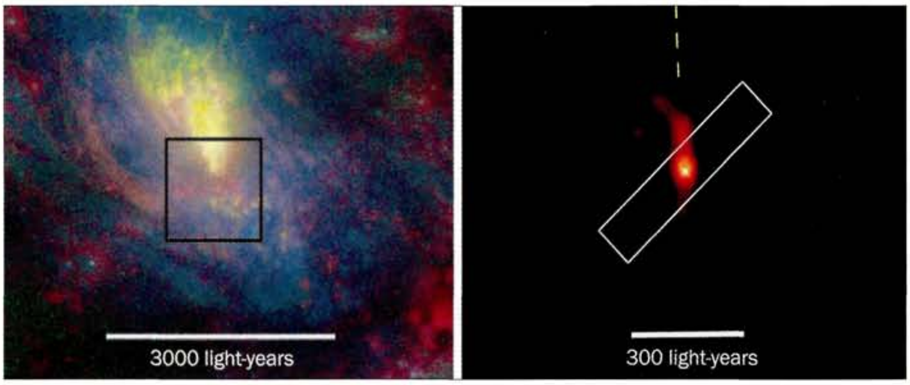
Observations with the Very Large Telescope Interferometer (VLTI) at the ESO Paranal Observatory in Chile are for the first time providing a clear picture of the immediate surroundings of the black hole at the centre of an active galaxy. They reveal the gas and dust torus that obscures the heart of the galaxy NGC 1068.

NGC 1068, also known as Messier 77, is located in the constellation Cetus (The Whale) at a distance of about 50 million light-years. It looks like an ordinary barred spiral galaxy, except that its centre is unusually bright. NGC 1068 was among a group of 12 galaxies identified by Carl Seyfert in 1943 as having a nucleus with a spectrum showing peculiar emission lines from highly ionized atoms. These so-called Seyfert galaxies can be thought of as low-luminosity quasars, as was proposed shortly after the discovery, in 1963, of the first quasi-stellar radio source (quasar).

The active nucleus of Seyfert galaxies and quasars emits radiation over the whole electromagnetic spectrum, from radio to X-rays and even gamma rays. The central engine at the origin of this activity is now known to be a supermassive black hole with a mass up to thousands of millions of times that of the Sun. The black hole is believed to be fed from a tightly wound accretion disc of gas and dust that encircles it. The compressed and heated matter spinning near the black hole at close to the speed of light is thought to give rise to the enormous luminosity of active galactic nuclei. Outside this disc matter is believed to form a toroidal (doughnut shaped) cloud of gas and dust, which absorbs the ultraviolet light from the central disc and emits infrared radiation. The observed characteristics of a given active galaxy would thus depend on whether this torus is blocking our view of the nucleus.

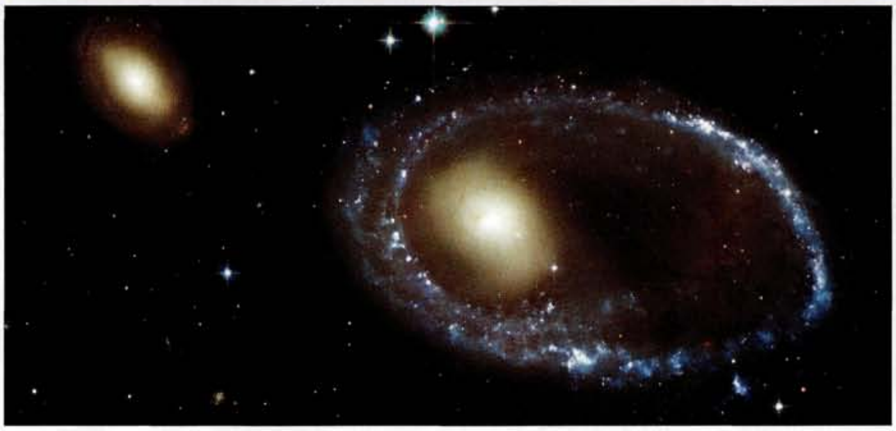
Infrared interferometry has now revealed for the first time the presence of such a torus in NGC 1068. The torus, heated to a temperature of about 50 °C, is found to be 11 light-years across and 7 light-years thick, with an inner, hotter zone (500 °C) about 2 light-years wide. Identifying such small regions at the distance of NGC 1068 corresponds to seeing a pinhead at a distance of 25 km. The necessary angular resolution of about 0.01 arcsec is achieved by combining the light from two 8.2 m telescopes in the VLTI separated by up to 200 m and using the mid-infrared interferometric instrument (MIDI), which is sensitive to light at a wavelength near 10 µm. The MIDI spectra of NGC 1068 also provide information about the possible composition of the dust grains. The most likely constituent is calcium aluminium-silicate ($Ca_2Al_2SiO_7$), a high-temperature species also found in the outer atmospheres of some super-giant stars.

These very first observations of an extragalactic object by the technique of long-baseline interferometry in the mid-infrared region open the way to a completely new field of astronomy: the study of gas and dust structures surrounding and feeding the heaviest black holes in the universe.



A zoom into the active galaxy NGC 1068. The picture on the left is a Hubble Space Telescope false-colour composite image of NGC 1068, and on the right is a VLTI/MIDI image showing the mid-infrared emission. (Courtesy European Southern Observatory.)

Picture of the month



This image of a beautiful ring of blue star clusters bigger than the size of our Milky Way galaxy was released to commemorate the 14th anniversary of Hubble's launch on 24 April 1990. This ring galaxy, known as AM 0644-741, lies 300 million light-years away in the southern constellation Dorado. It was once a normal spiral galaxy, before being crossed at its centre by a smaller galaxy. While the yellowish nucleus of stars was only mildly affected by the collision, the gas rushing outwards has formed a ring, like ripples in a pond after a rock has been thrown in. The compression of the gas in the ring triggers the intense star formation outlined by many blue star clusters, which contain massive, young and hot stars. (Credit: NASA/ESA/Hubble Heritage Team.)

Further reading

W Jaffe *et al.* 2004 *Nature* **429** 47–49.

The beginning of long-term planning in CERN

In its early days CERN was budgeting a year at a time, but after a crisis in 1961 it became clear that long-term planning was essential. **Mervyn Hine** looks back to the introduction of a four-year planning cycle.

When CERN was founded in 1954 the member states realized that they were making a long-term financial commitment to pay for a very large accelerator and for the operations that would go with it. A basic document, "CERN Gen 5", had suggested that a large capital cost would be spread over the building period, followed by a much lower annual operating budget. The decisions by CERN Council to build the Synchrocyclotron and the Proton Synchrotron (PS), which had large, but not clearly defined, capital cost, were backed by early annual budget decisions to support continuing construction. Then, towards the end of the PS construction, Council fixed a three-year ceiling for the budgets for 1959–1961, which was intended to allow the PS to start operating, but with the hope still in some people's minds that later budgets would be lower.

In 1961 it became clear that this ceiling was going to be breached by a significant amount, and that there was no hope for a future reduction. Council therefore set up a committee under the Dutch delegate Jan Bannier, with senior representatives from the major member states, to review the needs of CERN and make recommendations for future financial policy. CERN was represented by Sam Dakin, the director for administration, and myself, recently appointed as directorate member for applied physics.

Discussions inside CERN made it clear that more staff would be needed in all parts of the organization to build up the PS programme to "full exploitation". Based on empirical data for "costs per man", the total annual costs would rise in the following years, at a rate of 13% per annum. The shock this figure generated in the committee was somewhat damped when, following my request, the members produced forecasts for their own national science expenditures. Their figures, plotted logarithmically, showed large sums with steady exponential growth at rates of 20–25%. In comparison, CERN's 13% line at the bottom of the page looked modest and reasonable.

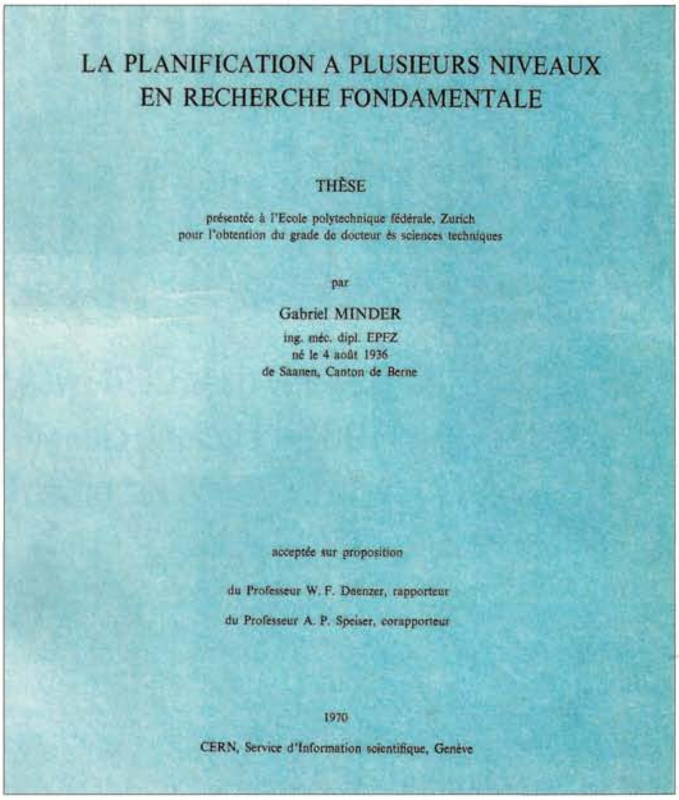
Another important input came from the UK administration delegate, who proposed a rolling four-year budget procedure following internal practice in the UK Treasury. In this procedure, Council would vote in December on the details of the budget for the coming year, within a total that had been fixed a year previously; it would make a "firm estimate" for the budget total for the next year and "provisional estimates" for budget totals for the following two years, with all figures being given at constant prices. In accepting this farsighted proposal, the Bannier committee also recommended that the budget should increase by 13% for two years and by not less than 10% for two years thereafter. Bannier also added a warning that the organization should consider the possibility of a large new project at a later date. Despite its experience with CERN Gen 5 and the three-year ceiling, in 1962 Council approved the committee's recommendations, showing how much CERN was blessed by the courage of its founding fathers.

Jan Bannier (right), Dutch delegate and later president of the CERN Council, chaired the committee that was set up in 1961 to review the needs of CERN and make recommendations for future financial policy. He is seen here in 1963 together with François de Rose, the French delegate to the Council.

It was then clear that CERN needed to establish effective internal procedures to provide well justified and reliable proposals for the programme and budget for four to five years ahead. These would have to be agreeable to the physics community, who were the users of the CERN equipment and services, and acceptable to a majority of the member states, who paid the bill. ▷

The director-general at the time was Viki Weisskopf, who had been appointed in mid-1961 just as the budget crisis was becoming apparent. At CERN the director-general is ultimately responsible to Council for all the work and finances of the laboratory. He therefore needs to have access to information and analysis on all the work in forms suitable for his policy decisions inside the laboratory, and for discussion with Council and its committees. Subject to pressure for resources from all sides, he also needs an independent source of information with high enough status to ensure good collaboration with all parties involved, and with access to their work. As a director with no division to manage and having worked with the Bannier committee I could fulfil such a role, despite my lack of qualifications, by thinking up a planning system to meet the needs of the Bannier budget procedure.

At that moment I was on my own and had to rely on the help of others to collect data. I was, however, accustomed to working alone, having been John Adams' technical aide in the design of the PS machine. I could fit in well with the director-general's policy of delegating work, by putting as much as possible into the hands of divisional planners, provided they followed agreed procedures. Fortunately, from 1963 on I had the good fortune to have Gabriel Minder, an engineer from ETH, Zurich, to work with me. Among other qualities he spoke eight languages, and the two of us did most of the thinking and detailed design work for planning procedures over the next few years. Minder eventually published this work as a CERN report (Minder 1970) and as a PhD thesis for ETH (Minder 1969).


LA PLANIFICATION A PLUSIEURS NIVEAUX
EN RECHERCHE FONDAMENTALE

THÈSE

présentée à l'Ecole polytechnique fédérale, Zurich
pour l'obtention du grade de docteur ès sciences techniques

par

Gabriel MINDER
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acceptée sur proposition

du Professeur W. F. Daenzer, rapporteur
du Professeur A. P. Speiser, corapporteur

1970

CERN, Service d'Information scientifique, Genève

Joining the ranks of PhD theses in research at CERN in 1970 was this report from Gabriel Minder on the development of planning in fundamental research.

The Functional Programme Presentation

I realized that I should minimize the disturbance to existing administrative systems – particularly the plan of accounts and the annual budget procedure under Georges Tièche, the head of the Finance Division – and not upset the detailed planning work inside the operating divisions. Thus the natural starting point was the existing plan of accounts. This had three main headings in each of the 12 divisions: personnel, operation and capital outlays. These headings were subdivided into some 2000 codes for different groups and sections inside divisions, and also for some detail on the kind of material or service concerned. This was very appropriate for financial control, but left personnel costs unallocated and gave little indications on the nature and type of work being done. By contrast, the top management needed information on how many people did or would do just what, for what purpose, how successfully and at what cost. This information would need to span several years both into the past and the future in an appropriate degree of detail for the questions in hand.

I decided that we needed to prepare figures not in terms of the divisions and groups working on parts of the programme, but in a functional form that could describe the state of identifiable activities of different types, covering perhaps several groups or sections, even across divisions, and that would be independent of current structures. Subactivities could be defined inside a division and could be combined to make divisional activities, and also CERN-wide activities where this would be coherent and useful.

A divisional (sub)activity would be an identifiable part of a division's work, specified by a description with the numbers of people and man-years involved each year, the annual cost and some measure of the resulting output. It would be aimed at programme planning and decision making for CERN, not at local financial management.

To be able to prepare such a Functional Programme Presentation, the FPP, I brought in early on the divisional assistants, who were already accustomed to preparing the detailed annual budget and accounts and who understood the workings of their divisions. With them we could establish agreed sets of divisional activities and subactivities, with their costs and manpower at that time. This required two judgements on the part of the divisional assistants: to allocate percentages of the manpower data of a division between its different subactivities and to identify which official accounts code applied to each subactivitiy. In 80% of the cases the accounts codes matched well enough with the subactivities, but for the remainder judgements were made on percentage splittings of amounts in account codes. These two sets of percentage keys would be revised once or twice a year as the work advanced.

At that point the central administration computer could be programmed to use these keys to convert standard divisional budget data into functional activity costs and manpower figures, without asking for extra work in the divisional offices.

The subactivity descriptions of measures of output could not be given simply as numbers, as staff and money could. They inevitably implied written work descriptions and statements of aims and of output, often with a subjective component. Nevertheless, by inspecting data for past years, simple numerical work indices could quite often be found, such as data on hours of operation and failure rates for equipment, installed kilowatts of power supplies, and square metres

The fruits of the Functional Programme Presentation: Mervyn Hine (left) arrives well supplied with information for the 33rd session of the CERN Council in December 1966, and talks with Kees Zilverschoon (centre) and Kjell Johnsen.

A CERN Council meeting when Viki Weisskopf (second from the right) was director-general of CERN and Jan Bannier (right) was president of Council. Mervyn Hine is on the left.

of floor space built or cleaned, which could be agreed by all parties to be relevant for evaluating aims and results, at least in the short term.

As an example, the Track Chamber Division (TC) programme in 1969 covered the research and development work described by 12 activities: bubble-chamber operations and development, particle-beam operations and development, picture-evaluation operation and development, low-temperature operations and development, the Big European Bubble Chamber (BEBC) project, additional laboratory staff, fellows and visitors, and divisional direction.

Although the activities were quite specific to the work in hand, they fitted into a few general classes, which formed the top level of the CERN FPP. They were R for research and operations, E for equipment and development, I and Z for improvements and major long-term projects, S for general services, and B for buildings and site equipment. Most of the TC programme fell into either the R or E classes, and BEBC into the I class. S and B covered the general administrative and technical services for the whole laboratory and the corresponding infrastructure, with similar subactivity structures at divisional and CERN levels.

An important point to note here is the clear separation between operations and development in all parts of a programme. These imply two different types of work, staff, expenditure and timetable, which should be kept clear in everybody's minds and in the forecasting.

The whole picture

The overall result of these steps of coding and combination was that about 2000 accounting codes could summarized into some 150 understandable divisional activities and then into 30 CERN activities. These gave a picture of the whole CERN programme, which was suitable for discussions of general policy before the finer details of any part of a programme were examined.

I should stress that this structure was built bottom-up by the divisional staff, who knew what they were doing and saying and only had very broad guidelines from me as the planning officer. This, I believe, helped to make the whole system well accepted throughout CERN.

In 1965 I sent Minder to Washington, DC, to the president's Office of the Budget and to NASA, to compare our FPP with the US Administration's new Planning-Programming-Budgeting System (PPBS), which the Department of Defense had set up in 1961 and many other federal and local agencies had adopted by 1965. However, the PPBS had not proven usable by US research laboratories, due to certain features related to the nature of basic research. We were pleasantly surprised to find those problems had been solved within the FPP. Minder also collected data at OECD in Paris for our long-term models, and we found that their figures could be inserted into our projections for expected users, e.g. the numbers of European graduate and post-graduate physicists.

