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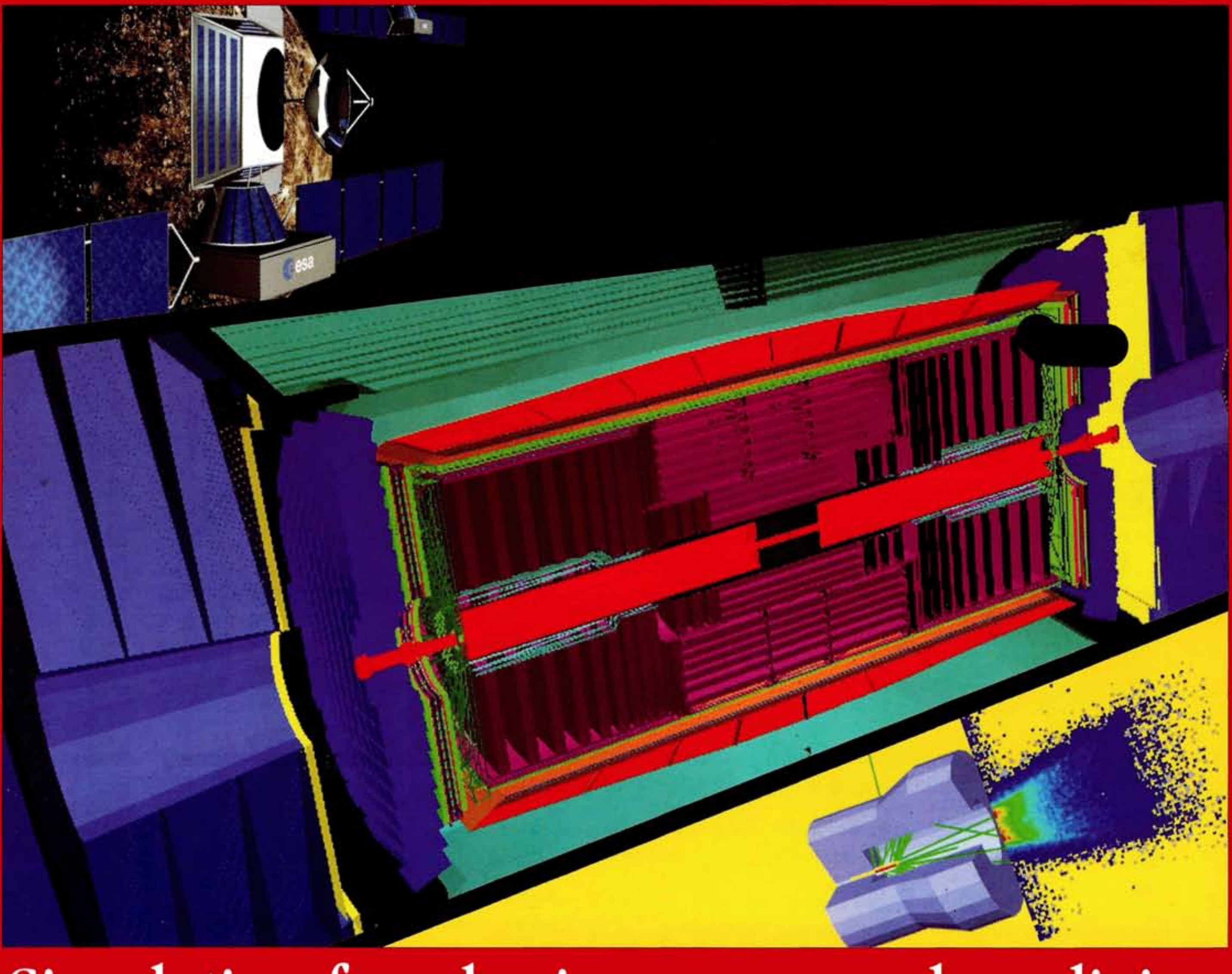

Simulation for physics, space and medicine

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TESLA
Electropolishing steers superconducting cavity to new record p10

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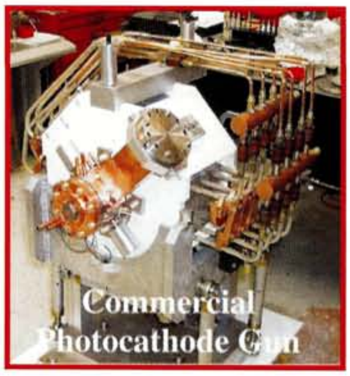
Cover: The Geant4 simulation package serves space, physics and medicine. The top image shows the BepiColombo spacecraft, to be launched in 2009 for exploration of Mercury (Photo ESA). The central image shows the geometry of the CMS detector in preparation for CERN's Large Hadron Collider. The bottom image is a cancer treatment brachytherapy applicator together with the dose distribution in human tissue (p33).


LEAF Beamline
at BNL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NEUTRINOS

Direct evidence seen for oscillations

Inside the Sudbury Neutrino Observatory. (Lawrence Berkeley National Laboratory.)

The Sun shines, just as described by our best theories of its thermonuclear furnace. Neutrinos oscillate - at least, electron-neutrinos change into another type. These are the main conclusions of the neutral-current (NC) results from the Sudbury Neutrino Observatory (SNO) in the Creighton Mine, Ontario, Canada.

In 1985, Herb Chen from the University of California, Irvine, first pointed out that heavy water offered a direct approach to solving the "solar neutrino problem" - the deficiency between the number of solar neutrinos detected on Earth and the flux predicted by the standard solar models. The discrepancy raised the possibility that the electron-neutrinos emitted by the Sun changed to another type (muon or tau) somewhere between emission and detection. Chen realized that an experiment was needed to detect all neutrino types equally, and that the way to do this was through NC interactions between neutrinos and nuclei. (Elastic scattering, or ES, between neutrinos and electrons is possible but more complicated because there are contributions from both NC and charged-current, or CC, reactions for electron-neutrinos, but not for the other species.) He proposed that heavy water would be the ideal detection medium. The NC reaction, due to all neutrinos, simply splits the deuterium nucleus into a proton and a neutron, while a CC reaction, due only to electron-neutrinos, changes the neutron into a proton accompanied by an electron. In both cases, the heavy water acts as both target and detector. The neutrons released in the NC reaction can be detected through the 6.25 MeV gamma ray released when they are captured by deuterium. The gamma rays and the electrons produced in the CC reaction are observed through the Cerenkov radiation they create in the water.

Chen's proposal led directly to the construction of the SNO (*CERN Courier* December 2001 p24), based on 1000 tonnes of heavy water, although sadly Chen himself did not live to see the detector he had envisioned. Last year the SNO collaboration published the first results from the CC and ES reactions (*CERN Courier* September 2001 p5). When combined with data from other detectors, these results provided strong evidence that neutrinos change type, or oscillate. Chen's dream has now been realized, and the first results from the NC interactions of solar neutrinos in heavy water have been announced. SNO has unambiguous evidence for neutrino oscillation in data from a single detector.

To detect the NC reactions, the SNO team looks for the Cerenkov light from the gamma rays from neutron capture. There are many background signals, in particular from daughter products of the natural uranium and thorium decay chains, which produce free neutrons through photodisintegration of deuterium. As Chen realized, the very nucleus that makes the detector effective is also the cause of its biggest background problem. The vessel containing the heavy water is therefore surrounded by 7000 tonnes of light water, to absorb gamma rays and neutrons from radioactivity in the surrounding rock. In addition, the SNO collaboration has developed a water purification system that reduces concentrations of elements from the uranium and thorium decay chains to a million times lower than those in natural water, which means impurity levels less than 10^{-14} g/g for the heavy water and less than 10^{-13} g/g for the light water.

So far the team has applied detailed analysis to data taken between November 1999 and May 2001. They use NC reactions to measure the total flux of solar boron-8 neutrinos (to which SNO is sensitive), which they find to be 5.09 + 0.44 - 0.43 (statistical) + 0.46 - 0.43 (systematic) × $10^6\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. This is completely consistent with standard solar models - there are no missing solar neutrinos. The measurements for the CC and ES reactions, in contrast, lead to the fluxes of electron-neutrinos and neutrinos of other types from the boron-8 decays in the Sun. The electron-neutrino component of the flux is found to be 1.76 + 0.05 - 0.05 + 0.09 - 0.09 × $10^6\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, while the non-electron-neutrino component is about twice as large, at 3.41 + 0.45 - 0.45 + 0.48 - 0.45 × $10^6\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, or 5.3 standard deviations above zero. This is compelling evidence that about two-thirds of the electron-neutrinos from the Sun do indeed change to another type or "flavour" before they are detected.

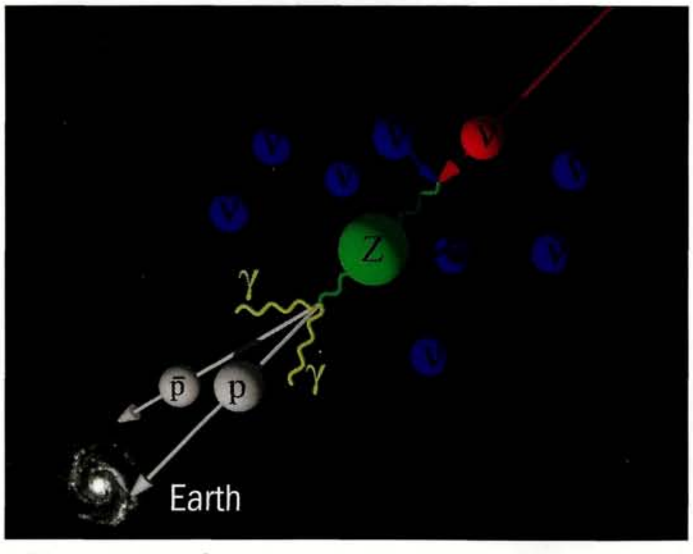
The challenge now is to discover more about the precise mechanism that mixes the different neutrino flavours and makes them oscillate from one type to another. SNO has already begun this further exploration through a first measurement of day and night energy spectra for solar neutrinos. Travel through the Earth might alter the spectrum according to certain theories of neutrino mixing, through enhancement by matter. The SNO finds a night-day asymmetry for electron-neutrinos of 7.0% ± 4.9% + 1.3% - 1.2%. A global fit to these SNO data and those from other experiments, in terms of oscillations between two flavours, limits possible theories by strongly favouring a solution with large mixing angles. The "missing" solar neutrinos may no longer be missing, but they are providing a means to learn more about the particles themselves.

Reference

Q R Ahmad *et al.* nucl-ex/0204008 and nucl-ex/0204009 at http://www.arxiv.org/.

NEUTRINOS

Cosmic-ray particles could give information about neutrino mass



A Z-burst resulting from the resonant annihilation of an ultrahigh-energy cosmic neutrino on a relic antineutrino.

Cosmic-ray particles with the highest energies could give us clues about the mass of the relic particles from the Big Bang with the lowest energies – neutrinos – according to recent research. Big Bang cosmology predicts the existence of a background gas of free photons and neutrinos. The measured cosmic microwave background radiation supports the applicability of standard cosmology back to approximately 100 000 years after the Big Bang. A measurement of the relic neutrinos, which are nearly as abundant as the relic photons, could provide a new window to earlier times when the universe was just 1 s old. Since neutrinos interact only weakly, however, relic neutrinos have not yet been detected directly in laboratory experiments.

A recently proposed possibility for detecting relic neutrinos indirectly is based on so-called Z-bursts resulting from the resonant annihilation of ultrahigh-energy cosmic neutrinos with relic neutrinos into Z bosons, mediators of the weak interaction. On resonance, the corresponding cross-section is enhanced by several orders of magnitude. If neutrinos have non-vanishing masses – for which there is convincing evidence in view of the observation of neutrino oscillations (p5) – the respective resonance energies, in the rest system of the relic neutrinos, correspond to around 4×10^{21} eV.

Such resonance energies are, for neutrino masses in the 1 eV range, remarkably close to the energies of the highest-energy cosmic rays observed at Earth by means of air-shower detectors such as the Akeno Giant Air Shower Array (AGASA) in Japan. Indeed, it has been argued recently that ultrahigh-energy cosmic rays above the predicted Greisen–Zatsepin–Kuzmin (GZK) cut-off around 4×10^{19} eV are mainly protons from Z-bursts. This would possibly solve one of the outstanding problems of ultrahigh-energy cosmic-ray physics – the observation of cosmic rays with energies above the GZK cut-off – in an elegant and economical way without invoking new physics beyond the Standard Model, other than neutrino masses.

The GZK puzzle hinges on the fact that nucleons with super-GZK energies have a short attenuation length of about 50 Mpc, due to inelastic interactions with the cosmic microwave background, while plausible astrophysical sources for those energetic particles are much farther away.

Ultrahigh-energy neutrinos produced at cosmological distances, on the other hand, can reach our cosmological neighbourhood unattenuated and their resonant annihilation with relic neutrinos could result in the observed cosmic rays of the highest energies.

The energy spectrum of the highest-energy cosmic rays depends critically on neutrino mass if they are indeed produced via Z-bursts. From a comparison of the predicted spectrum with the observed one, the required mass of the heaviest neutrino can therefore be inferred. It turns out to lie in the range 0.04–0.76 eV, which compares favourably with current experimental indications. The required ultrahigh-energy cosmic neutrinos should be observed in the near future by existing neutrino telescopes, such as AMANDA at the South Pole, and by cosmic-ray air-shower detectors currently under construction, such as the Pierre Auger Observatory (*CERN Courier* March p6). If they are not, the Z-burst hypothesis for the origin of the highest-energy cosmic rays will be ruled out.

Further reading:

Z Fodor, S D Katz and A Ringwald (2002) *Phys. Rev. Lett.* **88** 171101.

SWITZERLAND

Particle physics is thriving in Switzerland

Hans Weder (left), rector of the University of Zurich, with Claude Amsler (also of the University) at the recent RECFA meeting.

An update on particle physics and closely related topics in Switzerland was presented at the University of Zurich in March to a subpanel of the European Committee for Future Accelerators, RECFA. Members were welcomed to the meeting by the university's rector, Hans Weder. In his opening address, Professor Weder emphasized his belief in the importance of basic research. He said that the University of Zurich intends to be among the very best in basic research. As a theologist, he found particle physics "a most fascinating human endeavour". He concluded: "You may be proud of your contribution to human culture."

The position of the Swiss Government was described by Charles Kleiber, Secretary of State for education and science, who declared that "Switzerland believes in CERN" (see box below). An overview of particle physics in Switzerland was given by Claude Amsler, followed by several talks on the various Swiss activities in particle physics, in Europe and elsewhere, as well as a few contributions to spin-offs, such as medical applications involving particle physics techniques.

RECFA delegates were impressed by the extent and quality of the activities. Switzerland, in spite of being a small country, is almost omnipresent at CERN. Swiss scientists are active in a large number of experiments all the way from the lowest energies – experiments with antihydrogen – to the highest-energy experiments preparing for the Large Hadron Collider (LHC). There is also a very strong community of theoretical particle physicists in Switzerland.

An interesting recent development in Switzerland concerns a proposal by the Forum of Swiss High Energy Physicists to construct a dedicated Swiss facility to meet the challenges of the LHC computing. This is to be situated at the Swiss Center for Scientific Computing in the Italian-speaking Canton of Ticino. Switzerland also benefits from a large multidisciplinary national laboratory, the Paul Scherrer Institute (PSI). In addition to being a research laboratory, the PSI enables Swiss physicists to engage in activities beyond those that are possible at universities, such as building large equipment and having access to test-beams.

Are there then no clouds on the horizon for Swiss particle physics? The funding system is complicated, and post-doctoral fellows are expensive and not easy to find. However, Swiss particle physicists seem to have found their way through the funding labyrinths, and RECFA was pleased to find the Swiss particle physics community so strong and dynamic.

Switzerland believes in CERN

Swiss Secretary of State for education and science and head of the Swiss delegation to CERN Council, Charles Kleiber (second from right), visits CERN with (left to right) director-general Luciano Maiani, Guy Hentsch and Jean-Luc Baldy of CERN, and Swiss delegate to CERN Council, Jean-Pierre Ruder.

In telling RECFA delegates that Switzerland believes in CERN, the Swiss secretary of state for education and science, Charles Kleiber, said: "CERN is the world's focal point for high-energy physics and therefore an invaluable asset for research in this field. Moreover, member states have invested heavily in CERN and it would simply be a waste of money not to continue to use it to the maximum extent possible. CERN motivates young students to study physics and serves as a first-class learning site by offering excellent training possibilities for the next generation of physicists. CERN is also 'la part de rêve' which is so necessary today. CERN disposes of motivated and competent personnel with an excellent record of success, but working also with great passion – and sometimes under very difficult conditions – on the future of CERN. Let's protect and take advantage of the human resources available."

- **Charles Kleiber is the new head of Switzerland's delegation to CERN Council.**

NETWORKS

D0 physicists 'shake hands' across the Atlantic in key grid test

In an important test of datagrid technology, members of the D0 collaboration at Fermilab have successfully communicated across the Atlantic with colleagues in the UK. The aim of the grid is not only to make it possible to access data remotely on different machines, but also to enable data processing to take place on remote machines.

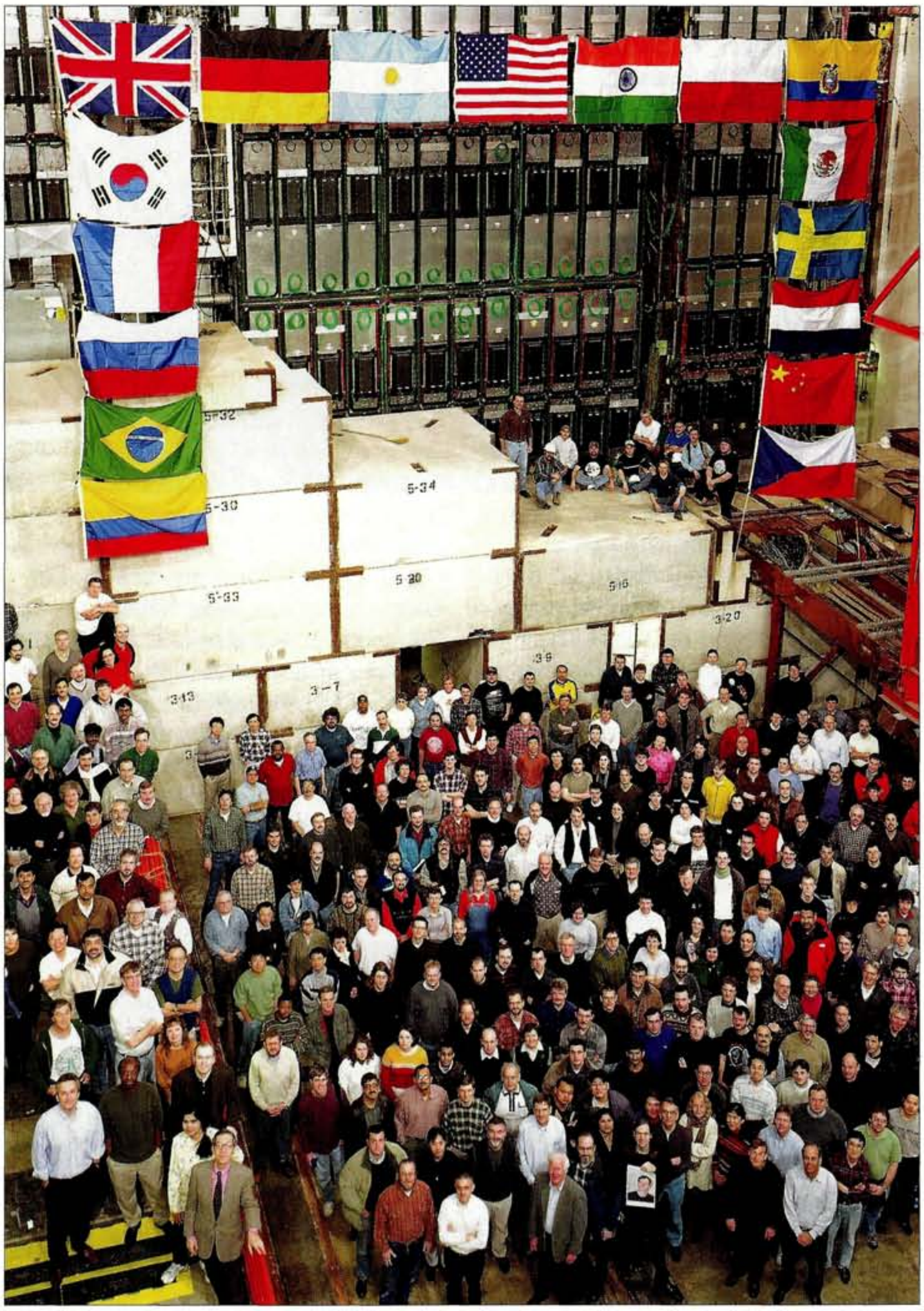
A vital first step in achieving this goal is to allow individuals wishing to access the grid to identify themselves and show that they are authorized users. A two-way trust must be established between the individual and the machine that is being used.

In the tests, carried out in February, Fermilab exchanged files with Lancaster University, UK and Imperial College, London, after the transfers had been authenticated using certificates issued by the Department of Energy ScienceGrid and the UK High Energy Physics Certificate Authority.

The "firewalls" installed in many computer systems are making it increasingly difficult to access computers remotely, which is the antithesis of the philosophy behind the grid. The authentication system is intended to provide a means of allowing secure access so that the grid can operate effectively. In February's tests the certificates were used to establish trust between users and machines at Fermilab, Imperial College and Lancaster.

Although in this case the users were members of the same collaboration, the transfers took place as though the users were completely unknown to one another. This approach was used to test the Globus Toolkit – the software tool that was used to build the authentication system.

This software is currently being developed by the US-based Globus Project to bring about the higher level of computer access that will be essential if the grid is to fulfil its promise in a wider context.

