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Focus on Grids: LCG, EGEE and CERN openlab

CERN COURIER

VOLUME 43 NUMBER 8 OCTOBER 2003

MINOS gets going on the far side

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

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LHC dipole coils delivered p5

40 teachers attend HST 2003 p28

Turner moves to the NSF p35

Cover: After four years of mining, construction and testing, the Main Injector Neutrino Oscillation Search (MINOS) collaboration has announced the start-up of its 5400 tonne "far detector" in the Soudan Underground Laboratory (p8), seen here looking along the top of the detector. (Jerry Meier.)

CERN

Industry delivers LHC dipole coils

An important milestone has been passed in the manufacture of the magnets for CERN's Large Hadron Collider (LHC). By the end of August 2003, 154 dipole coils – representing a whole octant of the LHC – had been produced, "collared" and approved. This shows that large-scale production of the dipoles is now under way.

This early engineering model of an LHC dipole shows the concept of the austenitic steel collars that surround the superconducting coils.

More than 80 LHC dipole cold masses have already arrived at CERN. This one is being installed in the robotic "crab", specially designed to carry the magnets around the CERN site.

The manufacture of the coils, which contain the superconducting cable to provide the all-important 8.33 T magnetic field for the LHC, represents 60% of the magnet production work. The niobium-titanium coils create the magnetic fields to guide the two counter-rotating proton beams in separate magnetic channels, but within the same physical structure. The coils are surrounded by non-magnetic "collars" of austenitic steel, a material that combines the required properties of good thermal contraction and magnetic permeability. The collars hold the coils in place against the strong magnetic forces that arise when the coils are at full field – the force loading 1 m of dipole is about 400 tonnes.

In the next stage of the process, each collared coil is installed in a magnetic yoke and a cryogenic vessel, ready for cooling to 1.9 K. This overall assembly is known as the "cold mass". The cold masses are then transported to CERN, inserted into their blue cylindrical cryostats, and tested. By the end of 2003 a whole octant of completed cold masses should have arrived at CERN.

The task of building the coils and assembling them into cold masses has been assigned to three firms or consortia – Alstom-Jeumont (France), Ansaldo (Italy) and Noell (Germany). Each of these three suppliers received an order for 30 pre-series magnets and a subsequent one for 386 series magnets. With the pre-series phase coming to an end – 85 cold masses have already been delivered to CERN – the three firms are now embarking on large-scale series production. To meet the schedule, each firm will have to produce three cold masses a week from the end of spring 2004 onwards.

For cold-mass assembly the firms will have to overcome two major difficulties: preserving the magnet geometry and welding the so-called shrinking cylinders, which contain the cold mass. The first challenge stems from the fact that the magnets must be slightly curved to follow the circular path of the LHC ring. Over the total 15 m length of each magnet, the sagitta (difference from a straight line between the ends and the centre) must be 9 mm, to a precision of just 1 mm. The welding of the two half-cylinders that make up a shrinking cylinder relies on a special technique developed at CERN and transferred to industry. To ensure that production is properly monitored and to help the three firms step up their production rates, 15 engineers and technicians from CERN are spending 50% of their work time at the premises of the three suppliers.

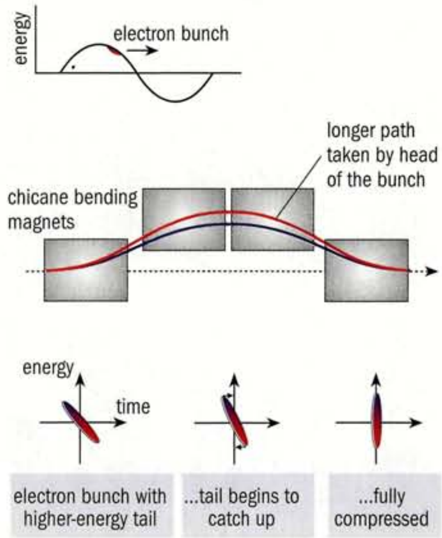
ACCELERATORS

SLAC makes world's shortest bunches

Using the full length of the linear accelerator, as well as loops and bends in the beam, and the usually troublesome effect of the wakefield, SLAC has made the world's shortest bunches of electrons – 12 μm in length and 80 fs in time. During its first run in May, the Sub-Picosecond Pulse Source (SPPS) made high-current, ultra-short bunches of electrons and turned them into very-bright, ultra-short pulses of X-ray light. These first X-rays made by a linear accelerator are in pulses 1000 times shorter than those made by storage rings such as SPEAR at Stanford in the US, enabling direct observations of atomic motion in matter that has never been seen before.

SPPS relies on several tricks to compress the bunches, which contain 2.1×10^{10} electrons, to reach a peak current of 30 kA. The gymnastics occur in three stages, starting as the bunches leave the damping rings near the beginning of the linac. At this point a bunch travels around the curve of the ring-to-linac (RTL) beamline and is compressed from 6 mm down to 1.2 mm. In the RTL, the bunch looks like a surfer climbing a wave – the front of the bunch has more energy (i.e. it is closer to the top of the radiofrequency wave) than the back. Going through the curved path of the bending magnets, the low-energy tail takes the shortest path and catches up to the head, making the bunch shorter.

The second step in bunch compression takes place at Sector 10, one-third of the way down the linac, where the electrons have been accelerated to 9 GeV. At this point the bunches are tipped to ride slightly ahead of the wave crest, so the rear is accelerated more than the front. Entering a chicane with four bends, the higher-energy tail is able to take the shortest path and catch up again, compressing the bunch to 50 μm.



To compress electron bunches, SPPS accelerates them below the crest of radio-frequency energy waves (top of figure). That way, one end of the bunch has more energy than the other. When the bunch goes through the chicane in Sector 10 (middle), the lower-energy head of the bunch takes the longer path and the tail catches up, effectively rotating the bunch to be shorter (bottom). (Patrick Krejcik, SLAC.)

The final step in compressing the bunch is something that can only be done at SLAC. It involves picking up energy along the remaining two-thirds of the linac and using an effect previously considered a nuisance. As the electron bunches travel at the speed of light, they generate an electric wake, which is known as a wakefield. In free space the wake would spread out perpendicular to the direction of travel of the electrons, but in the beam pipe the wake made by the head of the bunch bounces off the pipe and interferes with the tail. Thus the tail has less energy than the head when a bunch reaches the end of the linac.

Fortuitously, at SLAC the bunch can be routed through the Final Focus Test Beam, where the beamline jogs right then left. This geometry forces the higher-energy front to take a longer path, and the rear catches up again. Here, the bunch has rotated upright again and is now 12 μm long. At this length the bunch of 2.1×10^{10} electrons passes a fixed point in only 80 fs. After compression the bunches are wiggled by an undulator magnet, which is on loan from Argonne National Laboratory in the US, to generate the X-rays.

The SPPS will operate over the next two years, taking data in anticipation of the Linac Coherent Light Source that will make even brighter X-rays (*CERN Courier* March p5).

DETECTORS

Germanium crystals measure position

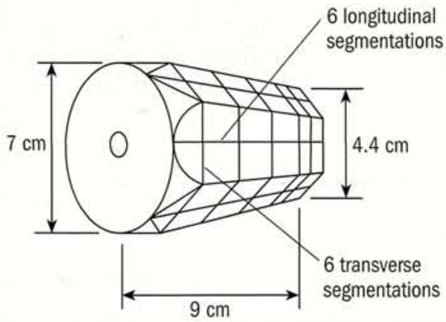
Germanium crystals have long been used to study photons with energies from 50 keV to 10 MeV. Their excellent energy resolution (approaching 0.1%) has created numerous applications in nuclear and particle physics, especially in studies of nuclear structure. Their major limitations are their poor position resolution and inability to reconstruct multiple interactions. Now, germanium crystals are being made to do "double duty", measuring the interaction points as well as the deposited energy, which allows for full 3D reconstruction of the energy deposition.

Photons with energies of less than a few million electronvolts interact primarily by Compton scattering. They usually interact several times before stopping, and many photons escape from conventional detector arrays without depositing their full energy. These partially reconstructed events constitute a substantial background to measurements. To reduce this background, existing germanium detectors are usually surrounded by thick anticoincidence (veto) counters. This veto greatly reduces the efficiency of large detector arrays.

The new breakthrough is to make germanium crystals work like miniature time-projection chambers, with the charge deposition measured at each point in the crystal. A central cathode embedded in the crystal generates a radial electric field. Electrons liberated by photon interactions in the crystals drift to segmented anodes that cover the crystal surface. Charge sharing between adjacent electrodes allows position resolutions of 1–2 mm, far better than the current one-crystal (5–10 cm) resolution. The electron drift time is also measured, which gives the depth of the interaction in the crystal and provides 3D space points. With good segmentation, complex interactions can be reconstructed, which greatly increases the photon detection efficiency while maintaining optimum resolution.

In many experiments to study very unstable nuclei, excited nuclei are produced at high velocities. To obtain gamma-ray spectra from these nuclei it is necessary to correct the photon energies for the nuclear Doppler shift; the accuracy of this correction depends on the precision of the photon position measurement. Another important application is precision nuclear spectroscopy, where the increased efficiency is needed to study multistep decays. For example, highly spinning nuclei may emit 20 or more photons as they de-excite. The ability to detect many photons in a single event greatly increases the experimental sensitivity to these reactions; high efficiency is critical for obtaining the required high-coincidence spectra.

The 36-fold segmented prototype of GRETA.



The segmentation of the surface anodes in the GRETA prototype.

Two large collaborations are developing gamma-ray tracking arrays using segmented crystals with appropriate read-out. In the US, the Lawrence Berkeley National Laboratory-led GRETA/GRETINA collaboration is building a segmented triple-crystal prototype module. Each crystal is covered with 36 electrodes (see figure). The read-out electrodes are segmented longitudinally and transversely. Each channel is instrumented with a low-noise pre-amplifier and a fast (100 Megasamples per second), accurate (14 bit) analogue-to-digital converter. The energy resolution is 1.9 keV for 1.33 MeV gamma rays, which is comparable to the best unsegmented detectors. GRETINA will be composed of 10 triple-crystal modules covering about 25% of 4π. It will travel from accelerator to accelerator, following the best physics. The follow-on to GRETINA, the 120-crystal GRETA detector, will have full 4π coverage.