By 1966 the FPP was beginning to come together, presenting the state of the laboratory over an eight-year period: the past four years, the current year and the three years ahead, where total budgets were known with varying degrees of certainty. At the CERN level it offered in particular a long-term view of two topics of importance for both the management and Council. They were the size and distribution of personnel and the balance between operation and investment.

To be an effective laboratory 10–15 years later, CERN had to maintain high investment in technical development and new equipment and infrastructures, in parallel with satisfying growing demands for resources from the short-term research and operational activities that came from the large and growing community of users. To make this investment visible I stressed the importance to divisional staff of clearly separating R-type work and costs, which were needed to run and maintain facilities, and E-type work aimed at improving facilities or extending their scale and future performance.

The FPP also clearly brought out staff numbers in different areas of activity, and made it clear if staff levels to operate new equipment were being properly planned. Staff numbers have always been a sensitive item for funding bodies, as they are a direct method of controlling expenditure, and staff can represent a long term commitment that is more difficult to undo than cancellation of orders for materials. ▷

Planning procedures: the annual cycle

The parties active in the annual cycle of the planning process were at three levels: Council, its finance and scientific policy committees; the directorate, finance and personnel divisions, the Programme Office and experiments committees; and the divisions, with their groups and planning staff. Two sets of documents were circulated during the year: the current divisional annual budget details, in plan of accounts format, and the Functional Programme Presentation (FPP) covering an eight-year span.

In autumn, the various divisions and the Finance Division jointly revised the annual budgets for the following year, in light of the previous FPP forecasts and the firm total CERN budget decided by Council the year before. There were naturally surprises, and claims for money to cover them, but if they could not be worked out within departments the director-general and top management had to arbitrate, according to possible changes in longer term trends in the programme. These would already be showing up in the revision of the FPP for future years, which had been going on throughout the year.

This revision would have already started in January, with a revised presentation of the then current FPP with the existing figures slid back one year, and a new proposed fourth-year figure added. The figures would be upgraded to take account of one year's inflation using the index approved by Council. The divisions and the Programme Office would then work on this revised version to review all the figures for future years, staying within the totals agreed by Council. These revisions would be reviewed by the directorate and would be the basis for an interim report to be presented to Council and its committees at the June session.

If this passed successfully, in the Autumn the new FPP figures would be discussed by the finance committee to allow them to make a recommendation to the coming December Council meeting, to confirm or modify previous decisions for future years, and to consider CERN's proposals for a new fourth-year provisional estimate.

What did the FPP give to CERN?

The FPP, with its planning cycle, gave CERN a tool that allowed people at all levels to work together each year to build up a rolling four-year forward plan that took account all parties' needs and that could be accepted by the member states with very little modification. It could accommodate the addition of major improvement projects and the building and operation of the Intersecting Storage Rings as a new CERN programme. For instance, the Swiss federal administrators of education and research, who wondered why they should support several CERN programmes, accepted to do so by discussing these in the FPP format.

The FPP was used from 1963 through to 1975, when the 300 GeV Super Proton Synchrotron was integrated into the CERN basic programme. At that point the new management changed the philosophy to planning in terms of projects rather than activities.

I am not aware of how well this new scheme worked in practice, as by then I was out of the management structure and working largely on my own. I can, however, see dangers in such a change. For example, accelerator operations are an activity requiring continuity over many years, without the end date and total cost that are suggested by the term "project". There is also the risk of not properly separating operations and investment. The top management could be faced with plans containing a large number of small-project proposals, which should really be decided at (inter)divisional level within the broader limits of agreed activities. I insisted that I did not want to have details of such divisional work formally reported to me, to avoid the temptation of micro-management by central staff. This policy, I believe, made the FPP well accepted by the divisions and helpful to them in clarifying their planning.

The intrinsic uncertainties of basic research have led to the idea that it cannot be planned, and this is certainly true at the level of its aims, which must depend on what nature offers us and not on what we would like it to tell us. However, the necessary continuity in exploring a fruitful line of enquiry for a certain period means that the effort and the cost can usefully be planned over that period. In some fields this time can be quite long, a decade or more, particularly where large equipment is involved. In elementary particle physics today this useful life is around 20 to 30 years, from the conception of a large facility to the time at which it may usefully be replaced or altered in a major way, with the cost of something completely new.

A four-year planning period, in which much of the work and cost has to be foreseen with some certainty, fits theoretically very well into the conduct of this type of research. The FPP is an existence proof that such a planning system can actually be implemented without disturbing the life of the laboratory, and without calling for a large central administration. This helps to avoid the directorate being tempted to become involved in micro-management, which is better left to lower levels in the organization. This is not, alas, always true in practice.

Further reading

G Minder 1969 PhD Thesis, ETH Zurich.
G Minder 1970 *Multi-level planning in fundamental research* CERN Report 70–2.

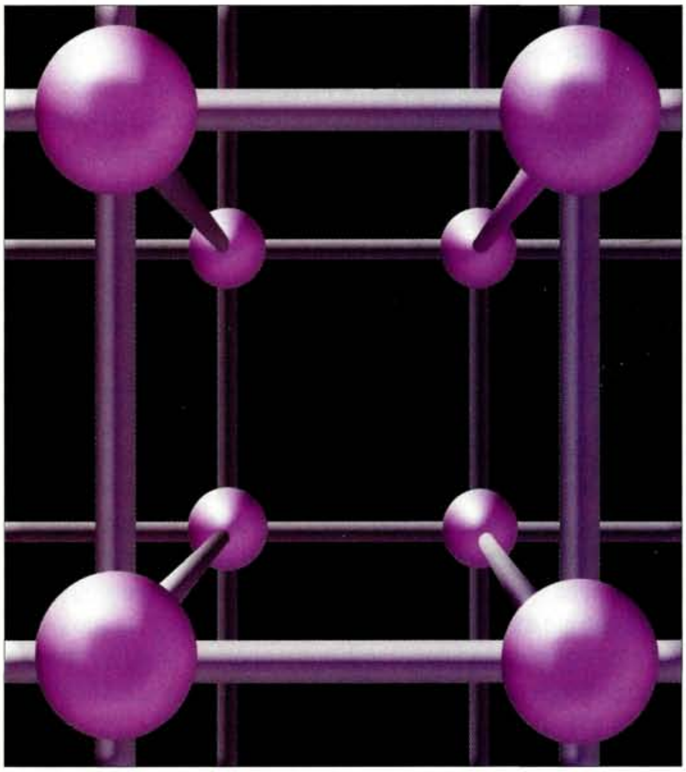
Mervyn Hine, *CERN directorate from 1960 to 1971.*

Mervyn Hine 1920–2004

Mervyn Hine, pioneer of the construction of CERN's Proton Synchrotron, and of computing and networking at CERN, passed away on 26 April following a serious accident in his home. He had recently completed this article for the CERN Courier *in the series "50 years of CERN", which we publish here as a tribute to an important figure and personality in the history of CERN. An obituary will appear in the next issue.*

Joining up the dots with the strong force

A new variation on an old technique is yielding the most precise results so far in lattice calculations of quantum chromodynamics, the theory of strong interactions, as **Christine Davies** explains.



In lattice QCD space–time is approximated by a four-dimensional box of points, similar to a crystal lattice. (Ian McVicar/Glasgow.)

Experimental particle physicists are well used to the fact that many years must elapse between the planning of a big experiment and the analysis of the results. Theorists do not generally have to wait so long for their ideas to bear fruit.

The attempt to solve the theory of the strong force by numerical simulation, however, has been a long-running saga. The technique, called lattice quantum chromodynamics, or more usually lattice QCD, was suggested 30 years ago and first attempted numerically in the late 1970s. Since then particle theorists have tried to monopolize each generation of the world's fastest supercomputers with their calculations, and battled with improved algorithms and sources of systematic error. Now they are close to a solution at last.

New calculations, which have simulated the most realistic QCD vacuum to date, have shown agreement with experiment for simple hadron masses for the first time at the level of a few percent. This is an important milestone. Only when well known quantities are accurately reproduced can we have faith in the calculation of other quantities that experiment cannot determine. A number of such calculations are eagerly awaited by the particle-physics community as a new era of high-precision calculations in lattice QCD begins.

Precision testing

Precise lattice QCD calculations are needed as part of the worldwide programme of testing the Standard Model so rigorously that flaws are exposed that will allow us to develop a deeper theory, explaining nature more completely. QCD is a key component of the Standard Model because any experiment aimed at the study of quark interactions must necessarily confront the issue that quarks are confined inside hadrons by the strong interactions of QCD. It is this feature of QCD that makes it hard to tackle theoretically as well. Although perturbation theory works well for QCD when high energies are involved, such as in jet physics, it is not an appropriate tool for physics at the hadronic scale. QCD interactions are so much stronger there that a fully non-perturbative calculation must be done using lattice QCD.

An important example of where lattice QCD calculations are needed is the attempt by experiments at B factories to test the self-consistency of the Standard Model through the determination of the elements of the Cabibbo–Kobayashi–Maskawa (CKM) matrix. This is now seriously limited by the precision with which QCD effects can be included in theoretical calculations of B-meson mixing and decay rates. Errors of a few percent are needed to match the experimental precision. Another important task is that of the determination of quark masses and the QCD coupling constant, α_s. Like the CKM matrix elements, they are fundamental parameters of the Standard Model that are *a priori* unknown and must be determined from experiment. Because quarks cannot be observed as isolated particles we cannot determine their masses or colour charges directly and theoretical input is required.

In lattice QCD the procedure is straightforward but numerically challenging. We must solve QCD for well known observable ▷

quantities, such as hadron masses, as a function of the quark masses and the coupling constant in the QCD Lagrangian. The value of a quark mass is then that which gives a particular hadron mass in agreement with experiment. The scale of QCD, Λ, is likewise determined by the requirement for another hadron mass to have its experimental value, and this is equivalent to determining the coupling constant. Quark masses, particularly those for u, d, s and c, are rather poorly known at present and this hampers a number of phenomenological studies. Precision of a few percent, rather than the current 30%, on the s quark mass would greatly reduce theoretical errors in the CP-violating parameter ε'/ε of kaon physics, for example.

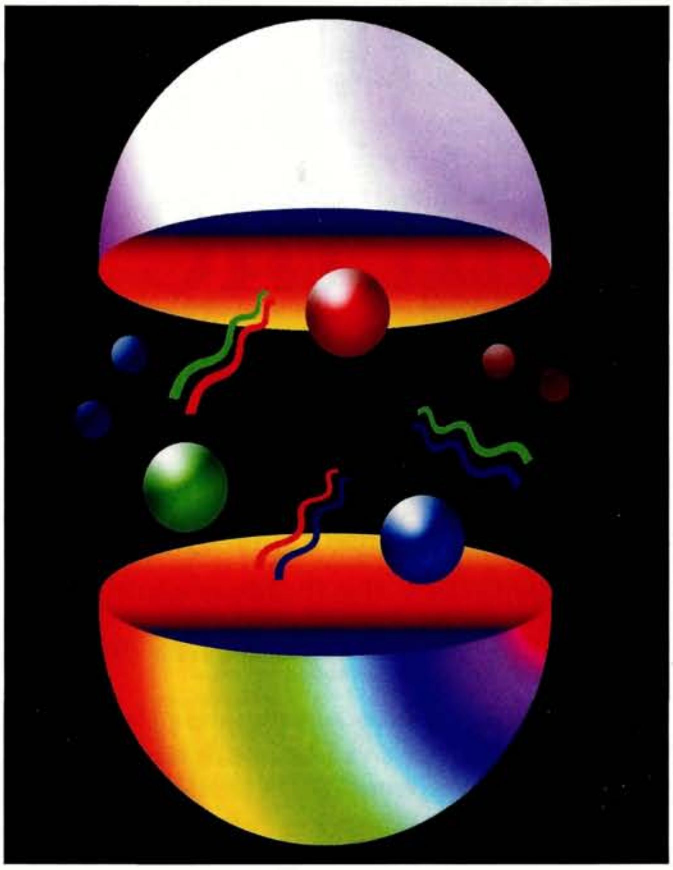
The space–time lattice

Lattice QCD proceeds by approximating a chunk of the space–time continuum using a four-dimensional box of points, similar to a crystal lattice (see figure, p23). The quark and gluon quantum fields then take values only at the lattice points or on the links between them, and the equations of QCD are discretized by replacing derivatives with finite differences. In this way a problem that would be infinitely difficult is reduced to something tractable in principle. We still have to perform a many-dimensional integral over the fields that we have, however, and this is done by an intelligent Monte Carlo process that preferentially generates field configurations of the QCD vacuum that contribute most to the integral.

This part of a lattice QCD calculation increasingly resembles a particle-physics experiment. Collaborations of theorists with access to a powerful supercomputer generate these configurations and store them for the second phase, which resembles the data analysis that experimentalists perform. In this phase hadron correlation functions are calculated on the configurations and fits are performed to determine hadron masses and properties. Many hundreds of configurations are typically needed to reduce the statistical error from the Monte Carlo to less than 1%.

Lattice QCD results are calculated for a lattice with a finite volume and a finite lattice spacing, but we want them to be relevant to the infinite volume and zero lattice spacing of the real world. For the accuracy we need we must understand how the results depend on the volume and lattice spacing, and reduce the systematic error from this dependence below the 1% level. The dependence on volume of most results falls very rapidly for large-enough volumes, so lattices 2.5 fm across or larger are thought to be sufficient for calculations at present. The dependence on lattice spacing is more difficult to remove and this was the subject of a great deal of work throughout the 1990s. The development of higher order, "improved" discretizations of QCD has allowed calculations to be performed that give answers close to continuum QCD, with values for the lattice spacing of around 0.1 fm. These are feasible on current supercomputers. With unimproved discretizations we would need to work with lattice spacing values 10 times smaller to achieve the same systematic error. This would cost, even naively, a factor of 10 000 in computer time, and in practice much more.

One key problem remained at the end of the 1990s. This was the huge computational cost of including the effect of dynamical (sea) quarks: u, d and s quark–antiquark pairs that appear and disappear through energy fluctuations in the vacuum (c, b and t quarks are too heavy to have any significant effect). The anticommuting nature of quarks, as fermions, means that their fields cannot be represented directly on the computer as the gluon fields are. Instead the quark fields are "integrated out" and the effect of dynamical quarks then appears as the determinant of the enormous quark interaction matrix that connects quark fields at different points. The dimension of the matrix is the volume of the lattice times 12 for quark colour and spin, typically 10^7.



The proton contains three valence quarks of three different colours (red, green and blue), but it also contains dynamical (sea) quarks. These are quark–antiquark pairs that appear and disappear through energy fluctuations in the vacuum. In the past these dynamical quarks presented big problems in lattice calculations of particle masses. (Ian McVicar/Glasgow.)

Honing techniques

The "quenched approximation", used extensively in the past, misses out the quark determinant entirely, and this is clearly inadequate for precision results. However, it has been a useful testing ground for theorists to hone their analysis techniques. More recently, dynamical quarks have been included, but often these are only u and d quarks with masses many times heavier than the very light values in the real world because the cost of including the quark determinant rises as the quark mass falls. A figure of merit for modern lattice calculations is how light the u and d quark masses (almost always taken to be the same) are in terms of the s quark mass (m_s). Given a range of u/d masses below $m_s/2$, it should be possible to

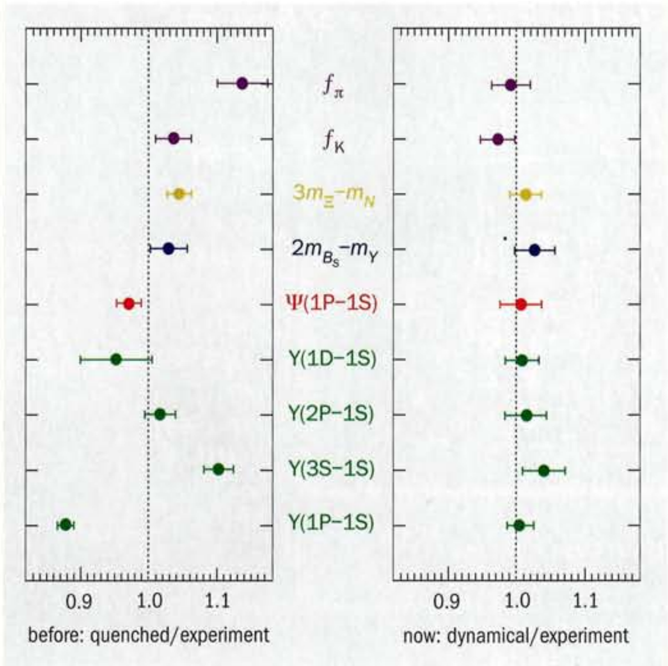


Fig. 1. New results (right) from lattice QCD calculations that include the effects of dynamical quarks come much closer to the experimental values for various quantities related to the hadron spectrum. On the left, similar ratios for a calculation that ignores dynamical quarks are plotted for comparison.

extrapolate down to physical results using chiral perturbation theory. Early simulations with dynamical quarks struggled to reach $m_s/2$ from above and so it was hard to distinguish results from the quenched approximation, although encouraging signs of the effects of dynamical quarks were seen.