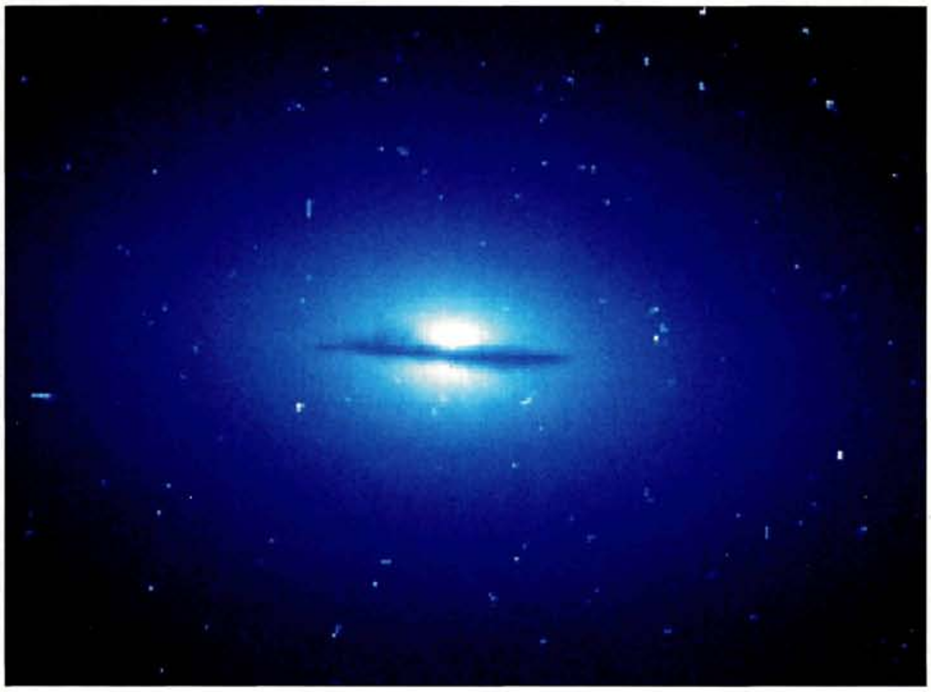


D0's international mixture of experimenters may sometimes get the chance to meet at Fermilab, but their data analysis relies on the power of processors at collaborating institutes across the world, which in future will be connected by the datagrid. (Fermilab Visual Media Services.)

COSMIC RAYS

Remnants reveal origins of cosmic rays

The 10 m CANGAROO II air Cerenkov telescope in Woomera, South Australia, is tracing the origins of cosmic rays. (CANGAROO.)



Scientists from Princeton University and NASA's Goddard Space Flight Center have identified four elliptical galaxies like this one. Each contains a central black hole of at least 100 million solar masses that, if spinning, could be the source of ultrahigh-energy cosmic rays. (NASA/HST/Timothy Hamilton.)

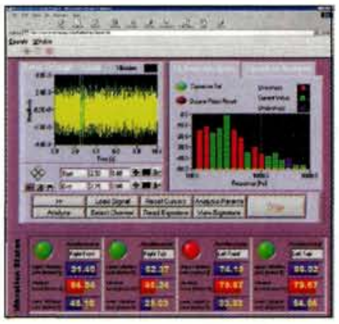
In the 90 years since the discovery of cosmic rays, there have been many theories about their origin, but little experimental evidence for actual sources. Now two groups have evidence for sources of cosmic rays in two distinct energy regions – up to about 10^{15} eV, and ultrahigh energies around 10^{20} eV.

The majority of cosmic rays are protons with energies less than around 10^{15} eV. In 1949 Enrico Fermi suggested that these particles could be accelerated in moving magnetic clouds, as in the shock waves surrounding a supernova. Direct evidence for acceleration in a supernova remnant has been found, but only for cosmic-ray electrons. Now, however, a team working with data from the CANGAROO II (Collaboration of Australia and Nippon for a GAmma Ray Observatory in the Outback) cosmic-ray telescope in Woomera, South Australia, has evidence that points to a specific supernova remnant as an accelerator of cosmic protons. CANGAROO II is a 10 m air Cerenkov telescope, which detects the electromagnetic showers created when gamma rays with energies of around 10^{12} eV strike the atmosphere. The team has analysed data from one of the intrinsically brightest sources of gamma rays in our galaxy, the supernova remnant RX J1713.7-3946. They found that the measured energy spectrum does not fit with models in which the gamma rays are emitted by accelerated electrons. However, it agrees well with the assumption that the gamma rays come from the decays of neutral pions, presumably produced by the interaction of high-energy protons accelerated in the supernova remnant.

The possible sources of ultrahigh-energy cosmic rays, with energies around 10^{20} eV, present a different problem. While undoubtedly exotic, the sources must also be relatively nearby, as otherwise the cosmic rays would lose energy through interactions with the cosmic microwave background radiation (the so-called GZK cut-off, after Griesen, Zatsepin and Kuzmin). Nearby dead quasars – or quasar remnants – which contain spinning supermassive black holes at their centre are one possibility, for which there is now some observational evidence. A team from Princeton University and NASA Goddard Space Flight Center has searched a catalogue of several thousand galaxies for those likely to be suitable quasar remnants nearer than 50 Mpc (or about 160 million light-years, the GZK cut-off for 10^{20} eV) and found a sample of 12 candidates. They then looked for correlations with the arrival directions for high-energy events from AGASA (Akeno Giant Air Shower Array) in Japan. Their results indicate a non-random correlation between three galaxies and 34 events with energies greater than 4×10^{19} eV; for 7 events with energies greater than 10^{20} eV, the correlation is less clear. The team does not yet know if the black holes in these galaxies are spinning – a necessary condition for the proposed cosmic-ray accelerator – but they do suggest further studies of nearby possible quasar remnants, particularly with the Auger Observatory (*CERN Courier* March p6).

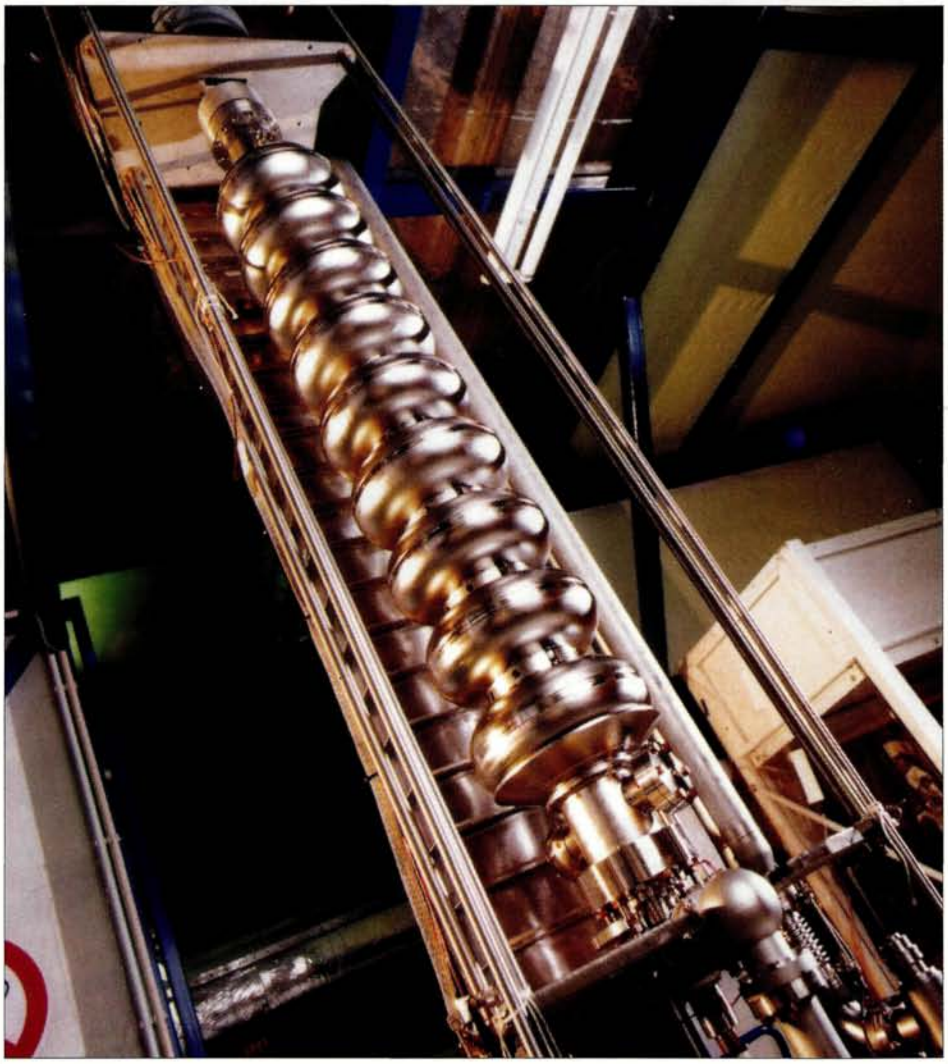
Further reading

R Enomoto *et al.* 2002 *Nature* **416** 823.
Diego Torres *et al.* astro-ph/02044191 at http://www.arxiv.org/.



TESLA

Smooth surfaces give boost to TESLA superconducting cavity



Electropolishing has allowed a nine-cell TESLA superconducting cavity like this one to reach a gradient of 35 MV/m.

Accelerating cavities for the proposed TESLA superconducting electron-positron collider routinely achieve the 25 MV/m accelerating gradient that is required to achieve a collision energy of 500 GeV in a 33 km collider. Now, for the first time, a nine-cell TESLA cavity has achieved 35 MV/m, which would be sufficient to operate the accelerator at 800 GeV.

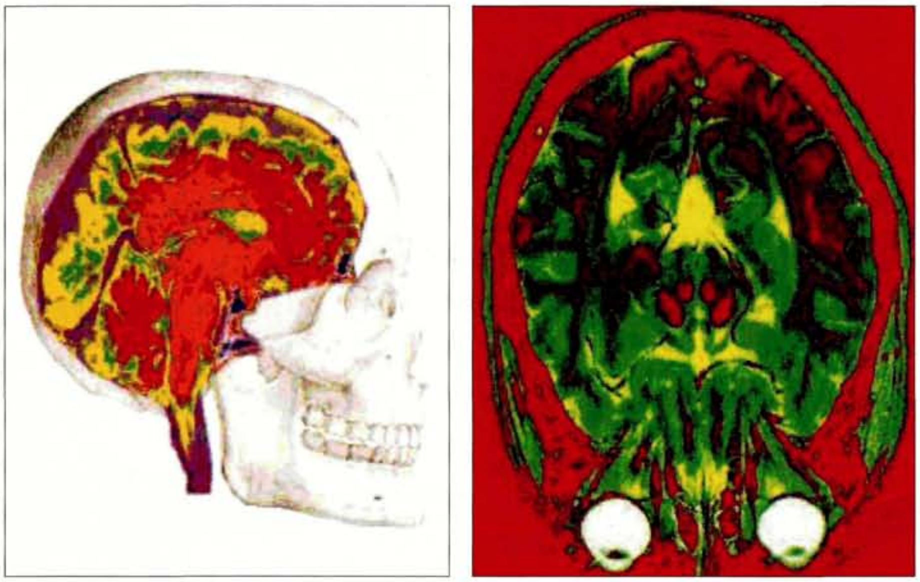
The secret of this achievement is a collaboration between Hamburg's DESY laboratory, which is driving the TESLA project (*CERN Courier* June 2001 p20), and the KEK laboratory in Japan. Until now, the niobium surface of the TESLA cavities has been chemically etched. Through the DESY-KEK collaboration, the new cavity has been electropolished by the Nomura Plating Company, resulting in a smoother surface. Moreover, baking the cavities at 100 °C has been shown to lead to further improvements, with 40 MV/m being reached in single-cell cavities.

An electropolishing facility for TESLA cavities is scheduled to be commissioned at the DESY laboratory in June.

PHYSICSWATCH

Edited by Archana Sharma

US team reports MRI at microtesla field



Left: an artificially coloured MRI image of the brain, superimposed on a classical drawing of the skull, produced using a 3 T machine operated jointly by the University of Florida's Shands Hospital and the Gainesville Medical Center in Virginia. Right: MRI enables high-resolution images of human tissue such as the brain from virtually any angle. (University of Florida.)

Imaging technologies are advancing at an incredible pace thanks to faster computers, more powerful magnets and more precise radioactive isotopes. One technique set to move forward is magnetic resonance imaging (MRI), which has been observed at microtesla fields for the first time.

The basis of MRI is that a strong magnetic field applied to randomly spinning protons inside the atoms of the body, particularly hydrogen, will cause them to line up and spin in the same direction. A radio signal beamed into the magnetic field knocks the protons out of alignment, and as they fall back into alignment they release energy in the form of radio waves. The amount of energy released and the time it takes for the protons to line up again is unique for different tissues in the body, so a computer can take this information and create an image of that tissue.

A tumour has a slightly different water density compared with surrounding healthy tissue, allowing computer processing and contrast enhancement to disclose its position to a trained observer.

Until now, large magnetic fields have been required for MRI, limiting the availability of the technique. Recently, however, researchers at the University of California, Berkeley, and the University of Florida have imaged four columns of fluid with a field of 10 μT over several hours.

In another recent development, researchers at the MRI Institute for Biomedical Imaging in St Louis have reported a new MRI technique called susceptibility weighted imaging (SWI). By measuring the differences in magnetic susceptibility of tissues in the brain, this technique gives unique information about veins and blood products. MRI images of blood vessels in the brain have been obtained with details never before possible.

SWI can potentially detect angiogenesis – the growth of blood vessels caused by cancer – and may improve diagnosis of Parkinson's and Alzheimer's diseases through its ability to monitor iron deposits in the brain. *AIP*

Further reading

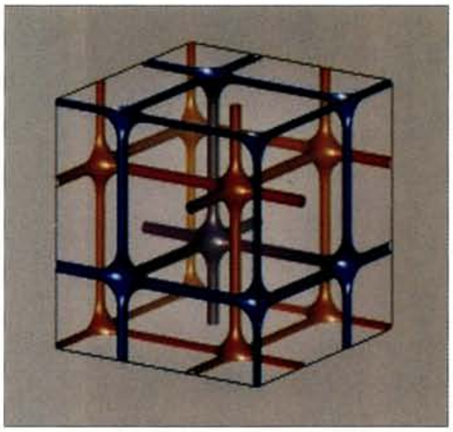
R McDermott *et al.* 22 March 2002 *Science.*

Cornell develops a flexible ceramic

Researchers at Cornell University have used an atomic self-assembly technique to create a promising hybrid material with the flexibility of polymers and the strength and functionality of ceramics. The material was made by blending a known self-assembling molecule called a diblock copolymer with a ceramic.

Although only small pieces have been made so far, they have enabled the material's properties to be tested. It is transparent, flexible and strong, and unlike a pure ceramic it does not shatter. In one form it is a good conductor of ions and could lead to a superior electrolyte for batteries and fuel cells. Another possible application is using the material to separate live proteins.

The self-assembly feature could be used to create large batches of the material in many molecular configurations, possibly opening up new avenues for materials science.



The molecular architecture of Cornell's flexible ceramic resembles a plumber's nightmare, but the new material has many valuable potential applications. (Wiesner research group, Cornell University.)

New international society formed

A new international society has been formed to address the demands for closer international co-operation for advancing muon spin rotation, relaxation and resonance (μSR) techniques. For more information see http://musr.triumf.ca/~isms/.

Edited by Emma Sanders

Debate sparked on quark stars

Recent observations of two neutron stars have led to the announcement that a new form of matter might have been found. Astronomers using NASA's Chandra X-ray observatory claim that one of the stars is too small, and the other too cold, for them to be ordinary neutron stars. They suggest the results are evidence for a new extreme form of matter – quark stars. However, the issue is far from clear cut.

Quark stars – if they exist – have a core made up of strange quarks. They were first postulated in the 1970s as an intermediate between neutron stars and black holes in both size and density. They can be more compact and cool faster than neutron stars.

This could explain the Chandra results: the neutron star RXJ1856 may have a radius as small as 4 km say astronomers, and radiation from the neutron star in 3C58 is less than 1 000 000°, which is much colder than expected. 3C58 is associated with the remnant of a supernova observed by the Chinese and Japanese in 1181, so the total cooling time is known.

This is not the first time that such claims have been made. Indeed, the radius of RXJ1856 was last year announced to be 6 km following observations using Rosat, the Extreme Ultraviolet Explorer and the Hubble Space Telescope. However, this result has recently been retracted as new parallax measurements used to calculate the distance to the star now suggest a radius of 15 km.

As far as 3C58 is concerned, observations were of emission from the nebula surrounding the neutron star. The lack of a black body component in this emission sets an upper limit on the temperature of the neutron star. However, different cooling models have been used to fit the data and suggest that a neutron star of this age could in fact exist at the observed temperature without the need for any exotic forms of matter.

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Pons *et al.* 2002 *Astrophys. J.* **564** 981–1006.

Walter *et al.* (submitted) *Astrophys. J. Lett.*

For 3C58:

Slane *et al.* To be published in *Astrophys. J. Lett.*

Yakovlev *et al.* To be published in *Astronomy & Astrophysics.*

Major upgrade prepares wizard telescopes for a good spell

The UK's 217 km MERLIN array of radio telescopes is undergoing a major upgrade. The array already has a resolution equivalent to that of the Hubble Space Telescope. But once the £2.4 million upgrade is completed, the array will be able to probe far deeper into the universe, achieving in 1 day what currently takes 3 years of continuous observations.

MERLIN, the Multi-Element Radio-Linked Interferometer Network, consists of seven radio telescopes stretching from the Welsh borders to Cambridge, giving the combined effect of a single giant radio telescope. The Lovell telescope, based at Jodrell Bank, is the cornerstone of the array.

The Lovell's surface panels are currently being replaced by new galvanized steel plates. After this stage modern holographic profiling techniques will be used to optimize the new surface for wavelengths as small as 5 cm – four times shorter than at present. The work will increase the telescope's sensitivity by a factor of 30.

A new control system is also being installed to improve the tracking of the stars and galaxies being observed as they move across the sky. This is important as the "beam" of the telescope becomes narrower at its new operating frequencies.

The Lovell telescope gets a face-lift as part of an upgrade to MERLIN. (NRAO, Jodrell Bank.)

Picture of the month

The Swan nebula: one of the stunning images taken using the Hubble Space Telescope's new Advanced Survey Camera (*CERN Courier* May 2002 p13). This starforming region is illuminated by the ultraviolet radiation from young massive stars. (ESA/NASA.)

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Symposium links physics disciplines

Europe's three principal physics research organizations, CERN, ESA and ESO, held a joint symposium in Munich in March. **Maurice Jacob** gives a glimpse of what proved to be a busy first encounter.

French scriptwriter Jean-Claude Carrière (left), seen here with ESO's director-general, Catherine Cesarsky, and head of ESA's research and scientific support department, Alvaro Gimenez, gave an interesting evening lecture at the symposium about how stage and film directors play with the flow of time.

Martin Rees (left), who gave the symposium's closing address, is seen here in conversation with the chair of the organizing committee, Peter Shaver of ESO.

Astrophysics, particle physics, cosmology and fundamental physics in space have much in common to bring their practitioners together. CERN and the European Southern Observatory (ESO) have already held several joint symposia, and in 2000 a workshop organized by CERN and the European Space Agency (ESA) was held in Geneva (*CERN Courier* June 2000 p11). In March this year, some 200 scientists travelled to ESO's headquarters near Munich for the first symposium to be hosted by all three organizations.

Following an introduction from ESO's director-general, Catherine Cesarsky, the global properties and evolution of the universe took centre stage. These have been studied in terms of a few parameters whose values have been broadly established in a remarkably short time. The universe is flat with a critical density ($\Omega = 1$), but baryons constitute only about 5%. Dark non-baryonic matter accounts for 25% of the overall density, and about 70% is "dark energy" with a negative pressure accelerating the expansion of the universe. All these contributions to the overall density should be precisely known within a decade. The apparent concordance of the parameters describing the universe obtained through very different measurements is already impressive, and leads to the question of why these parameters have the values they do.

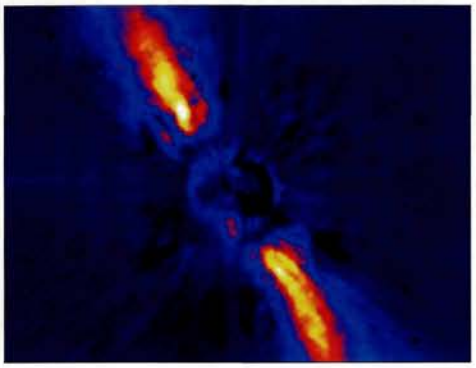
Some speakers were even tempted to raise the anthropic principle, although this tenacious myth is neither quantitative nor falsifiable, and does not teach us anything new. Nevertheless, it has gathered new momentum within a framework where many different universes could have been born, or even within a single universe where widely differing domains could exist and where we happen to live in the one domain providing for our needs.

Global properties

The global properties of the universe were covered in the opening sessions. Neil Turok of Cambridge spoke about the very early universe – past and future – since the universe he proposed has a succession of Big Bangs and Big Crunches. After discussing the different contributions to Ω, Turok stressed that each measurement has little value on its own unless it is assessed within a particular theoretical framework, and that we should keep challenging the framework.

An explanation for many observed features is found in the standard inflationary universe scenario, which Turok challenged with a model of colliding branes. He called for an open-minded approach to such ideas, and for further tests of inflation such as the polarization of the cosmic microwave background (CMB) and the observation of a background of long-wavelength gravitational waves.

Paolo de Bernardis of the University of Rome reviewed CMB ▷



This spectacular ESO image shows the dusty disk around the southern star Beta Pictoris, which is probably connected with a planetary system. (ESO.)

properties from an experimental point of view. The key result is the flatness of the universe, but the observation of peaks in the angular analysis of the CMB are what have allowed the baryonic density to be pinned down to 5%, and shown that temperature fluctuations are scale-independent. De Bernardis stressed, however, that measurements are currently restricted to a very limited coverage of the sky. This will be much extended with NASA's MAP and ESA's Planck missions, which will also measure CMB polarization.

A key feature is the current acceleration of the universe's expansion, direct evidence for which comes from observations of supernovae. ESO's Bruno Leibundgut showed how the observation of 27 low-redshift type 1a supernovae has built confidence that they are reliable standard candles. This has allowed observations of 54 high-redshift ones to be interpreted as fainter than expected from standard Hubble expansion. Taken at face value, this could result from a vacuum energy density of 0.7, which accelerates expansion today but would have led to a deceleration in the past when the matter density was higher. Leibundgut added a cautionary note, however, saying that much remains to be understood about the systematic uncertainties of type 1a supernovae. Much larger statistics, probing to higher redshift, are needed, as is a better understanding of the their explosion. Yannick Mellier of the Observatoire de Paris reviewed the complementary determination of the matter density via weak gravitational lensing. There is good agreement on the matter and vacuum density between six different teams. When combined with the analysis of the CMB, the matter density is pinned down to around 0.3 and the vacuum density to around 0.7. It is puzzling that the vacuum energy density should be so tiny compared with the Planck scale or electroweak breaking scale.

Dark matter

Direct searches for dark matter were reviewed by Charling Tao of Marseille. After recalling the first hints provided by the rotation curves of galaxies, interpreted as being due to a halo of baryonic matter, she explained how massive compact halo objects identified through gravitational lensing are too few to account for the effect. Underground experiments have looked for weakly interacting massive particles, so far to no avail. Concluding the discussion of exotic dark matter candidates was Georg Raffelt of the Max Planck Institute (MPI) in Munich, who described the CERN axion solar telescope, CAST (*CERN Courier* April 2001 p6).