The proposed 180-crystal (6500 channels) European AGATA array, also for nuclear spectroscopy, uses a similar technology to GRETINA. These arrays will have figures of merit that are several orders of magnitude better than existing large arrays, such as Gammasphere at Argonne and Eurogam at IReS in Strasbourg.

A few smaller arrays are already operational. At the Michigan State University cyclotron in the US, the SeGA array comprises 18 crystals, each with 32-segment read-out. These crystals are slightly smaller, with a 5 keV energy resolution. The EXOGAM array at GANIL in Caen, France, has 64 crystals, each with four segments, to measure the depth of interaction. Similarly, Miniball at CERN has 40 crystals with six segments. The proposed Canadian TIGRESS array at TRIUMF will comprise 64 eight-segment crystals.

Even for simple events, the improved position resolution is an important development. The resolution could lead to better images from positron emission tomography cameras, where two reconstructed 511 keV photons are used to localize positron annihilation in patients for various medical and biological applications.

The technique may also be used to reduce backgrounds in double beta decay and dark matter searches. The US Majorana collaboration proposes to build a 200-crystal germanium detector containing 500 kg of 86% enriched ^{76}Ge to study these topics. Simulations indicate that the position resolution obtainable with segmentation can lead to a factor of 5 to 8 rejection in backgrounds.

Further reading

For further information on some of these projects see:
http://greta.lbl.gov/
http://www-gsi-vms.gsi.de/eb/html/agata.htm
http://majorana.pnl.gov/

Spencer Klein, LBNL

NEUTRINOS

MINOS project gets going on the far side

On 14 August, after four years of mining, construction and testing, the Main Injector Neutrino Oscillation Search (MINOS) collaboration announced the start-up of its 5400 tonne neutrino detector in the Soudan Underground Laboratory in Minnesota, US. The completion of the "far" detector, located 700 m underground, came nine months ahead of schedule. The installation of a smaller "near" detector at the US Fermi National Accelerator Laboratory will begin next spring and completion is expected in August 2004. Using a new muon-neutrino beamline, currently under construction at Fermilab, the MINOS experiment will measure the energy dependence of the neutrino oscillation probability and provide precision measurements of neutrino oscillation parameters.

The 30 m long MINOS detector comprises 486 massive octagonal planes, lined up like the slices of a loaf of bread. Each plane consists of a sheet of steel that is about 8 m high and 2.5 cm thick, covered on one side with a layer of scintillating plastic. This photo shows the final plate in the assembly.

The 30 m long MINOS far detector comprises 486 massive planes, lined up like the slices of a loaf of bread. Each plane consists of an octagonal sheet of steel about 8 m high and 2.5 cm thick, covered on one side with a layer of scintillating plastic. With a total of 28 000 m^2, the far detector features the largest scintillator area of any particle physics detector in the world. A number of university and laboratory groups in the US and UK were involved in the mass production of the scintillator detector components, while the assembly of scintillator modules took place at the University of Minnesota, the California Institute of Technology and Argonne National Laboratory in the US.

Over the past three years the MINOS collaboration has conducted a series of calibration measurements with the CERN Proton Synchrotron proton beam. Led by a team from the UK, the collaboration has examined the response of a $1 \times 1 \times 3$ m mini-version of the MINOS detectors to pions, muons and other particles with energies from 0.5 to 10 GeV. The calibration of the electronics of the near detector will take place at CERN this autumn. The first half of the MINOS far detector has been in operation since July 2002, and the MINOS collaboration was able to present its first 12 atmospheric neutrino events at a conference in April 2003.

MINOS is the first large-scale underground neutrino experiment equipped with a magnetic coil. The 1.5 T magnetic field inside the detector allows muons and antimuons to be separated, hence distinguishing between neutrino and antineutrino interactions. The results will provide a basis for the first test of CPT symmetry in neutrino processes.

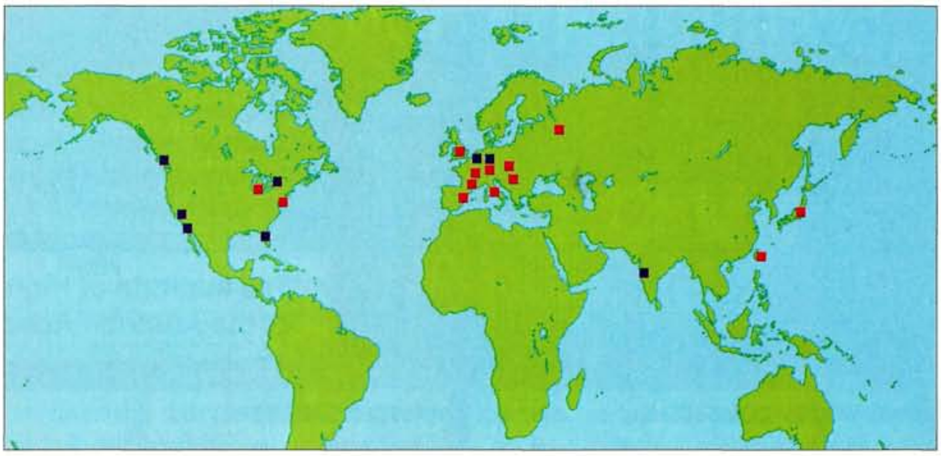
Early in 2005, when the commissioning of the neutrino beamline at Fermilab is complete, the experiment will enter its next phase. Fermilab's main injector will send 120 GeV protons onto a carbon target to create muon neutrinos with a median energy of about 3 GeV. The neutrinos will travel 735 km through the earth from Fermilab to Soudan. The near detector, located about 1 km from the carbon target, will verify the composition of the neutrino beam. The far detector will measure the deficit of muon-neutrinos caused by oscillations. More than 1000 billion (10^{12}) neutrinos in the beam per year will pass through the far detector, and about 1500 of them will make a collision with an atomic nucleus inside the detector. Most collisions will produce a muon, but some will create an electron or a tau, indicating an incoming electron-neutrino or tau-neutrino. Although the MINOS detector is not capable of identifying individual tau events, the experiment can statistically determine the dominant oscillation mode.

The MINOS experiment should provide the best measurement of oscillation parameters associated with the "atmospheric mass-squared region", for which the Super-Kamiokande and K2K experiments in Japan have obtained initial results. For the "solar mass-squared region", Super-Kamiokande and KamLAND in Japan, and the Sudbury Neutrino Observatory in Canada have provided the relevant results. OPERA and ICARUS, two future neutrino experiments to take place in the Gran Sasso Underground Laboratories in Italy, are aimed at directly observing the appearance of tau-neutrinos from muon-neutrinos. These experiments will use the 730 km muon-neutrino beam of the CERN Neutrinos to Gran Sasso project, which is currently under construction and scheduled to start up in 2006.

More than 200 people from 32 institutions in Brazil, France, Greece, Russia, the UK and the US are involved in the MINOS project. Most of the funding for the experiment and the neutrino beamline at Fermilab has come from the US Department of Energy, which will have provided $171 million. The UK's Particle Physics and Astronomy Research Council has contributed about $10 million, and about $4 million has come from the State of Minnesota, the University of Minnesota and the US National Science Foundation.

GRID COMPUTING

The LCG gets started...



Red squares indicate the computer centres active in LCG-1, the first phase of operations of the LHC Computing Grid, at the time of writing (Fermilab in Chicago and Brookhaven National Laboratory near New York, US; PIC in Barcelona, Spain; Rutherford Appleton Laboratory in Oxfordshire, UK; IN2P3 in Lyons, France; CERN; CNAF in Bologna, Italy; FZK in Karlsruhe, Germany; IPNP in Prague, the Czech Republic; RMKI in Budapest, Hungary; Moscow State University, Russia; Academia Sinica in Taipei, Taiwan; and University of Tokyo, Japan). Blue squares are centres that are planning to join within 6–12 months.

This summer the IT division at CERN was a hive of activity as dozens of young software engineers worked round the clock to launch the LHC (Large Hadron Collider) Computing Grid (LCG) into its first phase of operations. Meanwhile, similar hectic preparations were going on at other major computing centres around the world. The LCG project, which was launched last year, has a mission to integrate thousands of computers worldwide into a global computing resource. This technological *tour de force* will rely on novel Grid software, called middleware, and will also benefit from new hardware developments in the IT industry (see p31).

The challenge facing the LCG project can be summarized in terms of two large numbers. The LHC will produce more than 10 petabytes of data a year – the equivalent of a stack of CDs 20 km high – and require around 100 000 of today's PCs to analyse that data. Behind the numbers, however, is a new philosophy. The data and processing power should be available to the thousands of scientists involved in LHC experiments in a completely seamless fashion, independent of their location. This is the philosophy of computer Grids, which take their name from the ubiquitous, highly reliable electricity grid with its plug-in-the-wall simplicity.

The LCG project has been rapidly gearing up for this challenge, with more than 50 computer scientists and engineers from partner centres around the world joining the effort over the past year. The first version of the LCG, called LCG-1, is now up and running on a restricted number of sites (see map) and with limited functionality. Over the next few years, however, the plan is for the LCG to grow in size and complexity, absorbing new Grid technologies and integrating many more sites.

...while the EGEE gets ready

The success of the European Union (EU)-funded European Data-Grid (EDG) project – a three-year effort led by CERN, which is due to finish in spring 2004 – has generated strong support for a follow-up project. The objective is to build a permanent European Grid infrastructure that can serve a broad spectrum of applications reliably and continuously. Providing such a service will require a much larger effort than setting up the current EDG test bed. So CERN has established a pan-European consortium called Enabling Grids for E-science in Europe (EGEE) to build and operate such a production Grid infrastructure, providing round-the-clock Grid service to scientists throughout Europe.