Recent simulations by the MILC collaboration, however, have managed to include u, d and s dynamical quarks with four different values of the u/d quark mass below $m_s/2$ and going as low as $m_s/8$. This has allowed well controlled extrapolations to find the physical u/d quark mass where the (isospin averaged) pion mass agrees with experiment. Two different values of the lattice spacing have been simulated to check discretization errors and two different volumes (2.5 and 3.5 fm across) to check finite volume errors.

These results have been made possible by a new formulation of quarks in lattice QCD called the improved staggered formulation. The staggered formulation is an old one and has always been very quick to simulate. It uses the most naive discretization of the Dirac action possible on the lattice and the quark spin degree of freedom is then in fact redundant, immediately reducing the dimension of the quark interaction matrix by a factor of four. The discretization errors were originally very large with this formalism, however, and it is the realization that these can be removed using the improvement methodology discussed above that has enabled the improved staggered formalism to be a viable one for precision calculations.

One caveat remains. Because of the space–time lattice and the notorious "doubling" problem, the staggered formalism actually contains four copies (called "tastes") of each quark. This four-fold over counting is removed by taking the fourth root of the determinant of the quark matrix when generating configurations that include dynamical quarks. Some theorists object that the fourth root, despite being correct in perturbation theory, may introduce errors in a non-perturbative context. Extensive testing is required to be sure that we do have real QCD, but this is exactly the testing of lattice QCD that is necessary anyway to assure ourselves that precision calculations are possible. So far the formalism has passed with flying colours.

Figure 1 shows the results of an analysis using the MILC configurations by the MILC, HPQCD, UKQCD and Fermilab collaborations. Nine different quantities are plotted, covering the entire range of the hadron spectrum from light hadrons represented by the π and K decay constants (related to the leptonic decay rate) all the way to the heavy hadrons represented by orbital and radial excitation energies in the Υ system. Light baryons, B-mesons and charmonium are also included. These quantities have been chosen to be "gold-plated" – that is, masses or decay constants of hadrons that are stable in QCD and therefore well defined both theoretically and experimentally. Lattice QCD calculations of these must work if lattice QCD is to be trusted at all. The quark masses and QCD scale have been fixed (as they must be) using other gold-plated hadron masses that do not appear in the plot. These are the masses of the π, K, D_s and Υ, and the splitting between the Υ' and the Υ. In the figure on the left-hand side are plotted results in the quenched approximation, in which dynamical quarks are ignored. Some quantities disagree with experiment by 10% and there is internal inconsistency in the sense that quantities can be shifted in or out of agreement with experiment by changing the hadrons used to fix the parameters of QCD. On the right are the new results, which include u, d and s dynamical quarks. Now all the quantities agree with experiment simultaneously, as they must if we are simulating real QCD, and this is tested with a precision of a few percent.

Calculating with confidence

This is a major advance. Now calculations of other quantities can be carried out, knowing that the correct answer in QCD should be obtained. For example, calculations of leptonic and semileptonic decay rates for B and D mesons and B-mixing rates are in progress. Checks of the D results, providing confidence in the B results for the B factories, will be possible against measurements from the CLEO-c experiment at Cornell. Masses of hadrons that are unstable or close to threshold will be more difficult to calculate with high precision, but many of these, such as glueballs and pentaquarks, are very interesting states. Other quark formulations that escape the doubling problem but are much more costly to simulate will provide important checks once the necessary computational resources are available. Supercomputing for lattice QCD is just entering the teraflops era, and it promises to be a very productive one in which precision calculations are possible at last.

Further reading

C T H Davies *et al.* 2004 HPQCD/UKQCD/MILC/Fermilab collaborations *Phys. Rev. Lett.* **92** 022001.

Christine Davies, *University of Glasgow.*

Final beam for Orsay's accelerator


The 45-year-old linac at Orsay has delivered beam for the last time.

The linear accelerator that gave "LAL" at Orsay its name has delivered its last beam, but the laboratory's involvement with electron linacs remains as strong as ever.

On 19 December 2003 the Laboratoire de l'Accélérateur Linéaire at Orsay marked the final shutdown of its linear accelerator. The event, which was a highly nostalgic occasion, was commemorated by an official ceremony attended by many scientists, engineers and technicians. On 24 December 1958, almost 45 years earlier to the day, the linac had delivered its very first beam, a 3 MeV electron beam. One year later, the first section of the machine achieved an energy of 165 MeV, thus enabling the experiments to begin.

The decision to build a large linear electron accelerator at Orsay was taken in 1955, the year in which land in the Vallée de Chevreuse had been acquired with a view to extending the Faculty of Science in Paris. The specification for the linac and the responsibility for its construction were entrusted to Yves Rocard, head of the physics laboratory of the École Normale Supérieure, and to Hans Halban, head of research in nuclear physics at the laboratory. The CSF (Compagnie générale de télégraphie sans fil) played a major role in the construction. Right from the start, the laboratory housing the machine was named the Laboratoire de l'Accélérateur Linéaire, or LAL for short.

The advantage that a linear accelerator has over circular machines is that its energy can be pushed very high by adding additional sections. The Orsay linac's energy was gradually increased in this way, reaching 1.3 GeV in 1964 – which for a short time was the world energy record for electron linacs – and 2.3 GeV in 1968. As of 1963, the accelerator was also equipped to deliver a positron beam, whose initial energy of 250 MeV was later increased to 1 GeV.

From the outset the accelerator was also equipped with spectrometers, which became more and more powerful in order to keep up with the linac's increasing energy. Initially used in electron scattering experiments, whose purpose was to explore the internal structure of many nuclei and of nucleons themselves, they were later refined to allow the study of π-meson photoproduction and electroproduction, and then the photoproduction of K and η mesons. Tests of quantum electrodynamics were also carried out.

The initial goal of the positron beam was to compare these particles' scattering cross-sections with those of electrons, in order to measure interference between amplitudes involving the exchange of a single and two virtual photons. The positron beam later became a valuable tool in the implementation of collider and storage rings. The Orsay collider ring, ACO, came first, with the first experiment performed in 1967; then the DCI (Dispositif de collisions dans l'igloo), commissioned in 1977; and finally the Super-ACO ring, fully dedicated to the production of synchrotron radiation, with its first experiment in 1988. From 1985 onwards the linac was used exclusively as an injector for the latter two rings. In the case of the DCI, the quality of vacuum achieved through the machine's 26 years of exploitation – first for particle physics and then as an X-ray source – was such that it was enough to inject particles on Monday mornings for a sufficiently intense beam to be available throughout the following week.

Thus, during its 45 years of operation, the Orsay linac was used, in turn, for nuclear physics, particle physics and as an injector for the synchrotron light sources for LURE (Laboratoire pour l'Utilisation du Rayonnement Electromagnétique). The ceremony on 19 December 2003 marked the shutdown of the beams that were circulating in the DCI and Super ACO, and were being used by scientists at LURE.

Although the Orsay linac has not been used by the particle-physics community at LAL for almost 20 years now, the laboratory is still carrying out R&D and construction in the field of electron linear accelerators. In partnership with CERN, it designed and built the electron and positron injector, LIL, for LEP in the 1980s. Today, LAL is heavily involved in a study and test programme concerning the power couplers that will supply the superconducting cavities in the framework of the TESLA collaboration; it is also responsible for the electron gun and the pre-buncher cavities of the CTF3 (CLIC test facility) prototype at CERN. Thanks to this activity and the laboratory's ambition to take part in the construction of a future linear collider, which it is hoped will be undertaken by a worldwide collaboration, LAL continues to be an appropriate name for the laboratory, even if the accelerator from which it derives has now been closed down.

Jacques Haïssinski, *LAL, Orsay.*

CANDLE lights up r

As Armenian scientists continue their efforts to promote the
Vasili Tsakanov explains the importance of the pro

In late 2001 a new non-profit foundation, CANDLE (Center for the Advancement of Natural Discoveries using Light Emission), was established in Armenia. Its aim is the construction of a 3 GeV synchrotron light facility in the Armenian capital, Yerevan. The project is well supported by the Armenian government, which has provided the office building and 20 hectares of land for the creation of the new laboratory. In a letter to the president of the CANDLE foundation, the minister of foreign affairs of the Republic of Armenia, Vardan Oskanian, said: "We believe the project is worthy of support by the private sector, the international community, the US government and, of course, the Armenian government."

Early in 2002 the new institute received a $500 000 (~€419 000) grant from the US State Department for the design study of the facility (*CERN Courier* October 2002 p7). This was performed under a US Department of Energy contract with the director of CANDLE, Alex Abashian from Virginia Tech in the US, as principal investigator, and the work was undertaken by a team of Armenian scientists and engineers in close collaboration with colleagues from other countries. The design report was completed only six months later, in June 2002. Meanwhile, 69 user proposals from the international scientific community were submitted to a review panel established by the US State Department with the help of the National Science Foundation. The review panel, headed by Maury Tigner from Cornell University, held a special two-day meeting in Washington in August 2002 to evaluate the scientific, technical and organizational viability, as well as international aspects, of the proposed facility.

World class

The review panel reported that the CANDLE project would be a "world-class facility capable of enabling frontier work across the full range of physical, life and engineering sciences" and that it was highly likely that a reasonable user community could be developed. The report also described CANDLE as "an excellent investment from a scientific/technical point of view...providing a great opportunity to be the principal third-generation synchrotron facility, not only in Armenia but also the entire region." An important recommendation of the review panel relates to the funding of the new facility: "The committee urges the state department to consider an approach in which a construction funds commitment is contingent on the project delivering a plan for operations funding with hard commitments."

Several leading European synchrotron laboratories – ANKA, BESSY, DESY, ELETTRA and ESRF – along with the co-ordinator of the European Round Table on Synchrotron Radiation and Free-Electron Laser, Giorgio Margaritondo, have expressed their support for the creation of the new facility in Armenia. DESY has expressed its willingness to make an in-kind contribution to the project by providing the components of the S-Band linear accelerator for the injector system. The radiofrequency components will be transported to Armenia during 2004. The Scientific Committee of the University of Provence in Marseille has also expressed its support and interest. An official delegation from the university, headed by Jean-Marc

Signing the memorandum of understanding between Provence University (Jean-Marc Layet, left) and CANDLE (Vasili Tsakanov).

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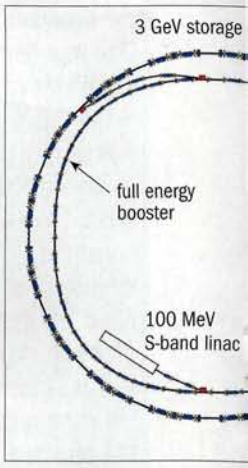
CANDLE: a light source for Armenia

The CANDLE project is a 3 GeV synchrotron light facility that will deliver photons in the energy range 0.01–50 keV, which is suitable for investigations at the level of cells, viruses, proteins, molecules and atoms. The facility will consist of a 100 MeV energy S-Band linear injector; a full-energy, 2 Hz repetition rate, booster synchrotron; and a storage ring with a circumference of 216 m.

A critical photon energy of 8.1 keV will be achieved from 1.354 T bends and an energy of 12 keV from a 2 T wiggler magnet. In total, 12 insertion devices can be installed in the ring. For the initial stage of machine operation, six beam lines are currently foreseen to support diffraction and scattering, X-ray absorption spectroscopy, imaging, LIGA, soft X-ray spectroscopy and small-angle X-ray scattering experiments.



The diagram above sho
the CANDLE facility. Th
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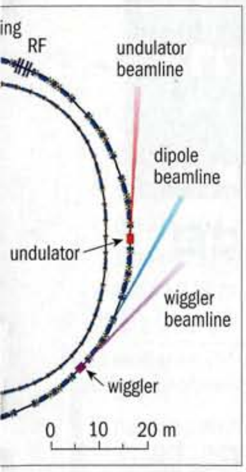
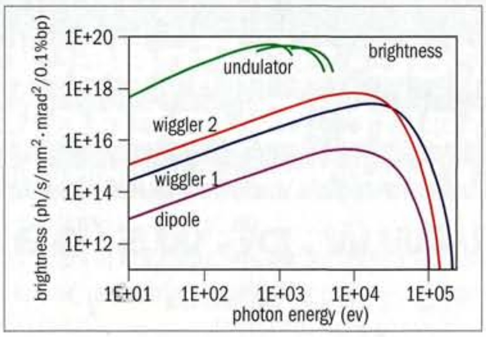
reation of the CANDLE facility, a third-generation light source,
ject both to the region and to international research.

it of the US scientific delegation to CANDLE in February 2004. From left: n Paul Neureiter (National Academies), Barry Barish (California Institute of ology), Vasili Tsakanov (CANDLE), Samuel Harutiunyan (Yerevan State sity) and John Dickson Baldeschwieler (California Institute of Technology).





Energy E	3 GeV
Circumference	216 m
Current I	350 mA
Number of periods	16
Tunes Q_x/Q_y	13.22/4.26
Emittance	8.4 nm
Beam lifetime	18.6 h

ws the general layout of e graph top-right depicts of CANDLE, and the s main parameters.

Layet, visited the new laboratory in Armenia in April 2003, when a memorandum of understanding on the co-operative programme to be conducted on the future facility was signed.

The voice of the international community indicates the high regard in which the Armenian project is held, and that the user case for the facility will be robust upon its completion. The facility will be unique within an area of 2000 km radius and will involve the huge intellectual potential of the region. In turn, the initiative of the Armenian scientists provides a good case for the promotion of synchrotron light based research worldwide.

Armenia's leaders fully appreciate the value of the project for the country's long-term development and its integration into the international scientific community. "The beneficial impact will extend well beyond the boundaries of research, producing a positive picture of a country oriented towards science and technology and is capable of mastering the most sophisticated and ambitious projects," said Margaritondo in a letter to the Armenian minister of science and education. The Armenian National Academy of Science, Yerevan State University, the Georgian Academy of Science, Tbilisi University, and prominent scientists from Armenia and the surrounding region have all expressed their support for the CANDLE project. They consider the creation of the new light source as an "engine" for the promotion of scientific co-operation both in the region and globally.

Encouraging signs

On 26 February this year the European Parliament voted for a special amendment related to scientific co-operation with the countries of South Caucasia, specifically stating that: "the commitment of the European Union to the Armenian synchrotron facility CANDLE will be an encouraging sign for this project, which primarily concerns European scientific research teams." At the same time the US State Department has renewed its consideration of the CANDLE project. Also in February, an official US delegation, including Barry Barish from the California Institute of Technology, visited the CANDLE laboratory to inspect the project and review the steps necessary for the continuation of the project.

More recently, a special session on "Synchrotron radiation research in developing countries and international scientific co-operation", organized by Herman Winick of the Stanford Synchrotron Radiation Laboratory and sponsored by the American Physical Society, took place in Montreal, Canada, on 22 March. In the session the regional impact of the Brazilian Light Source in South America, SESAME in the Middle East and SIAM in Southeast Asia were presented, together with the CANDLE project, which was described in an aptly titled talk: "Rejuvenating science in Armenia and its neighbours". Several US officials and experts attended the session, including Ray Orbach, director of the Office of Science at the Department of Energy.

Alex Abashian hopes that this latest effort will result in a green light for the CANDLE pre-construction stage during 2004, in line with the funding schedule and based on the report of the review panel. The pre-construction phase includes an extensive prototyping ▷

programme; test stands for radiofrequency, vacuum and magnet systems; site development; the establishment of machine and user advisory committees; and a number of international workshops on the facility and opportunities for users.

The vision behind the CANDLE project has been aptly summarized by the president of the foundation, Jirair Hovnanian, head of a New Jersey-based family-run building company: "It is our vision and desire that CANDLE will be an international facility that will provide opportunities for scientists in the region and beyond to have access to a user-friendly, world-class, third-generation light source. A natural by-product of CANDLE is the renewal of the scientific standards in Armenia to their past world-class level, and the provision of employment for Armenian, as well as neighbouring, scientists, both young and mature, thus reversing the brain drain from the region." Some of these aims are already bearing fruit: as early as May 2003 the ArmElectroMash company in Armenia had successfully completed the first prototype dipole magnet for the CANDLE booster synchrotron. This positive experience has made local fabrication of the magnets and vacuum chamber for the new facility a reality, providing benefits to Armenian industry, even at the construction stage. The CANDLE leadership believes that the continuation of the project will provide a good base for the commitments by other funding sources, and will strengthen international co-operation in setting up and using the new facility.

The first prototype dipole magnet for the CANDLE booster ring.