With their tiny but non-zero masses, neutrinos provide the first clear departure from the Standard Model of particle physics, but are no longer expected to provide an appreciable contribution to dark matter. Pilar Hernandez of CERN reviewed the status of neutrino physics. Oscillations with mass square differences of the order of 10^{-3}–10^{-5} eV^2 and maximal mixing are now favoured.

Reviews of the Standard Model of particle physics and the exciting prospects for research at CERN's forthcoming Large Hadron Collider were the subject of many presentations. Antonio Pich of Valencia spoke of low-energy Standard Model tests, while CERN's Fabiola Gianotti covered high-energy tests. John Ellis of CERN went beyond the Standard Model, raising the possibility of extra dimensions at short distances as a rival to supersymmetry.

Studying the extreme

Edward van den Heuvel of Amsterdam reviewed gamma-ray bursts (GRBs). A beautiful example of serendipity, GRBs were discovered while looking for something else – nuclear tests in the atmosphere. Now known as the most powerful cosmic explosions, they occur at the level of one per day with energy output reaching that of up to a million supernovae. They last from seconds to minutes and appear at random in the sky, which is to be expected, since their X-ray and visible afterglows are associated with highly redshifted host galaxies. Many efforts are underway to observe and study GRBs with redshifts up to z = 12.

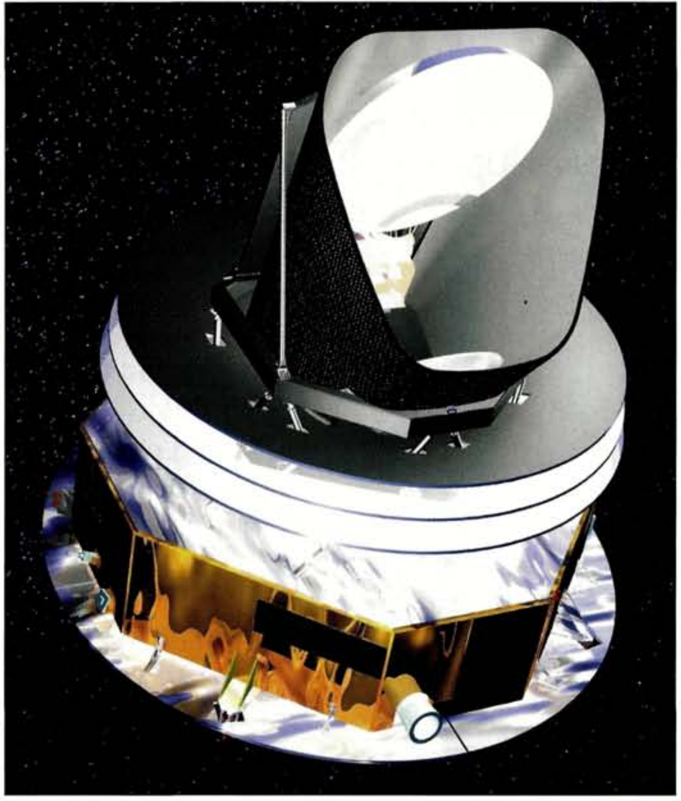
Remaining with the extreme, Heinrich Völk of Heidelberg discussed very-high-energy gamma rays, and Alan Watson of Leeds talked about the highest-energy cosmic rays. The observation of cosmic rays above about 10^{11} GeV is a puzzle, since as Greisen, Zatsepin and Kuzmin pointed out, the CMB should make space opaque to them. Understanding their origin will rely on observations with the Auger observatory (*CERN Courier* March p6) and later with ESA's Extreme Universe Space Observatory (*CERN Courier* March p8).

Francis Halzen from the University of Wisconsin-Madison talked about high-energy neutrinos from astrophysical sources. Detection at rates appropriate for meaningful study demands very large detectors such as the 1 km^3 Icecube detector (*CERN Courier* May 2001 p14) being installed deep under Antarctic ice, and underwater detectors such as ANTARES (*CERN Courier* December 2001 p12).

One session was devoted to massive objects. It now seems likely that massive black holes at the centre of galaxies fuel the massive energy output of quasars, equivalent to 10^{12}–10^{15} suns, and that all galaxies were once active. Quasar density peaks at a redshift of z = 2. In closer galaxies, the presence of a relatively quiet black hole of millions of solar masses is inferred from the swift motion of stars around a dark centre. The central part of our Milky Way, for example, has been observed to within 3 light years of the centre, where stars circle at velocities up to 1500 km/s. Interpretations more exotic than the presence of a giant black hole are not expected to hold.

Gravitational waves

Bernhard Schutz of the MPI in Potsdam gave a review of gravitational wave sources, while Karsten Danzmann of the MPI in Hannover discussed experimental searches. Gravitational waves carry huge energies but interact very feebly, crossing the universe almost unperturbed. Ground-based detectors, sensitive to frequencies above 10 Hz, are complementary to detectors in space, which



ESA's Planck mission will measure anisotropies and polarization in the CMB. This artist's impression of the Planck satellite is based on design work by Alcatel Space, ESA's prime industrial contractor for the mission. (ESA.)

will look for frequencies below 0.1 Hz. Both should be sensitive to amplitudes below 10^{-22}. In his talk, Stephano Vitale of Trento discussed several ESA fundamental physics missions including SMART-2, a test mission for the ambitious LISA gravitational wave interferometer, which should fly in 2006.

Other forthcoming space experiments include the ESA-NASA STEP mission, which will test the equivalence principle to six orders of magnitude better than the present limit. Roberto Battiston of Perugia described Alpha Magnetic Spectrometer (AMS) findings on properties of the cosmic-ray flux, and showed how future AMS missions could bring down the anti-helium to helium ratio from 10^{-6} to around 10^{-9}.

Planetary systems

Ewine van Dishoeck of Leiden discussed the formation of star and planetary systems from large clouds of gas and dust, saying that around 15% of stars have a disk from which planets could form. Solar system formation would take some 100 million years. This field will soon see major developments with new tools such as the Atacama Large Millimetre Array, ESA's Infrared Space Observatory, NASA's Space Infra Red Telescope Facility and the Next Generation Space Telescope.

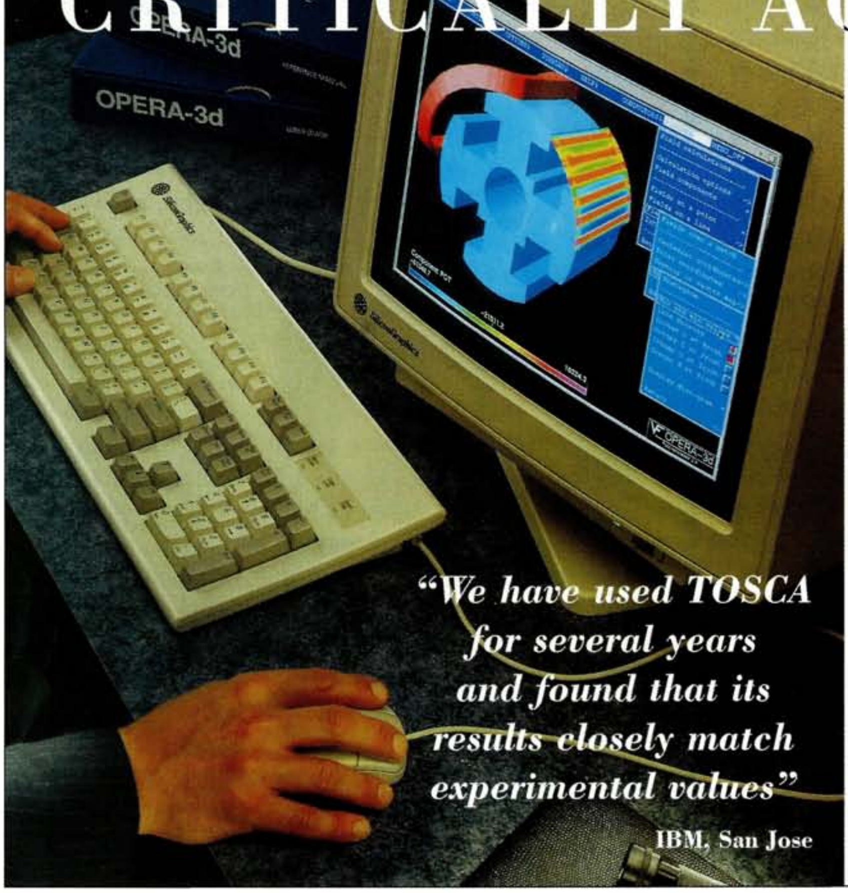
Michel Mayor of Geneva recalled that more than 80 extra solar planets have already been seen, some of them with masses as low as 50 times the mass of the Earth. He discussed how planets are found through radial velocity surveys and planetary transit, the latter giving direct evidence for gaseous giants like Jupiter. The diversity of planets observed was not anticipated - some have very short periods, elongated orbits or very large masses up to 10 times the mass of Jupiter. Michael Perryman of ESA showed how missions under study could make the search for Earth-like planets possible, saying these may be as numerous as one per thousand stars. Many conditions, however, would need to be satisfied to make life possible. Perryman outlined a "habitable zone" requiring the presence of a Jupiter-type planet as a protection against meteorites, and stressed that it would need to exist over billions of years.

The meeting drew to a close with presentations about future directions at CERN, ESA and ESO. Exciting projects are being completed, are under construction or are at the planning stage in all three organizations. The closing lecture was given by Martin Rees of Cambridge, who brought the symposium to a brilliant finale with the conclusion that we live in exciting times.

Further reading

ESA SP-469 2001 *Fundamental Physics in Space & Related Topics.*
Europhysics News 2001 "Physics and the Universe" 32-6.
Proceedings of the 2002 ESO-CERN-ESA symposium, Springer Verlag (to be published).

Maurice Jacob, *chair, Joint Astrophysics Division of the European Astronomical and Physical Societies.*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US facility explores wakefield acceleration

The US Department of Energy funded Argonne Wakefield Accelerator facility provides a platform for developing advanced technologies for high-energy physics machines. The facility aims to develop acceleration methods for more efficient, more compact and less expensive particle accelerators.

At work on the drive line of the Argonne Wakefield Accelerator Facility. The witness line can be seen in the background.

A group of scientists at the Argonne National Laboratory in the US is pursuing the novel technique of electron beam-driven wakefield acceleration. This uses the strong electromagnetic fields that follow in the wake of an electron beam to accelerate a second electron beam. A general-purpose wakefield measurement system, invented at Argonne, is being applied to study the technique. It uses a "witness beam" to map out directly the longitudinal and transverse wakefields in any device. This technique has also been used to perform wakefield measurements of the very first prototype detuned accelerating structure for the proposed Next Linear Collider, and to measure critical components for the ill-fated Superconducting Super Collider.

Wakefield acceleration

A charged particle beam leaves wakefields behind when it passes a discontinuity in a beam line. If this discontinuity is a resonant structure, the beam will drive the structure's accelerating modes, which can then be used to accelerate a second beam. The fundamental concept of electron beam-driven wakefield acceleration is that a high-current, low-energy electron beam can be used to accelerate a separate low-current electron beam to high energies. This idea is also the basis of plasma wakefield acceleration, where the electron beam is used to excite large-amplitude electrostatic oscillations in a plasma, which then accelerate the second beam.

The aim of the Argonne Wakefield Accelerator (AWA) programme is to demonstrate high-gradient acceleration in wakefield devices, and to develop high-current electron sources that are good enough to power them. Commissioned in 1996, the AWA's present configuration (figure 1 overleaf) includes a high-current 16 MeV drive line consisting of a drive photoinjector and linac, and a low-current 4 MeV witness beam photoinjector. The drive photoinjector produces a 100 nC beam pulse; this is two orders of magnitude greater than similar photoinjectors had attained at the time it was first switched on.

While the drive beam is always delivered to the drive-line wakefield device, the path of the witness beam depends on the mode of operation. In collinear mode, the witness beam is magnetically steered into the drive-line wakefield device. In parallel mode the witness beam is delivered into the witness-line accelerating structure. Since both beams originate in photoinjectors, the time separation between the beams can easily be varied by adjusting the optical path of one injector's laser input pulse with respect to the other.

Experimental programme

Among the most interesting experiments carried out at the AWA are those concerning the so-called dielectric step-up transformer. This device has recently been successfully used to accelerate the ▷

witness beam. The acceleration method is similar to the two-beam acceleration concept currently being developed in CERN's compact linear collider (CLIC) project. It uses two dielectric structures, one for the drive and one for the witness beam, coupled by a waveguide. A train of drive bunches (that can easily be generated from a photoinjector by optically splitting the laser pulse) passes through the drive structure.

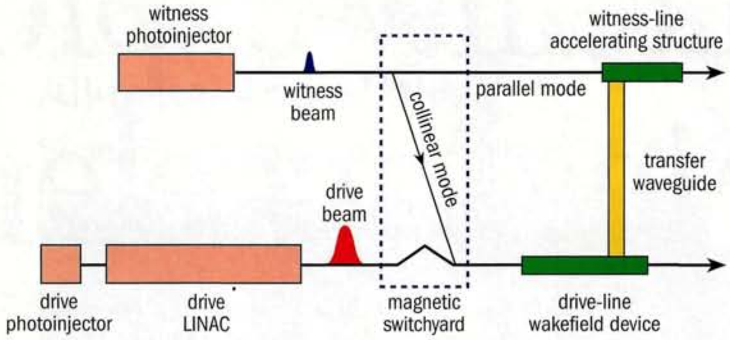
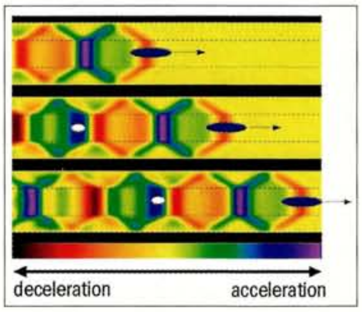


Fig. 1. In the Argonne Wakefield Accelerator, a high-current 16 MeV drive beam is steered into the wakefield device. The low-current 4 MeV witness beam can be delivered to either of the devices.



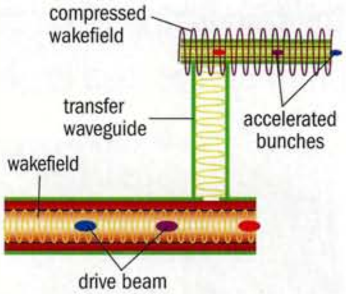


Fig. 2, left. This simulation of the collinear dielectric wakefield accelerator experiment shows three snapshots in time. In each (left to right) the drive beam (dark oval) excites decelerating (red regions) and accelerating (blue regions) wakefields. The latter can be used to accelerate a beam (white oval) in an accelerating bucket. Fig. 3, right. A high-current drive train excites a wakefield that is transferred and compressed to accelerate the low-current bunches.

The radiofrequency (RF) pulse that is generated by the wakefield of the drive-bunch train is transported via the waveguide to the witness structure. If the dielectric material and geometry have been chosen appropriately, the RF pulse is compressed longitudinally as well as transversely. This provides a field step-up so that the ratio of the accelerating field in the witness structure to the decelerating field in the drive structure can be made much greater than two, which is the maximum in most collinear wakefield accelerators.

The AWA team has carried out experiments with a 7.8 GHz prototype step-up transformer. Careful bench measurements and iterative adjustment of the coupling-slot shape and the taper angle of the dielectric tube solved the potential obstacle of obtaining good coupling between the two beam lines. Initial experiments concentrated on directly measuring the RF power envelope extracted from the drive line using a high-frequency diode detector. The forward power levels peaked at 4 MW.

Steps up to success

Witness beam measurements of fields in the witness line showed that the anticipated step-up ratio of four was achieved. Although the gradients in the prototype were a modest 8 MeV/m, these experiments have provided an important proof of principle. Moreover, the high power levels generated in the drive line could be used for powering a conventional RF accelerating cavity. With this in mind, the AWA group has investigated using this device as a CLIC power extraction/transfer structure.

The AWA team has also carried out experiments on beam-driven plasma wakefields, in collaboration with the University of California at Los Angeles. Using the high-charge beams available from the AWA drive line, plasma wakefields with gradients as high as 30 MeV/m have been measured and an electron beam has been observed propagating through a self-focused ion channel in a plasma for the first time in a plasma wakefield accelerator.

Another line of research uses a test stand that allows cavities to be tested under high power without disrupting operation. Several designs from other institutions have been tested including the prototype Tesla Test Facility photoinjector and a photoinjector for Taiwan's Synchrotron Radiation Research Centre.

Looking ahead

The AWA is currently being upgraded to obtain extended beam acceleration in high-gradient dielectric wakefield structures. The quality of the drive beam will be improved by an upgraded drive photoinjector, higher quantum efficiency photocathodes for the production of long drive beam trains, and an all solid-state titanium-sapphire laser system.

The new photoinjector uses a combination of high photocathode electric field and high exit energy to maintain a short drive bunch. For a 100 MV/m surface field in the cavity, an improvement in beam quality of a factor of 50 is expected over the already record-breaking original AWA drive photoinjector. The upgraded facility is expected to produce 10 kA micropulses at 18 MeV and an emittance that is 10 times lower than the original.

Operating the dielectric wakefield transformer at high gradients over extended distances requires a long, high-current drive pulse train. This is obtained by sending the output of the laser system through a laser-pulse splitter to generate 16 successive bunches at 40 nC each, spaced by 760 ps. Since each laser pulse will have its energy reduced by a factor of 16, a high quantum efficiency photocathode is needed to produce the high-charge electron beams.

The next goal of the AWA programme is to use the step-up transformer to increase the energy of a high-quality 1 nC witness beam by 100 MeV in less than 1 m – a major milestone in the field.

Further reading

The AWA website is at www.hep.anl.gov/awa.

John Power *and* **Paul Schoessow**, *Argonne.*

Fermilab turns up the heat on electron cooling

A technique that was first proposed by Gersh Budker in 1966 is being injected with new life by a team of physicists at Fermilab in the US. **Kurt Riesselmann** reports.

Fermilab physicist Alexander Shemyakin at work inside the laboratory's Pelletron accelerator.

In February Sergei Nagaitsev and his group at the US Fermi National Accelerator Laboratory (Fermilab) reported a breakthrough. Working on an ambitious electron-cooling project, the team set a new world record for DC beam power – they maintained a continuous 3.5 MeV electron beam with a current of more than 500 mA for up to 8 h with only short interruptions.

These figures may not, at first sight, seem significant. After all, half an amp is the current flowing through a typical light bulb. However, the beam electrons travel at a much higher energy than those in an electric wire, leading to a record beam power of about 2 MW in the short prototype beamline.

Nagaitsev's group aims to use an electron beam to cool antiprotons inside Fermilab's 3 km Recycler antiproton storage ring and boost the luminosity of the laboratory's Tevatron collider. When the electron-cooling system is complete, electrons and antiprotons will travel side by side in the Recycler. The electrons will absorb the excess heat of the antiprotons, shrinking the size of the antiproton beam. To be efficient, the electron beam must contain many more particles than the antiproton beam, requiring scientists to develop a high-current electron system.

The cooling process only consumes a fraction of the 2 MW beam power because scientists can recirculate the electrons and their power. The electrons start at the top of an 8 m high Pelletron accelerator – a Van de Graaff-type device developed by the National Electrostatics Corporation (NEC) – where they gain energy by travelling through a 3.5 MV electrostatic accelerating tube. They then pass through a loop and re-enter the Pelletron, where they are decelerated by traversing the electrostatic field in the opposite direction. A beam collector at the top of the Pelletron receives the electrons and supplies them for re-acceleration. Only a few electrons, about 20 in every million, are lost each trip. A 200 μA Pelletron-charging current is sufficient to ensure stable operation of the recirculation ▷

Left: the world's first electron-cooling device installed in the NAP-M ring at Novosibirsk in the early 1970s. Right: Fermilab's electron-cooling project facility is based on a Pelletron accelerator (left), which produces a continuous high-current electron beam. An 18 m cooling section is under construction (right). (Fermilab Visual Media Services.)

system and to restart beam recirculation within 20 seconds if the machine trips off. The Fermilab recirculation system is unique in sustaining such a high current with so little loss at an energy that is significantly more than a few hundred kilo-electron-volts.

A versatile machine

NEC, a Wisconsin-based company that received a Small Business Innovation Award in 1984 from the US Department of Energy, has made more than 140 Pelletrons and sold them in 38 countries. The machine gets its name from the chains of metal cylinders – pellets – that replace the belts of conventional Van de Graaff generators.

Pelletrons are used in applications such as surface analysis and doping of computer chips. But the machines are also valuable beyond the field of physics. The new security inspection system for the Channel Tunnel, for example, uses two Pelletrons to produce X-rays for scanning loaded trucks and containers. Pelletrons are also used for carbon dating in accelerator mass spectrometry.

Most Pelletrons operate as non-recirculating accelerators, typically featuring one-way beams of less than 50 μA. In contrast, Fermilab's electron-cooling project relies on a continuous high-current beam, which can only be achieved through recirculation. "People in this business know how hard it is," said project leader Nagaitsev. "Everybody is pushing the envelope. People working on related projects in the US and Europe are waiting for our results. Our success or failure means quite a bit at other laboratories."

More collisions

With the help of electron cooling, Fermilab scientists will create a larger number of collisions inside the Tevatron. "The goal of our R&D project is simple – construct and commission an electron-cooling device that is ready to be moved to the Fermilab Recycler," said Nagaitsev. A dedicated building to be located next to the Recycler is already being designed to house the electron-cooling equipment.

Nagaitsev's team is currently working in a building more than a kilometre away from the Recycler. So far, electrons haven't mingled with a single antiproton as the team is still making improvements on operating the Pelletron, producing an electron beam in stable mode for long periods of time. The Fermilab group plans to increase the beam energy to 4.3 MeV and the current to more than 1 A. So far, they have attained a 750 mA current for short periods of time.

The next step is to improve the quality of the electron beam as it travels through a special cooling section – initially without the presence of antiprotons. Only when that is achieved will the electron beam be used to cool antiprotons. "Depending on the efficiency of the Recycler," said Nagaitsev, "maybe we can increase luminosity by a factor of two, maybe more."