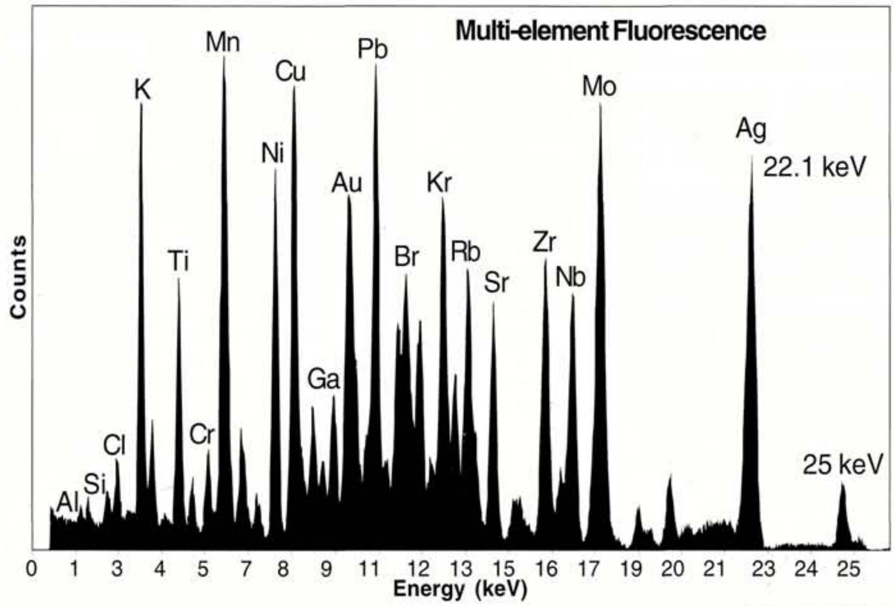
A proposal for such a project was submitted to the EU 6th Framework Programme in May 2003, where some €50 million has been earmarked by the commission for major Grid infrastructure projects. This proposal, again led by CERN, involves some 70 partners, encompassing all major computer centres in Europe as well as leading American and Russian centres. EGEE, following a positive evaluation by EU independent experts, has been invited to negotiate a contract with the EU for the major part of the allocated funds. Final contract negotiations with the EU are planned for November, and if all goes well the project should get under way by next spring.

The LHC Computing Grid will provide the springboard for EGEE, and in turn benefit from Grid software engineering that is part of the EGEE project. However, the mission of EGEE is also to extend the potential benefits of a Grid infrastructure beyond high-energy physics. The first target is biomedical applications, with other scientific and technological fields not far behind.

European projects galore

EDG and EGEE are by no means the only Grid projects that involve CERN. For example, DataTAG aims to provide high-speed connections between Grids in Europe and the US. In May, the project set its latest land-speed record, transferring data at nearly 1 Gbit/s (equivalent to nearly two DVD films a minute) between CERN and Chicago using the new IPv6 Internet protocol.

CrossGrid aims to extend the functionality of the EDG to advanced applications such as real-time simulations. The GRACE project is developing a decentralized search engine based on Grid technology. MammoGrid is dedicated to building a Grid for hospitals to share and analyse mammograms to improve breast-cancer treatment. GridStart aims to co-ordinate the efforts of the major Grid initiatives in Europe and disseminate information about the benefits of Grid technology to industry and society.



XR100CR X-Ray Detector with Power Supply & Amplifier

XR100CR fitted for vacuum applications

Compiled by Steve Reucroft and John Swain

Fluorine improves plastic semiconductors

Scientists at Northwestern University in Evanston, Illinois, and Lucent Technologies in Murray Hill, New Jersey, US, have announced what could be a major breakthrough in plastic semiconductors. Tobin Marks and colleagues have developed a new class of organic molecules that can be made into either n-type or p-type semiconductors. Until now, most organic materials that have looked like good candidates have been p-type only, but without both types it is difficult to make interesting devices. The potentially useful molecules are based on six thiophene units (rings made of five carbon atoms and one sulphur) strung together. Swapping various thiophenes with fluorinated six-membered carbon rings then makes the molecules n-type or p-type.

This work is in its early stages, with many improvements still possible, but the group has already demonstrated working transistors. The natural limits to which this sort of technology could be pushed would include circuits that could essentially be printed (literally) with modified ink-jet printers, leading to fantastic decreases in production costs and a proliferation of disposable electronic devices.

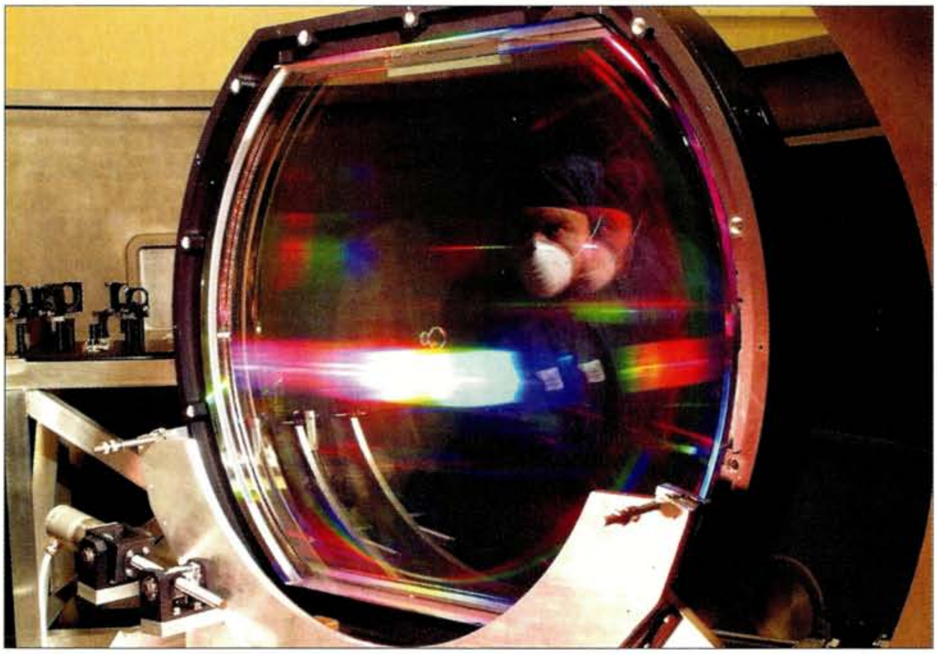
Further reading

Antonio Facchetti *et al.* 2003 *Angew. Chem. Int. Ed.* **42** 3900.

Laser alchemy could burn nuclear waste

A new approach to disposing of radioactive waste without using intense sources of neutrons is based on nuclear alchemy by laser. Ken Ledingham and colleagues from Strathclyde University, Glasgow University and Imperial College in the UK, the Rutherford Appleton Laboratory (RAL) in the US and the Institute for Transuranium Elements in Karlsruhe, Germany, have harnessed the ability of intense laser–plasma interactions to produce gamma rays that can be used for nuclear transmutation.

Working with the petawatt facility of the VULCAN glass laser at RAL, the team used a 0.7 ps pulse of 360 J to focus on a gold target with an intensity of about 5×10^{20} W cm^{-2}. Electrons from the plasma formed in this way reached relativistic energies and emitted bremsstrahlung gamma rays as they stopped in the gold. The team used these gamma rays to irradiate a sample prepared with waste solution from a fuel processing plant. They found that the irradiation changed iodine-129 into iodine-128. While both these isotopes are radioactive, the change is important because it corresponds to swapping a half-life of 15.7 million years for one of 25 minutes.



A grating to recompress the 500 J pulse to about 500 fs in the petawatt facility of the VULCAN glass laser at RAL, which has been used in experiments on nuclear transmutation. (CCLRC.)

This work follows on from earlier research, which showed that intense laser pulses could trigger fission of uranium-238. It is still not clear if lasers are the way to go in disposing of nuclear waste, but similar reactions could be useful in creating short-lived isotopes for medical applications with rather modest facilities that could be accommodated in many hospitals.

Further reading

K W D Ledingham *et al.* 2003 *J. Phys. D* **36** L79.

Terahertz radiation lights up cancers

With wavelengths between those of visible light and microwaves, terahertz radiation, or T-rays, are able to distinguish cancerous and healthy tissue below the surface of the skin that would otherwise be invisible. In a recent trial with ten patients who had skin cancers surgically removed, T-ray imaging proved extremely accurate in identifying those regions of excised tissue that were cancerous and those that were not.

Teraview, the Cambridge-based company that has developed this technology, is not yet certain why this sort of imaging works so well, but it could be linked to the fact that cancerous tissue can take up relatively large amounts of water, and water absorbs strongly in the terahertz region. The technology is also very promising for non-medical applications, such as airport security, as T-rays are quite penetrating but non-ionizing (*CERN Courier* January/February p6).

Further reading

New Scientist 2003 **179** 11.
www.teraview.co.uk/home_index.htm.

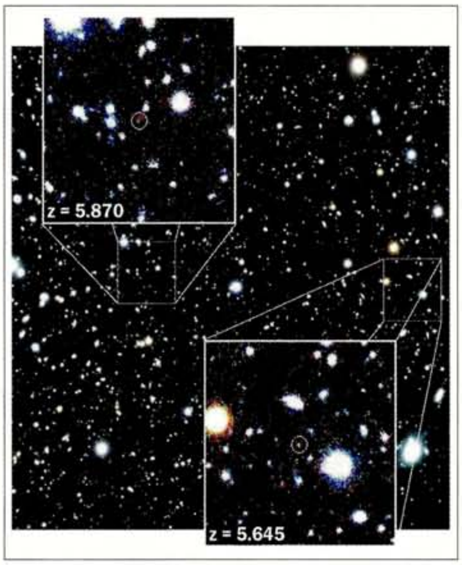
Compiled by Marc Türler

Looking back to the cosmic renaissance

Six of the most distant galaxies ever seen have been discovered in a small area of the sky less than five per cent the size of the full Moon. Located approximately 12 600 million light-years away, we observe these galaxies as they were at a time when the universe was very young, less than about 10% of its current age. At this time the universe was emerging from a long period known as the "dark ages" and was entering the luminous "cosmic renaissance" epoch.