Further reading

A Abashian *et al.* 2002 CANDLE Design Report, ASLS-CANDLE R-001-02; see also www.candle.am/~TDA/.
V Tsakanov *et al.* 2002 Status of 3 GeV Intermediate Energy Light Source Project in Republic of Armenia, EPAC 2002.

Vasili Tsakanov, *technical director, CANDLE.*

The search for the disappearing neutrinos

A series of three workshops has considered a new generation of experiments at nuclear reactors, which could help to pin down the neutrino mixing matrix.

The participants at the third workshop on future low-energy neutrino experiments, held in Niigata, Japan.

In late March in Japan only a few buds from the cherry blossom trees are beginning to show their shades of pink, but in Niigata this year new ideas for neutrino experiments at nuclear reactors were in full bloom. It was here that an international group of physicists met to discuss these ideas at a workshop hosted by the University of Niigata and the Tokyo Electric Power Company. This was the third in a series on future low-energy neutrino experiments that had begun in Alabama in April 2003 and proceeded to Japan via Munich, in October 2003.

The basic idea being considered is to use several detectors to search for anti-electron neutrino disappearance, as this can provide evidence for a non-zero value of the parameter θ_{13} in the Maki–Nakagawa–Sakata (MNS) mixing matrix, the analogue for neutrinos of the Cabbibo–Kobayashi–Maskawa matrix for quark mixing. In its simplest form the 3×3 neutrino MNS matrix can be parameterized with three angles and one phase. Experiments using atmospheric neutrinos have shown clear evidence for neutrino oscillations, with the mixing angle – the parameter θ_{23} – near its maximal value of 45°. The long-standing solar neutrino problem has also been solved by neutrino oscillations with a large value of the parameter θ_{12}. This result has been confirmed by the reactor neutrino experiment KamLAND, which has an average distance to the reactors of 180 km.

The current best limit for θ_{13} comes from the reactor experiment CHOOZ. This was originally designed to look for a large signal from θ_{12} related to the atmospheric neutrino anomaly, and used only one detector. Now, however, it has been realized that an experiment with two (or more) detectors could greatly reduce the dominant systematic uncertainties from the reactor fuel cycle and detector efficiencies. This would allow a more sensitive search for θ_{13}.

The meeting in Niigata began with a number of talks reviewing the theoretical situation. Hisakazu Minakata from Tokyo Metropolitan University described how a neutrino measurement of θ_{13} could be combined with measurements from future long-baseline accelerator experiments to measure the sign of Δm^2 and the CP parameter δ. He also introduced a concept for a θ_{12} experiment that would use the Kashiwazaki–Kariwa nuclear-reactor complex near Niigata and a detector on Sado Island, about 70 km away. Morimitsu Tanimoto from Niigata University then addressed the issues of why θ_{13} is so small, why θ_{23} is near maximal and why θ_{12} is not maximal. He covered several theoretical frameworks: anarchy (in effect, random oscillations), radiative origins, grand unified theories and texture zeros (very small entries in the mass matrices). In one example of texture zeros the small value of θ_{13} could be related to the smallness of the neutrino masses. However, even in that case he concluded that only experiment could reveal the real size of θ_{13}.

The recent increase in interest in a new reactor experiment goes hand-in-hand with ideas for large "off axis" long-baseline neutrino experiments at accelerators to measure ν_μ–ν_e oscillations. Unlike reactor experiments, accelerator experiments are also sensitive to CP-violating effects in the neutrino sector and to matter effects. This is both an advantage and a disadvantage. The advantage is that there is obviously a richer physics programme to investigate. The disadvantage is that a particular measurement is more difficult to interpret due to ambiguities and degeneracies. Takashi Kobayashi from KEK described the status of the T2K experiment, which was recently approved to send a beam from the new JPARC accelerator at Tokai to the Super-Kamiokande facility in the Japanese Alps, a distance of 295 km. The first beam is currently expected in 2009. Bob McKeown from Caltech then showed how reactor and accelerator measurements could be combined to provide greater precision and insights. As examples, he used both the Japanese experiment T2K and the proposal for an off-axis experiment at the NuMI beam in the US, now called NOνA.

The main parameters of a reactor neutrino disappearance ▷

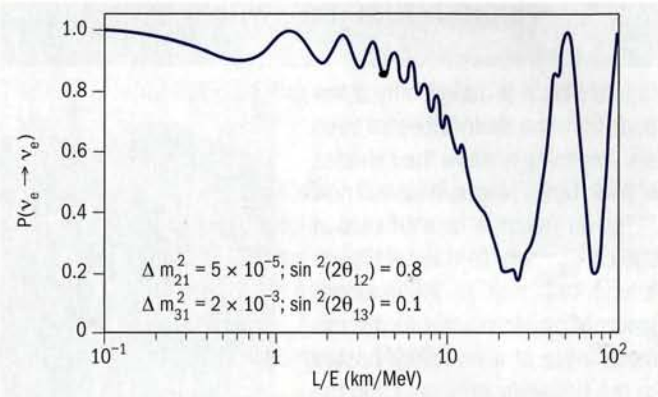
A comparison of the features of some of the proposed reactor sites

Proposed site	Power (GW)	Baseline near/far (m)	Detector mass near/far (tonnes)	Overburden near/far (MWE)
Angra dos Reis (Brazil)	4.1	300/1300	50/50	60/600
Braidwood (US)	7.5	200/1500	25/50	250/250
Double CHOOZ (France)	8.4	150/1050	10/10	50/300
Daya Bay (China)	11.6	300/1500	25/50	200/1000
Diablo Canyon (US)	6.4	400/1800	25/50	100/700
KASKA (Japan)	24.3	400/1300	8/8	120/350
Krasnoyarsk (Russia)	3.2	115/1000	46/46	600/600

experiment were outlined in the talk by Karsten Heeger from the Lawrence Berkeley Laboratory. This also served as an excellent summary for the three workshops on this subject as he addressed three main questions. Why do a new reactor experiment? How would such an experiment be configured? What are the experimental challenges that new multi-detector reactor experiments face? Heeger concluded that a disappearance measurement of θ_{13} with reactor neutrinos is a promising method to measure the true value of $\sin^2 2\theta_{13}$, but it is experimentally challenging. Combined with the result of a five-year experiment with a high-intensity neutrino "superbeam", reactor measurements can provide significant new constraints and perhaps even decide the neutrino mass hierarchy and yield information on the CP-violating phase angle in the MNS matrix. The sensitivity to a normal mass hierarchy is better. An optimized baseline of 1.7 km helps to reduce the impact of systematics, and limits of the order of $\sin^2 2\theta_{13} < 0.014$ are achievable. Smaller, quicker reactor experiments will yield $\sin^2 2\theta_{13} < 0.04$.

Talks and discussion at the meeting also explored six projects that are under development in five countries and on three continents (see table "A comparison of the features of some of the proposed reactor sites"). In Japan, the Kashawazaki–Kariwa nuclear-power complex consists of seven nuclear reactors. Located about an hour from Niigata, it is the highest power nuclear site in the world. The Tokyo Electric Power Company arranged a tour for conference participants, who – after the appropriate security and radiation protection requirements – were able to stand on top of one of the seven cores, 20 m from the release of enough energy to power 3% of the Tokyo area. Fumihiko Suekane from Tohoku University showed the design for the KASKA (Kashawazaki–Kariwa) project, in which 8 tonne gadolinium-loaded liquid-scintillator detectors would be placed deep in shafts at two near-detector locations and one far location, with an average distance 1.3 km from the reactor cores. Osamu Yasuda from Tokyo Metropolitan University demonstrated that for multiple reactors and near-detectors the uncorrelated error is reduced and there is no loss of precision.

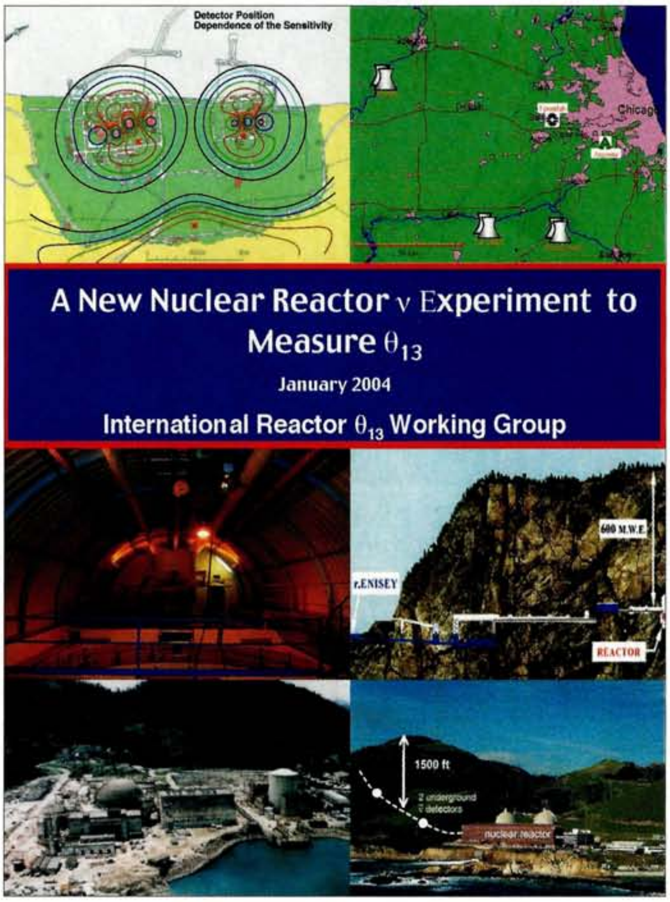
Turning to the US, Ed Blucher from the University of Chicago and Jonathan Link from Columbia University described progress on the proposal to use a site at Braidwood in Illinois, about 80 km from Chicago. One way to control systematic errors is to move the detectors between the near and far sites, and the relatively flat terrain in Illinois allows this to be done relatively inexpensively. A cost estimate has been made for the underground construction of two shafts, 300 and 1800 m from the centre of the two reactor cores at the Braidwood nuclear plant. The next step is to drill boreholes to full depth at the positions of both shafts, to provide information about geology, radioactivity and density. A site-specific estimate of isotope production by muons is being used to calculate the optimum depth for the detectors. Karsten Heeger described similar considerations for the Diablo Canyon site in California.



Illustrative plot of the L/E distribution for a hypothetical value of θ_{13}. Note that θ_{12} and both values of Δm^2 are approximately known, and that a large value of θ_{13} has been used. The huge dip at L/E ~25 km/MeV is what has been measured by the KamLAND reactor experiment with an average distance of 180 km. The new reactor experiments would go back to L/E ~0.5 km/MeV and look for the smaller disappearance effect.

In Europe the original CHOOZ experiment, 1050 m from the reactor cores, is still available. Thierry Laserre from CEA/Saclay and Herve de Kerret of APC (AstroParticule et Cosmologie)/Collège de France presented the Double CHOOZ concept, with a larger detector and the possibility of placing a relatively shallow near-detector about 100–200 m from the reactors. A dense mound of shielding would probably be needed to reduce backgrounds. A letter of intent by a proto-collaboration from France, Germany, Italy and Russia is nearing completion, and early stages of approval have already been obtained.

For South America, a site at Angra in Brazil is a possibility, as described by Orlando Peres from the State University of Campinas (UNICAMP) and David Reyna from Argonne National Laboratory. Due to a favourable local geology, two 50 tonne detectors could be placed 350 and 1350 m from the reactor core. Back in Asia, the



The cover of a white paper written about potential reactor experiments to measure θ_{13}. Clockwise from upper left they represent the Kashiwazaki–Kariwa complex (KASKA) in Japan, reactors in Illinois including Braidwood, Krasnoyarsk Russia, Diablo Canyon California, Angra Brazil and CHOOZ France.

site at Daya Bay in China was described by Yifang Wang from the Institute for High Energy Physics in Beijing. Located near Hong Kong, the power plant has four reactor cores in two clusters, providing a total thermal power of 11.6 GW, with two further cores (6 GW) planned for 2011. A tunnel that would service two near-detector locations and one far-detector location is being considered, as well as a design for multiple 10 tonne detectors.

In addition to describing the site characteristics, most speakers also addressed a myriad of issues, including optimal distances, detector design, scintillator properties, backgrounds, calibration and systematic errors. Two talks focused on the progress in understanding gadolinium-loaded liquid scintillators. The neutron absorption cross-section on gadolinium is so high that it provides an attractive target for this kind of experiment. Both the high cross-section and large energy release (8 MeV) provide a high efficiency to look for the neutron in coincidence with the positron in inverse beta-decay. However, previous experiments have found large degradations as a function of time of the light attenuation length in gadolinium scintillators, which would make a precision experiment more difficult. Francis Hartmann from the Max Planck Institute in Heidelberg described the progress that is being made there in scintillator chemistry, including the promising metal beta-diketone structure that is being investigated. Dick Hahn from the Brookhaven National Laboratory reported on a series of tests undertaken at Brookhaven and elsewhere to understand the optical properties of gadolinium-loaded scintillators in various solvents and with a variety of concentrations.

The unit of luminosity for reactor experiments is gigawatt-tonne-years, a product of the reactor power, the detector size and the running time. Manfred Linder from the Technical University Munich had shown in earlier workshops that there were two limiting cases, low luminosity (below 400 GW-tonne-years) and high luminosity (above 8000 GW-tonne-years). The former allows a measurement of rates, while the latter allows the shape of the energy distribution to be studied. However, different systematic errors are important for the different ranges of luminosity. David Reyna from Argonne National Laboratory focused on the advantages of using larger detectors to get enough statistics to see the change in shape of the energy distribution due to electron–antineutrino disappearance.

Although the main goal of the experiments being discussed in Niigata is to discover and measure θ_{13}, there are other physics goals that could be pursued. Valery Sinev from the Kurchatov Institute considered the sensitivity of such an experiment to sterile neutrinos. He also looked at the issues of "burn-up" (changes in fissile content based on changes in the antineutrino rate) and changes in the energy distribution at the near-detector as studies in reactor physics. Michael Shaevitz from Columbia University presented a study showing that the events from the near-detector, if it is deep enough, could be used to measure neutrino–electron elastic scattering with an accuracy good enough to make a measurement of the weak mixing angle. This could be valuable as the NuTeV neutrino experiment has a measurement of this angle that is somewhat in conflict with other ways to measure it. A measurement of the antineutrino flux from reactors could also prove useful for the International Atomic Energy Association in its monitoring of the fuel cycle of nuclear reactors, as Thierry Laserre described.

The three workshops in this series have been useful in providing motivation for the experiments and sharing strategies for how to go about them. While the theorists refused to give a firm prediction for θ_{13}, the experimentalists in Niigata conducted a poll of their expectation of what θ_{13} might turn out to be. More than 80% of their values were within the sensitivity of the proposed new reactor experiments. Since no large civil construction is needed, the quickest opportunity is for the Double CHOOZ experiment, with a detector that could be taking data in 2008. Participants were also in agreement that another experiment beyond Double CHOOZ was necessary in order to cover the range of parameter space that is reasonably accessible. They left Niigata convinced that they needed to form the collaborations, get the experiments approved and find the value of θ_{13}.

Further reading

The international working group of 126 physicists from 40 institutions in nine countries has collaborated on writing a white paper entitled "A New Nuclear Reactor Neutrino Experiment to Measure θ_{13}", which was published in January 2004. See www.hep.anl.gov/minos/reactor13/white.html.

Maury Goodman, *Argonne National Laboratory.*

Theory and experiment peer across the frontier

The fourth conference in the "Beyond" series presented a clear overview of – and beyond – the current frontiers of particle physics, astrophysics and cosmology.

The participants at the "Beyond 03" conference enjoyed a broad range of topics, from fundamental to astroparticle physics.

New developments in extensions of the Standard Model, through supergravity, superstrings and extra dimensions, were among the highlights of "Beyond the Desert 03 – Accelerator, Non-accelerator and Space Approaches", which was held last year in Castle Ringberg in Tegernsee, Germany. Supergravity had recently celebrated its 20th birthday and two of its "inventors" – Pran Nath and Richard Arnowitt – were among the participants at the conference.

Nath, of Northeastern University, Boston, summarized the developments of minimal supergravity grand unification (mSUGRA) and its extensions since the formulation of these models in 1982, while Arnowitt, from Texas A&M, highlighted the connection to dark matter and the value of g-2 of the muon. Focusing on quantum gravity, Alon Faraggi of Oxford argued that the experimental data of the past decade suggest that the quantum-gravity vacuum should possess two key ingredients – the existence of three generations and their embedding into SO(10) representations. He explained that the $Z1 \times Z2$ orbifold of the heterotic string provides examples of vacua that accommodate these properties. He also showed that three generations require a non-perturbative breaking of the grand unification gauge group, and in this context examined the issue of mass and mixing in the neutrino versus the quark systems.