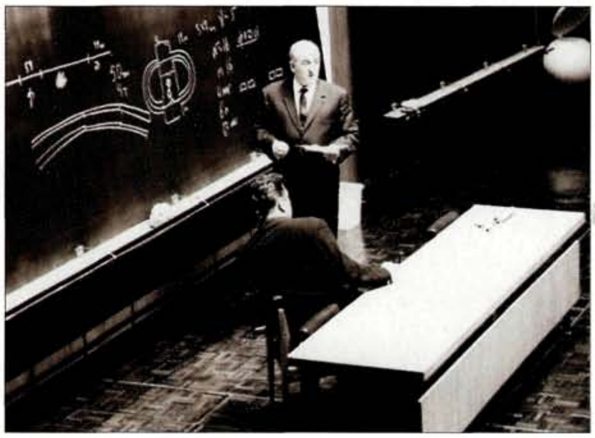
A test beamline with a nine-module cooling section is currently being incorporated into the Pelletron recirculation loop. This will enable the Fermilab team to study the electron beam carefully in the environment of the cooling section, determining the exact beam energy and the size of the high-current beam. Ultimately the electrons must travel parallel to the antiprotons, so the challenge is to put electron and antiproton beams on top of each other to within 50 μm.

In the final phase of the project, anticipated for 2003 or 2004, scientists will install the 20 m cooling section in the Recycler ring and send electrons and antiprotons through the cooling section at the same time. If everything works well, each antiproton will find itself surrounded by a cloud of electrons. Antiprotons going too fast will slow down as they bump against electrons in front of them. Antiprotons going too slow will speed up as electrons kick them from behind. With each collision, the lighter electrons will reduce the spread of energy within the antiproton beam. All of this will happen in a gentle way, since the masses of the particles make the collisions reminiscent of ping-pong balls bouncing off a bowling ball.

Cool idea

Gersh Budker first proposed the idea of electron cooling in 1966. It was first tested in 1974 at the Institute of Nuclear Physics in Novosibirsk, Russia, using proton beams. In 1976, David Cline, Peter McIntyre and Carlo Rubbia proposed using electron cooling for antiproton beams at Fermilab. Due to technical difficulties with cooling hot antiprotons, Fermilab turned to stochastic cooling, an alternative beam cooling technique developed at CERN by Simon van der Meer. The electron-cooling equipment went to the Indiana University Cyclotron Facility, where the equipment is still in use and provides electrons with a maximum energy of 300 keV.

CERN also developed electron-cooling systems, starting with the ICE ring in the late 1970s. CERN's Low Energy Antiproton Ring (LEAR) used a 30 keV electron-cooling system from 1992 until 1996. Today, low-energy electron-cooling systems are used successfully at many facilities around the world. The Fermilab team is the first to develop the technique for electrons in the MeV range.



Gersh Budker, the father of electron cooling, giving a seminar at CERN in 1967.

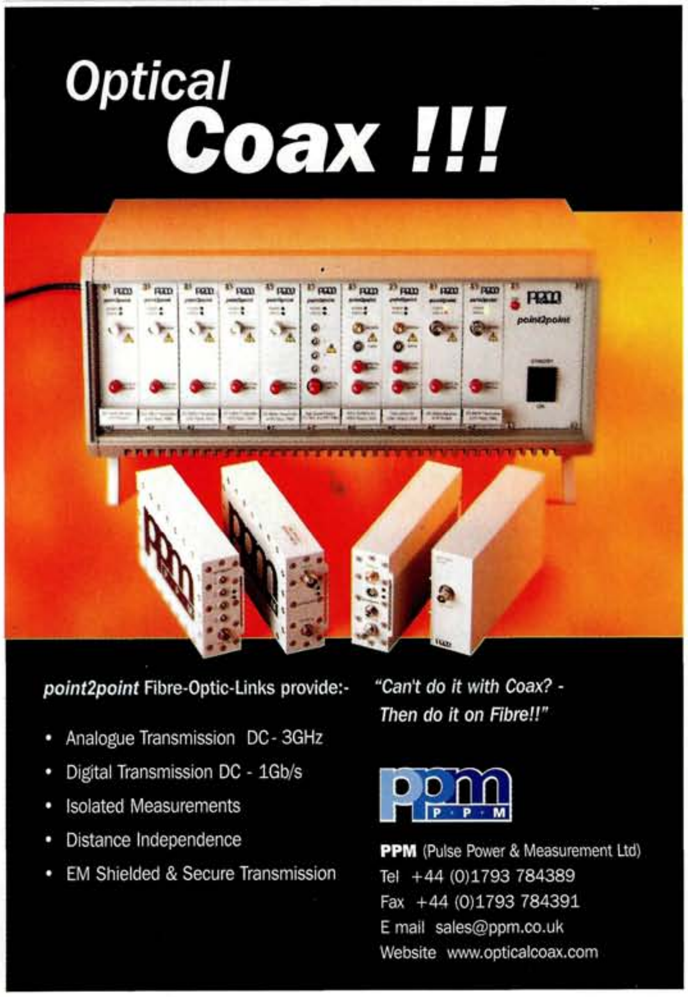
Potential applications for a recycled electron beam go beyond the world of particle physics, and the Fermilab result is attracting the attention of Free Electron Laser (FEL) builders around the world. FELs are powerful light sources that have many applications in molecular biology, materials science and chemistry. Rather than throwing away the electrons and their energy, recycling the beam could allow scientists to produce laser light with little electrical power input. Scientists at the University of California Santa Barbara have worked on Pelletron-driven FELs and beam recovery systems since the early 1980s using pulsed electron beams. The group has also looked at low-current continuous beam options, which were a precursor to the Fermilab project.

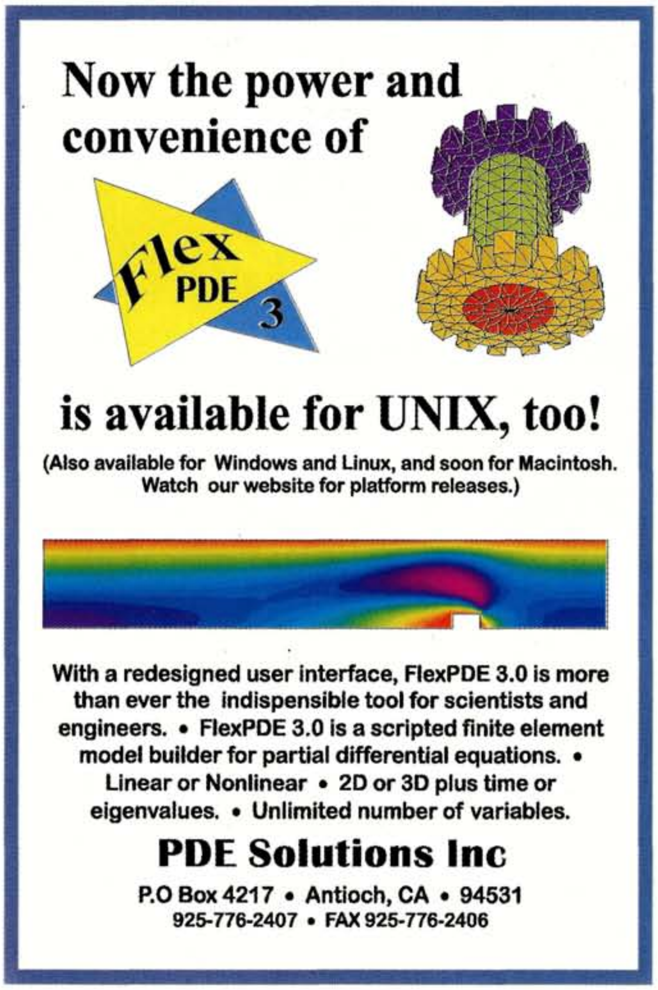
In particle physics, the future for electron cooling of antiproton beams looks bright. Stochastic cooling is limited, and to decrease beam temperature further, electron cooling is needed. Sergei Nagaitsev's team has taken a big step in that direction. Some day, cooling antiprotons may be as easy as switching on a fridge. Although there is still a long way to go, it might be time to start chilling some champagne.

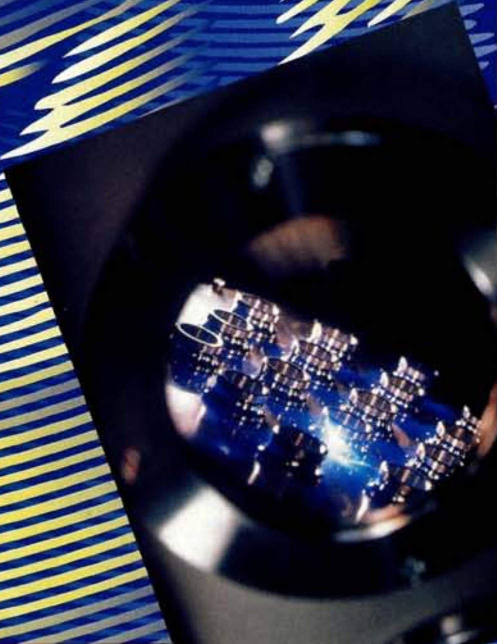
Further reading

http://www-ap.fnal.gov/ecool/.

Kurt Riesselmann, *Fermilab.*

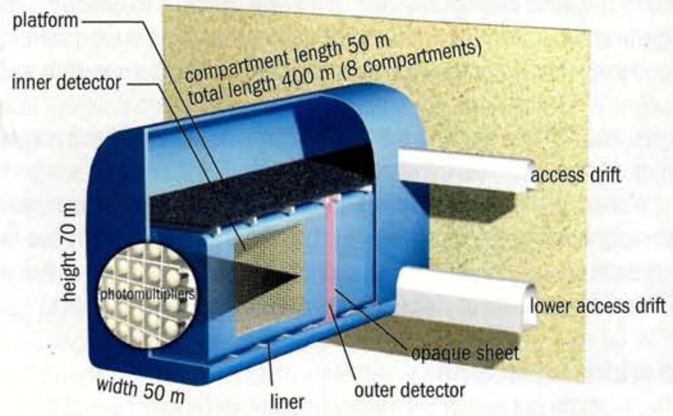




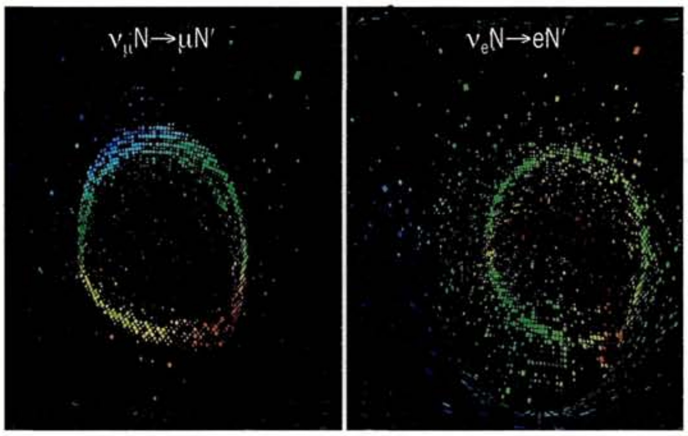


New detectors for physics at a new mass scale

Workshops on next-generation neutrino detectors and devices to detect possible nucleon decay have been held since 1999. **Jacques Bouchez** of the French atomic energy commission (CEA) reports on the most recent one, which was hosted by CERN in January.



From kilotons to a megaton: extrapolating from the highly successful Superkamiokande detector, plans are being drawn up for a detector about 20 times its size, named "HyperK" in Japan (seen here) or "UNO" in the US version.



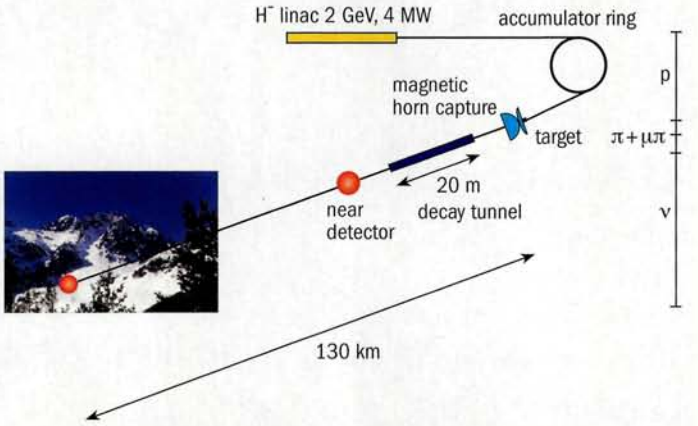
A muon neutrino interaction in a large water Cerenkov detector produces a muon, which leads to a sharp ring (left). Interactions of electron neutrinos produce electrons, which are identified by a fuzzy ring (right).

Great achievements have been made in recent years using the very large underground detectors initially designed to observe possible proton decays. The pioneers in this field were KOLAR in India, IMB in the US, Kamiokande in Japan, and NUSEX and Fréjus in Europe, the largest of which used an instrumented mass of the order of 1 kiloton. Through the non-observance of proton decays it was possible to reject the simpler versions of grand unification theories (which unify the weak, strong and electromagnetic interactions under the same theory). However, the actual results harvested were far more plentiful – a detailed study of atmospheric neutrinos (produced by cosmic rays in the Earth's atmosphere), which constituted the main background of the sought-after decays, provided hints of an anomaly in the flavour composition of these neutrinos. These measurements have since been refined by the 50 kiloton Superkamiokande detector, which has unambiguously established the existence of flavour oscillations, where muon neutrinos transform into tau neutrinos (*CERN Courier* September 2000 p8).

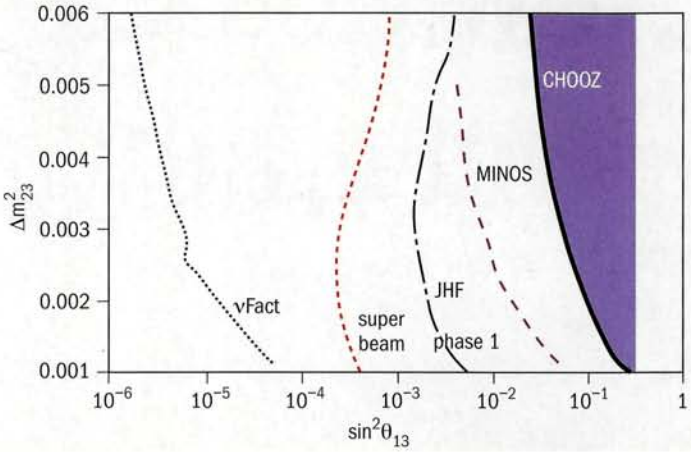
In 1987 the Kamiokande and IMB detectors, both water Cerenkov counters with an energy threshold of only a few MeV (made possible by the high level to which the water was purified), observed a small burst of neutrinos coming from supernova 1987A. This observation opened the way for neutrinos to be used as the messengers of the universe, an avenue since pursued by experiments such as AMANDA at the South Pole and ANTARES, which is currently being deployed in the Mediterranean Sea. Thanks to their very low energy thresholds, Kamiokande and Superkamiokande have also been able to measure the neutrino flux from the Sun and confirm that a large deficit exists, which also hints at neutrino oscillation. This interpretation was confirmed in spectacular fashion in June 2001 and reinforced this April by results from the Sudbury Neutrino Observatory's unique 1 kiloton heavy water Cerenkov detector in northern Ontario, Canada (p5), bringing positive evidence that neutrinos have mass.

These advances have led physicists to consider the possibilities offered by detectors not of 1 or 50 kilotons but of 1 megaton. Such devices would be capable of detecting proton decays at the very weak rates predicted by the latest supersymmetric grand unification theories. They would allow the tens of thousands of neutrino interactions produced by a supernova in our galaxy to be observed in a matter of seconds, thus supplying a wealth of information on explosion mechanisms. Such detectors could also act as targets for the neutrino superbeams currently being studied in Japan, the US and Europe.

▷



This layout of a speculative superbeam experiment from CERN shows the neutrino beam from a 2.2 GeV superconducting proton linac sent to the underground laboratory of Modane where a megaton detector would be protected from the cosmic background by Mont Fréjus.



This graph shows sensitivity for the small mixing angle θ_{13}, and the path of future experiments. From right: the present CHOOZ limit; the resolution achievable with MINOS; with the Japan Hadron facility to Superkamiokande beam; with a superbeam and megaton detector; and the resolution of a neutrino factory.

A workshop on megaton detectors was held at CERN in January to take stock of developments in this field. It brought together 65 participants from Europe, 25 from America and 10 from Asia. The speakers addressed three main themes in detail – proton decay, supernovae and superbeam-assisted neutrino oscillations – from both theoretical and experimental points of view. They described very large Cerenkov detector projects and the underground sites that would potentially house them. Japanese, American and French engineers discussed the problems associated with digging deep underground cavities with a volume of 1 million m^3. Suggestions were also made for alternatives to the Cerenkov technique. These included a liquid-argon detector along the lines of the ICARUS detector being prepared for Italy's Gran Sasso underground laboratory, but with a mass of up to 100 kilotons, and the specialized OMNIS detector, for which a UK–US collaboration proposes a lead target for supernova neutrinos. Fine-grained calorimetric detectors that may be envisaged for high-energy neutrino superbeams were also discussed.

On the experimental side, the workshop brought together two communities of physicists – those interested in neutrinos and those interested in non-accelerator physics – which now require similar types of detector. The convergence of several themes around a single detector capable of addressing them all can only strengthen these ambitious projects, which require worldwide collaborations. The theoretical implications of both proton decay research and a fine study of neutrino mixing are of fundamental importance as they open up windows beyond the Standard Model. These subjects can tell us about the structure of grand unification theories and baryogenesis, topics that must be understood to explain the domination of matter over antimatter in our universe.

As far as proton decay is concerned, in the $e^+\pi^0$ decay channel a 500 kiloton water Cerenkov detector can provide a sensitivity of 10^{35} years for the lifetime of the proton, compared with the current limit of the order of 5×10^{33} years. The $K^+\nu$ decay channel, favoured in certain scenarios, is a more difficult task for water Cerenkov detectors, and for this decay a more ambitious 100 kiloton liquid-argon detector could achieve a similar sensitivity.

With megaton detectors, the search for supernovae can be spread to neighbouring galaxies (we would observe some 20 neutrinos for an explosion in the Andromeda galaxy), and this has the virtue of increasing the rate of visible explosions to one every 10 years.

Neutrino superbeams

The most recent subject of study concerning the potential of megaton detectors relates to neutrino superbeams. These are similar to current neutrino beams in their method of production, but will use much more intense primary proton beams. Such proton supermachines are currently being considered for a range of applications including hybrid nuclear reactors and waste reprocessing plants, spallation neutron sources, intense sources of radioactive nuclei, and as the first component of a neutrino factory or a muon collider. These are low-energy machines (at the GeV scale) with about 1 MW of power (compared with several hundred kilowatts at machines such as CERN's SPS). These machines could supply superbeams of unrivalled intensity for neutrino research.

Today we know that neutrinos have a mass and that they mix, giving rise to the oscillation phenomenon. But there is one oscillation we have yet to observe – that which links muon and electron neutrinos with the frequency observed for atmospheric neutrinos. This oscillation is weak since it is governed by a mixing angle (θ_{13}) that, thanks to the French CHOOZ reactor-based experiment, we know to be lower than 10°. The entire neutrino factory programme hinges on the existence of this tiny oscillation. Neutrino superbeams will therefore be used to demonstrate its existence for θ_{13} values down to 1°. Such an observation would be reassuring before the construction of a neutrino factory can be launched.

To this end, the Japanese will soon have a 0.8 MW proton accelerator at the Japan Atomic Energy Research Institute, and in 2007 plan to send a neutrino superbeam to the Superkamiokande detector 300 km away (*CERN Courier* May p7). A sensitivity of 2.4° for θ_{13}

American physicist and long-time organizer of workshops on next-generation neutrino detectors and devices to detect possible nucleon decay, Chang Kee Young (left), enjoys the workshop dinner in the company of workshop secretary Tjitske Kehrer.

is expected. To get the sensitivity down to 1°, Japanese physicists envisage increasing the proton power to 4 MW after 2012 and building a 1 megaton detector, Hyperkamiokande, on the Kamioka site.

In Europe, CERN's superconducting proton linac (SPL) project aims to supply 2.2 GeV protons at 4 MW by 2012. The optimal baseline for studying the oscillation in question corresponds to the distance between CERN and the Fréjus laboratory. The forthcoming construction of a gallery parallel to the existing road tunnel at Fréjus provides the opportunity to dig a cavern capable of housing a megaton detector comparable to the UNO underground nucleon decay and neutrino observatory being designed in the US. Such a project would provide a sensitivity of 1° on θ_{13}. The SPL would also allow long-lived radioactive nuclei to be produced and stored in storage rings whose straight sections, aimed at the Fréjus underground site, would supply electron-neutrino beams that, in conjunction with the muon-neutrino superbeam, would open up the possibility of studying time-reversal symmetry-breaking in the neutrino sector.

US scientists are looking into using the beam that will be sent from Fermilab to the MINOS detector (*CERN Courier* April p7) in 2005 and increasing the proton power from 0.4 to 1.6 MW. A superbeam is also being considered at Brookhaven. It will still be necessary to dig a cavity to house a very large detector, and this could be done at the Homestake mine (which has recently been transferred to the Department of Energy) or elsewhere. The current Fermilab beam will provide a sensitivity of 4° on θ_{13} using a 5–20 kiloton detector. Future projects could lower this limit to around 1.5° by using either UNO or a 70 kiloton liquid-argon detector.

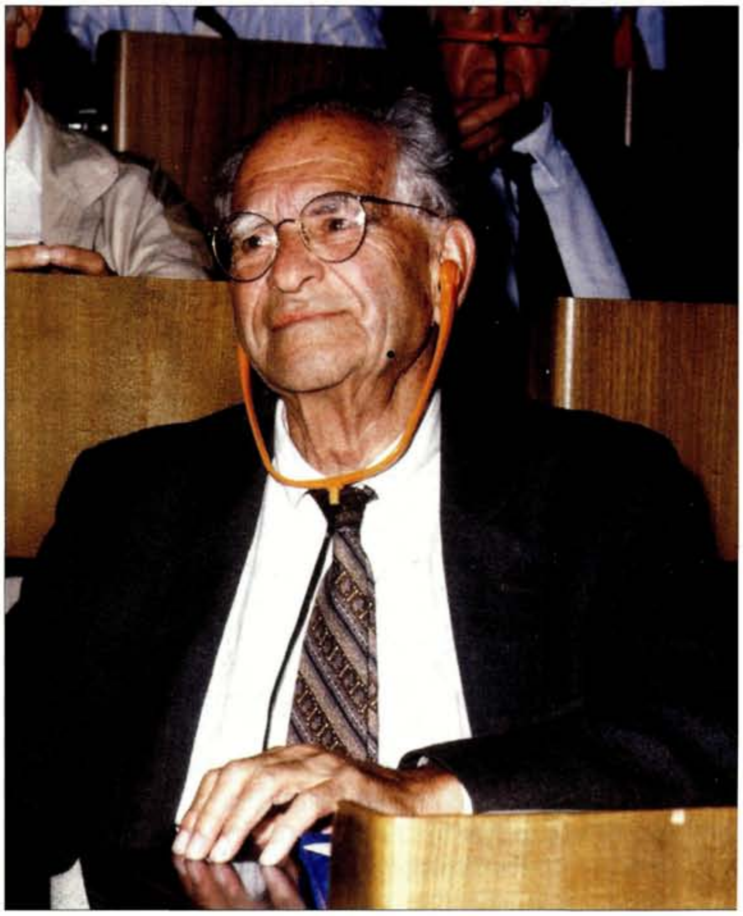
Looking to the future

Although none of these plans has yet been approved, it seems likely that such a project will be realized. It will form a key component of the global fundamental physics infrastructure of the future, and its location remains to be decided. Europe has a strong track record in the field, but the Japanese project, in its first phase using the Superkamiokande detector, is currently the most advanced. The workshop held at CERN provided the opportunity for a first round of discussions between Europeans, Americans and Japanese with a view to worldwide collaboration around this Japanese first phase. If no oscillation is discovered it will then be necessary to move into the megaton phase, and the siting of such a detector is, for the moment, an entirely open question. Multipurpose megaton detectors will address many open physics issues, and promise, in parallel to CERN's Large Hadron Collider and the electron–positron linear colliders, to provide exciting results in the decades to come.