The discovery of these new galaxies, with redshift z between 4.8 and 5.8, by Matthew Lehnert from Germany and Malcolm Bremer from the UK, was made possible thanks to a deep-field observation with the Very Large Telescope (VLT) of the European Southern Observatory. Very distant galaxies (with a redshift z greater than five) have been discovered previously, but this is the first time that so many have been found together in a small area of the sky. The two astronomers conclude on the basis of their unique data that there were considerably fewer luminous galaxies in the universe at this early stage than there were 500 million years later. This suggests that the newly discovered sources are indeed some of the very first luminous galaxies after the Big Bang. Their spectra have revealed that at the time they emitted the light, these galaxies were actively forming stars and were probably no older than 100 million years, perhaps even younger.

Nowadays, the universe is pervaded by energetic ultraviolet radiation produced by quasars and hot stars. The short-wavelength photons liberate electrons from the hydrogen atoms that make up the diffuse intergalactic medium, and the latter is therefore almost completely ionized. There was, however, an early epoch in the history of the universe when this was not so. This epoch follows the recombination of the nuclei and electrons to form atoms, some 100 000 years after the Big Bang. The universe became transparent at that time and released the cosmic microwave background radiation we can still observe from all directions.



Close-up views of two out of the six very distant galaxies (circled), which were discovered in a deep-field VLT image covering an area less than 5% the size of the Moon.

This was also the time when the universe plunged into darkness. On one side, the relic radiation from the primordial fireball had been stretched by the cosmic expansion towards longer wavelengths and trapped again by the newly formed hydrogen atoms. On the other side, no stars or quasars had yet been formed that could illuminate the vast space.

These "dark ages" were ended after a few hundred million years by the formation of the first generation of stars and, somewhat later, the first galaxies and quasars. Little by little their intense ultraviolet radiation re-ionized the intergalactic gas in steadily growing spheres around the ionizing sources. At some moment, these spheres had become so big that they overlapped, completely lifting the fog over the universe. This re-ionization epoch is sometimes referred to as the "cosmic renaissance".

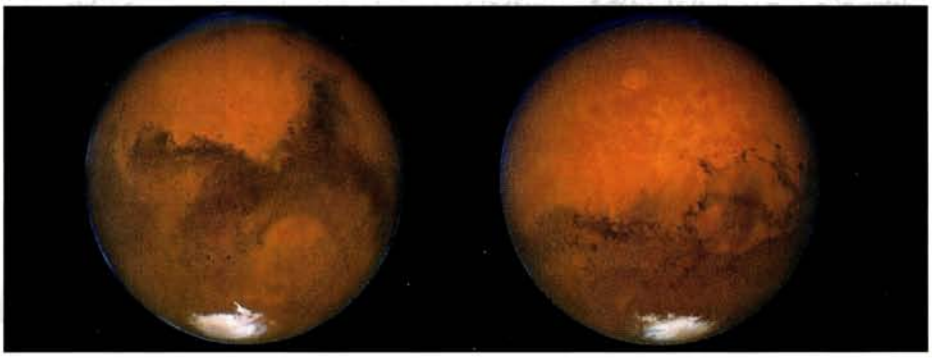
"Our findings show that the combined ultraviolet light from the discovered galaxies is insufficient to fully ionize the surrounding gas," explained Malcolm Bremer. "This leads us to the conclusion that there must be many more smaller and less luminous galaxies in the region of space that we studied, too faint to be detected in this way. It must be these still unseen galaxies that emit the majority of the energetic photons necessary to ionize the hydrogen in the universe."

"The next step will be to use the VLT to find more and fainter galaxies at even higher redshifts," added Matthew Lehnert. "With a larger sample of such distant objects, we can obtain an insight into their nature and the variation of their density in the sky."

Further reading

M D Lehnert and M Bremer 2003 *ApJ* **593** 630.

Picture of the month



Mars completed almost half a rotation between these two observations, taken 11 hours apart with NASA's Hubble Space Telescope (the left image was taken on 26 August 2003 at 23:00 UT and the right image on 27 August 2003 at 10:00 UT). These two sides of Mars were photographed as the red planet was making its closest approach to Earth in almost 60 000 years. (NASA, J Bell (Cornell University) and M Wolff (SSI).)

Faster, brighter, shorter

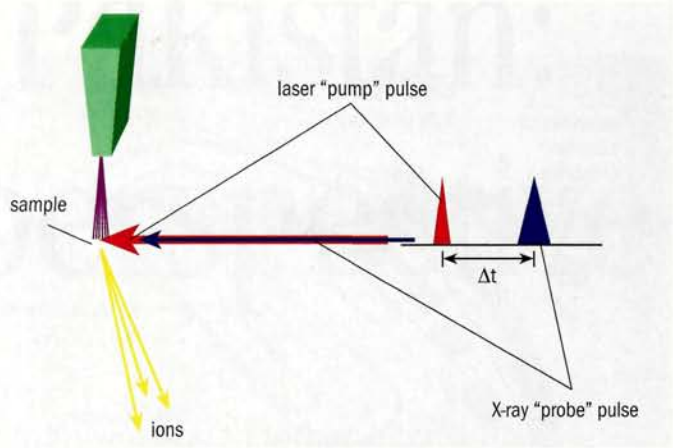


Fig. 1. A schematic showing the pump-probe concept. A laser pulse excites or "pumps" the sample into a state, which then evolves in time. An ultrafast X-ray pulse arriving at time Δt after the pump pulse then momentarily probes the state of the sample at that time – in this example by causing the emission of ions that are then detected.

A proposed new facility, called LUX, will be able to combine accelerator and laser systems to study ultrafast dynamics across a wide range of sciences.

Ultrafast X-rays have been identified in numerous workshops and reports around the world as a key area that is ripe for new scientific investigations – with femtosecond pulses allowing the detailed study of atomic motion during physical, chemical and biological reactions. Ultrafast lasers covering most of the visible, infrared and ultraviolet regions of the spectrum already provide the capability to measure bond breaking in chemical reactions with both excellent timing resolution and very short pulses. Thus, experimenters have used lasers to tremendous advantage in thousands of investigations of time dynamics, many of which are absolutely critical to research in solid-state physics, semiconductors, photochemistry and photobiology. However, until now, ultrafast time-domain studies in the X-ray region have been almost completely lacking, even though they are needed to refine the picture of dynamics at the timescales of atomic vibration periods – about 100 fs or less, and even the possibility of resolving electron dynamics with sub-femtosecond resolution.

Through the use of synchrotron radiation, and by the novel conversion of intense laser pulses into soft and hard X-rays, scientists have recently been able to perform some innovative experiments for the first time, such as Bragg diffraction studies of phase transitions and even attosecond electron redistribution in Auger electron processes. However, the laser-based X-ray fluxes are low, the signal levels weak and the experiments are challenging to accomplish.

LUX – a Linac-based ultrafast X-ray/laser facility – is a concept that is designed to produce ultrashort X-ray pulses in a highly refined manner for experiments across all areas of the physical, chemical and biological sciences. The facility will provide an increase of X-ray flux by several orders of magnitude, and would be accessible to a large number of users. Ultrafast lasers would be available for "pump-probe" experiments at femtosecond resolutions, where a pulse from a laser excites or "pumps" the system under study, while the X-ray pulse is used to probe the system configuration as a snapshot in time after the pump pulse. Figure 1 shows a schematic of this concept.

While the approximately 40 available light sources in the world are largely limited to static spectroscopies, microscopies and structures, LUX will be the first to be designed from the start as a user facility for femtosecond X-ray dynamics, with precise timing as an integral requirement. It will offer high repetition rates, tunability and multiple laser sources for excitation and probe experiments, with pulses 1000 times shorter than typical third-generation light sources.

Although pump-probe experiments represent some of the most important techniques, involving a femtosecond laser as a pump and the ultrafast linac-based X-ray source as the probe, the facility will also be designed to accommodate multidimensional coherent laser spectroscopies, such as three-laser pump beams and an X-ray probe, as well as two X-ray wavelengths for double-resonance X-ray pump and probe spectroscopies. Most of these novel forms of spectroscopies with X-rays have not even been delineated yet.

The LUX proposal is based on a recirculating electron linac, which provides a compact and cost-effective configuration for the production of intense ultrafast extreme ultraviolet (EUV) and X-ray pulses, with tight synchronization to sample excitation lasers. The provision of a broad photon spectrum covering the whole range from EUV to hard X-ray wavelengths allows for both spectroscopy and diffraction studies, probing nuclear positions as well as electronic, chemical or structural properties. The design specification of a 10 kHz pulse repetition rate is matched to pump-probe experiments and allows rapid data acquisition and sample relaxation or replacement.

The facility is designed to produce ultrafast EUV and soft X-rays by a harmonic-cascade free-electron laser (FEL) technique, while hard X-rays are produced by a novel manipulation of the electron bunches followed by compression of the photon beam. The FEL ▷

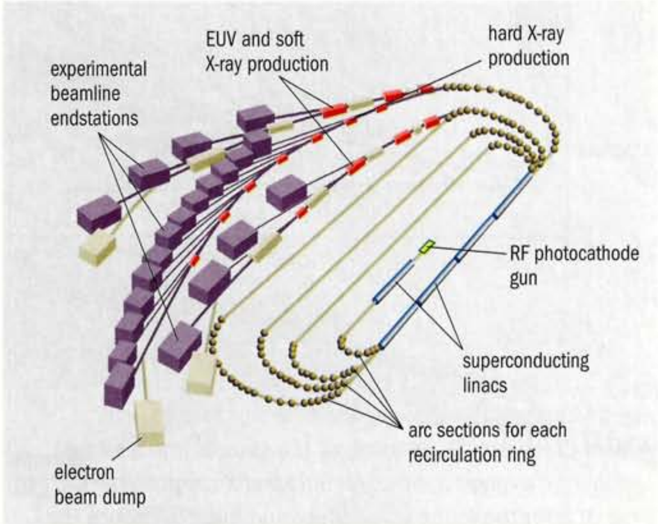


Fig. 2. The layout of the LUX machine, showing experimental beamlines, harmonic-cascade FEL chains and major accelerator components. The footprint of the machine is approximately 150 x 50 m, and a capacity of around 20 beamlines is shown.

process is initiated by a "seed" laser, which allows tunability of both wavelength and pulse duration from hundreds to tens of femtoseconds. Hard X-ray pulses are produced in superconducting insertion devices – undulators produce narrow-band peaks with harmonics out to 10 keV and higher, and wigglers produce broadband pulses extending to even shorter wavelengths.