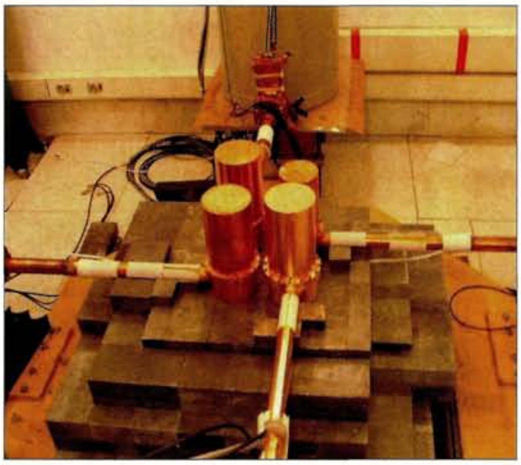
Fundamental physics, including fundamental symmetries, formed another important aspect of the meeting. Peter Herczeg from Los Alamos reviewed CPT-invariant, and CP- and P-violating electron–quark interactions in extensions of the Standard Model. Turning to fundamental constants, Harald Fritzsch of Munich discussed astrophysical indications that the fine structure constant has undergone a small time variation during the cosmological evolution, within the framework of the Standard Model and grand unification. The case where the variation is caused by a time variation of the unification scale is particularly interesting.

Interferometry

The potential of neutron interferometry for tests of fundamental physics was outlined by Helmut Rauch of Vienna. Recent experiments in neutron interferometry, based on post-selection methods, have renewed the discussion about quantum non-locality and the quantum measuring process. It has been shown that interference phenomena can be revived when the overall interference pattern has lost its contrast. This indicates a persistent coupling in phase ▷

space, even in cases of spatially separated Schroedinger-cat-like situations.

Interesting developments in general relativity and aspects of special relativity were also discussed at the conference. Mayeul Arminjon of Grenoble presented a new "scalar ether theory" of gravitation. One of the motivations for trying such an alternative approach is to solve problems that occur in general relativity and in most extensions of it – namely the existence of singularities and the interpretation of the gauge condition. Arminjon showed that this scalar theory fits nicely with observations on binary pulsars. Lorenzo Iorio of Bari reported on new perspectives in testing the general relativistic Lense–Thirring effect. Turning to experiment, the present status of the search for gravitational waves was outlined by Peter Aufmuth of Hannover. Only astrophysical events, such as supernovae, or compact objects, for example, black holes and neutron stars, produce detectable gravitational wave amplitudes. The current generation of resonant-mass antennas and laser interferometers has reached the sensitivity necessary to detect gravitational waves from sources in the Milky Way. Within a few years the next generation of detectors will open the field of gravitational astronomy.



The set-up of four enriched ^{76}Ge detectors of the Heidelberg–Moscow double beta decay experiment during the period 1995–2003, shown here without the shielding.

Cosmological connections

Talks about the early universe included cosmological, quantum-gravitational and other possible violations of CPT symmetry. Nick Mavromatos of King's College, London, discussed the various ways in which CPT symmetry may be violated, and reviewed their phenomenology in current or near-future experimental facilities, both terrestrial and astrophysical. First he outlined violations of CPT symmetry due to the impossibility of defining a scattering matrix as a consequence of the existence of microscopic or macroscopic space–time boundaries, such as Planck-scale black-hole event horizons or cosmological horizons due to the presence of a positive cosmological constant in the universe. Second he discussed CPT violation due to the breaking of Lorentz symmetry, which may characterize certain approaches to quantum gravity. He stressed that although most of the Lorentz-violating cases of CPT breaking are already excluded by experiment, there are some (stringy) models that can evade these constraints.

Trans-Planckian physics was discussed by Ulf Danielsson of Uppsala, who outlined how the cosmic microwave background radiation might probe physics at or near the Planck scale. Danielsson reviewed a potential modulation of the power spectrum of primordial density fluctuations generated through trans-Planckian (maybe stringy) effects during inflation.

Margarida Rebelo of Lisbon discussed CP violation in the leptonic sector at both low and high energies in the framework of the "see-saw" mechanism. She pointed out that leptogenesis is a possible and likely explanation for the observed baryon asymmetry of the universe. It seems to be one of the most promising scenarios, in view of the fact that several other alternative proposals are on the verge of being ruled out. The leptogenesis scenario implies constraints on both light and heavy neutrino masses, which, as she showed, are consistent with the present value obtained from the double beta decay of ^{76}Ge.

Cosmoparticle physics was another major theme of the conference. Maxim Khlopov of Rome and Moscow gave a broad overview of the topic, calling it the "Challenge for the Millennium", and results linking particle-physics experiments with cosmological problems, and vice versa, were among the experimental highlights.

The existence of dark matter in the universe has for many years been an intriguing problem. Rita Bernabei of Rome presented the final results of the DAMA dark-matter experiment, which confirm their first indications for the observation of cold dark matter at a 6σ level. Measurements of the cosmic microwave background by the Wilkinson Microwave Anisotropy Probe (WMAP), which are revealing the proportions of dark matter – and dark energy – in the universe, were presented by Eiichiro Komatsu of Princeton. Neutrino parameters are also deducible from this experiment, as well as from current large-scale galaxy surveys, as Steen Hannestad of Odense described. However, the cosmic microwave background experiments cannot at present differentiate between the different neutrino-mass scenarios.

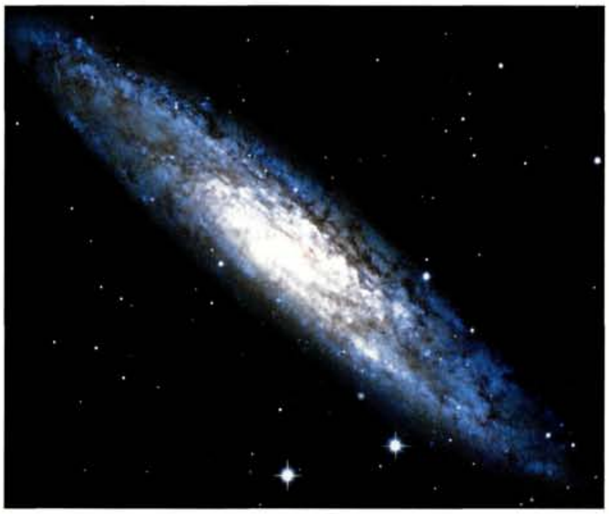
Neutrino highlights

Moving on to ground-based studies of neutrino properties, the Heidelberg–Moscow double beta decay experiment in the Gran Sasso Laboratory has results for the period 1990–2003, which were presented by Hans Volker Klapdor-Kleingrothaus of MPI Heidelberg. With three additional years of data included in this analysis, the evidence for neutrinoless double beta decay has now improved to a 4.2σ level. For 10 years this experiment has been the most sensitive double beta experiment worldwide, and with the statistics now reached, it has essentially already achieved scientifically what was expected from the larger GENIUS project proposed in 1997. The conclusion from this result is that the total lepton number is not conserved (neutrino oscillations reveal only the violation of family lepton number). This has fundamental consequences for the early universe. Furthermore, according to the Schechter–Valle theorem, the existence of neutrinoless double beta decay implies that the neutrino is a Majorana particle. (The announcement of the start of the GENIUS Test Facility in Gran Sasso, in May 2003, was now of most interest in the context of the search for dark matter (see *CERN Courier* July/August 2003 p9). The goal of the GENIUS Test Facility is to confirm the DAMA result by looking for the seasonal modulation signal.)

On the theoretical side Mariana Kirchbach of San Luis Potosi in Mexico stressed the importance of double beta decay for fixing the absolute scale of the neutrino mass spectrum. She showed that in the case of Majorana neutrinos, in single beta decay the mass might lead to unexpected results. In this scenario a sensitive tritium decay experiment should see no mass if the neutrino is a Majorana particle, while the dependence of the neutrinoless double beta decay rate. Ernest Ma of Irvine outlined how a rather precise knowledge of neutrino oscillation parameters, i.e. the correct form of the 3 x 3 neutrino mass matrix, may be obtained from symmetry principles. He showed that the latter predict three nearly degenerate Majorana neutrinos with masses in the 0.2 eV range. This theoretical result is of great interest, in view of the results from double beta decay, WMAP, etc.

Contributions to fundamental physics, obtained using Penning traps, were outlined by one of the pioneers of the field, Ingmar Bergstrom of Stockholm. A Penning trap is a storage device in which frequency measurements can be used to determine the mass of electrons and ions, as well as g-factors of electrons and positrons, with extremely high accuracy. Bergstrom has recently measured, for example, the Q value of the double beta decay of ^{76}Ge with unprecedented precision.

Left to right: conference chairman Hans Volker Klapdor-Kleingrothaus (MPI Heidelberg), Ingmar Bergstrom (Stockholm), scientific conference secretary Irina Krivosheina (NIRFI Nishnij Novgorod and MPI Heidelberg) and Dick Arnowitt (Texas A&M).



High-energy gamma rays may cast light on the origin of cosmic rays. The CANGAROO detector in Australia has observed TeV gamma rays from the spiral galaxy, NGC253. (Courtesy Todd Boroson/NOAO/AURA/NSF.)

Other experimental highlights on neutrinos included the results obtained for solar neutrinos by the Sudbury Neutrino Observatory (SNO). As George Ewan of Kingston, Canada, described, SNO now has strong evidence at a 5.3 σ level, and independently of the details of solar models, that neutrinos change flavour on their way from the Sun to the Earth. These results, together with those of other neutrino experiments, among them the Japanese 250 km long-baseline experiment that was presented by Takashi Kobayashi of KEK, mean that our knowledge of neutrino properties has improved considerably over the past few years. In this context, Oliver Manuel of Missouri gave a highly interesting, non-mainstream view of the structure of the solar core.

Supernova and relic neutrinos were the topic of another session. Irina Vladimirovna Krivosheina of Heidelberg and Nishnij-Novgorod, who was a member of the Baksan group that was one of three groups which observed neutrinos from the supernova SN1987A, gave a retrospective view of this exciting event and some insider details of its discovery. Mark Vagins of Irvine and Shinichiro Ando of Tokyo discussed further the observation of relic and supernova neutrinos, one of the future tasks of the Super-Kamiokande experiment in Japan.

Accelerator approaches

Turning to the physics of nuclei, results on superheavy elements have reached an exciting level. Dieter Ackermann showed that elements 107–112 have been synthesized and unambiguously identified at GSI, Darmstadt. The observation of elements 112, 116 and 118 by the Oganessian group at Dubna was also announced by Vladimir Utyonkov. At the interface between nuclear physics and particle physics, the status of the search for a phase transition between hadronic matter and a quark–gluon plasma at Brookhaven's Relativistic Heavy Ion Collider was outlined by Raimond Snellings of Amsterdam, and compared with measurements at CERN's Super Proton Synchrotron.

Several sessions were devoted to the search for new physics with colliders. The final analyses of the search for Higgs bosons, R-parity violation, leptoquarks and exotic couplings at CERN and Fermilab, presented by Rosy Nikolaidou of CEA Saclay, Silvia Costantini of Rome "La Sapienza", Stefan Soeldner-Rembold of Manchester and others, show no indication of physics beyond the Standard Model. This reinforces the observation that the only new physics to emerge recently is from underground experiments.

Particles from space

Nearly a century after the discovery of cosmic rays, their origins are still unknown. Eckart Lorenz of Munich reviewed the status and perspectives of ground-based gamma-ray astronomy, where new telescopes under construction, such as MAGIC, should lead to a big step in sensitivity. At gamma-ray energies of around 10–30 GeV the universe becomes basically transparent, so gamma-emitting objects as far as red-shifts of more than three should become visible, that is, up to a time where star and galaxy formation has been particularly strong. New projects like MAGIC will allow the gap to be closed between satellite-borne instruments and previous, ground-based telescopes. Exciting results from the CANGAROO ▷

experiment, an array of four imaging Cherenkov telescopes in Australia, were presented by Ken'ichi Tsuchiya of Tokyo. The team has observed TeV gamma rays from SNR SN1006 and from new types of objects, such as gamma rays from a normal spiral galaxy showing starburst activity, NGC253. This is the first detection of gamma rays from an extragalactic object other than active galactic nuclei, and is the largest structure ever detected.

The Auger Observatory is under construction and will look for cosmic rays at the highest energies. It will be the largest cosmic-ray detector ever built, covering 3000 square kilometres in both the southern and northern hemispheres in its final configuration. Johannes Bluemer of Karlsruhe described the present status of the construction at the southern site in Argentina, which began in 1999.

The highest cosmic energies, beyond the Greisen–Kuzmin–Zatsepin limit, find an interesting theoretical explanation in the Z-burst scenario, in which a large fraction of the cosmic rays are decay products of Z-bosons produced in the scattering of ultra-high-energy neutrinos on cosmological relic neutrinos. This was discussed by Daniel Fargion of Rome and Sandor Katz of DESY and Budapest. Interestingly, they find that neutrinos should have a mass in the range of 0.1–1 eV – which is consistent with the result of the HEIDELBERG–MOSCOW experiment – in order to make this explanation work properly.

Hunting for antimatter

The search for antimatter (and dark matter) with the Alpha Mass Spectrometer, which is planned to be installed on the International Space Station in 2005/2006 for a three-year mission, was discussed by Frank Raupach of Aachen. The existence of large domains of antimatter in the universe is still an open question. The observed uniformity of the cosmic microwave background indicates that no voids exist at all between matter and antimatter worlds, hence annihilation processes should be inevitable and the resulting diffuse gamma-ray spectrum might be observable.

Returning to neutrinos, but this time from space, Christian Spiering of Zeuthen gave an overview of results from AMANDA, the neutrino telescope at the South Pole, and Jan-Arys Dzhilkibaev reviewed the status and perspectives of the Baikal Neutrino Project. Finally, Yoshitaka Kuno from Osaka outlined the goals of future neutrino and muon factories. A neutrino factory would have great potential for examining the mass hierarchy of neutrinos, the matter effects, and CP violation in the neutrino sector. A rich physics programme would also be possible with a high-intensity muon beam at a muon factory, ranging from searches for muon processes that violate lepton flavour (such as μ^- to e^- conversion) and the muon electric dipole moment to further precision measurements of the muon magnetic moment (g-2). Lepton flavour violation in the charged sector will be studied also by the muon to electron conversion experiment, MECO, presented by Michael Herbert of Irvine.

In summary, the lively and highly stimulating atmosphere during this Beyond meeting reflected a splendid scientific future for particle physics. The proceedings of Beyond 03 are now available as a book, *Beyond the Desert 2003*, Springer Proceedings in Physics, vol 92.

Hans Volker Klapdor-Kleingrothaus, *MPI Heidelberg.*

AWARDS

UNESCO and AIP honour Schopper

Herwig Schopper has received two prestigious awards for his pivotal role in building up international scientific co-operation. UNESCO awarded him the Albert Einstein Gold Medal at a ceremony in Paris on 15 April, while on 2 May in Denver the AIP (American Institute of Physics) presented him with the Tate Medal for International Leadership in Physics, together with a prize of $10 000.

Now president of the SESAME Council – the International Centre for Synchrotron Light for Experimental Science and Applications in the Middle East (*CERN Courier* November 2002 p6), Schopper was director-general of CERN from 1981 to 1988. He has also been president of the European Physical Society, from 1994 to 1996, and a member of the Scientific Council of the Joint Institute for Nuclear Research, in Dubna, from 1993 to 2002.

At the ceremony in Paris, Koïchiro Matsuura, director-general of UNESCO, acknowledged Schopper's active participation in UNESCO's science programme. Currently president of the Ad hoc Committee of Experts for the International Basic Sciences Programme, Schopper has been a member of the Physics Action Council and also chaired the Scientific Council of UNESCO's Venice office between 1999 and 2002.

Herwig Schopper (right) receives the Albert Einstein Gold Medal, for his work in aiding international scientific co-operation, from Koïchiro Matsuura, director-general of UNESCO.

Berners-Lee wins Millennium Technology Prize

Sir Tim Berners-Lee has been awarded the first Millennium Technology Prize by the Finnish Technology Award Foundation, which recognizes technological innovations of lasting benefit to society. Berners-Lee created the first Web server, browser and editor, the HTML code, the URL address and the HTTP transmission protocol at CERN in 1990.

His invention "perfectly encapsulates the spirit of the prize", according to Pekka Tarjanne, chairman of the award jury and former secretary-general of the International Telecommunication Union. "The Web is encouraging new types of social networks, contributing to transparency and democracy, and is opening up new avenues for information management and business development." Berners-Lee will be presented with the award, which is accompanied by €1 million, by Tarja Halonen, the president of the Republic of Finland, at the Finlandia Hall in Helsinki in June.

Sir Tim Berners-Lee (left) is congratulated by Jukka Valtasaari, Finland's US ambassador.