Jacques Bouchez, *CEA Saclay.*

Victor Weisskopf: looking ba

Wolfgang Kummer pays tribute to former CERN director-general Victor Weisskopf, who died on 22 April at the age of 93.



In the spring of 1960, CERN's proton synchrotron (PS) was delivering its first beams. In the middle of this critical phase for European particle physics, CERN's director-general, Cornelis Bakker, was killed in an aeroplane accident. Although CERN's governing Council acted swiftly by appointing John Adams as acting director-general, this step necessarily prolonged the period that in retrospect may be characterized by the dominance of brilliant accelerator scientists.

At the same meeting in June 1960 which confirmed Adams' appointment, the "modern" structure of research committees with at least as many members from outside as inside the laboratory was also approved, and the search for Bakker's successor began. In any case, Adams would have to leave CERN to take up an important position in the UK. The discussion centred around two eminent scientists – Hendrik B G Casimir and Victor F Weisskopf. Weisskopf was already well known at CERN, having worked in the Theory Division from 1957 until 1958. With characteristic modesty he doubted his talents for such a position, but he expressed his willingness to act as a director of research. Casimir made it clear that his position with Philips would make it very difficult to take over the post of CERN director-general.

During the following months, a formal nomination procedure of candidates in the Scientific Policy Committee (where Weisskopf was formally proposed by Greece), extensive deliberations and successful persuasion led to Weisskopf's election by Council on 8 December 1960. His term was envisaged to run from 1 August 1961 until 31 July 1963, but this was later extended until 31 December 1965. It is no exaggeration that in that period, under Weisskopf's guidance, the future of CERN was shaped for many years to come.

CERN was fortunate to be led by a personality such as Weisskopf at this time. The difficult situation for the laboratory, whose harmonious development had been interrupted at a critical point in its evolution, needed a director-general with special abilities. Every fast-developing scientific organization must cope with the effects that its very size has on its aims. Scientists with little inclination towards administrative matters must submit to administrative and bureaucratic rules, especially in an international organization.

The selection of collaborators and the future style of work is determined at the stage of most rapid initial growth, because the natural inertia of a structure made up of human beings makes it extremely difficult later on to rectify earlier mistakes. At the end of 1960 the number of CERN staff and visiting scientists was 1166; this rose to 2530 at the time of Weisskopf's departure in 1965.

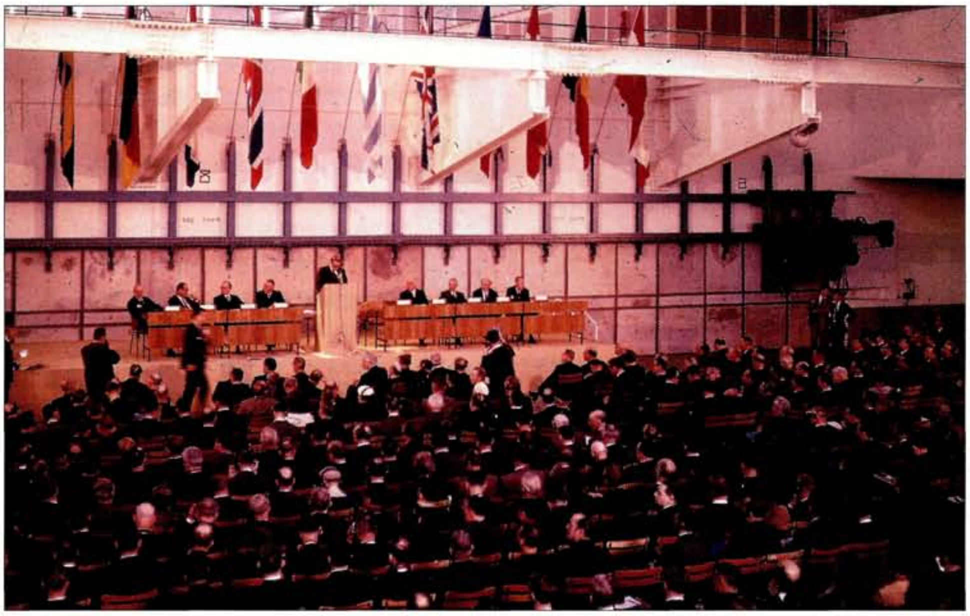
Therefore, at this time in the history of CERN even more than at others, the director-general had to be a physicist who set the direction of the laboratory towards an absolute priority of science. To achieve this he had to rely on a high reputation in his field, together with an ability to deal with the administrative needs of a rapidly growing organization. CERN was placed in the delicate position of having to restore European research parity with that of the US, profiting as much as possible from the experience gained already in the US, while retaining the European character of the new organization.

Distinguished career

Born in Vienna in 1908, Weisskopf followed a truly cosmopolitan scientific career as a theoretical nuclear physicist, working with the most important founding fathers of modern quantum theory, and contributing important results himself. He was familiar not only with Germany (his collaboration with Heisenberg), Switzerland (with Pauli) and the Nordic countries (with Niels Bohr at Copenhagen) from extended stays in these countries, but also with Russia (with Landau at Kharkov), and eventually accepted a position at Rochester, US, in 1937.

His qualities as a leader of a technological project in which theoretical physics only played an auxiliary role was exploited in the Manhattan Project (Los Alamos) towards the end of the Second

ck on a distinguished career



Left: Weisskopf at a CERN event to mark his 80th birthday in 1988. Above: the formal inauguration of CERN's PS proton synchrotron in 1960. During Weisskopf's time as director-general, the project was given the necessary infrastructure and improvements to make it the centre of a flourishing research programme.

Wolfgang Kummer (right) of Vienna Technical University, president of CERN Council from 1985 until 1987, congratulates Weisskopf at his 80th birthday celebrations.

World War. The European background of many of his collaborators there was an excellent preparation for the task of leading a European laboratory. Even when pursuing the same scientific goal, the individual style of scientists varies greatly, especially if they are of different nationalities.

After the war, as professor at the Massachusetts Institute of Technology (MIT), Weisskopf resumed contacts with Europe, which was slowly recovering from the dark years. In addition to his outstanding qualifications as a theoretical physicist and as a leader of scientific enterprises, Weisskopf possessed a special quality that physics in Europe is lacking to a large degree. Possibly because of the general structure of secondary education in Europe, mathematics plays an extremely important role in theoretical physics. Hence theoretical physics frequently becomes almost a mathematical discipline, with the physical ideas being submerged by an overemphasized mathematical formalism. Among experimentalists this can cause uncertainty or even refusal as far as the judgement of theoretical ideas is concerned.

In the US only a handful of gifted physicists knew how to bridge this gap. Weisskopf was a master of this. Before coming to CERN, he had already taught a generation of nuclear physicists how to pick out the essential physical ideas which are always transparent and simple (once they have been understood), but which may be hidden under many layers of mathematical formalism. The true masters of mathematical physics always knew how to isolate the physical content of complicated mathematical arguments, but unfortunately the majority of theoreticians in Europe are to this day sometimes overfascinated by the mathematical aspects of the physical description of nature.

The understanding of physical phenomena often does not even require the use of precise formulae. Students at MIT had invented the notion of the "Weisskopfian", which naturally takes care of numerical factors such ± 1, i, 2π, etc. Also in the book *Theoretical Nuclear Physics* by John M Blatt and Weisskopf, which remains a standard textbook to this day, the emphasis on simple, physically transparent arguments by Weisskopf and the more precise, but more formal presentation topics by his co-author are clearly discernible.

From MIT to CERN

To facilitate his transition from MIT to CERN, and to make optimal use of his period as director-general of CERN, Weisskopf became a part-time member of the CERN directorate in September 1960, dividing his time equally between MIT and CERN. Unfortunately in February 1961 he was involved in a traffic accident, and needed complicated hip surgery and a long stay in hospital. At the start of his term as director-general and less so during a large part of his stay in Geneva, Weisskopf was hampered in his movement. I vividly remember his tall figure walking with crutches through the corridors, obviously in pain, but he never lost his friendly disposition.

The first progress report to CERN Council in December 1961 clearly reflects the situation of CERN at the beginning of the Weisskopf era. Two years after the first beam at the PS, ▷

breakdowns and construction work on beams had prevented completely satisfactory use of this machine, whereas the smaller synchrocyclotron was working very well. Research director Gilberto Bernardini aptly remarked that European researchers with a nuclear physics background had had little difficulty orienting their work towards the synchrocyclotron. The PS, on the other hand, was a novelty for physicists, so certain mistakes had been made, particularly with insufficient time for preparation of experiments.


Weisskopf assured CERN that it would have the ISR, the world's first proton collider. At the machine's inauguration ceremony on 16 October 1971, ISR project leader Kjell Johnsen (right) is seen handing a symbolic key to Council president Edoardo Amaldi. Also on the podium are (left to right) Weisskopf, French Secretary of State Marcel Antonioz, CERN director-general Willibald Jentschke and Werner Heisenberg.

Nevertheless, 1961 was the first year with a vigorous research programme at CERN. Not surprisingly, organizational problems and difficulties in the management of relations with universities in the member states became acute. It was recognized that at least track chamber experiments required the collaboration with institutes outside CERN for the scanning, measuring and evaluation of data. For electronic experiments such a need was not yet seen.

The construction of the 2 m bubble chamber was continuing well, but experimental work was still done on the basis of data from the tiny 30 cm chamber and with the 81 cm Saclay chamber. The heavy liquid chamber had looked in vain for fast neutrinos in the neutrino beam. Simon van der Meer's neutrino horn, intended to improve this situation, had just finished its design stage.

Addressing Council for the first time on the problem of the term future of CERN, the new director-general already strongly emphasized two directions of development which, as subsequent history has shown, were decisive for the laboratory's future success. One project, based upon design work by Kjell Johnson and collaborators, foresaw the construction of storage rings; the other was aimed at a much larger 300 GeV accelerator.

The financial implications of such proposals and the necessity to formalize budget preparations more than a year in advance led to the creation of a working group headed by the Dutch delegate, Jan Bannier. From this group emerged the remarkable "Bannier procedure", under which firm and provisional estimates of budget figures for the coming years are fixed annually. It was decided that the cost variation index should not be provided automatically, and that Council should make a decision on this index each year.

First research successes

The discovery that different neutrinos came from electrons and from muons was made in 1962, not at CERN, but at Brookhaven. In retrospect it was clear that CERN's attempt was bound to fail for technical reasons. However, the disappointment did not overshadow some remarkable successes in the first full year of CERN under Weisskopf's leadership. The shrinking of the diffraction peak in elastic proton collisions was first seen at CERN – in agreement with the new ideas of Regge pole theory, which had also originated in Europe. The cascade antihyperon was found simultaneously with Brookhaven, but the beta decay of the π meson and the anomalous magnetic moment of the muon were "pure" CERN discoveries. For the first time development of a novel type of scanning device for bubble-chamber pictures (the Hough–Powell device) which started at CERN was taken over by US institutions. However, Weisskopf had to complain to Council about the "equipment gap" at the PS, caused by the lack of increase in real value of the budgets in 1960 and 1961.

In some sense, the most important experimental result of 1963 was the determination of the positive relative parity between the Λ and the Σ hyperon, obtained at CERN in the evaluation of data from the 80 cm bubble chamber. This result was in disagreement with some much-publicized predictions from Heisenberg, and gave further support to the growing confidence in internal symmetries. Despite a long shutdown of the PS in order to install the fast ejection mechanism giving extracted beam energies up to 25 GeV, it now began its reliable and faithful operation, which to this day is the basis of all accelerator physics at CERN. Thanks to a neutrino beam 50 times more intense than that at Brookhaven, the first bubble-chamber pictures of neutrino events were made.

Parliament

In 1963 a new body of European physicists was created under the chairmanship of Edoardo Amaldi. Taking into account future plans outside Europe, this body strongly recommended the storage ring project, as well as the plans for a 300 GeV accelerator. CERN Council authorized a "supplementary programme" for 1964 to study the technical implications of these two projects. This Amaldi Committee was set up as a working group of CERN's Scientific Policy Committee, and was the forerunner of the European Committee for Future Accelerators (ECFA), which was founded three years later, again under Amaldi's chairmanship. ECFA has been the independent "parliament" of European particle physicists ever since.

Weisskopf's clear vision of the importance of education resulted in his legendary theoretical seminars for experimentalists at CERN. I had the privilege of collaborating with him at that time on some aspects of the preparation of these seminars, and my view of theoretical physics has been decisively influenced by his insistence on stressing the physical basis of new theoretical methods.

From 1964, CERN's synchrocyclotron started to concentrate on nuclear physics alone, whereas the PS was now the most intensive and most reliable accelerator in the world. Another world premiere was the first radiofrequency separator, allowing K-meson beams of unprecedented energy. At CERN, also for the first time, small online computers were employed in electronic experiments. A flurry of fluctuating excitement was caused by the analysis of muon and muon-electron pairs in the neutrino events seen in the spark chamber. When it turned out that they could not have been produced by the intermediate W-boson (to be discovered at CERN exactly 20 years later at much larger energies), these events were more or less disregarded. Only 10 years later, after the charmed quark was found in the US, was it realized that these events were examples of charm decay – admittedly very difficult to understand on the basis of the knowledge in 1964. The unsuccessful hunt for free quarks also started in 1964, together with the acceptance of the concept of quarks as fundamental building blocks of matter.

Weisskopf (rear) is seen here in 1964 with CERN founding father Pierre Auger (right) and Jan Bannier, who was the Netherlands delegate from the inception of CERN until 1977, and who chaired an important working group which established new funding procedures for CERN. Bannier served as president of CERN Council from 1965 until 1967.

Making decisions

Thanks to Weisskopf's relentless prodding in 1964, CERN member states were convinced that the time was ripe for a decision on the future programme of CERN. Rather than rush into an easier but one-sided decision, Weisskopf was careful to emphasize the need for a comprehensive step involving three elements:

- further improvements of existing CERN facilities, comprising among other things two very large bubble chambers containing respectively 25 m^3 of hydrogen and 10 m^3 of heavy liquid;
- the construction of intersecting storage rings (ISR) on a new site offered by France adjacent to the existing laboratory;
- the construction of a 300 GeV proton accelerator in Europe.

Although a decision had to be postponed in 1964 – due to the difficult procedure to be set up for the site selection of the new 300 GeV laboratory – optimism prevailed that such a decision would be possible in 1965. After recommending the ISR supplementary programme in June 1965, the formal decision by Council was finally taken in December 1965.

The novel ISR project had no counterpart elsewhere in the world. Although experience had been gained at the CESR test ring for stacking electrons and for high ultravacuum, this decision reflected the increasing self-confidence of European physics. Thus the foundation was laid for the dominating role of European collider physics which eventually led to the antiproton–proton collider, the LEP electron–positron collider, and the LHC proton collider. At the same time as the ISR project was authorized, a supplementary programme for the preparation of the 300 GeV project was also approved.

When Weisskopf's mandate ended at the end of 1965, particle physics had passed through perhaps its most important stage of development. From being an appendix to nuclear physics and cosmic-ray experiments, it had become a field with genuine new methods and results. The many new particle states disentangled by CERN and other laboratories gradually found a place in a framework determined by a new substructure, the quarks. In addition, many new discoveries in weak interactions, and especially at the unique neutrino beam of CERN, showed close similarities between weak and electromagnetic interactions, and paved the way for their unified field theory.

Human touch

Much of the enthusiasm that enabled CERN experimentalists to participate so successfully was due to Weisskopf. He made a point of regularly talking to the scientists, and more than once he visited experiments during the night. These frequent contacts on the experimental floor with physicists at all levels gave CERN a new atmosphere and created contacts between different groups – something which was lacking before. Weisskopf himself was aware of this. When asked on his departure from CERN what he thought his main contribution had been, he replied that the administration and committees would have functioned perfectly well without him, but that he thought he had given CERN "atmosphere".

During the Weisskopf era, directions were set for the distant future. Almost 40 years later, the basis of the CERN programme is still determined by those decisions taken in 1965. How could Weisskopf have been so successful in his promotion of CERN in Europe, at a time when there was always at least one member state with special problems regarding the support of particle physics and CERN?

Politicians must trust valued experts. Weisskopf achieved so much for the laboratory because he was deeply trusted by the representatives of the member states. Although enthusiastic in the support of new ideas in scientific projects, he never lost his self-critical attitude, and was quick to try to understand opposing points of view in science and in scientific policy. The enthusiasm, honesty and modesty of Victor Weisskopf have proved to be a rich inheritance, and have determined the future of CERN.

An obituary for Victor Weisskopf appears on p42.

Wolfgang Kummer, *Vienna Technical University.*

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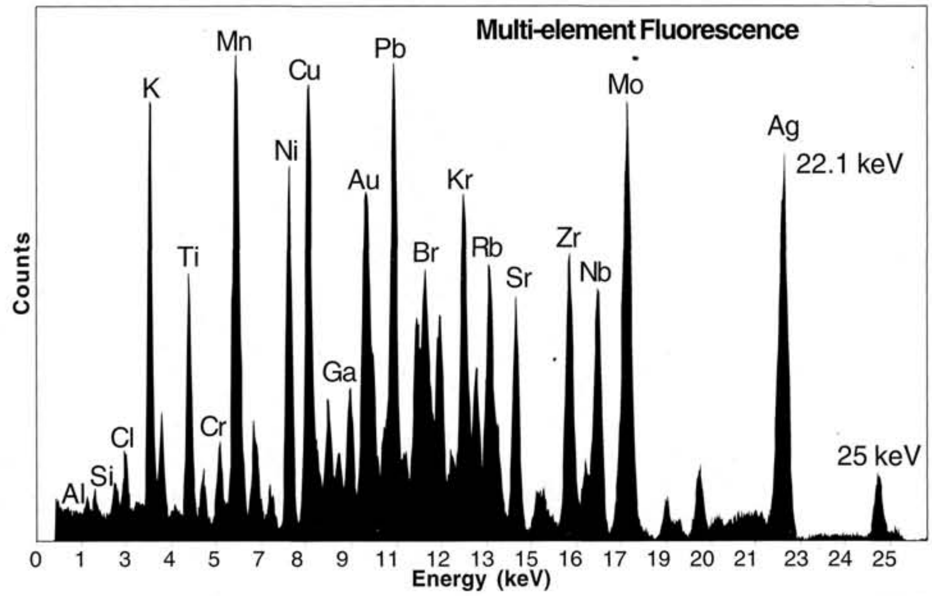

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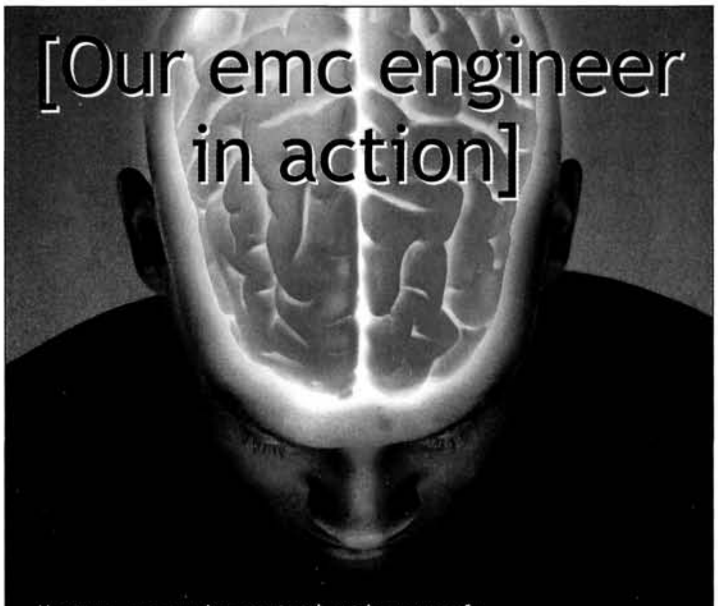

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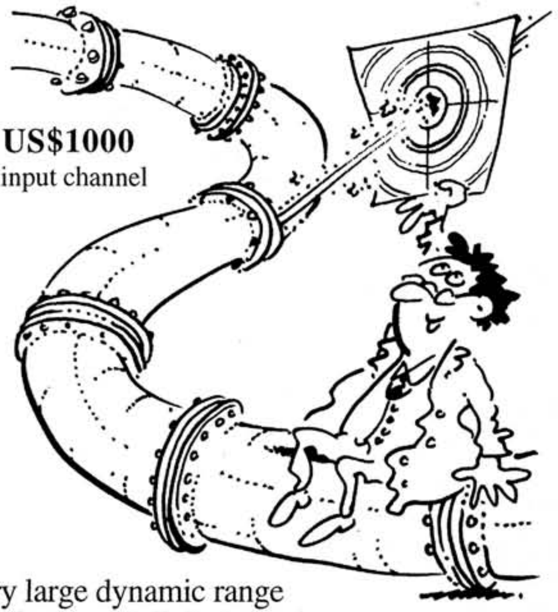

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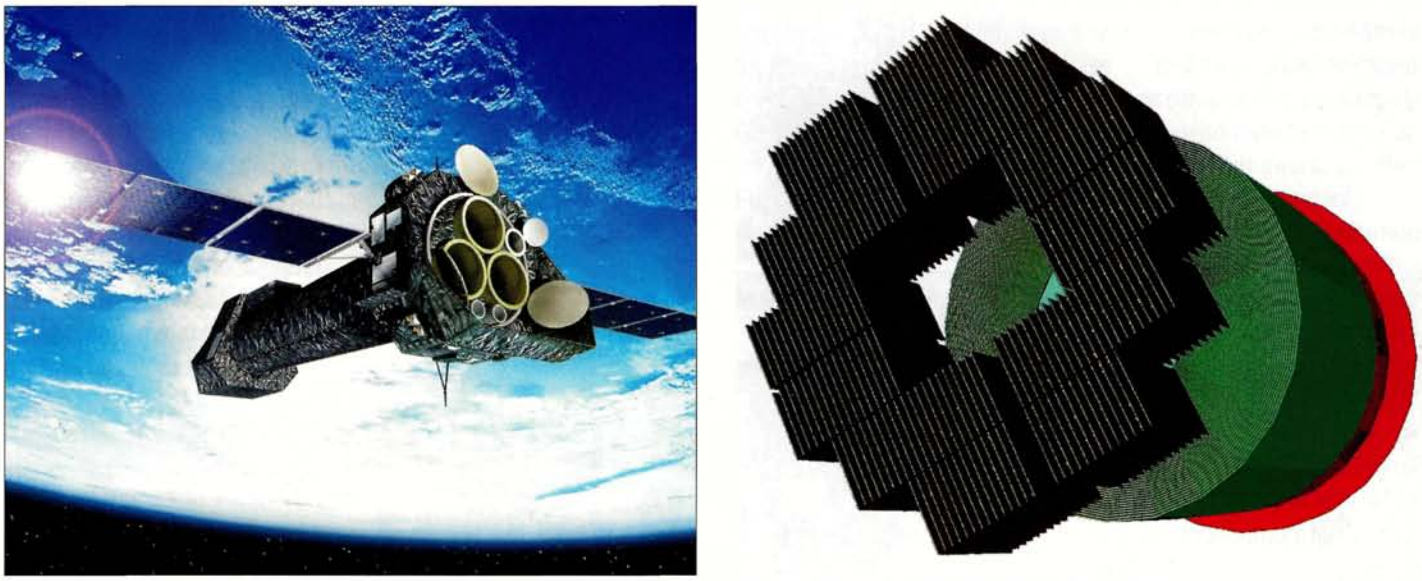
Particle physics software aids space and medicine

Geant4 is a showcase example of technology transfer from particle physics to other fields such as space and medical science, argue **Maria Grazia Pia** and **Jürgen Knobloch**.