The major components and systems of LUX involve existing accelerator technologies: radiofrequency (RF) photo-injector guns, superconducting linear accelerators, magnet lattices in the arcs and straight sections, transversely deflecting cavities, harmonic generation in FELs, narrow-gap short-period undulators, X-ray manipulation in optical beamlines, and a variety of short-pulse laser systems. Figure 2 shows the layout of the machine. In LUX, high-quality (low emittance, high charge) electron bunches produced in an RF photocathode are accelerated to approximately 100 MeV in an injector linac before being turned into the main linac. The main linac accelerates the electron bunches by about 700 MeV on each pass, resulting in a final energy of approximately 3 GeV after four passes. After acceleration to 3 GeV the electron bunches pass through insertion devices to produce radiation, supplied to multiple beamlines.

The beam-quality requirements of the RF photocathode gun have already been demonstrated, with a normalized emittance of approximately 3 mm mrad at 1 nC charge. The flexibility of the LUX lattice design allows the control and preservation of the transverse and longitudinal emittances of the electron beam, minimizing the influence of collective effects and allowing the manipulation of the picosecond electron bunches to produce femtosecond X-ray pulses.

To produce ultrafast hard X-rays, at the exit of the final arc the electron bunches receive a time-correlated vertical kick in a dipole-mode RF cavity – the head is kicked up and the tail is kicked down, while the centroid is unperturbed. The electrons then radiate X-rays in the downstream chain of undulators and wiggler magnets, imprinting this head-tail correlation in the geometrical distribution of the X-ray pulse. The correlated X-ray pulse is then compressed using asymmetrically cut crystal optics in order to achieve the ultrashort X-ray pulse length.

Sophisticated laser systems will be an integral part of the LUX facility, providing experimental excitation pulses and stable timing signals, as well as the electron source through the photocathode laser.

In addition, high-flux, short-pulse photons will be produced over an energy range of tens of electron volts to a thousand electron volts using a laser-seeded harmonic-cascade FEL. The high-brightness electron beam is extracted from the recirculating linac and passed through an undulator, where a co-propagating seed laser results in a modulation of the charge distribution over a short length of the bunch. This modulation enhances radiation in a following undulator at shorter wavelengths that are harmonically related to the seed. The process is repeated by modulating a fresh portion of the beam, this time with the harmonic radiation produced in the previous undulator.

Sophisticated laser systems will be an integral part of the LUX facility, providing experimental excitation pulses and stable timing signals, as well as the electron source through the photocathode laser. Each endstation will have its own dedicated laser system with optical filtering and diagnostics, all contained within a stable and controlled environment. Multiple tunable lasers covering infrared to ultraviolet wavelengths with a range of pulse durations are required for experiment initiation, together with sophisticated temporal and spatial filtering to optimize the performance for specific experimental applications.

The synchronization and timing of the ultrashort X-ray pulses with respect to the experimental excitation pulse is critical in studies of ultrafast dynamics. For LUX, the techniques of optically seeded systems and bunch manipulation prove insensitive to the usual timing jitter that arises from electron acceleration in RF systems. A laser master oscillator provides stable optical pulses, and optical distribution systems transport these pulses to each beamline, with feedback based on interferometric measurements to stabilize the path lengths. The conversion to microwave signals by photodiodes allows the generation of the RF signals for the accelerator, and for phase-locking of endstation lasers. The lasers may also be optically seeded directly from the master oscillator.

The LUX project is currently in a pre-conceptual design phase, and the facility design is being optimized in order to meet the demands of the growing number of scientific applications. Combining state-of-the-art accelerator and laser systems to produce a unique X-ray facility for the study of ultrafast dynamics presents some exciting challenges and the prospect of a bountiful future in new areas of science.

Further reading

More information can be found at http://lux.lbl.gov.

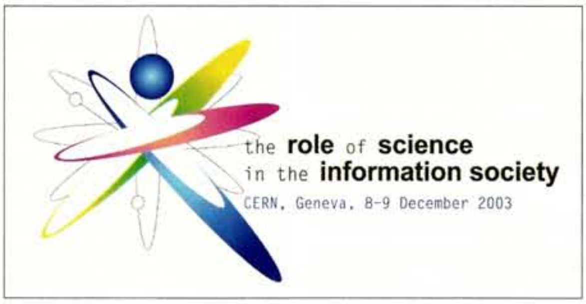
John N Corlett, **Stephen R Leone** *and* **Alexander Zholents**, *Lawrence Berkeley National Laboratory.*

CERN and Pakistan: a personal perspective

How can a country like Pakistan benefit from working together with CERN? **Ishfaq Ahmad** explains.

From its inception, CERN was international in character. The construction of its first 600 MeV accelerator was a fine example of international co-operation. After the Second World War, a group of European scientists realized that the brain drain during the war was a serious problem, which was continuing even after the war had ended. This realization gave birth to the idea of a European laboratory funded by several European nations. These scientists had a strong will, considerable political influence in their own countries and a commitment to do basic research, while recognizing that no single country had sufficient resources to build a large accelerator. CERN owes its creation to the dynamism and indomitable will of scientists such as Isidor Rabi, Eduardo Amaldi, Pierre Auger, John Cockroft and others. Thanks to their efforts, CERN, when it became operational, was gradually able to reverse the brain drain.

The informal scientific co-operation between CERN and Pakistan dates back to the 1960s, when Pakistan was introduced to CERN through Abdus Salam, the country's only Nobel Laureate. Salam had a desire that a group of Pakistani scientists commit themselves to both theoretical and experimental high-energy physics. On the suggestion of Salam, stacks of nuclear emulsion exposed at CERN were provided to Pakistan for the study of pions, kaons and antiprotons. In this informal co-operation, Owen Lock from CERN and the newly created Pakistan Atomic Energy Commission (PAEC) played an important role. Nuclear emulsions were later superseded by newer particle-detection techniques, and gradually this activity faded away. Meanwhile, some theoretical physicists from Pakistan had the opportunity to work at CERN through short visits. During the 1980s, some of the experimental physicists from Pakistan, specializing in the technique of Solid State Nuclear Track Detectors (SSNTD), also benefited from CERN by exposing the stacks in the beam at the Super Proton Synchrotron (SPS).

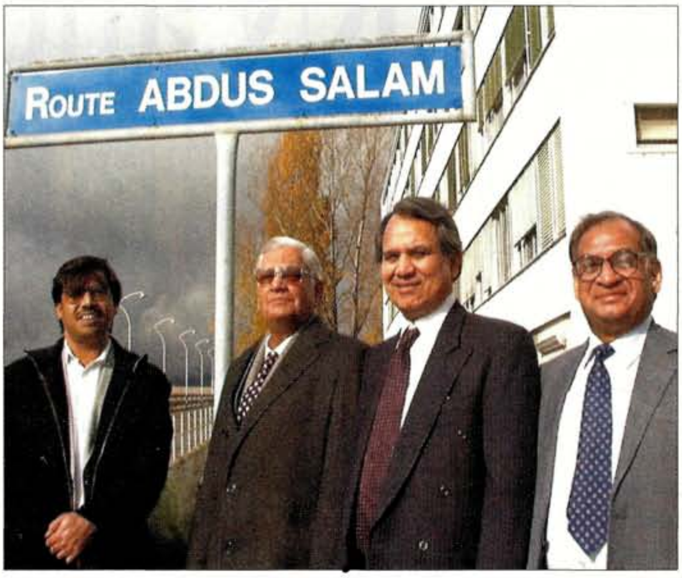


Ishfaq Ahmad (left), as chairman of the Pakistan Atomic Energy Commission, shakes hands with Chris Llewellyn Smith, director-general of CERN in 1997, after signing an agreement between Pakistan and CERN for a contribution to the CMS experiment.

In 1994 I visited CERN as chairman of PAEC. The visit took place on the initiative of Pakistani physicist Ahmed Ali, who works at DESY. It brought back good memories of my earlier visits, which date back to 1962 when I came to CERN as a young post-doctoral fellow working at the University Institute of Theoretical Physics in Copenhagen (now the Niels Bohr Institute) to perform a nuclear emulsion experiment. During my visit in 1994, I was fascinated to see the exciting developments in physics that were taking place at CERN, and I had only one wish – that my own country, Pakistan, should somehow become involved in scientific collaboration with CERN, and that our physicists and engineers could also become part of the most advanced, challenging and rewarding scientific endeavour: the Large Hadron Collider (LHC).

On my return to Pakistan, I kept my contacts with CERN, and a few months later a co-operation agreement was approved by the government of Pakistan, which was signed by me, as chairman of PAEC, and the then director-general of CERN, Chris Llewellyn Smith, who has now been appointed as director of the UK Atomic Energy Authority's fusion programme (*CERN Courier* September 2003 ▷

The arrival of the first four support feet, which were manufactured in Pakistan for the CMS experiment.