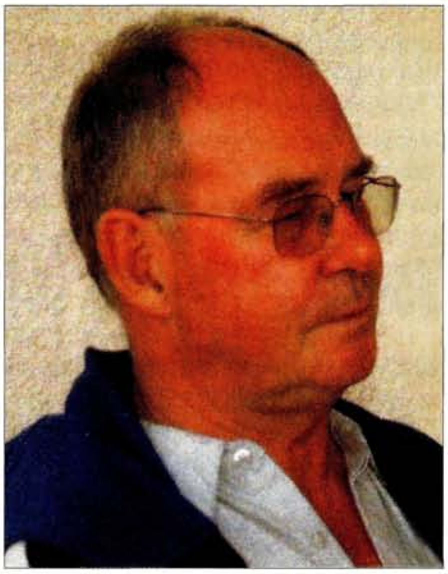
FAREWELLS

David Olive loosens the strings with Swansea...

Swansea University recently marked the official retirement of David Olive, a well known figure in the particle-theory community, with a "Strings, Gauge Fields and Duality" conference on 24–27 March. Olive had a long career at Cambridge University and Imperial College, London, as well as some six years at CERN, before setting up the new particle-theory group at Swansea in 1992, with Ian Halliday (currently chief executive of the UK's Particle Physics and Astronomy Research Council). In 1997 he was awarded the Dirac Medal of the Abdus Salam International Centre for Theoretical Physics, together with Peter Goddard (now director of the IAS Princeton). This honoured Olive's work with Ferdinando Gliozzi and Joel Scherk on the space–time supersymmetry of the spinning string theory, which made possible the idea of superstrings, as well as pioneering insights about magnetic monopoles made in 1977 with Goddard and Jean Nuyts.

Well known physicists from around Europe, the US and the UK came to speak at the conference, which was organized as a workshop on the latest developments in string theory and supersymmetry – both of which involve a number of Olive's pioneering ideas. However, it also featured some retrospective talks on his early work. Several speakers recalled the "golden years" of string theory in the early 1970s in the theory division at CERN, when Daniele Amati collected an active group of researchers including Lars Brink, Olive and many others. For the conference programme and online versions of the talks, see http://pyweb.swan.ac.uk/diofest.

...and Alan Grant takes his leave of CERN



Alan Grant, an archetypal "go-between" in technical design, the construction of apparatus, physics and analysis, retired from CERN at the end of March after 40 years. He came to the laboratory after completing his PhD at Glasgow University, following an invitation from Pierre Lazeyras to join his group on separated particle beams for bubble chambers. By the end of the bubble-chamber era for hadron physics he had designed the optics for most of the separated pion and kaon beams at CERN for BEBC, and at Protvino for MIRABELLE.

With the realization that BEBC was a good instrument for neutrinos, Grant's second trademark came into being: neutrino beams and neutrino physics. He improved the inadequate iron shielding in the West Area Neutrino Facility and developed one of the first hadronic cascade codes for shielding calculations. He was also in charge of the specifications of the External Muon Identifier (EMI) for BEBC and of setting up the EMI team, in fierce competition with the 15 foot bubble chamber at Fermilab.

In the early 1990s Grant joined DELPHI, where he was initially responsible for the development of the graphics software and the muon detection system. For the past decade he has worked on the NOMAD detector searching for neutrino oscillations, which were unfortunately out of reach of the experiment.

VISITS

The CERN delegation, right, meets the JINR directorate and representatives of their labs.

CERN's director-general, Robert Aymar, visited the Joint Institute for Nuclear Research (JINR) in Dubna on 16 April, together with advisors for non-member-state relations, John Ellis and Nicolas Koulberg. The delegation from CERN toured the laboratories, the experimental workshop and the technological sites at JINR, where a number of systems and parts to be used at the Large Hadron Collider are currently being developed.

HONOURS

On 10 April **Philippe Blanchard**, professor in mathematical physics at the University of Bielefeld, received the cross of chevalier of the French "Ordre National du Mérite". Blanchard, who is a former vice-rector of the university, and author of several books on mathematical physics, has interests that include stochastic aspects of quantum theory, percolation theory and self-organized criticality.

The **Institute for High Energy Physics** (IHEP), in Protvino, Russia, has received the diploma and medal of the Fifth International Forum "Advanced Technologies of the XXI Century". The forum was held in Moscow on 19–23 April and the award is "For the development, organization of manufacturing and the promotion of high technologies to internal and external markets."

The institute's achievements in detector and accelerator technologies are one of the factors contributing to the receipt of the award. A long-term collaborator with CERN, IHEP is strongly involved in the production of the equipment for the Large Hadron Collider, as well as for the ATLAS and CMS experiments.

LETTERS

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

Emulsion work in the 1930s

As contributors to the recently published biography of Marietta Blau, we appreciated the review (*CERN Courier* January/February 2004 p56) and the letter from Don Perkins in the same issue (p50).

In reviewing the biography, Cecilia Jarlskog thinks that the authors exaggerated the significance of Blau's work for the later discovery of the pion. We do not feel that there was such exaggeration when discussing the role of Blau's work in the research by Cecil Powell and the Bristol group. It seems relevant to refer to Powell's own remarks in his autobiographical notes: "...I became interested in nuclear physics and I was determined in 1935 to build a Cockroft and Walton generator of 750 kV in order to work in this field...The original intention was to study the scattering of fast neutrons by protons using a Wilson Chamber filled with hydrogen...But about this time, W Heitler, who had been in Bristol for some years, pointed out that Blau and Wambacher had successfully used 'half-tone' photographic emulsions to detect particles in the cosmic radiation and...he thought we might begin by sending similar plates on to a mountain... We were very encouraged by the early results, we found 'stars'...These modest successes encouraged us to consider the possibility of using photographic emulsions in our experiments...." (Powell 1972.)

Powell also reflected on the reasons why they quickly made progress, one of them being that the first emulsions they employed "were among the best of the type we encountered". It is evident that in selecting the emulsions for their first experiments, Powell and colleagues utilized the experience of Blau and Wambacher, who had first used emulsions bathed in solutions of pinacryptol yellow to detect protons, but had then found out that no pretreatment was required with the new half-tone emulsions from Ilford Ltd. From 1936 onward they used these Ilford emulsions in all their experiments, in particular for their exposures on the Hafelekar and the Jungfraujoch. On their request, Ilford prepared emulsions of 70 μm thickness for them, while the normal plates were only 14–20 μm thick (Blau and Wambacher 1937). This was a first co-operation between Ilford and nuclear physicists. It was just this material, half-tone emulsions 70 μm and then 100 μm thick, that was used by Powell and collaborators when they started their experiments in 1939. (Heitler *et al.* 1939, Powell 1940).

The decisive breakthrough for the discovery of the pion, kaon and further particles was of course made possible by the production of the concentrated emulsions after 1946, as pointed out by Perkins in his letter. But in evaluating the earlier steps, Blau's contributions should be seen as very significant, not least her study of range-energy relations, the selection of the most suitable emulsions, and her thorough study of cosmic-ray-induced events. Her identification of proton tracks was most convincingly presented and she reported 60 stars in her first full paper, giving detailed measurements for 31 of them of all particle tracks (Blau and Wambacher 1937).

Further reading

M Blau and H Wambacher 1937 *Sitz. Ber. Akad. Wiss. Wien IIa* **146** 259; 469.
W Heitler *et al.* 1939 *Nature* **144** 283.
C F Powell 1940 *Nature* **145** 155.
C F Powell 1972 "Fragments of autobiography" in E H S Burhop *et al.* "Selected papers of Cecil Frank Powell" p17.

R Rosner and T Schoenfeld, Vienna.

CORRECTION

On p24 of the March issue, the article "German astroparticle physics shows its strength" states that the ANTARES collaboration plans to install six detector strings in the Mediterranean by 2006. The collaboration in fact plans to install 12 strings by 2006.

MEETINGS

The 1st Summer School on QCD Spin Physics is to take place at the Brookhaven National Laboratory on 5–12 June. The school will give a pedagogical introduction to heavy-ion collisions and to the research programme underway at the Relativistic Heavy Ion Collider. It is intended for graduate students and beginning postdoctoral researchers in both theory and experiment. Full and partial scholarships are available. See www.bnl.gov/qcdsp/.

An **International Workshop on Particle Multiplicity in Relativistic Heavy Ion Collisions (Focus on Multiplicity)** will be held in Bari, Italy, on 17–19 June. The workshop is intended to review the available data on particle multiplicity, both in proton- and ion-induced collisions collected at different centre-of-mass energies, and their current theoretical interpretations, including microscopic Monte Carlo modelling. For more information, see www.ba.infn.it/~mplicity.

HiX2004, the Workshop on the Structure of the Nucleon at Large Bjorken-x, will be held on 26–28 July in Luminy, Marseille, France. The aim is to bring theorists and experimentalists together to discuss the latest developments and perspectives in this subject. For more details see www.cpt.univ-mrs.fr/hix2004.

A course, **Introduction to Accelerator Physics**, organized by the CERN Accelerator School and HEPHY, Vienna, will take place on 12–24 September at the Hotel Schloss Weikersdorf, Baden, Austria. The course will focus on the basics of accelerator physics, such as transverse and longitudinal dynamics, beam measurements and an introduction to multiparticle dynamics. For further details, see http://cas.web.cern.ch/cas/Baden/Baden-advert.html.

A Tribute to René Turlay is to take place on 24 September in Paris. Turlay, who died in 2002, discovered CP violation in 1964, together with J Christenson, J Cronin and V Fitch. The day will be mainly devoted to discussions concerning the future of high-energy physics. For more details, see http://events.lal.in2p3.fr/conferences/turlayday.

The 2004 DESY Theory Workshop on Particle Cosmology will be held at DESY on 28 September to 1 October. Topics include dark matter, dark energy, the early universe and high-energy cosmic rays. The deadline for abstracts for contributions is 15 July. See www.desy.de/desy-th/workshop2004.

SPIN2004, the 16th International Spin Physics Symposium, will take place on 10–16 October in Trieste, Italy. It will be organized by the Trieste section of INFN and hosted by the Abdus Salam International Centre for Theoretical Physics in Miramare, Trieste. Topics range from spin and fundamental symmetries to polarized sources, beams, targets and future facilities and experiments. The deadline for abstracts for contributed talks is 30 June; for registration 31 July. For further information, see www.ts.infn.it/events/SPIN2004.

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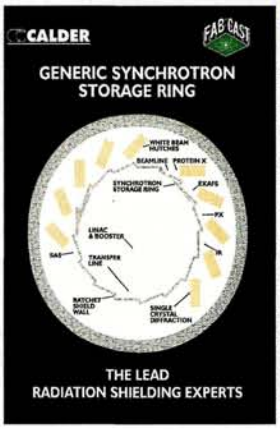

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NEW PRODUCTS

ACT/Technico has announced a new 6U single-slot disk module for CompactPCI-based systems. The CPIStor provides a 32-bit, 33 MHz CompactPCI interface with an on-board ATA controller and is available with 2.5" ATA hard drives up to 80 GB, or CF-II (Compact Flash) drives up to 4 GB each. It is supported using drivers for Linux, VxWorks and Windows. For more details, see www.act-technico.com/CPIStor_96.pdf, call +1 215 957 9102, or e-mail sales@acttechnico.com.

Anest Iwata has introduced a new oil-free scroll vacuum pump, the DVSL-500B, with a high tolerance for water vapour and particles. With a pumping capacity of 520 l/m and base pressure of 10 Pa (0.075 torr), the pump has a patented scroll design that removes all seals, shafts and bearings from the gas path and vacuum. For further information, see www.synergyvacuum.com.

FIZ Karlsruhe, the European partner of the online service STN International, has launched DWPI First ViewSM, a new companion file to the Derwent World Patents Index (DWPI). This allows DWPI users to access previews of the latest published patents documents in advance of their inclusion in the DWPI. For more information, contact +49 7247 808 555, e-mail helpdesk@fiz-karlsruhe.de, or see www.stn-international.de or www.fiz-karlsruhe.de.

IXYS Semiconductors GmbH and **Westcode Semiconductors** have extended their range of isolated base power modules. Thyristor modules are rated for an average current of 500 A and diode modules for 600 A, with four voltage ratings: 1.2, 1.4, 1.6 and 1.8 kV. Westcode Semiconductors has also announced a new high-voltage IGBT gate drive unit. The C0030BG400 is capable of driving devices rated up to 5200 V and 1500 A, at frequencies from DC up to 20 kHz. For further information, call +44 1249 444525, or e-mail WSL.sales@westcode.com.

LEDtronics has introduced the PNL-1145 Series LED Lamps that are high-voltage panel indicator lamps. These energy-efficient, long-lived lamps feature a fixed LED, a removable lens, a threaded metal shaft and can be mounted in panels up to 56 mm thick. They are available in the following DC voltages: 24, 48, 125 and 250 V, and may also be ordered in AC. For further information, contact Jordon Papanier at +1 310 534 1505, e-mail: jpapanier@ledtronics.com, or see the web www.ledtronics.com/pages/News130.htm.

Nanotec Electronic GmbH has announced a new small stepper motor, the ST2018. With a size of 20 mm and a step precision of 1.8°, the motor has a holding torque ranging from 1.5 to 4 Ncm. For further information, call +49 89 900 6860, e-mail sales@nanotec.de, or see the web http://nanotec.de.

OBITUARIES

Rafael Armenteros 1921–2004

Rafael Armenteros passed away on 5 March 2004. With his passing we have lost a great scientist and a friend. As a researcher he had outstanding and, in many respects, rare qualities. He never spoke about the results of his experiments before carefully examining them in the closest detail. He was interested in neither titles nor honours.

Rafael left Spain for France, together with his family, in 1938 when General Franco seized power at the end of the Spanish Civil War. He did not stay long in France, as he was soon to take up his studies in England, where he obtained a physics degree at the University of London. In 1947 he moved to the University of Manchester, where he joined Patrick Blackett's group. The group was well renowned and at that time specialized in the analysis of cosmic-ray-generated particles using cloud chambers. It had just published studies of V-shaped tracks produced in the showers generated by cosmic-ray interactions with matter upstream from the chamber. These so-called Vs corresponded to either a neutral particle decaying into two charged particles or a charged particle giving rise to one neutral and one charged particle.

At the beginning of his career Rafael participated in the construction of a large magnetic cloud chamber, which was installed at the Jungfraujoch Laboratory in Switzerland in 1951. He also studied how to measure the time-of-flight of particles using Geiger–Muller counters. But his main interest was the analysis of cosmic-ray interactions in the data taken by a small cloud chamber installed at the Pic du Midi de Bigorre in southern France. The results of his analysis were remarkable. When examining the Vs in these pictures, which had been interpreted as being left by neutral particle decays, Rafael introduced a kinematic variable (called α) associated with each selected V and then analysed the resulting distribution. He then demonstrated that, in order to explain the shape of the distribution, the Vs had to come from two sources, one corresponding to a decay into $p\pi^-$ of a particle with a mass of 2200 m_e, now known as the Λ^0, and the other corresponding to a decay into $\pi^+\pi^-$ of a particle with a mass of 800 m_e, now known as the K^0. This discovery

marked a turning point in methods of analysis, as the probabilistic approach to hypotheses was novel at that time. It was also an important breakthrough because it highlighted to the rest of the physics community the wealth of possibilities offered by the fledgling discipline of elementary particle physics. It must be pointed out that this was in fact the discovery of the strange quark. Shortly afterwards, through the analysis of charged Vs in the same experiment, he also discovered the particle known as the cascade or Ξ.

Rafael subsequently joined the laboratory of Louis Leprince-Ringuet at Paris's École Polytechnique and continued the investigation of charged Vs with Charles Peyrou, Bernard Gregory, Francis Muller, André Lagarrigue and Leprince-Ringuet. In this research group were three future CERN physicists of high renown (Armenteros, Peyrou and Muller), one future CERN director-general (Gregory), one future chairman of the CERN Scientific Policy Committee (Leprince-Ringuet) and last but not least the principal actor in one of CERN's foremost discoveries, that of neutral currents (Lagarrigue). This group had already brought to light the $\mu^+\nu$ decay mode of the K^+ and the $\pi^+\pi^+\pi^-$ decay mode (the so-called τ-decay) of the K-meson. Rafael then went on to the precision measurement of the K and Λ masses and of the three-body leptonic decay of the K^0.

Rafael later made his way to the Chacaltaya Laboratory in Bolivia, where he organized an experiment to measure the cosmic-ray flux and helped to develop a long-term research programme on that site. From Bolivia, he moved to the Lawrence Berkeley Laboratory where he measured the cross-section of antiprotons. Upon his return to Leprince-Ringuet's laboratory in 1959, he became involved in setting up the first experiments at CERN, in particular Saclay's new 81 cm hydrogen bubble chamber (HBC-81 cm), which was under construction. In 1961 he joined Peyrou's Track Chamber Division as head of the division's physics programme.

Ever a researcher at heart, he organized an experiment using the HBC-81 cm to analyse antiproton annihilations in liquid hydrogen. This proved to be a fruitful venture as it was credited with the discovery of two new resonances, $E/\iota \Leftrightarrow \eta^0(1440)$ and the $C \Leftrightarrow K(1270)$, the precision measurement of the ω^0 width and the first indication of the spin of the $K^*(892)$.