ESA's X-ray Multi Mirror mission (XMM) telescope (left) and its geometry implemented in Geant4. (ESA.)

Simulation programs play a fundamental role in optimizing the design of particle physics experiments. In the development of reconstruction programs, they provide the necessary input in the form of simulated raw data. In the analysis process they are required to understand the systematic effects resulting from detector resolution and acceptance, as well as the influence of background processes. The predecessors of the Geant4 toolkit – which were written in the now almost obsolete Fortran language – were successfully used at CERN for experiments at the laboratory's Large Electron–Positron collider and for the design of experiments for the Large Hadron Collider (LHC).

Geant4 was launched as an R&D project in 1994 to demonstrate the suitability of object-oriented programming technology for large software projects in particle physics. The initial collaboration of members of particle physics institutes around the world has since been joined by scientists from the European Space Agency (ESA) and members of the medical community.

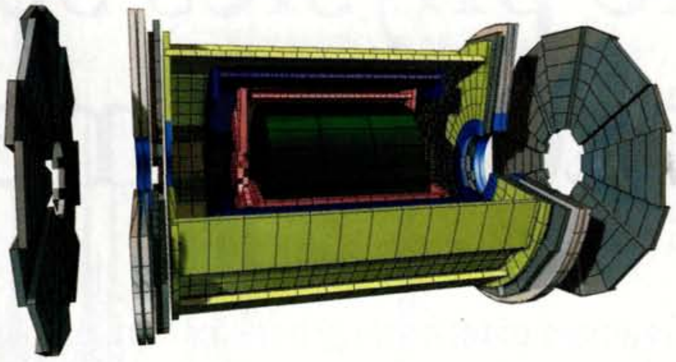
The Geant4 software toolkit was designed to simulate particle interactions with matter for particle physics. It contains components to model in detail the geometry and materials of complex particle detectors. The simulated particles are propagated through magnetic and electrical fields and through the materials of the detectors. The core of the program contains information on numerous physics processes that govern the interactions of particles across a wide energy range. Visualization tools and a flexible user interface are available as separate components. Rigorous software engineering makes Geant4 open to change in a rapidly evolving software environment, while at the same time ensuring that it can be easily and fully maintained over the lifetime of large-scale experiments.

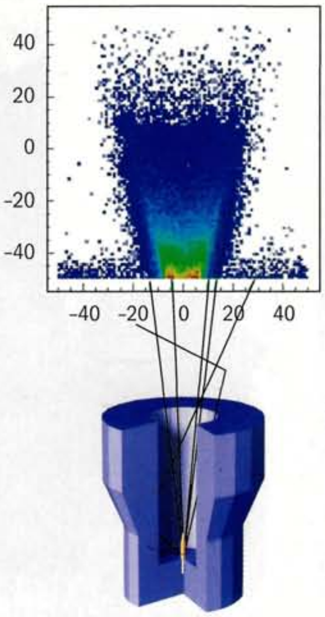
Accurate simulations

Geant4 was publicly released in December 1998 and has since been further developed. All Geant4 code and documentation is openly available via the Web. At a recent conference on calorimetry in particle physics at the California Institute of Technology, US, the quality of Geant4's simulation of the response of electromagnetic and hadronic showers in calorimeters was demonstrated in comparisons of test-beam data with simulation. One of the speakers for the ATLAS experiment (currently in preparation for the LHC) concluded that Geant4 is mature enough as a toolkit, with sufficient ▷

physics for electromagnetic showers implemented, to be considered for large-scale detectors.

Other speakers reported on the first results of ongoing comparison projects of hadronic interactions in calorimeters. These first results look very promising. In fact, Geant4 is used in production for the BaBar experiment at the Stanford Linear Accelerator Center, US, and more than 300 million events have been simulated already. This, together with the fact that Geant4 applications are as fast as similar Fortran-based applications, shows that object-oriented technology is capable of standing up to the challenge.





Above: the ATLAS experiment for CERN's forthcoming LHC has used Geant4 to simulate its muon detectors. (ATLAS collaboration.)
Left: a superficial brachytherapy device and the resulting dose distribution, simulated with Geant4 and analysed with CERN's Anaphe system. (National Institute for Cancer Research, Genoa/ INFN Genoa.)

Simulation is equally important in space-based astroparticle physics. Most space probes need to be able to operate for many years without the possibility of physical repair after launch. It is therefore essential to be able to predict the behaviour of all components in the space environment, and in particular to judge the likely effect of radiation on on-board electronics and detectors. The availability of the ISO standard for the exchange of product data (STEP) interface in Geant4 is especially advantageous, as the use of professional computer-aided design tools is commonplace in the aerospace industry.

Geant4 was first used for space applications by ESA in 1999, when ESA and the US National Aeronautics and Space Administration (NASA) each launched an X-ray telescope. Both telescopes follow highly eccentric orbits, reaching at their far point one-third of the distance to the Moon. NASA's Chandra was launched in July 1999. During the initial phase of operation, some of the front-illuminated charge-coupled devices (CCDs) experienced an unexpected degradation in charge-transfer efficiency. ESA scientists, who had been planning to launch their X-ray multi-mirror (XMM) Newton Observatory in December 1999, needed to understand the possible origin of this problem to protect their detectors from similar damage.

The geometries of both telescopes, including the concentric mirror systems, were described using the Geant4 toolkit. Particles, in particular low-energy protons trapped by the Earth's magnetosphere in the Van Allen radiation belts, were simulated entering the apertures of the telescopes. The simulation revealed that these particles are scattered at shallow angles from the mirror surfaces and are focused onto the surface of the sensitive CCD detectors, completely bypassing the collimators and other elements that were supposed to shield the devices.

This simulation explained why NASA's emergency measure to move the detectors out of the focal plane during the passage of the radiation belt prevented any further degradation. With the Geant4 study's input, the operational procedures of XMM Newton were arranged so that the detectors were powered off during the passage of the radiation belts for about 8 h of the 48 h orbit. Both telescopes now deliver magnificent scientific data.

The dose estimation by simulation of the International Space Station (ISS) radiation environment project (known as DESIRE) aims to use Geant4 to calculate radiation levels inside the Columbus ISS module and to estimate the radiation doses on the astronauts. Apart from assessing the risk involved in space missions from exposure to radiation, Geant4 plays an important role in evaluating the performance of particle detectors. For the ESA BepiColombo mission to Mercury, currently planned for launch in 2009, detectors will analyse the spectrum of fluorescence from planetary material induced by solar flares. Using Geant4, the spectra and expected detector response have been simulated and the optimization of the detector technology in the severe radiation environment close to the Sun is under way.

Medical applications

Geant4's extended set of physics models, which handle both electromagnetic and hadronic interactions, can be used to address a range of medical applications from conventional photon-beam radiotherapy to brachytherapy (using radioactive sources), hadron therapy and boron neutron capture therapy. The tools for describing geometries, materials and electromagnetic fields can precisely model diverse real-life configurations. An interface to the Digital Imaging and Communications in Medicine (DICOM) standard will soon make it possible to import computer tomograph images directly into a Geant4 geometrical model. The quality-assurance methods applied in Geant4, its open-source distribution and its independent validation by a worldwide user community are particularly important in the medical domain.

> The quality assurance methods applied in Geant4, its open-source distribution and its independent validation by a worldwide user community are particularly important in the medical domain.

Geant4 can play a significant role in estimating the accuracy of radiotherapy treatment planning, exemplified by comparisons of its simulations with commercial software and experimental data. One study exploited Geant4's accurate simulation of electromagnetic interactions down to very low energies to account precisely for effects resulting from source anisotropy. The same method has also been applied to calculate dose distribution for certain superficial brachytherapy applicators where no other treatment-planning software is available.

Other studies have exploited Geant4's capability for precision-modelling of geometries, materials and physics processes to provide accurate dose distributions in heterogeneous geometries. High-precision dose evaluation is important because, in some tumour sites, a 5% under-dosage would decrease local tumour-control probability from around 75% to 50%. As with typical physics applications, in which simulation is used to optimize the design of particle detectors, Geant4 has allowed the optimization of brachytherapy seeds, improving the treatment's effectiveness while sparing surrounding healthy tissue. The suitability of Geant4 has been demonstrated in advanced radiotherapy techniques, such as intra-operatory and intensity-modulated radiotherapy. Several projects also apply Geant4 in the domain of radiodiagnostics. Possible future extensions include modelling the effects of radiation at the biomolecular level.

Geant4 is developed and maintained by an international collaboration of physicists and computer scientists. The open and collaborative relationship between the development team and its user communities has led to a two-way transfer of technology, with users from fields other than particle physics actively contributing. The expertise of the biomedical and space user communities in simulation has resulted in many significant contributions to Geant4 in areas such as testing and validation, as well as extensions of functionality. These developments bring valuable enhancements to Geant4's applications in particle physics.

Further reading

More information is available at http://cern.ch/geant4-tt.

Maria Grazia Pia, *INFN Genoa, and* **Jürgen Knobloch**, *CERN.*


The European Physical Journal A
The European Physical Journal B
The European Physical Journal C
The European Physical Journal D
The European Physical Journal E
Soft Matter
EDP Sciences
Springer

New tools help libraries to harvest literature

Electronic publishing makes material accessible to more people, but this is not always a problem-free process. **Ingrid Geretschlager** and **Jocelyne Jerdelet** describe how the CERN library got to grips with a bewildering array of formats and approaches.

For more than 40 years, CERN's library has collaborated with institutes and universities worldwide to collect carefully documented results of scientific research. Initially, this prodigious output was all on paper, and the CERN library regularly received papers from scientists at these institutes and universities via mailing lists. Because of its visibility, CERN received far more of this material than most institutes, and a major attraction of a visit to CERN was to peruse the latest pre-prints on view in the library.

With the advent of electronic publishing, more and more documents became accessible online. To complete the picture, documents still received on paper were scanned to offer Web access. Today this practice is diminishing as grey literature (library-speak for pre-prints and other material not published by a publishing house) in science, particularly in physics, is more widely available in electronic form.

Times have changed since Herbert Coblans (right), CERN librarian in 1961, showed visitors CERN's pre-print collection.

Saving time and money

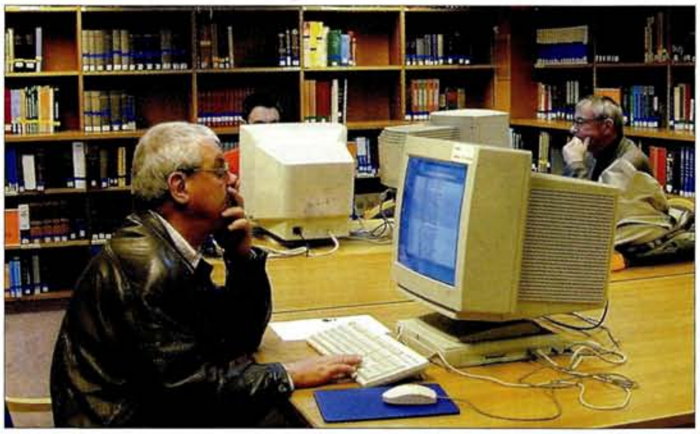
Having distributed documents for some years both on paper and electronically, many institutes have now chosen to use only the electronic route. This offers undeniable advantages: cost savings; quick and easy distribution; full text availability at a distance; the possibility of enriching the catalogue; and cheap online access, for example. The virtual library has become a reality. Paper documents are increasingly rare, and authors generally prefer to submit their papers electronically. Most major research centres also offer Web access to their documents and have ceased to send out paper copies via mailing lists, encouraging other scientific libraries and the researchers themselves to consult their Web pages and databases.

Faced with this evolution, library acquisition policies must be reconsidered and adapted to the new standards of scientific information dissemination.

The problem in this new context is the multiple consultation of databases. To find a document, a researcher must consult many resources, which is a time-consuming and tedious task with often dubious results. To facilitate searching and to offer users a single search interface, the CERN library chose to import as many electronic documents as possible. In 1999 the information support team introduced its Uploader program, which allows automatic importation of bibliographic records extracted from several sources. This has led to three main advantages: papers can now be found directly from institutes' sites; the number of documents received from different research centres has increased; and new databases have been explored.

From any database or Web page, Uploader formats the records and adapts them to the cataloguing format used at CERN – Machine Readable Cataloguing (MARC). The program also updates existing records, searching for duplicates before importation. Which databases to explore was a difficult choice. First, the websites of all institutes from which CERN still received paper documents were consulted to see if the institutes offered the same documents online. This showed that more or less all institutes offer their publications on the Web in some form.

This study also revealed that CERN received, via mailing lists, ▷



The display shelves (left) that used to serve up pre-prints to CERN library users have been replaced by computer terminals.

only a third of the documents available on the Web. There are two possible explanations for this: perhaps for economic reasons research centres make a selection of which documents to send out; and mailing lists are not always kept up to date. The need for automatic importation of these documents from websites became obvious, but there were technical problems to overcome.

Diverse sources

Sources can be divided into two types: Web pages and online databases, which are handled differently. Medium-sized research centres and information sources that do not offer online databases generally offer Web pages presenting the work of their researchers (usually theses). Searching can be primitive if no real search engine is implemented. The number of documents is also often limited. This means that manual submission of the full text of the documents is the most efficient way of acquiring the documents. The constant evolution of Web pages also argues against automatic importation. Since alerting services for such sites are rare, the CERN library set up its own alert system for some 80 information sources at 30 institutes. This tells the librarians when the available information changes, allowing them to acquire new documents as they become available.

Online databases often allow multicriteria searching. In contrast to Web pages, however, it is usually impossible to put an alert on the search results. This means that for online databases that do not offer an alert system, a different approach is needed. The method adopted by the CERN library is a monthly or annual search.

The Uploader program helps CERN's librarians to manage an effective document supply service, but the huge diversity of online information sources means that there is no shortage of work for the librarians. Document structure can vary from page to page, or even within the same page. In the majority of cases the pages are therefore presented as free text with no common structure. With virtually no constraints imposed by databases, no common import protocol is possible, and material must be input manually. Inconsistencies can arise when Web pages are not handled rigorously, causing confusion in bibliographic cataloguing – most frequently for authors' names. Some databases allow external submission of documents and bibliographies, which results in many irregularities and loss of homogeneity in the presentation of the documents. Information can be presented in multiple forms. Pre-print numbers, for example, can appear as IUAP-00-xxx (number not yet attributed), CERN-TH-2K-1 (instead of CERN-TH-2000-1) or MPS15600 (instead of MPS-2000-156). Vital pieces of information, such as collaboration lists, are sometimes missing. All of these problems require traditional librarianship skills. CERN's library aims to offer a coherent and homogeneous database, validation and improved metadata. Knowledge databases recognize retrievable work and provide links to relevant articles on the Web, while a computer program appends and corrects bibliographic data, keeping manual checking to a minimum.

Electronic advantage

There is no doubt that electronic uploading saves a considerable amount of time compared with manual submission. It has also greatly increased the number of documents made accessible and available at CERN. However, source databases must be carefully selected. The richer the database, the more time-consuming the procedure becomes. In addition, the volatility of Web pages requires close follow-up. Automatic importation has taken over from manual submission, but specialist monitoring remains essential.

The electronic approach was initially investigated at CERN on a test basis, to ascertain technical feasibility and to judge what the advantages would be. Since then, its use has spread and the laboratory has reached agreements with Cornell, Fermilab and several other information sources. Today, more than 90% of the material entering the CERN library database is imported or created electronically. Of this, only 8% comes from CERN.

Ingrid Geretschlager *and* **Jocelyne Jerdelet**, *CERN.*

PEOPLE

CERN

UNESCO meeting takes place at CERN

Hans Hoffmann chaired a UNESCO meeting about recreating scientific links between south-east Europe and the rest of the region.

CERN director for technology transfer and scientific computing, Hans Hoffmann, chaired a meeting at CERN in April to discuss the development of an electronic regional research and education infrastructure aimed at re-integrating the countries of south-east Europe into the broader European infrastructure. Bringing together UNESCO regional representatives and representatives of the Max Planck Society, it follows UNESCO's March 2001 conference of experts on the reconstruction of scientific co-operation in south-east Europe, which was held in Venice.

The conference aimed to re-establish scientific links not only between the countries of south-east Europe, but also between them and the rest of Europe. It identified several courses of action to take, the first of which was a round table of science ministers hosted by UNESCO last October in Paris. CERN was chosen to host the second follow-up meeting because of its long-standing experience in computing and networking infrastructure, and in collaboration at a distance.

PRIZES

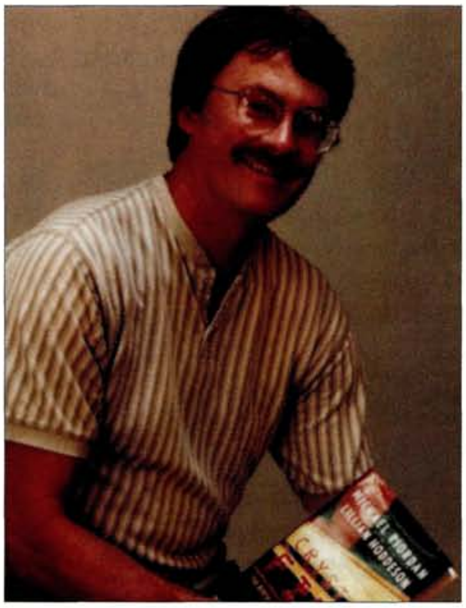
Riordan wins AIP communication award

The American Institute of Physics has awarded its 2002 Andrew Gemant Award for communicating physics to Michael Riordan (right) of Stanford University and the University of California, Santa Cruz.

Riordan, who has been *CERN Courier's* long-standing correspondent for the Stanford Linear Accelerator Center (SLAC), is the author of several books including *The Hunting of the Quark*, which draws on his experience as a graduate student on SLAC's landmark deep-inelastic scattering experiments of the 1960s and 1970s, and the award-winning *Crystal Fire*. He wrote this book, which traces the history of transistors, with Lillian Hoddeson.

The award is named after Andrew Gemant, a physicist who wrote six books, 16 volumes of short stories and 280 scientific papers. It has been awarded annually since 1987, and previous winners include Stephen Hawking, Steven Weinberg and Freeman Dyson.

"It's a great honour to be included in the company of these scientists, who have excelled in communicating physics and the role it plays in the wider web of human culture," said Riordan.



Christian Fabjan (left), technical coordinator of the ALICE heavy-ion experiment at CERN, received the Gold medal of the Faculty of Mathematics, Physics and Informatics at Comenius University in Bratislava, Slovakia, from the dean of the faculty Ludovit Fischer last December. The award recognizes Fabjan's fruitful co-operation with particle physicists from the university extending over 25 years.

His Excellency Jiaer Chen (centre), president of the National Natural Science Foundation of China, visited CERN in April. Here Jean-Luc Baldy, head of CERN's civil engineering group, discusses work in progress at the site of the future ATLAS experiment. ATLAS collaboration spokesman Peter Jenni is to Chen's left.

Future accelerator physicists hold symposium at CERN

German physicists and engineers visited CERN for a 4 day symposium.

A group of 42 students, postdocs and scientists from a German graduate college on the physics and technology of accelerators recently held a 4 day symposium at CERN. The college brings together physicists and electrical engineers from different departments of the Darmstadt University of Technology (TUD), the universities of Mainz and Frankfurt and the GSI laboratory. Supported by the Deutsche Forschungsgemeinschaft, it is built around the superconducting linear electron accelerator S-DALINAC at TUD, the electron microtron MAMI at Mainz, the various injector experiments at Frankfurt and the numerous heavy-ion developments at GSI. The college's experimental and theoretical work concentrates on improving existing electron and heavy-ion machines as well as the design and construction of future facilities.

The symposium at CERN gave participants the opportunity to take a critical look at existing and future accelerators such as the laboratory's proton synchrotron complex and the compact linear collider study. Participants also investigated the sophisticated technology of detectors such as CMS and COMPASS. A highlight was a visit to CERN's facilities for the construction, assembly and testing of the superconducting magnets for the Large Hadron Collider.

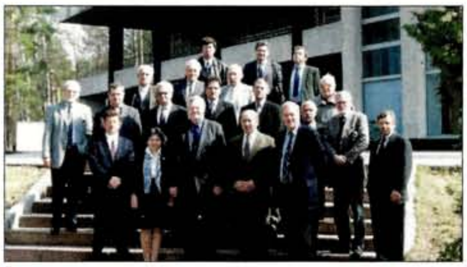
CERN research director Roger Cashmore (standing, second from right) visited the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, in April to take stock of JINR activities in CERN experiments. He is seen here at JINR's laboratory for particle physics with (left to right) JINR laboratory directors Vladimir Kekelidze and Nikolai Russakovich, JINR vice-director Alexei Sissakian, Nicolas Koulberg of CERN, JINR laboratory director Yuri Kiryushin and Alexandre Smirnov (seated).