Visitors from Pakistan – including Ishfaq Ahmad (second from left) and Muhammad Afzal, minister (technical affairs) (third from left) – pose on the road at CERN that has been named in honour of Abdus Salam, Pakistan's first Nobel Laureate.

p39). In 1997, PAEC signed an agreement for an in-kind contribution worth one million Swiss francs for the construction of eight magnet supports for the CMS detector. The signing of the agreement was followed by the visit of Llewellyn Smith to Pakistan in 1998. The agreement provided an entry point for Pakistani scientists and engineers into the CMS collaboration.

In 2000, CERN's new director-general, Luciano Maiani, visited Pakistan, and during this visit another agreement was signed, which doubled the Pakistani contribution from one to two million Swiss francs. This new agreement covered the construction of the resistive plate chambers required for the CMS muon system. Recently, a protocol has been signed enhancing Pakistan's total contribution to the LHC programme to $10 million. I very much hope and wish that these developments may eventually lead to Pakistan becoming an observer state at CERN.

A source of inspiration

One of the inspirations for scientific co-operation with CERN was Salam's theories, which were always at the forefront of CERN's scientific programme. Salam, Sheldon Glashow and Steven Weinberg formulated the theory that unified the electromagnetic and weak interaction and predicted the existence of weak neutral currents. In 1973, neutral currents were observed at CERN, verifying the theory. The discovery created quite a lot of excitement in Pakistan because of Salam. A later important breakthrough was the discovery of the intermediate vector bosons, W and Z, at CERN's SPS in 1983. This provided yet another verification of the theory of Glashow, Salam and Weinberg (*CERN Courier* May 2003 p26).

The Large Electron Positron (LEP) collider was built at CERN to study electroweak theory and the Standard Model in more detail. It started up in 1989 and operated for 11 years, making precision tests of different aspects of the Standard Model. In particular, LEP experiments measured the number of neutrinos, and for the first time the mass of the Z boson was measured to an accuracy better than 2 MeV. However, one important ingredient of the Standard Model that is still missing is the Higgs boson, which is the elusive particle that in the Standard Model is responsible for giving masses to elementary particles.

It is hoped that the LHC, now under construction at CERN, will discover the Higgs boson, not withstanding the bet of famous physicist Stephen Hawking, and possibly physics beyond the Standard Model. The LHC will be able to explore physics at the TeV scale, where it is certain that some new physics will be found, most probably supersymmetry. Supersymmetry may explain a number of unsolved problems in the Standard Model, such as why masses differ by an order of magnitude as one moves from one quark family to another; why there are three families of quarks and three families of leptons; and how to explain the dark matter predicted by astrophysical models.

The importance of the Grid

The amount and size of experimental data generated at the LHC will pose the greatest challenge to the physicists. The collection, storage, retrieval and analysis of LHC data will require novel techniques in the field of information technology. The physicists working in different institutions around the globe will access LHC data; this implies a need for distributed computing (see p9). In recent years, a new approach in computing is emerging, called the Grid. The Grid is a natural evolution of the World Wide Web, which was invented at CERN in 1991. While the Web made information retrieval via the Internet extremely easy and simple, the proper implementation of the Grid will allow information processing and the solving of complex problems that would otherwise require supercomputers, in a very simple manner. Grid computing will be particularly useful for developing countries, where the cost of a supercomputer is prohibitive and there are also political difficulties in their purchase. It is very important for Pakistan to establish the proper infrastructure for Grid computing to acquire the full benefits of its investment in the LHC.

Information technology, on which CERN is to hold an important conference, "The Role of Science in the Information Society (RSIS)", in December this year, is going to have a tremendous effect on billions of human beings who are being increasingly exposed to pressures due to the unabated instinct of the poor to reproduce and the insatiable desire of the rich to consume. Our planet is, of course, limited in space and resources. The new interactive electronic communications will have a strong impact on society. The hope is that Grid technologies, like the Web, will be widely used in both developed and developing countries alike. In its wake, the Grid will bring many changes to the socio, economic and cultural fabric of society.

Coming back to Pakistan, it is important to note that due to the influence of Salam, a number of high-calibre Pakistani theoretical particle physicists were trained in the latter part of the 20th century. On the other hand, Pakistan has always lagged behind in experimental particle physics due to a lack of resources. It was strongly felt by the scientists of Pakistan that a national centre for physics of very high international standards was needed. In 1994, I led a group of physicists to meet the president of Pakistan to discuss this issue, and the president very kindly approved the concept of such a centre. So in 1998, during the inauguration ceremony of the 23rd International Nathiagali Summer College on Physics and Contemporary Needs, I announced the creation of the National Centre of Physics (NCP) and invited the well-known Pakistani theoretical physicist Riazuddin to head the centre, which he kindly accepted.

The NCP is the cradle and the focal point for all CERN-related activities in Pakistan. At present, the centre is involved in a number of LHC-related activities such as detector construction, detector simulation, physics analysis and Grid computing. Several other Pakistani institutes are also collaborating with CERN indirectly through the NCP. The activities of these institutes cover areas such as software development, manufacturing of mechanical equipment, alignment of the CMS tracker using lasers, and the testing of electronic equipment.

Former CERN director-general Victor Weisskopf wrote in his book *The Joy of Insight* that anybody who enters CERN should be regarded as European and no longer a citizen of any nation. Now CERN is open to any scientist from anywhere in the world. Moreover, beyond its 20 European member states, CERN currently has cooperation agreements with 30 countries. Had Weisskopf been alive today, he would probably have rephrased his remark by saying that "anybody who enters CERN is a citizen of the world".

- For more information about RSIS, see http://cern.ch/rsis.

Ishfaq Ahmad, *special advisor to the prime minister of Pakistan and former chairman of the Pakistan Atomic Energy Commission.*

Journey to the centre of the Earth

One of the first applications of neutrinos to science beyond particle physics could tell us about the heat produced by radioactivity in the Earth.

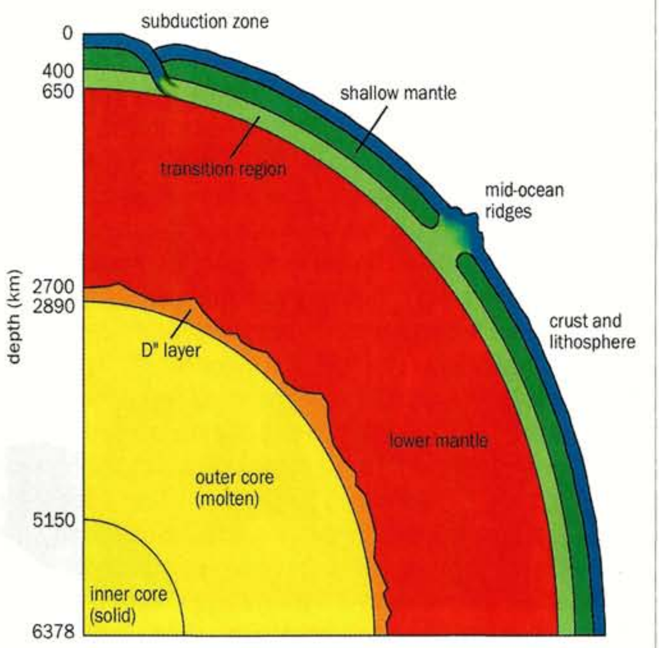


Fig. 1. A cross-section of the Earth, showing the main geological layers. The abundance of the radiogenic elements in the different layers determines the heat flow.

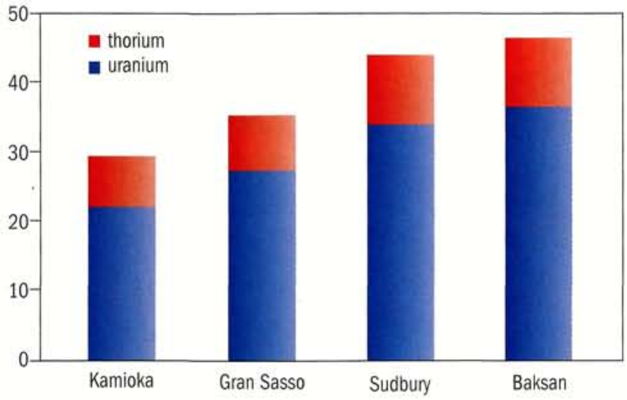


Fig. 2. Predicted geoneutrino events in different laboratories for exposures of 10^{32} protons per year and 100% efficiency.

Some 120 years ago, X-rays opened up a new era in medicine and science, allowing doctors "to see the man inside us". Since the 1970s we have been using neutrinos in a similar way to monitor the "physiology" of the deep solar interior, and in 1987 neutrinos revealed the "pathological" state of a collapsing star, in supernova 1987a, heralding a new era in astronomy. Indeed, "If there are more things in heaven and Earth than are dreamt of in our natural philosophy, it is partly because electromagnetic detection alone is inadequate," as Lawrence Krauss, Sheldon Glashow and David Schramm wrote in 1984 when they proposed a programme of antineutrino astronomy and geophysics, which would open vast new windows for exploration both above us and below.

However, unlike with X-rays, the potential of neutrino observations could not initially be fully exploited because the neutrino survival probability was not known, as testified by the 30-year-long solar neutrino puzzle. As the physics of the emission process was mixed with uncertainties in the evolution of neutrinos, it was difficult to learn much from neutrinos. But this situation changed dramatically with the results from the Sudbury Neutrino Observatory, which clearly proved the oscillation of electron neutrinos (*CERN Courier* June 2002 p5). Now we know the fate of neutrinos, so we can really learn from them. It is therefore time to tackle the kind of programme that was proposed by Krauss and colleagues, which includes a detailed study of the Sun, the cosmic abundance of the relic neutrinos from past supernovae, and last but not least the interior of the Earth.

The KamLAND experiment in Japan has already opened up a new field of research that exploits the special ability of neutrinos to reveal what is hidden to other probes of the Earth's interior. The experiment, which confirmed neutrino oscillations by detecting antineutrinos emitted from nuclear reactors, can also discriminate events from antineutrinos of terrestrial origin, the so-called geoneutrinos (KamLAND collaboration 2003). Nine such events have been reported from the first exposure of six months, providing us with a first glimpse of the interior of the Earth.