Rafael then embarked upon a systematic search for Y* hyperons with the partial-wave analysis of all two-body channels coupled to the K^-p system, and proceeded to a systematic investigation of mesonic resonances through the analysis of three-body reactions (the K^-p 4.2 GeV/c, π^-p 3.9 GeV/c experiments). It is fair to say that many of the states recorded in the *Particle Data Book* passed through his hands. He determined the mass, width and quantum numbers for many of them, and it is the SU_3 group classification of this collection of objects with their characteristics that demonstrated the validity of the quark model. This is yet another instance where Rafael contributed to an important new advance in particle physics.

After the heyday of the bubble chambers, Rafael continued to follow his inquisitive instincts by joining the ASTERIX experiment, which used rapid detectors to analyse proton–antiproton annihilations in gaseous hydrogen. The antiprotons were produced using the antiproton storage ring, LEAR. ▷

This method gave access to initial states very different from those found in bubble chambers, with annihilation in the P-wave instead of the S-wave. This work was complementary to the liquid-hydrogen experiments and led to confirmation of the spin/parity analyses of the various states produced in annihilations at rest, providing at the same time a better understanding of the annihilation process. This was the last experiment in which Rafael played an active role.

After the death of Franco in 1975, Rafael frequently returned to his native Spain and helped in the development of elementary particle physics there.

In every experiment in which he was involved he was an affable friend, quick to launch into discussion with his collaborators and always keenly interested in physics. He also had a great human touch: quiet, patient, and anxious to understand and attempt to resolve people's problems. Most importantly though, one can say that throughout his life he behaved as a real gentleman – a very rare accomplishment indeed in an environment unusually beset by fierce competition. With the passing away of Rafael Armenteros we have lost a great figure of particle physics and one of CERN's most prolific founding fathers.
Paul Baillon, CERN.

Alexey Tyapkin 1926–2003

Alexey Alexeyevich Tyapkin, a legendary figure of the physics community at the Joint Institute for Nuclear Research (JINR) and an outstanding Russian scientist well known for his pioneering research in high-energy physics, passed away on 10 November 2003. His bright ideas, original theoretical developments and experimental results, along with his extreme dedication to science and his independent and earnest character, raised the level of what a physicist can mean and do for society.

He began his scientific career at the Kurchatov Institute of Atomic Energy after graduating from the Moscow Physics Engineering Institute. Tyapkin came to JINR Dubna in 1953, where he developed several original methods for experiments and used them at the first high-energy proton accelerator in Russia. In 1955, independently of the Italian physicist Marcello Conversi, he proposed and applied a new method for a controlled pulsed high-voltage supply for Geiger counters. His Geiger hodoscopes were used in several sophisticated experiments. Later the method of the controlled pulsed high-voltage supply became the basis of a new type of detector – the spark chamber. Tyapkin was one of the pioneers who studied the properties of spark chambers and was ahead of many other researchers in the world. A 5 m long magnetic spectrometer with spark chambers was constructed under his leadership and used at the 70 GeV accelerator in Protvino in a CERN–JINR–USSR experiment that discovered radially excited states of the pion and confirmed other known resonances.

Tyapkin was able to develop important ideas in independent scientific directions during several decades. In 1953 he proved theoretically that strong particle focusing could be obtained in a sign-variable magnetic system. The Physics Institute of the Russian Academy of Sciences implemented his idea in the design and construction of an electron prototype of the ring cyclotron. In 1975 he proposed the possibility of charmed supernuclei production, and in 1976 put forward an original idea to develop the model of Sakata baryons. Later, in 1993, he proposed the existence of sub-threshold Cherenkov radiation and carried out related measurements at CERN.

Tyapkin had a wide range of scientific interests, which impressed his colleagues and students. He was a professor at Moscow State University (MSU) and lectured to students there for 43 years; for the last 15 years he headed the Particle Physics Department of the MSU Physics Faculty. In 1988 he also became a member of the editorial board of the journal *Foundations of Physics Letters*.

Tyapkin was not only an outstanding scientist but also a bright, extraordinary personality. He was a skillful sportsman throughout his life, and was particularly fond of water skiing. He had a masters degree in this field and contributed much to the foundation and development of the sport in Dubna, which later became internationally renowned for producing champions. Everyone who was lucky enough to have collaborated with Alexey Tyapkin, or to have simply communicated with him, will remember a pioneer of high-energy physics, a bright personality, and a generous and friendly man.

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: mono $74/€68/£47, single colour $76/€71/£49, full colour $80/€74/£51. Please contact us for more information about publication dates and deadlines.

PHYSICIST/DEVELOPER

Brookhaven National Laboratory's Physics Department seeks a SR. APPLICATIONS ENGINEER (I-8) for a term appointment. Requirements include a Ph.D. in high energy or nuclear physics and a strong background in computing. Three years of related experience and expertise in C++ is required; familiarity with grid computing, web services, python, java, and mass storage systems desirable. Database experience is strongly preferred, experience in the collaborative development of core offline software in large experiments is desirable. Will participate in the development of the core offline software of the ATLAS experiment at the LHC, with a particular focus on the data storage, data management and database challenges presented by the petabyte-scale data volumes of ATLAS. The Physics Applications Software Group responsible for the development of the physics data management system and the distributed data analysis system of ATLAS.This position will be based at Brookhaven or CERN, depending on preference and responsibilities.

Brookhaven offers a stimulating work environment and a comprehensive benefits package. For consideration, please forward your resume, responding to Position #NS3177, to: Nancy L. Sobrito, Brookhaven National Laboratory, P.O. Box 5000, Bldg. 185-HR, Upton, NY 11973. BNL is an equal opportunity employer committed to workforce diversity.

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L I P

Applications are invited for a post-doctoral position at LIP-Lisbon (www.lip.pt).

Applications are invited for a post-doctoral position at LIP-Lisbon (www.lip.pt). The position is funded by the European Research Training Network 'Physics Reconstruction and Selection at the Large Hadron Collider' (http://cern.ch/sphicas/PRSATLHC/). The main purpose of the proposed network is to study, design and implement the physics event selection of the CMS experiment in the LHC environment.

The position will be given for 2 years with a highly competitive salary determined according to qualification. Qualifications required include a PhD or equivalent in High Energy Physics, and a clear demonstration of the ability to carry out a research program. Knowledge of modern programming techniques, Object-Oriented software and C++ will be an asset.

Applicants must satisfy the EU RTN eligibility criteria **(http://www.cordis.lu/improving/networks/faq.htm#q5).** The position will remain open until suitable candidates are found.

Applications, including CV and reference letters, should be sent to:
Laboratory for Instrumentation and Experimental Particle Physics
Research Training Network-PRSATLHC
Av.Elias Garcia, nº 14 –1º , 1000-149 LISBON, PORTUGAL
e-mail: joao.varela@cern.ch

The University of Sheffield

Department of Physics & Astronomy

Postdoctoral Physicist in Particle Physics

£18 - £28K pa

The appointee will develop energy flow reconstruction software for the ATLAS experiment at the CERN Large Hadron Collider (LHC) in Geneva. They will have extensive experience of Object Oriented programming techniques. The post holder should be self-motivated and possess a PhD or equivalent in particle physics or a related discipline, preferably with a strong computing element. Excellent problem solving and communication skills are also required. The post will involve regular travel to Geneva to present the results of work and is available from 1 July 2004 for up to 3 years.

Closing Date: 14 June 2004 Ref. R3313

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POSTDOCTORAL ASSOCIATE

LABORATORY FOR NUCLEAR SCIENCE

The Laboratory for Nuclear Science at MIT has immediate openings for postdoctoral research associates within the Hadronic Physics Group. The group is seeking research associates to join the experimental programs currently underway at the MIT-Bates Linear Accelerator Laboratory, the Thomas Jefferson National Accelerator Facility (JLab), and at the MAMI facility in Mainz.

The BLAST experiment at the MIT-Bates Laboratory utilizes a polarized electron beam, polarized gas targets of ^1H, ^2H, and ^3He, and a large acceptance general purpose detector to study the spin dependent electro-magnetic interaction. This experiment will provide precise, systematic measurements of the nucleon form factors as well as study the structure of few-nucleon systems. The experiment has begun collecting data and we are looking for someone to take a leading role in the ongoing analysis. Bates is located approximately 20 miles north of MIT.

The experiments at JLab in Newport News, Virginia and at MAMI in Mainz, Germany are complementary precision measurements of parity violating asymmetry in electron – proton elastic scattering. These measurements will determine the contribution due to strange quarks in the proton form factor and permit a measurement of the weak form factors G^s_E and G^s_M. A new experiment, QWEAK, is being designed to measure the weak charge of the proton $Q^p_w = 1 - 4\sin^2 \Theta_W$ at low Q^2 for comparison with the theoretical Q^2 evolution of the weak mixing angle $\sin^2 \Theta_W$. A successful candidate could be based either at JLab or Mainz.

Applicants should have a Ph.D. in experimental nuclear or particle physics. Interested candidates should provide a curriculum vita, publication list, and arrange for three letters of reference to be sent to: **Prof. R.P. Redwine, 4-110, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139-4307.**

MIT is an Affirmative Action/Equal Opportunity Employer. Qualified women and minority candidates are especially encouraged to apply.

Massachusetts Institute of Technology

web.mit.edu/hr

SCIENTIFIC STAFF POSITION

The Physics Department of Brookhaven National Laboratory (BNL) presently has an excellent opportunity available for a Scientist.

This position, under the direction of H. Gordon, requires a PhD., demonstrated leadership and innovation in collider physics analysis, at least 3 years experince beyond Ph.D. (more senior candidates will be considered), and knowledge of experimental high-energy physics. Experience with hadron collider analysis is preferred. The research will focus on the software development leading toward physics analysis of the ATLAS expeiment. BNL has a leading role in ATLAS liquid argon calorimetry, the muon spectrometer, software and is the location of the U.S. Tier 1 computing facility. Will work with staff to develop the capability for physics analysis.

Interested candidates should submit a cover letter indicating research interests, a curriculum vitae and arrange to have three letters of recommendation sent to Dr. Howard Gordon,, Physics Department, Building 510A, Brookhaven National Laboratory, Upton, NY 11973-5000. BNL is an equal opportunity employer committed to workforce diversity.

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The University of Sheffield

Department of Physics & Astronomy

Chair in Experimental Particle Physics

Salary: By agreement

As an established experimental particle physicist of recognised international reputation the post-holder will be responsible for leading the existing Sheffield ATLAS group, building on our involvement in SCT and Inner Detector commissioning to take a prominent role in the exploitation of physics data. The post forms part of an ongoing initiative by the University to form a vigorous centre of excellence crossing Particle Physics and Particle Astrophysics. This has already led to the establishment of a new cross-discipline theory group (Prof. L. Roszkowski) and the rapid expansion of the neutralino Dark Matter group (Prof. N. Spooner). Benefiting from this environment the post-holder will be encouraged to build and lead new academic strength in particle physics, work for positions of national and international leadership within ATLAS and develop new technologies compatible with the team's priorities including under-pinning plans for the long-term future of the LHC programme.
Informal enquiries are welcome and should be directed to Prof. Neil Spooner (n.spooner@sheffield.ac.uk), tel +44 (0) 114 222 4422.

Closing Date: 1 July 2004 Ref. R3310

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University of Heidelberg

The **Faculty of Physics and Astronomy of the Ruprecht-Karls-University** in Heidelberg invites applications for an

Associate Professor of Computer Science/Computer Engineering

The position is associated to the chair of computer science/computer engineering at the Kirchhoff-Institut for Physics (www.ti.uni-hd.de).

Possible research activities include parallel and distributed computer architectures and applications in natural science, in particular within the framework of existing interdisciplinary research in the physics field. We are seeking a person with proven, excellent qualification in computer science/computer engineering. For details please contact Prof. V. Lindenstruth (ti@kip.uni-heidelberg.de). The Kirchhoff-Institut for Physics offers a modern laboratory infrastructure, in particular including a very well equipped ASIC laboratory. Candidates should be prepared to participate actively in the teaching of computer science at all levels. The faculty explicitly encourages young scientists to apply.

The Federal State of Baden-Württemberg intends to transpose the Federal Professorial Remuneration Reform Law into state law on 1st January 2005. For an appointment from that date, the new W remuneration arrangements are hence expected to apply.

This is essentially a permanent position. The first contract will be based on regulation § 67 Abs. 1 UG and will be temporary. Exceptions to the temporal initial contract can be made under special circumstances and especially for applicants from outside Germany or outside academia if she/he would not consider the position otherwise. Should the position be made permanent after the initial period then this will not require a new application process.

The University of Heidelberg especially encourages women to apply for this position. Given equal qualification handicapped applicants are preferred.

Letters of application including a curriculum vitae, a list of publications and an outline of past and planned research should be sent in paper and electronic form to the **Dean of the Faculty of Physics and Astronomy of the University Heidelberg, Albert-Ueberle-Str. 11, D-69120 Heidelberg, Germany.**

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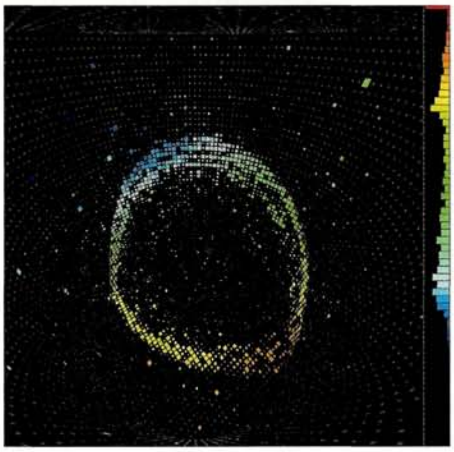
BOOKSHELF

Neutrino Physics by Kai Zuber, Institute of Physics. Hardback ISBN 0750307501, £80.00 ($125.00).

This excellent introduction to neutrino physics describes, in 14 chapters and more than 400 pages, the past, present and future experiments and essential developments in one of the most exciting fields of fundamental physics today. Ranging from "Important historical experiments" to "Neutrinos in cosmology", it is perfect that this comprehensive overview on neutrino physics was published shortly after the Nobel Prize for Physics was awarded to two neutrino physicists, Raymond Davis and Masatoshi Koshiba, for their pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos.



The signature of an atmospheric muon–neutrino captured in the Super-Kamiokande detector. (Courtesy Tomasz Barszczak.)

Neutrinos – first postulated in the 1930s and detected in 1956 by Clyde Cowan and Fred Reines – are one of the most fundamental particles in the universe, but they are also one of the least understood. The author, Kai Zuber from Oxford University, begins with some personally selected historical milestones and theoretical background. He then proceeds to give the fundamental properties of the neutrino, address the questions of neutrino mass, and looks at the place of the neutrino within and beyond the Standard Model. Zuber continues with a discussion of the role of neutrinos in modern astroparticle physics and ends with neutrinos in cosmology and the problem of dark matter, thus covering the full range of neutrino physics. It is remarkable that Zuber describes, over many chapters, not only neutrino experiments, detectors and spectrometers in operation, but also those that are at present under construction or planned, such as the KATRIN experiment and the neutrino factory.

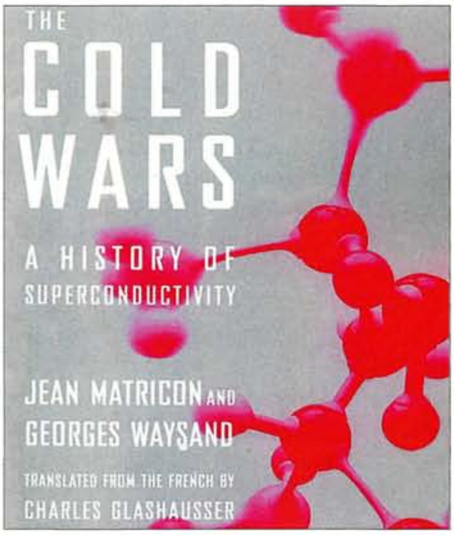
The book ends with a summary and personal outlook, a comprehensive list of references and a detailed index. All of this helps the reader to enjoy a fascinatingly written overview of this exciting field of physics, where "you always have to expect the unexpected". The only weak point is that some of the figures are of poor quality, making it difficult to see what is shown.

Neutrino Physics is a textbook at a level that is suitable for graduate students in physics and astrophysics. It can be highly recommended to anyone interested in this field, and to any advanced student who wants to learn more about this research topic and who needs to understand neutrino physics.
Klaus Blaum, CERN.

The Cold Wars – A History of Superconductivity by Jean Matricon and Georges Waysand, Rutgers University Press. Hardback ISBN 0813532949, $65; paperback ISBN 0813532957, $26.