Call for European research proposals

The Laboratori Nazionali di Legnaro (LNL) of Italy's Istituto Nazionale di Fisica Nucleare, have been recognized by the European Commission as a Major Research Infrastructure for the period 1 November 2000 – 31 October 2003. The contract offers European research groups performing experiments at LNL facilities the opportunity to be refunded for subsistence and travel.

Eligible research teams are groups from all European countries and the associated states. Calls for proposals are issued twice a year, with deadlines for submission usually falling in January and June. The next deadline is 7 June. Proposals will be evaluated on the basis of their scientific merit by user selection panels. For further information and application forms see www.lnl.infn.it/~lsf_secr or email lsf_secr@lnl.infn.it.

JINR committees see Russia in the spring



JINR delegates discussed the institute's scientific programme for the next 7 years.

The JINR programme advisory committee for particle physics met in Dubna, Russia, in April. Along with delegates from the institute's committees for condensed matter and nuclear physics, delegates heard reports from the organization's scientific council and the committee of plenipotentiaries of JINR member state governments. The agenda included preparing the institute's scientific programme for the next 7 years and the prospect of developing a university-type educational process at JINR. The particle-physics programme advisory committee discussed the status of JINR activities in the ATLAS, CMS and ALICE experiments at CERN.

Spring came to the Fermilab prairie early on 22 April when the first two new arrivals of 2002 joined the laboratory's famous buffalo herd. Mothers and babies are all doing well.

Jacques Lemonne (centre), former Belgian delegate to CERN Council and rector of the Vrije Universiteit Brussel, attended his last session as a Flemish member of the Francophone Committee for Particle and Nuclear Physics of the Belgian National Fund for Research (FNRS) on 21 February. He is standing between the chair of the committee **Denis Favart** and the secretary-general of the FNRS, **Marie-José Simoen**, who is also a delegate to CERN Council.

MEETINGS

The XXX SLAC Summer Institute: Secrets of the B Meson will be held at Menlo Park, California, US, on 5–16 August. The Institute begins with 7 days of pedagogical lectures designed for beginning post-doctoral experimentalists and theorists and advancing graduate students. It concludes with a 3 day Topical Conference. Contact Maura Chatwell at ssi@slac.stanford.edu or see http://www-conf.slac.stanford.edu/ssi/ for more information.

Diffraction 2002, the second international conference of a series that began in Cetraro, Italy, will be held in Alushta, Crimea, on 31 August – 5 September. Organized by the Bogolyubov Institute for Theoretical Physics, the Ukrainian Academy of Sciences, the University of Calabria and the Joint Institute for Nuclear Research, the conference will be followed by the XXXII International Symposium on Multiparticle Dynamics. Details are available at http://www.gluk.org/hadrons/diff2002.

The XXXII International Symposium on Multiparticle Dynamics, organized by the Joint Institute for Nuclear Research, JINR, in Dubna and the Bogolyubov Institute for Theoretical Physics (BITP) in Kiev will be held in Alushta, Ukraine, on 7–13 September. The symposium covers the most important topics of multiparticle dynamics in the physics of elementary particles, heavy ions and astrophysics. Details are available at http://thsun1jinr.ru/ismd2002/; email ismd2002@thsun1.jinr.ru.

The 9th Euro Summer School on Exotic Beams will be held in Les Houches, France, and at CERN on 12–20 September. The school is intended for PhD students and young postdocs starting to work in fields related to radioactive ion beams. The school begins with a number of lectures on general topics given at CERN, with the main lecture programme following at Les Houches. Programme and registration details are available at http://cern.ch/euroschool2002.

The 2002 DESY Theory Workshop in Hamburg, Germany, on 24–27 September will focus on quantum chromodynamics (QCD). Topics will include hard processes, lattice QCD, QCD at non-zero temperature and density, and QCD and the physics of flavour. Full details of the programme and registration arrangements are available from http://www.desy.de/desy-th/workshop2002.

The 8th Topical Seminar on Innovative Particle and Radiation Detectors will take place at the University of Siena, Italy, on 21–24 October. It will focus on advanced technologies for experiments in particle physics and astrophysics. Particular attention will be given to the application of such detectors in other fields such as medicine and biology, security control and environment monitoring. Attendance will be by invitation and will be limited to approximately 150. Those interested should write to the organizing committee indicating name, address, affiliation and, if applicable, the title of a contribution. The deadline for submitting a 1 page abstract is 15 September. Further information is available from kaos@bo.infn.it, arco.paganoni@cern.ch or pelfer@fi.infn.it; or contact Professor F-L Navarria, Dip. di Fisica, Viale C Berti-Pichat 6/2, I-40127 Bologna, Italy. Tel. +39 051 2095082; fax +39 051 2095296.

The XXI Texas Symposium on Relativistic Astrophysics will be held in Florence, Italy, on 9–13 December. The programme will cover recent developments in astrophysics and cosmology along with related topics in gravitation and elementary particle physics. Details are available at http://www.arcetri.astro.it/~texaflor/.

OBITUARIES

Victor Weisskopf 1908–2002

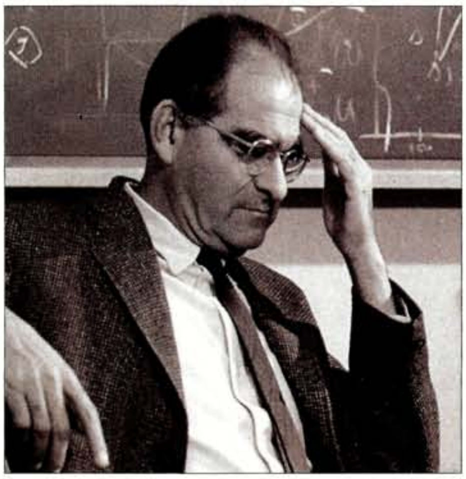
A colossus of modern physics, Victor Weisskopf died on 22 April at the age of 93. His career spanned and moulded the recent history of the subject. As well as increasing our understanding of the subnuclear world, he was also a key player in great dramas that unfolded during the 20th century.

Serving as director-general of CERN from 1961 until 1965, and taking on a number of responsibilities in the US, he was a true world citizen. In all of his roles, as both a scientist and a scientist-administrator, he left a mark. As Chairman of CERN's Scientific Policy Committee from 1964–66, the great French physicist Louis Leprince-Ringuet said of Weisskopf: "The spirit of CERN is his creation."

Born in Vienna in 1908, Weisskopf witnessed the development of quantum mechanics in the 1920s as a graduate student in Max Born's school in Göttingen, where Ehrenfest, Heisenberg, Jordan, Pauli and Wigner, among others under Born's guidance, were carving out the new theory. After Göttingen, Weisskopf worked with Schrödinger in Berlin, with Bohr at Copenhagen, then with Dirac and Peierls at Cambridge, before being invited by Pauli to be his assistant in Zurich. In 1937 he moved to the US, working at Rochester with Hans Bethe. During the 1930s, Weisskopf greatly influenced the development of quantum field theory.

The Second World War saw an abrupt change in career path when Weisskopf was appointed deputy to Bethe, the leader of the Theory Division at Los Alamos. The atmosphere at Los Alamos groomed him for further high responsibility and greatly influenced his characteristic style of management. Following this experience, his warnings of the dangers of nuclear weapons were highly influential.

Immediately after the war, he moved to MIT, which was his US base for the rest of his life. Returning to quantum field theory, in 1947 he was one of the discussion leaders at the historic conference on Shelter Island, New York, where the modern theory of quantum electrodynamics first emerged. In 1950 he was appointed "professeur étranger" at the Sorbonne in Paris, France. He continued to work on fundamental physics problems, and his 1971 paper with Julius Kuti helped pave the way for the modern theory of quantum chromodynamics. His contributions to basic physics therefore spanned almost half a century. He was also quick to spot new talent – in 1948 he invited the 18-year-old Murray Gell-Mann to come to MIT as a research student.



Victor Weisskopf 1908–2002.

In 1960, while serving as president of the American Physical Society, he was appointed to the CERN directorate. He became director-general the following year, succeeding John Adams who had taken on the responsibility following the death of the incumbent director-general, Cornelis Bakker, in an air accident.

It was during Weisskopf's historic mandate as CERN director-general that the infant laboratory's role in life was charted, and major new investments made. Weisskopf elevated the organization from an experiment in international collaboration to a mission, and endowed it with the necessary stature. Under his guidance, the future of CERN was shaped.

The Intersecting Storage Rings, the world's first proton collider, was identified as a major goal. A parallel but more distant aim was a larger proton synchrotron – the 300 GeV project – which eventually led to the SPS. This foresight opened the way for the SPS proton–antiproton collider, the LEP electron–positron collider and finally the Large Hadron Collider. Weisskopf also ensured that the PS synchrotron became equipped with the right infrastructure to become the hub of all CERN's particle beam requirements. Later he described his five years at CERN as "among the most wonderful of my life".

His other lasting creations include the European Committee for Future Accelerators and the US High Energy Physics Advisory Panel, both of which continue to influence and guide the evolution of high-energy physics on their respective sides of the Atlantic.

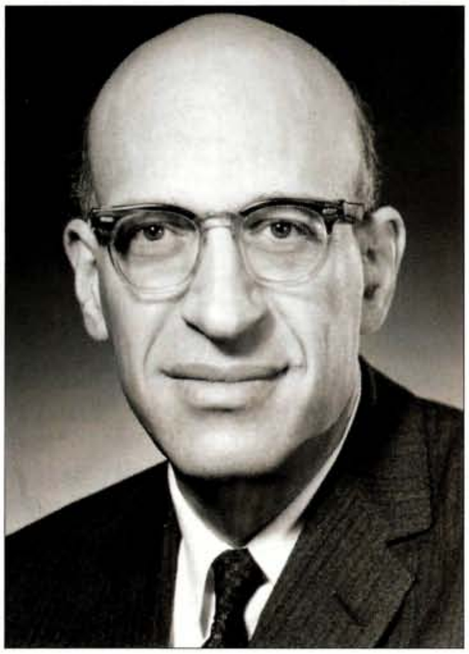
His great contemporary, Hans Bethe, lists three major contributions Weisskopf made to basic physics: calculating the width of energy levels and their fundamental relation with lifetime; the mathematical divergence of the electron's self-energy; and, with Herman Feshbach, elucidating ideas on nuclear scattering. Others would list more. With Fermi and Teller, he showed that the cosmic ray "mesotron" interacted far too weakly to be the carrier of the Yukawa nuclear force. His book *Theoretical Nuclear Physics* with John Blatt is still classic reading. In later years, he was continually in demand as a lecturer and author. As well as numerous scientific monographs and memorial volumes, his books include *Physics in the 20th century*, *Knowledge and Wonder*, *The Joy of Insight* and *The Privilege of being a Physicist*.

After leaving CERN in 1965, he maintained a nearby house in the Pays de Gex, France, to which he returned every summer until 1998, when travel became difficult for him. For many years, his lectures to summer students were a highlight at CERN. Delivered with minimal notes, these delightful talks were full of anecdotes and insight. With Kurt Gottfried as co-author, this material was published as *The Concepts of Particle Physics*. With wide interests in music and the arts as well as in science, it was fitting that from 1975 until 1978 he was president of the American Academy of Arts and Sciences.

Weisskopf was showered with honours and received almost every distinction imaginable. (And some not so imaginable, including honorary "sapeur-pompier", or fireman, in the French village of Vesancy, a distinction of which he was especially proud.) Only the Nobel prize was to elude him.

But it is at CERN, which he was fond of describing as the "United Scientific States of Europe", where his influence is most greatly felt. In his final progress report to CERN Council as director-general in 1965, he confidently predicted that "the real golden age of CERN is ahead of us".

Ralph Shutt 1913–2001



Ralph Shutt 1913–2001 (Brookhaven National Laboratory.)

Born in Switzerland, Ralph Shutt first worked with cloud chambers in Berlin before emigrating to the US in 1939. After the Second World War he played a leading role in track chamber physics with the new high-energy synchrotrons. Using an innovative "diffusion cloud chamber" at the Brookhaven Cosmotron in 1953, he and his colleagues saw that highly unstable particles are produced in pairs – "associated production". This discovery soon led to the idea of strangeness as a quantum number. At the Brookhaven Alternating Gradient Synchrotron, Shutt led the effort to develop and exploit the newly invented bubble chamber. This led to the discovery of many new resonances and particles, culminating with the 1964 discovery of the omega-minus, which confirmed the SU3 classification of particle states. He subsequently transferred his attention to the development of superconducting magnets, work that eventually bore fruit for the RHIC heavy-ion collider.

Pierre Marin 1927–2002

Pierre Marin died on 15 April of a heart attack, aged 74. A tireless worker, he devoted his entire life to particle physics and the physics of accelerators. By setting up and running many leading projects in these fields, he contributed greatly to major scientific breakthroughs. He was an experimentalist of imagination and rigour; a totally upright man with no inclination to compromise. He was also a committed researcher and supported a great number of generous initiatives.

He completed his PhD in nuclear physics in the 1950s at the Clarendon Laboratory in Oxford, where Hans Halban was his supervisor. Afterwards he was among those who moved with Halban to Paris to set up an experimental nuclear physics group in the Physics Laboratory at the Ecole Normale Supérieure. There, Marin built and ran two proton accelerators, where a whole series of projects was conducted, some of them led by himself. He later spent a year at CERN, working with Hyams and Backinstoss on generating an intense 7 GeV muon beam in order to measure its polarization.

In the summer of 1961, Marin travelled to Frascati to find out about the tests run there on the AdA electron–positron ring by a team of Italian physicists and engineers under Bruno Touschek. On returning to Paris from Rome, he suggested to André Blanc-Lapierre, who had by then succeeded Hans Halban as head of the Laboratoire de l'Accélérateur Linéaire (LAL), that they invite the Frascati team to LAL (together with the AdA ring, which was transported by truck to Orsay from Rome), and also to build a an e^+e^- collider ring with an energy of 2 × 550 MeV.

Following the Frascati group's arrival at LAL, Marin joined a Franco-Italian collaboration that ran numerous beam studies on AdA which eventually led to the achievement of the first ever collisions in an electron–positron ring. At the same time, he directed the building of the ACO ring, which stored its first beam on 25 October 1965. He then supervised the first two particle physics theses based on findings from ACO. The machine paved the way for in-depth studies on ρ, ω and Φ vector mesons and the first direct evidence of vacuum polarization effects in the s-channel (by analysing the $e^+e^- \rightarrow \mu^+\mu^-$ process at the Φ energy).

Pierre Marin 1927–2002.

Marin went on to direct the building and operation of the DCI collider, with its energy of 2 × 1.85 GeV, and later the Super-ACO ring, designed specifically for synchrotron radiation. With his dual background as engineer and researcher, he had total mastery over the different aspects of operating the highly innovative machines that are storage and collider rings. He also acted as a consultant for numerous machines built in France or abroad.

More recently Marin was an ardent backer of SOLEIL, the French national machine project for a third-generation synchrotron radiation source intended to serve the needs of a wide community of users. His great expertise in the ultravacuum field was also brought to bear on the VIRGO interferometer, which is designed to detect gravitational waves.

His many colleagues and friends are dismayed at his loss.

Jacques Haïssinski, LAL Orsay.

Giustina Baroni 1923–2002

Giustina Baroni died on 24 March following a disabling illness. A full professor at the University "La Sapienza" in Rome, she retired from academic and scientific activities in 1996.

Baroni was well known in the high-energy physics community. With her two degrees in chemistry and physics, she was a pioneer in the use of nuclear emulsions, from the study of the detection process with an electron microscope to the first exposures at the Pic du Midi to study the soft component of cosmic radiation. A significant highlight was the launch from the Sardinian coast of balloons carrying stacks of stripping emulsions, which reached heights of 26 000 m. This was the first of the large European collaborations, and marked a change of style in the work of our laboratories. Baroni cared especially about the few tau decays and their spin-parity analysis, thus fitting her pieces into the theta/tau puzzle. By then, the time was ripe for a switch to accelerator-produced particles.

In the emulsions returned to Rome from one of the balloon flights, an event was found with the features of a negative proton. After the successful outcome of the Berkeley experiment on antiproton production, a Berkeley–Rome collaboration was set up to expose stacks of emulsions to the antiproton beam, leading to an extensive study of antiproton interactions in emulsions. These studies were, in part, superseded a few years later when liquid hydrogen bubble chambers of large dimensions provided a large amount of clean proton–antiproton data. Another turning point came with the commissioning of CERN's proton synchrotron, and the possibility of using a pulsed magnetic field of very high intensity. There followed a search for Dirac magnetic monopoles, and the first very precise measurement of the magnetic moment of hyperons.

In 1965 Baroni became leader of the emulsion group in Rome and enthusiastically entered the "new age" of nuclear emulsions, with the so-called hybrid experiments. There, a very sensitive emulsion target was connected to electronic devices surrounding it, thus allowing special events to be selected. This was rewarded at Fermilab with the observation of a likely example of charmed particle decay produced in a neutrino beam. The Super Proton Synchrotron (SPS) at CERN was the natural site for these hybrid experiments. A powerful collaboration was set up with the other European emulsion groups, especially with the Brussels, University College London, Dublin, Turin and Bari groups. From 1975 for about 10 years, this group formed the basis for success in the search for short-lived particles. The first observations of charm and beauty mesons and baryons, and measurements of their lifetimes, were done at the SPS, in the WA17 and WA75 experiments.


Giustina Baroni 1923–2002. (Diotallevi.)

Throughout this period Baroni also actively contributed to setting up a successful collaboration with Nagoya and other Japanese emulsion groups in view of the detection of tau neutrinos. Heavy-ion interactions were another field of interest, starting from carbon at the CERN Synchrocyclotron to oxygen-16 at the highest energies available at the SPS.

Baroni was a very good teacher and scientific leader, and many of her students are active in elementary particle and nuclear physics experiments. She shared her talent for physics analysis and technical developments with her collaborators with great generosity. Beyond her professional life she was a knowledgeable and refined lady, and it was always a pleasure for her colleagues to converse with her on diverse cultural and social topics. Roman archaeology was one of her greatest passions, and many friends still recall affectionately her accounts of her several trips to archaeological sites throughout the world.

Giustina Baroni will be remembered by friends, colleagues and students as a fine example of culture and humanity.

RECRUITMENT

For advertising enquiries, contact CERN Courier recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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EPFL
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FÉDÉRALE DE LAUSANNE

Assistant Professor of Theoretical Physics

at the Swiss Federal Institute of Technology Lausanne (EPFL)

The EPFL, in close collaboration with the University of Lausanne (UNIL), plans a substantial expansion in the basic sciences, including a significant reinforcement of physics, chemistry and mathematics and a major new effort in biological sciences.

As part of this broad program, we anticipate a tenure track Assistant Professor position in the Institute of Theoretical Physics, tentatively beginning in the fall semester of 2002. We invite applications from outstanding young physicists with well recognized accomplishments in condensed matter theory and a clear promise for future growth. The area of specialization should preferentially be nanoscale condensed matter physics, quantum optics, or statistical physics of soft matter.

The appointee will establish and lead a vigorous independent research program, interact with existing projects in condensed matter physics and will be committed to excellent teaching at undergraduate and graduate level. Start-up resources will be available. Exceptionally experienced candidates seeking a higher level position may also be considered.

We offer internationally competitive salaries and benefits.

Applications with curriculum vitae, publication list, concise statement of research and teaching interests as well as the names and addresses (including e-mail) of at least five references should be sent by **June 30, 2002,** to

Professor Giorgio Margaritondo
Dean
Faculty of Basic Sciences
EPFL
CH-1015 Lausanne, Switzerland

For additional information on the EPFL, please consult:
http://www.epfl.ch, http://sb.epfl.ch/,
http://www-sphys.unil.ch/ipt/ and
http://dpwww.epfl.ch/instituts/ipt/ipt.html

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UNIVERSITY OF
OXFORD

Mathematical and Physical Sciences Division

Department of Physics
in association with New College

University Lecturership in Theoretical Physics

The Department of Physics proposes to appoint a University Lecturer in Theoretical Physics with research interests in the area of elementary particle theory with effect from 1st October 2002 or as soon as possible thereafter. The successful candidate will be offered an Official Fellowship by New College, under arrangements described in the further particulars. The combined University and College salary will be according to age on a scale up to £41,570 p.a.

Preference will be given to applicants with expertise in physics "beyond the Standard Model". The successful candidate will be expected to participate actively in undergraduate and graduate teaching, research and relevant administration.

Further particulars of the post are available from Professor David Sherrington, Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, England, tel. +44 (0)1865 273952, fax: +44 (0)1865 273947, e-mail: d.sherrington1@physics.ox.ac.uk Applicants should submit nine copies (one in the case of applicants based overseas) of a letter of application supported by a curriculum vitae and statement of research interests, together with the names of three referees (not more than two from the same institution). The applications should be sent to Professor Sherrington at the above address to arrive no later than 14th June 2002.

The University is an Equal Opportunities Employer.

Ruprecht-Karls-Universität Heidelberg
Physikalisches Institut
Prof. Dr. Johanna Stachel

Postdoctoral Research Associate High Energy Heavy Ion Physics

The high energy heavy ion group is searching for scientists collaborating in the construction, execution, and analysis of experiments at CERN. Presently, the group is active in the CERES/NA45 experiment. Another major activity is the preparation of the LHC experiment ALICE.

The successful applicant has a Ph.D. in experimental particle or nuclear physics and is familiar with the usual software and simulation tools. Particularly desirable would be experience in one of the following areas: detector hardware, electronics and signal processing, or object oriented programming.

For interested candidates, the possibility of 'habilitation' exists. The salary follows the German BAT schedule (BAT 2 a) or is according to C1.

Applications with a C.V. and names for letters of recommendation should be addressed to:

Professor Johanna Stachel
Physikalisches Institut der
Universität Heidelberg
Philosophenweg 12
69121 Heidelberg
e-mail: schneyder@physi.uni-heidelberg.de
www.physi.uni-heidelberg.de

HEAD OF COMPUTING DIVISION

Fermi National Accelerator Laboratory, dedicated to fundamental research in particle physics and related fields, and home to the world's highest energy accelerator, has an exceptional opportunity available for a professional to lead one of its four major scientific divisions.

The Computing Division at Fermilab is highly coupled to the physics program of the laboratory. It supports all scientific computing in the laboratory's program, including the CDF and D0 Collider experiments currently running at the world's most powerful particle accelerator, the planned neutrino experiments MiniBooNE and MINOS, and the anticipated flavor experiments CKM and BteV. The Computing Division is also the host division for the Experimental Astrophysics Group (Sloan Digital Sky Survey, PRIME), the Fermilab Lattice Gauge Theory Facility and a Tier 1 center for the CMS experiment at the Large Hadron Collider in Geneva, Switzerland. The Division furnishes and operates the campus-wide network, and several computing facilities, including central facilities in the Feynman Computer Center (FCC). These facilities include large computer clusters for simulation, reconstruction and analysis of scientific data as well as substantial data storage capacities of more than one Petabyte of robotic tape storage and about one hundred Terabytes of disk storage.