Neutrinos and the Earth's heat

One hundred and forty years after Jules Verne's voyage, the deep interior of the Earth remains *de facto* an unexplored frontier to mankind and, despite recent progress in geological and planetary research, the number of open problems possibly exceeds the number of known facts. A central issue concerns the source of terrestrial heat. The Earth re-emits in space the radiation that comes from the Sun (1.4 kW/m^2), adding to it a tiny flux of heat produced from its interior (about 80 mW/m^2) to give a total of 40 TW, the equivalent of some 10 000 power plants. The origins of terrestrial heat are not understood in quantitative terms: such a heat flow can be sustained over geological times by any energy source, be it nuclear, gravitational or chemical. In the words of John Verhoogen: "Radioactivity itself could possibly account for at least 60%, if not 100%, of the Earth's heat output...If one adds the greater rate of radiogenic heat production in the past, possible release of gravitational energy (original heat, separation of the core...), tidal friction...and possible meteoritic impact ...the total supply of energy may seem embarrassingly large." The relevant questions are: how large is the radiogenic contribution to heat flow? Which nuclei are relevant? Where are they?

The answer to which nuclei are relevant is relatively simple. The main sources of natural radioactivity are currently uranium, thorium and potassium, through the decay chains: $^{238}U \rightarrow {}^{206}Pb + 8\,{}^{4}He + 6e + 6\bar{\nu} + 51.7$ MeV; $^{232}Th \rightarrow {}^{208}Pb + 6\,{}^{4}He + 4e + 4\bar{\nu} + 42.8$ MeV; $^{40}K + e \rightarrow {}^{40}Ar + \nu + 1.513$ MeV (11%); $^{40}K \rightarrow {}^{40}Ca + \bar{\nu} + e + 1.321$ MeV (89%). Specifically they release, for natural isotopic abundances, 0.95 (uranium), 0.27 (thorium) and 3.6×10^{-5} (potassium) erg per second per gramme of the corresponding chemical element.

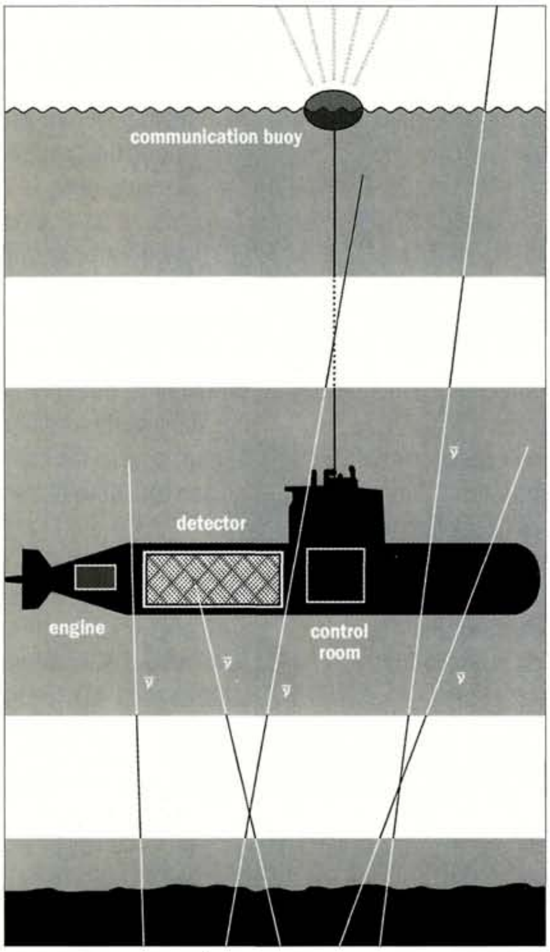


Fig. 3. Schematic showing the conversion of a submarine to a kilotonne antineutrino detector.

To answer the question about how large the radiogenic contribution is to the heat flow, we need to know the abundances of the radiogenic elements in the Earth's different layers (figure 1), as the radiogenic heat flow depends on three basic pieces of data: the total masses of uranium, thorium and potassium, which are related to the total radiogenic heat flow H by the equation $H = 9.5\,M_U + 2.7\,M_{Th} + 3.6\ 10^{-4}\ M_K$, where H is in TW and the masses are in units of 10^{17} kg. However, observational data on the amounts of uranium, thorium and potassium in the Earth's interior are rather limited, as only the crust and the upper part of the mantle are accessible to geochemical analysis. As uranium, thorium and potassium are lithofile elements, they accumulate in the continental crust.

Estimates for the uranium mass in the crust are in the range $(0.2\text{–}0.4) \times 10^{17}$ kg, and while concentrations in the mantle are much smaller, the total amounts are comparable due to the much larger extension of the mantle. Estimates for the mantle are in the range $(0.4\text{–}0.8) \times 10^{17}$ kg. Note, however, that these estimates are much more uncertain than for the crust as they are obtained by analysing samples emerging from the upper mantle (at a depth of a few hundreds of kilometres) and extrapolating the results to the completely unexplored lower mantle (approximately 3000 km). Based on geochemical arguments, uranium should be negligible in the core, which is completely inaccessible to observation.

As for the abundance ratios, one estimates Th/U ~ 4, which is consistent with the meteoritic value, whereas for potassium one generally finds on Earth that K/U ~ 10 000, a puzzling value as it is a factor of seven below that of the oldest meteorites. The abundance of potassium in the Earth's interior, the possibility that some is buried in the Earth's core, and its contribution to terrestrial heat, are issues that are still debated among geochemists (Rama *et al.* 2003).

Geoneutrinos allow a direct and global measurement of the actual abundances of uranium, thorium and potassium, which can provide important information for discriminating among different models for heat production and, more generally, for the formation and evolution of the Earth. In fact, for each element there is a well-fixed ratio of heat to neutrinos (antineutrinos): $L_{\bar{\nu}} = 7.4\,M_U + 1.6\,M_{Th} + 27 \times 10^{-4}\,M_K$; $L_{\nu} = 3.3 \times 10^{-4}\,M_K$, where the luminosities L are in units of 10^{24} particles per second.

The neutrinos from the Sun completely swamp those emitted from the Earth, but not so with antineutrinos. These can be detected with a distinctive signature via the inverse beta-decay reaction: $\bar{\nu} + p \rightarrow n + e^{+} - 1.804$ MeV, which is possible with antineutrinos from the uranium and thorium chains, but not with antineutrinos from potassium. A liquid scintillator detector could record some 20–50 events from uranium and thorium geoneutrinos per kilotonne per year, depending on the assumed abundances and on the location. Geoneutrinos from uranium and thorium can be further distinguished through the different energy spectra.

The theoretical discussion of geoneutrinos was introduced in the 1960s by Gernot Eder, and extensively reviewed 20 years later by Krauss, Glashow and Schramm. Now these ideas have become more relevant. With KamLAND a handful of geoneutrino events has been extracted from the data after the subtraction of reactor and background events. The KamLAND results thus provide a first look at the amount of radiogenic material inside the Earth. In this context, a group of physicists from the universities of Cagliari and Ferrara, together with Earth scientists from Siena, has recently built a reference model for estimating neutrino fluxes according to the best geological and geochemical information (see for instance Fiorentini *et al.* 2003). The team has studied the possibility of detecting geoneutrinos at various underground laboratories (figure 2).

A look forward

While the KamLAND results, obtained from a short exposure, are an important first step, they are not sufficient for a determination of the geoneutrino flux and for discriminating between different models of heat production in the interior of the Earth. However, continuing ▷

observation will allow for a significant statistical increase, which will be particularly important if some nearby reactors are temporarily switched off. The comparison with measurements from Borexino at the Gran Sasso Underground Laboratories, where the reactor background is much smaller, will provide a significant addition to the data. Detectors at other underground laboratories could also make important contributions to a full map of antineutrinos from the Earth. Moreover, a detector far away from the continental crust would provide direct information on radioactivity from the mantle, which is the most uncertain issue. In principle, one could fit a detector of a few kilotonnes in a (conventionally propelled) submarine and move it around the world, at depths of a few hundred metres in an experiment lasting several years (figure 3).

Other proposals have been put forward for studying the Earth with neutrinos. For example, Ara Iaonnisian and Alexei Smirnov have considered solar neutrinos for oil prospecting. Detection would consist of measuring modulations of the ^{7}Be flux in a large deep underwater detector-submarine that could change its location. In the 1980s, Alvaro De Rujula, Sheldon Glashow, Robert Wilson and Georges Charpak proposed using neutrinos produced by a multi-TeV proton synchrotron as a tool for geological research. Few-TeV neutrinos are suitable for "tomography" of the Earth because they have a range comparable to the Earth's diameter. Related ideas are now being revived in the context of neutrino factories.

In 1942 Bruno Pontecorvo, one of the founding fathers of neu trino physics, published an important paper, little-known amon particle physicists, in the *Oil and Gas Journal*, entitled "Neutro well logging – A new geological method based on nuclear physics' It described the "neutron log", an instrument sensitive to water an hydrocarbons that is now widely used by geologists. It clearl stemmed as an application from the celebrated studies at Rom on slow neutrons, and it testifies to Pontecorvo's promptnes in transforming basic physics into a tool that could be used i other disciplines.

Likewise, neutrinos have now reached a phase where they can b exploited in different fields of science. In this respect, the dete mination of the radiogenic contribution to terrestrial heat, an im portant and so far unanswered question, is probably the first fru we can expect to obtain.

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New light shed on strange physics

The latest generation of high-current electron accelerators in the GeV energy range is breathing new life into a variety of investigations based on the photoproduction of kaons, as **Terry Mart** explains.