After carefully investigating the behaviour of matter under new conditions, physicists then try to explain what they find. So it happened with cryogenics. It is much easier to light fires than to invent refrigerators, so the physics of high temperatures was initially much more familiar. However, the laws governing the behaviour of hot gases when extrapolated backwards suggested that something strange should happen if matter could be cooled to −273 °C, "absolute zero" on the new Kelvin temperature scale. Fourteen billion years after the Big Bang, the natural universe is screened from absolute zero by the all-permeating cosmic background radiation at 2.7 K, the faint echo of the Big Bang, and only recently have laboratory experiments descended the last few rungs of the temperature ladder. But such a natural barrier was long unsuspected, and in the second half of the 19th century one gas after another was liquefied triumphantly in the quest to approach absolute zero. However, helium remained stubbornly gaseous until Kamerlingh Onnes established a purpose-built laboratory in Leiden.

After setting this scene, *The Cold Wars* (what "wars"?) charts the progress of cryogenic physics after the liquefaction of helium at 4.2 K in 1908 opened up a new frontier. Painstakingly probing the behaviour of materi-



als at these temperatures, Onnes discovered the phenomenon of superconductivity – the virtual disappearance of electrical resistance. The origins of this phenomenon, and its interplay with magnetic fields, long remained a mystery. Meanwhile, physicists noticed that liquid helium itself behaved bizarrely below about 2.2 K – becoming a superfluid with almost no viscosity. With the emergence of quantum ideas in the 1920s, attention focused on the possible link between superfluidity and Bose–Einstein condensation – when particles sink into the lowest possible quantum energy state, creating new types of matter. Thirty years later, John Bardeen, Leon Cooper and Robert Schrieffer suggested that pairs of electrons could account for the mystery of superconductivity.

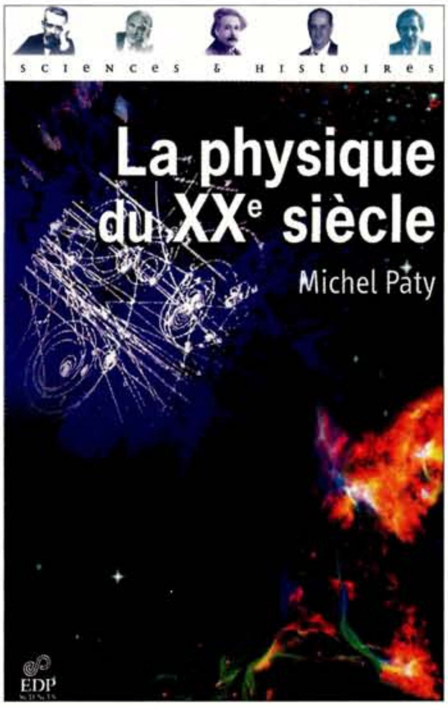
The Cold Wars enthusiastically traces the history of cryogenic physics and superconductivity, with its triumphs and disappointments, and is a good introduction to an intriguing subject. However, it does not venture into the elegant modern quantum theory of phase transitions, which satisfyingly relates to a wider range of phenomena. Superfluid helium is still some way from absolute zero, and only in the past decade have physicists been able to achieve total Bose–Einstein condensation and demonstrate what happens when all particles accumulate into a single energy state, but this too is beyond a strictly superconducting horizon.

A major area for applications of superconductivity is in the powerful magnets that guide charged-particle beams in modern accelerators, but the book only covers ▷

this in passing and does not mention the world's largest superconducting project – the 27 km LHC ring using superfluid helium that is now being constructed at CERN. (The only reference to particle-physics developments is an achievement of high magnetic fields at Fermilab "in 1963" – which was before plans for that US laboratory had even been drawn up.)

The Cold Wars is the English translation, with French government support, of *La guerre du froid* (Editions Seuil). The book concludes with the emergence of the new cuprate "high-temperature" superconductors. The search for superconductivity at still higher temperatures and the explanation of how this happens remains a glamorous research focus, and a final chapter updates these developments beyond what could have been described in the original 1994 edition.

Gordon Fraser, Divonne-les-Bains.



La physique du XXe siècle by Michel Paty, EDP Sciences, Collection Sciences et histoires. Paperback ISBN 286883518X, €34.

The title Michel Paty has chosen for his book, *La physique du XXe siècle* (Physics of the 20th century), is an ambitious one. Summarizing the main advances in physics over the past 100 years in 276 pages, as well as demonstrating their impact on other fields of science, seems like an impossible task. Indeed, the author himself, a physicist and science historian, questions whether it is possible to single out the 20th century's most important and most characteristic developments in science in general and physics in particular. He takes up the challenge all the same, painting a general panorama of physics in the 20th century.

He begins by reviewing the main concepts of physics, describing the historical background to them, and the men and women associated with them. These include relativity, quantum physics, atoms and states of matter, the nucleus, elementary particles, fundamental fields, dynamic systems and phase transitions. He then turns to fields closely related to physics, namely geophysics, astrophysics, cosmology and, more generally, the search for the origins of the universe. At the end, he examines the subject of physics and the associated methods, and comes back to the emergence of Big Science in the 20th century. Finally, in his conclusion, he describes the lessons to be learnt from the past and looks to the future with confidence.

For the student or curious novice, Paty's book can quickly become a reference manual, whose use will vary according to individual requirements. It provides the reader with a general introduction to the main fields of physics research and helps him or her along with historical references. The photographs (essentially portraits), boxes, diagrams and tables, which are simple and well chosen, offer an alternative means of getting to grips with the subject. Finally, a detailed bibliography invites the reader to further exploration. Paty has thus essentially met the challenge he set himself, as his book opens up the door to those who wish to enter the universe of physics.

Sophie Della Mussia, CERN.

Books received

Gauge Theories in Particle Physics, Volume 2 by Ian Aitchison and Anthony Hey, Institute of Physics Publishing. Paperback ISBN 0750309504, £29.99 ($45).

Subtitled "QCD and the Electroweak Theory", this is the second volume of the third edition of a highly successful textbook, which has now been substantially enlarged and updated. It builds on the foundations laid in volume 1, which led up to quantum electrodynamics, and deals with the other two gauge theories of the Standard Model: quantum chromodynamics (QCD) and electroweak theory. It includes new chapters on QCD, as well as extensions to the discussion of weak interaction phenomenology.

Symmetry and Modern Physics: Yang Retirement Symposium by A Goldhaber *et al.* (eds), World Scientific. Hardback ISBN 9812385037, £43 ($58); paperback ISBN 981238530, £25 ($34).

In 1999 a symposium was held at the State University of New York at Stony Brook to mark the retirement of C N Yang as Einstein Professor and director of the Institute for Theoretical Physics, and to celebrate his many achievements. This book contains a selection of the papers presented at the symposium, including contributions from such luminaries as Freeman Dyson, Martinus Veltman, Gerard 't Hooft and Maurice Goldhaber.

High Magnetic Fields: Science and Technology, Volumes 1 and 2 by Fritz Herlach and Noboru Miura (eds), World Scientific. Hardback ISBN 9810249640 (vol 1) and 9810249659 (vol 2), £41 ($55) each.

These are the first two volumes of a three-volume set intended to provide a comprehensive review of experiments in very strong magnetic fields, which can be generated only with special magnets. Volume 1 is devoted to magnet technology and experimental techniques, while volumes 2 and 3 contain reviews of the different areas of research where strong magnetic fields are an essential tool. Volume 3 is scheduled to appear in autumn 2004.

Renormalization Methods: A Guide For Beginners by W D McComb, Oxford University Press. Hardback ISBN 0198506945, £39.95 ($74.50).

Occupying a gap between standard undergraduate and more advanced texts on quantum field theory, this book covers a range of renormalization methods, including mean-field theories and high-temperature and low-density expansions. It proceeds by easy steps to the epsilon expansion, ending up with the first-order corrections to critical exponents beyond mean-field theory. Macroscopic systems are also included, with particular emphasis on fluid turbulence. Requiring only the basic physics and mathematics known to most scientists and engineers, the material should be accessible to readers other than theoretical physicists.

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More than just a conference

The European Particle Accelerator Conference, EPAC, has developed a distinctive role on the world stage, explains **Christine Petit-Jean-Genaz**, the EPAC conferences coordinator.

When CERN's Kurt Hübner and Günther Plass travelled to Rome in 1986 to join Sergio Tazzari of the Frascati Laboratory in search of a venue for the first European Particle Accelerator Conference, they set in motion the machinery that was to give the European accelerator community its own conference, 20 years after the birth of the American Particle Accelerator Conference, PAC. Two decades later, with science funding tight and justifiably under close scrutiny, it is interesting to assess the value, and also the spin-off, of this event.

In July EPAC'04 will welcome around 800 delegates from more than 30 countries to the ninth conference in the series. Sixty-five oral presentations are scheduled and more than 1000 posters will be displayed during the lively sessions. Two European accelerator prizes, first introduced in 1994, will also be awarded, one for a recent significant, original contribution to the accelerator field from a scientist in the early part of his or her career, and one for outstanding achievement in the accelerator field. This will precede a regular conference highlight, the "entertainment" session, with a talk on cosmic accelerators. The industrial exhibition and its associated session on technology transfer and industrial contacts completes the picture, demonstrating the vital communication between scientists and representatives of industry. This is a very different conference from the first one in 1988.

EPAC'88, held at the Hotel Parco dei Principi in Rome, was a victim of its own success. When the estimated 400 delegates expanded to 700 there was "controlled chaos" as closed-circuit TV had to relay the oral presentations, authors shared poster boards, a lack of air-conditioning caused delegates to flee the industrial exhibition and a lack of space meant the plenary sessions were relocated to the Aula Magna of the "La Sapienza" University of Rome. Alas, it was too late to relocate the conference dinner. Those who recall the fountains dancing in time to the strains of a string quartet in the gardens of the Villa Tuscolana will also remember the mouth-watering buffet,

which was woefully insufficient and had vanished before the guests finished arriving.

However, the learning process had begun, and the venue for EPAC'90 was a purpose-built conference centre in Nice. Only one detail escaped the vigilant local organizing committee: the unique banquet venue able to cater for 800 people was outdoors, on a beautiful, unsheltered, Mediterranean beach. A week of perfect weather was marred only by the cloud that burst that particular evening. Who recalls the drenched delegates arriving following a 200 metre sprint in a tropical downpour?

During this period, Maurice Jacob, chairman of the European Physical Society (EPS), convinced EPAC's organizers to form an EPS Interdivisional Group on Accelerators (IGA), and the successive EPS–IGA elected boards have since formed the EPAC organizing committees. A biennial, one-third turnover of the 18 members ensures continuity, while encouraging new members to introduce new ideas. To promote communication between the regional conferences, the organizing committees welcome representatives of US and Asian PACs, and the chairmen meet informally each year. The EPS–IGA has undertaken a number of initiatives such as the Student Grant Programme which, with the sponsorship of European laboratories and industry, enables young scientists to attend EPAC; around 60 will attend EPAC'04 under this scheme.

Continuity, coordination and communication characterize EPAC organization. Participation has increased steadily, with almost half the participants coming from non-European countries. Improved management techniques have streamlined the workload and contained registration fees. This was also a result of publishing the proceedings in CD-ROM and Web format, rather than expensive paper-hungry hard-copy volumes.

An unexpected spin-off of regional collaboration has been the creation of the Joint Accelerator Conferences Website (JACoW). The suggestion by Ilan Ben-Zvi of the Brookhaven National Laboratory in the mid-1990s to create a website for the publication of regional accelerator conference proceedings has developed into a flourishing international collaboration. It now extends to a whole range of conference series on accelerators – CYCLOTRONS, DIPAC, ICALEPCS, LINAC and RUPAC. The editors of all eight series, led by CERN's John Poole, get hands-on experience in electronic publication techniques during each PAC and EPAC. Furthermore, the yearly team meetings have led to the development of a Scientific Programme Management System. This is an Oracle-based application capable of handling conference contributions from abstract submission through to proceedings production. Twenty-three sets have been published since 1996, including scanned PAC proceedings dating back to 1967. The EPAC and LINAC series plan to follow suit and scan their pre-electronic era proceedings too.

EPAC has evolved into an established, respected forum for the state of the art in accelerator technology. Delegates meet at unique venues, where the varied cultural heritage constitutes real added value. Strengthened ties with other regional and specialized conferences have enhanced international collaboration in the accelerator field, to the undoubted benefit of the community worldwide.

- EPAC'04 will take place on 5–9 July in Lucerne, Switzerland, see www.epac04.ch. For more about JACoW, see www.jacow.org.

Christine Petit-Jean-Genaz, CERN.

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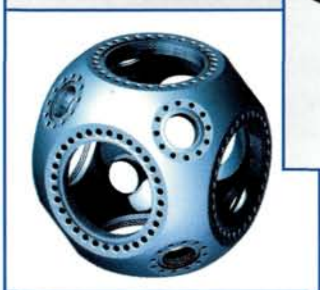

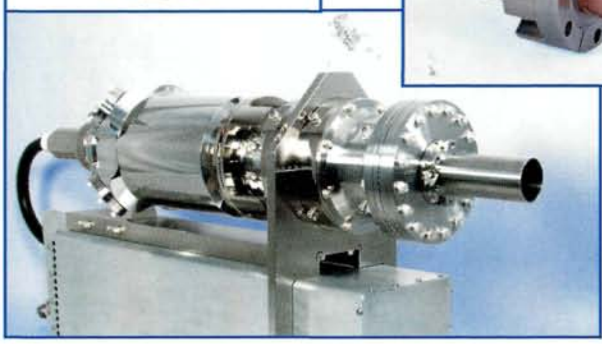

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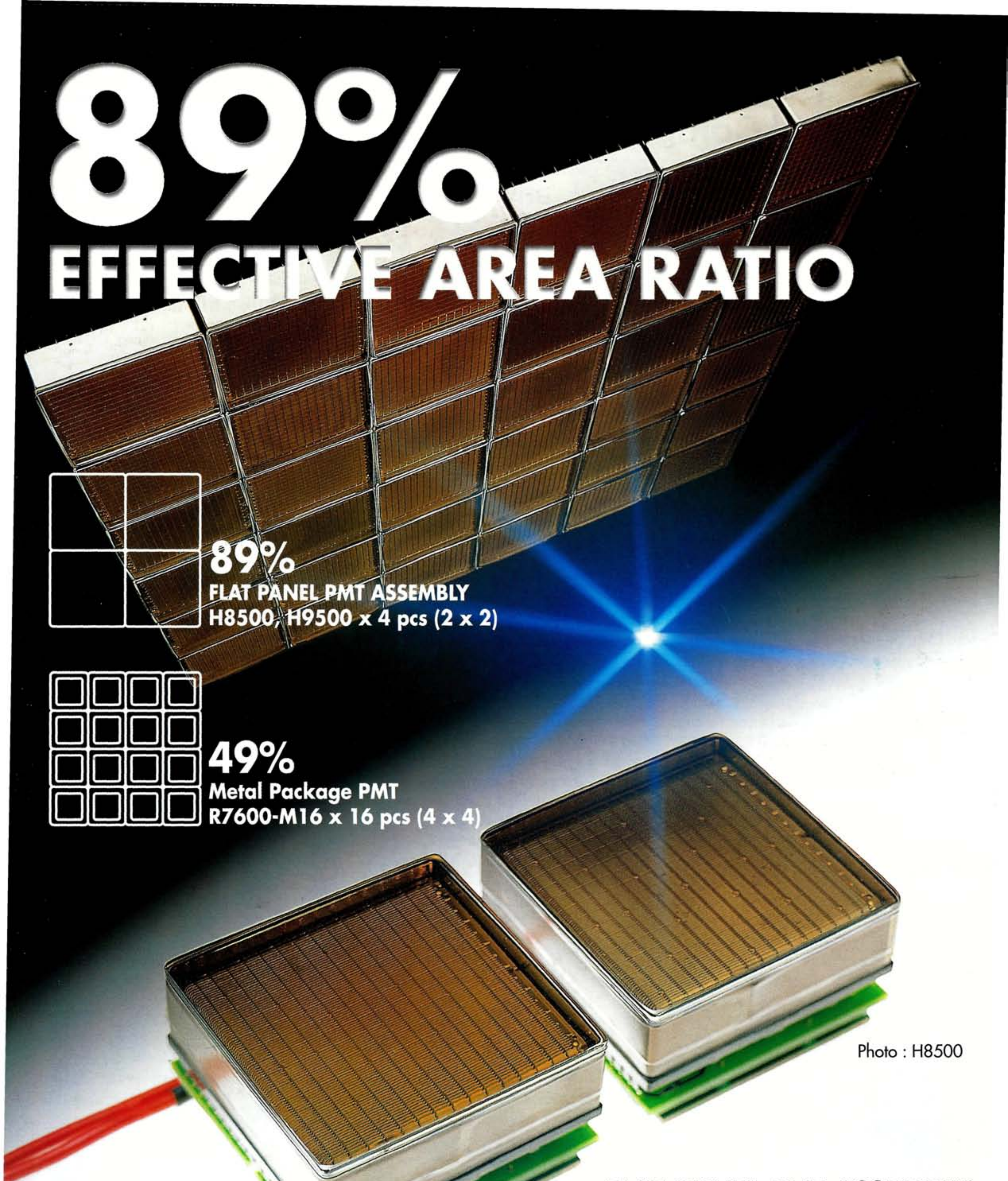

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