The Division assists in developing systems requirements for future computing and storage needs, and also develops the software for operating these systems as required. The Division staff has a substantial involvement in the development of scientific software, including physics simulation and computational codes. Many of these activities are carried out in collaboration with the worldwide high-energy physics community. The Division receives substantial support for these activities from competitively awarded funding sources. The Division staff supports the data acquisition systems of experiments. The Division manages Fermilab's high bandwidth connections to public and private wide area networks that support its worldwide scientific collaborations. The Division supports the general computing infrastructure at the Laboratory, including many aspects of computer security.

Reporting to the Fermilab Director of Research, the selected candidate will lead more than 250 computer professionals, engineers, technicians and physicists to work effectively with the large physics collaborations at Fermilab. Specific responsibilities include contributing to the setup and operation of LHC computing, supporting the US scientific HEP community involved in the LHC program, supporting the computing infrastructure of the Laboratory, and participating in R&D projects to prepare computing for future HEP programs.

Qualified candidates must possess the capability to provide leadership in the operational, computing, R&D, and physics roles of the Division. A broad and deep understanding of the present state of computing technologies and the trends that project these technologies into the future, both in the commercial, open source, and academic computer science sectors, is required. Management and organizational skills in a highly technical environment are essential, as is exposure to science, based on large facilities and dispersed collaborations of scientists. The individual selected must be familiar with Department of Energy regulations and take responsibility for elements of the Laboratory's computing in these matters. Experience in high-energy physics is an advantage, but not required.

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Fermilab

UNIVERSITY OF ALBERTA

FACULTY POSITIONS IN EXPERIMENTAL SUBATOMIC PHYSICS

The Department of Physics at the University of Alberta invites applications for two positions in experimental subatomic physics with a starting date of 1 July 2003. The second position is dependent on establishing funding. These positions will be at the assistant or associate professor level. Outstanding candidates could be hired at the associate professor level with tenure. We are interested in candidates who have leadership potential and an excellent record of research. These qualities plus ability and interest in teaching at the undergraduate and graduate levels will constitute the primary selection criteria.

Our current program of experimental research is focused in three areas: collider physics at CERN (OPAL and ATLAS), fixed target experiments (HERMES at DESY, TWIST at TRIUMF and ISAC at TRIUMF) and astroparticle physics (Alberta Large Area Time Correlation Array and STACEE in New Mexico). Potential candidates may find additional information about our research program at http://csr.phys.ualberta.ca

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.
If suitable Canadian citizens or permanent residents cannot be found, other individuals will be considered.

The closing date for applications is 1 September 2002. Applicants should send a curriculum vitae, a research plan, and a description of teaching experience and interests. The applicants must arrange to have at least three confidential letters of reference sent to the address below, on or before September 1, 2002:

Experimental Subatomic Physics Search and Selection Committee
Dr. J. C. Samson, Chair
University of Alberta
412 Avadh Bhatia Physics Laboratory
Edmonton, Alberta T6G 2J1, Canada
Fax: (780) 492-0714
Email: dept@phys.ualberta.ca

The records arising from this competition will be managed in accordance with the provisions of the Alberta Freedom of Information and Protection of Privacy Act (FOIPP).

The University of Alberta hires on the basis of merit. We are committed to the principle of equity in employment. We welcome diversity and encourage applications from all qualified women and men, including persons with disabilities, members of visible minorities, and Aboriginal persons.

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PHYSICIST/ENGINEER

in the field of Cryogenics

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Your prime responsibility will be to identify opportunities for development of advanced cryogenic concepts of MRI magnets, develop them into successful products and ensure the smooth introduction of processes into production. You will be contributing to create new market opportunities from cryogentically effective systems, which will satisfy our customers for their ease of handling as well as their cost effective designs.

For this role you will have a Master or PhD in either physics, thermodynamics engineering or a comparable subject. A team player and a creative but pragmatic problem solver, a proven background in cryogenics would be a distinct advantage. In this position we would expect you to be literate in application of existing and definition of new numerical tools.

We encourage applications both from individuals with recent degrees and experimental experience as well as those with a professional background in industry or science.

These roles provide real opportunities to work with leading edge technology together with an attractive benefits package, which includes company pension, private healthcare, permanent health insurance and subsidised restaurant.

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Closing date: 14th June 2002

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COMPUTING PROFESSIONAL/ RESEARCH ASSOCIATE

The elementary particle physics group at Cornell University has an opening for a Computing Professional/Research Associate to work on projects related to the CLEO/CLEOc experiment and R&D for a Linear Collider. The person filling this appointment will have major responsibilities for the upgrade, optimization, and maintenance of the CLEO offline analysis software, databases for calibration and data access, and eventually software development for a Linear Collider. Membership in the CLEO Collaboration and the opportunity for half-time data analysis are possible though such activities are not required.

A PhD in experimental elementary particle physics or advanced degree in Computer Science, and at least 3 years experience with software development are required. Expertise is necessary in the following areas: The UNIX operating system, object-oriented programming, C++, UNIX shell scripting, and large-scale software design. It is also highly desirable for the applicant to have familiarity with the computing tasks common in experimental high energy physics such as data management, physics analysis, and Monte Carlo simulations, as well as LINUX, FORTRAN, and code management and versioning systems.

Please send an application including curriculum vitae, publication list, and resume of computer experience, and arrange for at least three letters of recommendation to be sent to

Prof. Lawrence Gibbons,
Newman Laboratory, Cornell University,
Ithaca, NY 14853.

E-mail correspondence may be directed to **search@lns.cornell.edu**

Cornell is an equal opportunity/affirmative action employer.
Women and minorities are encouraged to apply.

McGill

Postdoctoral Research Position in Ground-based Gamma-ray Astronomy

The high energy astrophysics group at McGill University is seeking applications for a research associate position in ground based gamma -ray astronomy. We are founding members of the STACEE collaboration, which is operating a detector at Sanida National Labs in Albuquerque, NM. The detector has recently been completed and we are engaged in a multi-year observing campaign targeting active galactic nuclei, supernova remnants and other sources at energies between 50 and 500 GeV. We are also investigating options for participation in future collaborations. The McGill team comprises two faculty members and three graduate students.

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

Please send a CV and arrange to have three letters of reference sent to:

Professor D. Hanna
Physics Department, McGill University
3600 University Street
Montreal, QC, H3A 2T8, Canada
hanna@physics.mcgill.ca

Applications will be considered until the position is filled.

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

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research for the future

Experimental Physicist

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Your profile

You completed recently your PhD thesis in physics. Preferably, you are familiar with the use of liquid helium and you acquired experience in one or more of the following fields: dynamic nuclear polarization, NMR, ESR, small angle neutron scattering, polarized neutrons, low temperature techniques below 1 K. You like to work in a small team of physicists and technicians collaborating with user groups of the PSI facilities. A good command of English is required.

For further information please contact Dr B. van den Brandt, telephone +41 56 310 40 27, e-mail: ben.vandenbrandt@psi.ch.

Please send your application to PAUL SCHERRER INSTITUT, Human Resources, Mr. Thomas Erb, ref. code 3012, CH-5232 Villigen PSI, Switzerland.

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July/August issue: 14 June

Publication date: 27 June

Contact Ed Jost:

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RESEARCH ASSOCIATE IN EXPERIMENTAL PARTICLE PHYSICS

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The Particle Physics Department at the CLRC Rutherford Appleton Laboratory invites applications for a Research Associate position in particle physics, to work on the CMS experiment. The appointment will initially be for three years.

The RAL CMS group has responsibility for the design and production of important components of the readout electronics for the CMS silicon strip tracker. The group is also committed to produce both on-line and off-line software to ensure that the tracker data can be successfully read out. The appointee will participate in the development of this software.

Applicants should have a PhD in experimental particle physics, or have equivalent experience. A proven aptitude for setting up and debugging the hardware, or a willingness to acquire such skills, will be essential.

Further details can be obtained from Dr Ken Bell (email: K.W.Bell@rl.ac.uk), or from http://cern.ch/kwb/cms/tracker/radetails.htm.

Starting salary for this post is up to £25,510 on a salary range of £20,410 to £28,060, salary on appointment is dependent upon relevant experience. A non-contributory pension scheme and a generous leave allowance are also offered.

Application forms can be obtained from Operations Group, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, telephone +44 1235 445435 (answer-phone) or email recruit@rl.ac.uk, quoting reference VN2260. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 8th July, 2002. Interviews will be held on 22nd July 2002.

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Degree of requirement: PhD, or equivalent

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Applications, including curriculum vitae, a list of publications and a short research plan should be sent to
the Dean of the Faculty of Sciences,
30 Quai Ernest-Ansermet,CH-1211 Geneva 4
Closing date for applications: Sept 30, 2002

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If you are a proactive and flexible team player who enjoys being continually challenged by analytical work, we'd like to hear from you. Please send your CV to the **Human Resources Department** at the address below or contact **Lisa Hazell** on **01865 850506** for an application form.

Closing date: 14th June 2002

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HEAD OF FERMILAB BEAMS DIVISION

Fermilab seeks an exceptional scientist to serve as Head of its Beams Division. Located on a 6,800 acre campus 40 miles west of Chicago, Illinois, Fermi National Accelerator Laboratory operates the world's highest energy particle accelerator for research into the fundamental properties of matter. Fermilab is operated by the University's Research Association for the US Department of Energy. The Beams Division holds responsibility for the operations of all accelerators on the Fermilab site and for research and development for new accelerators to support the long-term future of the laboratory. The Beams Division is supported with an annual budget of approximately $85 million and employs approximately 600 people.

The Beams Division Head provides leadership and management of the Beams Division in execution of its responsibilities including the establishment and achievement of technical, budgetary, schedule, staff development, and ES&H goals. In addition, the BD Head plays a leadership role within Fermilab in charting the operating program and future directions for the laboratory.

The successful candidate for this position will have demonstrated leadership, management, communications, and technical abilities. A strong background in accelerator technologies and a PhD in high energy or accelerator physics, or other related field, is required.

Interested parties requiring more information, or applicants for this position, should contact:

Steve Holmes, Associate Director for Accelerators
Fermilab, MS105
Job Code: HBD-CC
P.O. Box 500
Batavia, IL 60510, USA
E-mail: holmes@fnal.gov
Ph: 630-840-3211

Applications should include a curriculum vitae, publication list, and three letters of reference. Fermilab is an Equal Opportunity/Affirmative Action Employer.

Fermilab

www.fnal.gov

NSCL

MICHIGAN STATE UNIVERSITY

Executive Director

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) is seeking applicants for the position of Executive Director. The Executive Director reports to the NSCL Director and is responsible for management of the fiscal and human resources affairs of the Laboratory.

The NSCL is the leading rare isotope research facility in the United States and is used by researchers from across the country and the world. The Laboratory operates two coupled superconducting cyclotrons for advanced research in fundamental nuclear science, nuclear astrophysics, and accelerator physics. Funded primarily by the National Science Foundation and MSU, the NSCL maintains a permanent staff of approximately 130 people. In addition, the NSCL employs about 50-60 individuals as post doctoral researchers, graduate students, or sabbatical visitors, and a comparable number of undergraduate students.

The Executive Director is responsible for planning the fiscal and personnel needs of the Laboratory, preparing budgets required for internal NSCL operation and grant or university funding, monitoring project/grant progress, and adhering to funding restrictions and federal regulations. Supervision of the NSCL accounting, purchasing and personnel activities are additional responsibilities.

A minimum of a Bachelors degree in science or engineering is required and an advanced technical or management degree is desirable. Applicants should have 10-15 years experience in management of the technical, personnel and fiscal aspects of research or design projects and/or organizations.

The appointment will be made in the NSCL Continuing Appointment System that approximately parallels the university tenure-stream faculty system. The position carries excellent benefits including: health and dental plans, generous retirement, educational assistance, plus paid holiday, sick and vacation leave.

Please send a resume plus names and contact points of three professional references to

Ms. M. Chris Townsend, Laboratory Administrator,
National Superconducting Cyclotron Laboratory,
Michigan State University, East Lansing, MI 48824-1321

or e-mail townsend@nscl.msu.edu.

Michigan State University is an Affirmative Action/Equal Opportunity institution. Women and minorities are especially encouraged to apply.

UCLA

The UCLA Department of Physics and Astronomy
invites applications for an appointment at the
assistant professor level in the physics of particle beams and accelerators.

The search for filling this tenure-track position is aimed toward finding a superior physicist with interests and demonstrated expertise in experimental and/or computational aspects of free-electron lasers. However, candidates in other areas of interest to the UCLA program in beam physics will be considered. These areas include particle beam and electromagnetic radiation instrumentation, novel x-ray sources, high intensity beam physics, beam-plasma interaction and advanced acceleration techniques. The successful candidate will be expected to conduct a vigorous research program, complementing the existing strengths in particle beam physics at UCLA.

Applications, addressed to

Professor Claudio Pellegrini, Chair,
UCLA Department of Physics and Astronomy,
405 Hilgard Ave., Los Angeles, CA 90095-1547,

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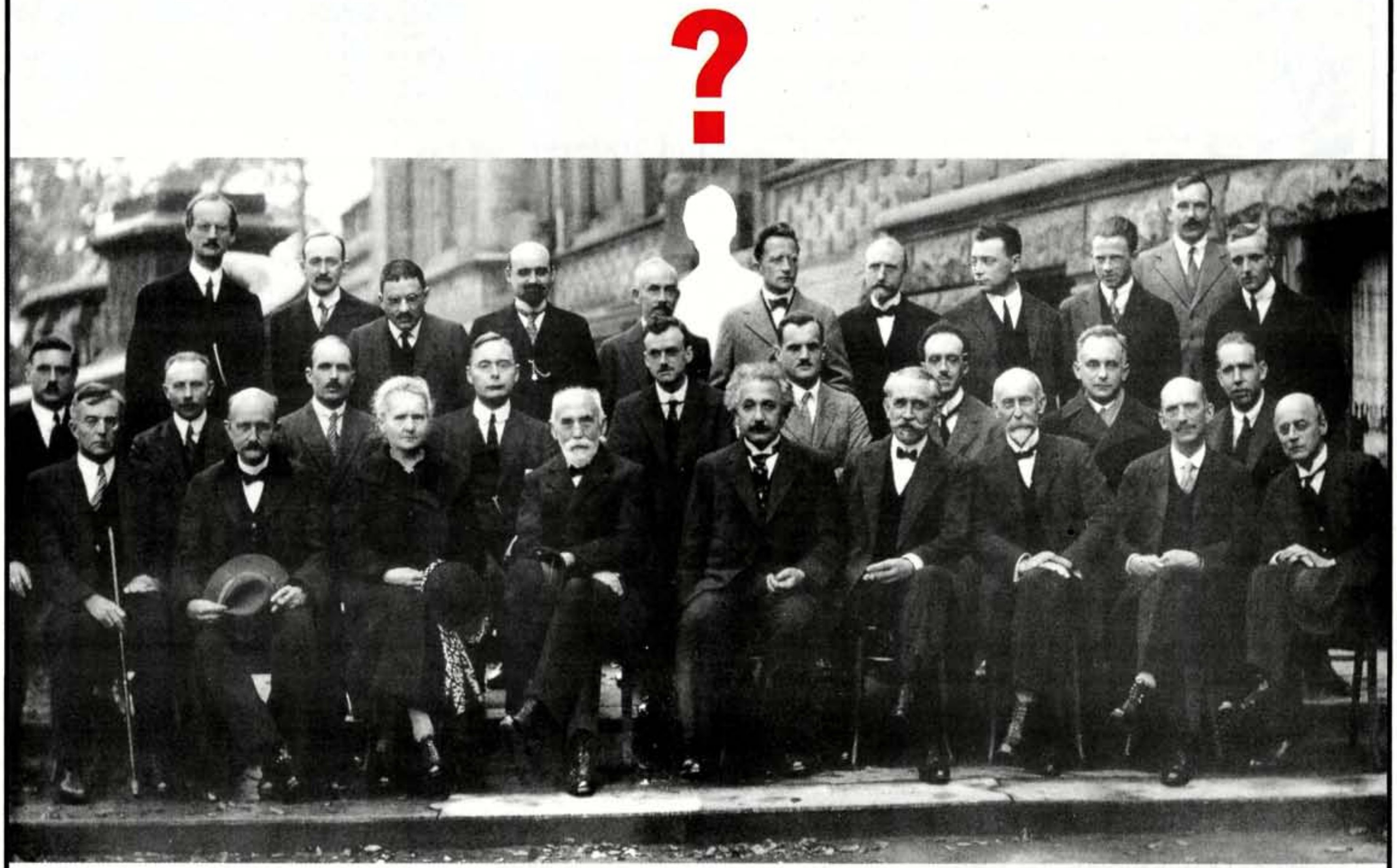

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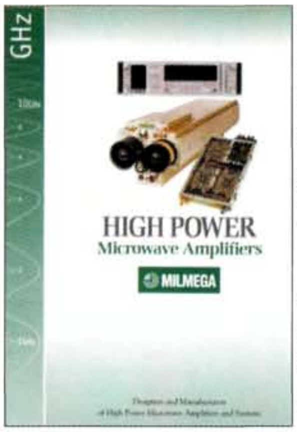

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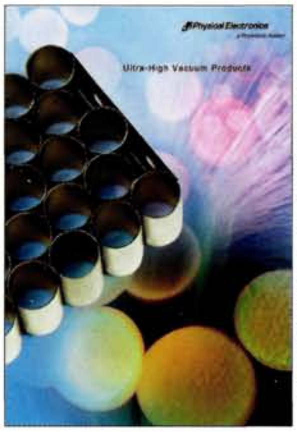

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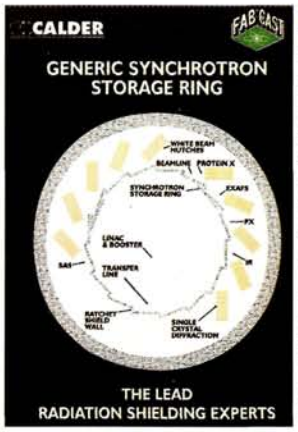

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VIEWPOINT

Changing the culture of big science

As scientific facilities become larger and more costly, so the management challenge grows. CERN director-general **Luciano Maiani** says that lessons learned from the LHC cost overrun will ultimately benefit the Geneva laboratory and help secure its future.

The Large Hadron Collider (LHC) is without a doubt the most technologically challenging project that CERN has ever embarked upon. It is also the most costly, and it was approved under the strictest financial conditions that CERN has ever faced. This should have been cause for the laboratory to reflect on its way of working, but reflection did not come until September last year, when the results of a comprehensive cost-to-completion review showed that CERN would have to find an additional SwFr 850 million for the LHC and its experiments.

CERN is built on a tradition of excellence, in terms of both its personnel and its facilities. In the world of particle physics, the laboratory has a well deserved reputation for building the finest machines. Our first big accelerator, the PS, was completed in 1959 and is still going strong. And had the SPS not been built to CERN's exacting standards, the Nobel prize-winning antiproton project might never have got off the ground. With the LHC being inaccessibly encased in its cryostat, high standards are needed more than ever. CERN, however, must also become more cost-aware.

Moving forward

At 18% of the material cost, the LHC overrun does not seem excessive for a project of this complexity, and is comparable to the percentage overrun incurred in the construction of the Large Electron Positron (LEP) collider. But the bill for the LHC is three times that for LEP. The lesson we have learned is that contingency in big projects must now be measured in absolute and not percentage terms. Our mistake was that we failed to realize that the scale of the LHC would require new monitoring and control systems at all levels of the laboratory.

Such systems are now being introduced with advice from an External Review Committee (*CERN Courier* January/February p4). CERN will introduce earned-value management techniques to allow the financial health of the laboratory to be easily monitored at any time, and we will move to full personnel-plus-materials accounting, which will introduce greater transparency. These measures are essential for completing the LHC within the boundaries set by last year's cost-to-completion review, and they will position CERN well for the longer term.

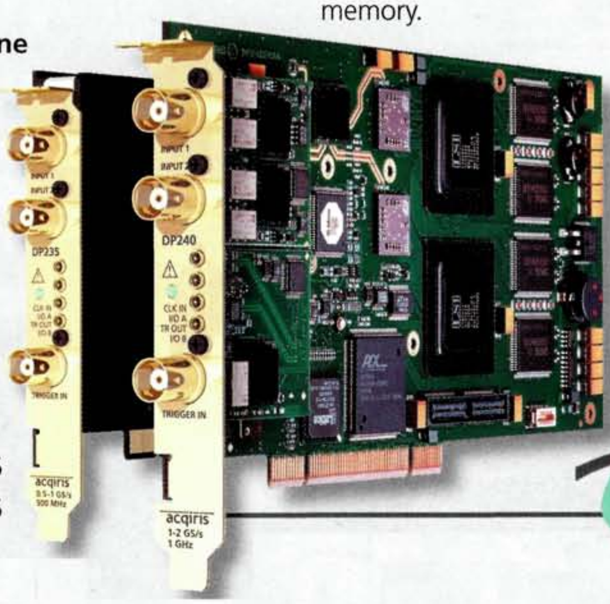
CERN's mission is to provide the facilities that its user community wants. In the past, that has meant a diverse range of particle beams serving a wide range of relatively small experiments. With the LHC, our user base has consolidated to give a smaller number of much larger experiments, and we must adapt our facilities accordingly. That means a narrower programme, focused on the LHC. A large part of the required resources can be found by reallocating budget and personnel to the LHC. Further reallocations will come from internal restructuring, postponing the start-up of the LHC until 2007, extending the pay-back period until 2010 and cutting back on accelerator R&D until the LHC is running.

I am convinced that these moves will allow CERN to maintain its tradition of excellence. We continue to host a lively and diverse low-energy programme. The LHC will be the world's foremost facility for high-energy physics, and by maintaining a minimum R&D base, we are providing a platform for the long term.

However, we are not yet out of the woods. An important part of the resources we plan to reallocate to the LHC has been identified but not yet secured. It will take a coherent effort across the laboratory to ensure that human resources released by the reduction of non-LHC activities are effectively deployed to the LHC. However, we are heading in the right direction, and I have every faith in the ability of CERN's staff and users to meet the challenge.

The lessons CERN has learned are lessons for us all. The need to measure contingency in absolute terms requires management tools, risk analysis and strategy tuned to the size of the projects, much as we choose our physics instruments in relation to the precision we are aiming to achieve. Time will tell how these considerations can be applied to future projects. For now, however, we have learned our lesson and CERN is set to emerge leaner and fitter to face the future.

Luciano Maiani, CERN.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