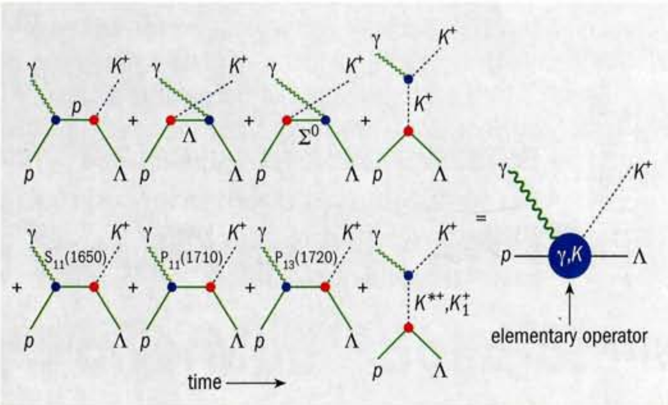

Fig. 1. The tree-level Feynman diagrams for electromagnetic production of the kaon on a proton. The amplitude obtained from these diagrams is called the elementary operator, which is very useful in studying some of the phenomenological aspects related to kaon–hyperon production.

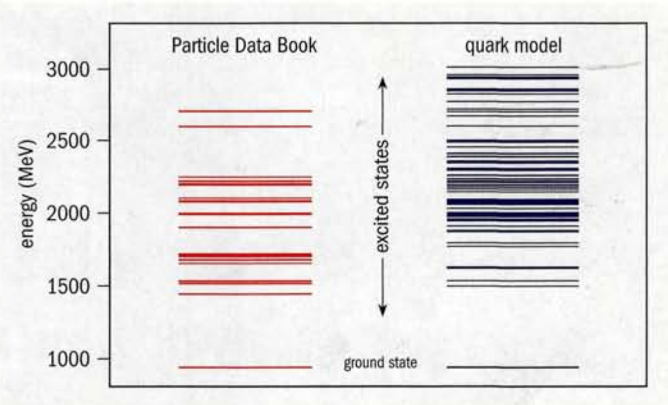

Fig. 2. Diagram showing the nucleon's ground state (proton and neutron) and excited states (nucleon resonances), as reported by the Particle Data Book and as predicted by a quark model (Capstick and Roberts 1994). Does the Particle Data Group really miss these resonances?

Since the discovery of strangeness by Murray Gell-Mann and Kazuhiko Nishijima almost five decades ago, interest in this degree of freedom has remained alive, with investigations now spanning the range from quarks to nuclei. For nuclei in particular, strangeness has given experimenters a new tool for probing all nuclear levels while avoiding "Pauli blocking", which is an inherent problem for conventional nuclei where low levels are already filled with neutrons and protons. Hypernuclear systems are therefore very promising subjects of study in nuclear physics, and there have been considerable efforts in theory and experiment alike to uncover the behaviour of nuclei "doped" with one or several hyperons.

Hypernuclei can also be produced using electromagnetic processes, such as kaon photoproduction off a nucleus. Compared with the conventional hadronic mechanism, electromagnetic production of hypernuclei has a clear advantage: since the photon and kaon interact weakly with the nucleus, the process can occur deep inside the nuclear interior. Furthermore, electromagnetic processes are fully controllable in comparison with hadronic ones, so the photoproduction of a kaon plus a hypernucleus provides a clean way to study hypernuclear spectra. In addition, the associated production off a deuteron can be used to study the hyperon–nucleon interaction in the final state, while the quasi-free kaon photoproduction off nuclei serves as an important tool for investigating kaon–nucleus and hyperon–nucleus optical potentials.

While the history of kaon photoproduction off the nucleon goes back to the mid-1950s, a more serious phenomenological study was begun in 1966 by H Thom at Cornell (Thom 1966). Extensive investigations continued until the early 1970s, but then interest temporarily declined, mainly due to the lack of experimental facilities. The field was revived in the late 1980s after the construction of a new generation of high duty-factor electron accelerators providing continuous, high-current and polarized beams in the energy region of a few GeV. Now, the operation of these accelerators, such as ELSA in Bonn, MAMI in Mainz, CEBAF at the Jefferson Laboratory in Virginia, GRAAL in Grenoble and Spring-8 in Osaka, has boosted efforts to advance our knowledge in the strangeness sector through the electromagnetic production of kaons. Recently, there has been a great deal of excitement concerning the detection of a five-quark state – the "pentaquark" – in kaon photoproduction at ELSA, CEBAF and Spring-8 (*CERN Courier* September 2003 p5), and while it is clear that kaon electroproduction contains a lot of rich information, this article will concentrate on several other aspects that make kaon photoproduction an up-to-date research topic.

Kaon photoproduction processes cannot be properly understood without an elementary production operator that describes the production mechanism off the nuclear constituents (proton or neutron). At the elementary level, the investigation is most effectively performed in the framework of an isobar approach based on nucleons and hyperons – that is, the corresponding operator is constructed from the Feynman diagrams shown in figure 1. (Quark models can also be used but they are beyond the scope of this article.) Furthermore, the isobar approach has the advantage that it has several simple phenomenological applications, as discussed later.

As can be seen from figure 1, several "ingredients" enter the elementary photoproduction operator via intermediate particles. Among them, the most crucial are: the number of meson and baryon resonances participating in the reaction, the properties of those resonances, hadronic and electromagnetic vertex factors, and methods to maintain fundamental symmetries of the operator.

Understanding these ingredients from first principles is currently beyond our capabilities, and this leads to some intrinsic problems on the theoretical side. The best we can do in the mean time is to restrict the number of resonances in the model to as few as possible by following the recommendation from the Particle Data Book, that is, including only the resonances that have significant decay widths to kaon channels, and fitting all unknown factors or constants (Hagiwara *et al.* 2002). Although this procedure may seem too pragmatic, the result shows good agreement with experimental data and has a wide range of applications in processes involving kaons and hyperons.

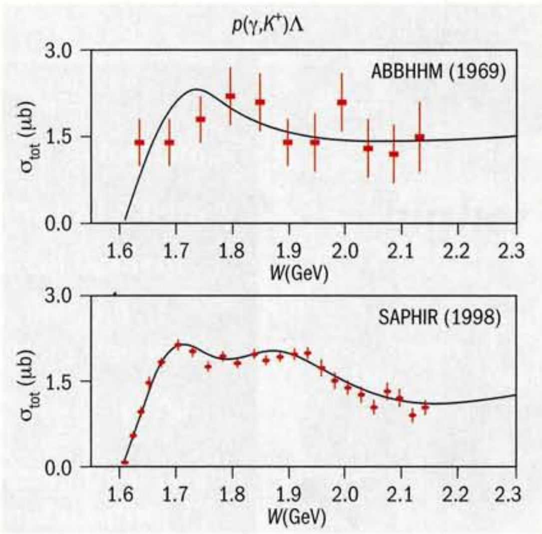

Fig. 3. A comparison between old and new measurements of the kaon photoproduction $\gamma p \rightarrow K^+\Lambda$ total cross-section. While in the old data no structure can be detected, the new high-quality SAPHIR data show a clear peak around W = 1.9 GeV. Mart and colleagues proposed that this structure reveals a missing resonance that was previously predicted by a quark model. Curves in both panels show the best fit to the data.

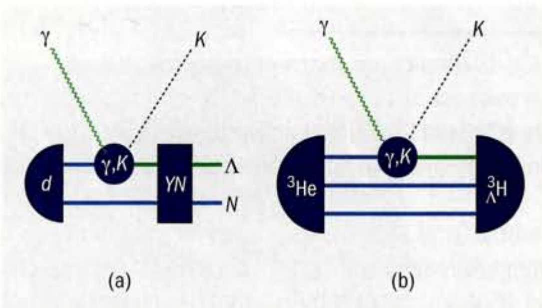

Fig. 4. A schematic description of kaon photoproduction off (a) a deuteron, where one can study the hyperon–nucleon potential, and (b) a helion, with which we can investigate some of the properties of the lightest hypernucleus.

The search for 'missing' resonances

The physics of nucleon-resonance excitation continues to provide a major challenge to hadronic physics due to the nonperturbative nature of quantum chromodynamics (QCD) at these energies. While methods such as chiral perturbation theory are not amenable to N^* physics, lattice QCD has only recently begun to contribute to this field. Thus, most of the theoretical work on the nucleon excitation spectrum has been performed in the realm of quark models. Interestingly, these models predict a much richer resonance spectrum than has been observed in $\pi N \rightarrow \pi N$ scattering experiments (see figure 2), the main source of the Particle Data Book. The obvious question is: where are the other resonances? One may argue that perhaps they are hiding behind some prominent resonances and we need better resolution to single them out. On the other hand, quark models themselves have suggested that those "missing" resonances may couple strongly to other channels, such as the Λ and Σ channels.

Recently, much improved data have become available in the $\gamma p \rightarrow K^+\Lambda$, $\gamma p \rightarrow K^+\Sigma^0$ and $\gamma p \rightarrow K^0\Sigma^+$ channels, from total cross-sections to polarization observables. The new SAPHIR total cross-section data for the $\gamma p \rightarrow K^+\Lambda$ channel, shown in figure 3, indicate for the first time a structure around a centre-of-mass energy of W = 1.9 GeV. This structure could not be resolved before due to the low quality of the old data. Indeed, these new data can guide us to select the most important resonances in this process. Cornelius Bennhold and I have interpreted this structure as the evidence for the missing resonance $D_{13}(1895)$ (Mart and Bennhold 2000). This was previously predicted by a constituent quark model to have a mass of 2080 MeV (Capstick and Roberts 1994). Although we found a remarkable agreement between the predicted and the extracted photocouplings, firmer evidence awaits rigorous calculations using a coupled-channels approach.

Searching for "missing" resonances is not only the business of studies in kaon–hyperon production – several other studies have tried to find these resonances in vector meson production. A new organization, BRAG (Baryon Resonance Analysis Group), has been set up to form a network between researchers working in this field and to optimize the available resources. More than 100 physicists from 18 countries have now joined this network. Clearly, this field will attract more attention from the hadronic physics community around the world in the coming years. ▷

From deuterons to hypernuclei

The electromagnetic production of kaons can also be performed off a deuteron target, where one of the nucleons inside the deuteron absorbs the photon and transforms into a kaon and a Λ hyperon, as shown in figure 4a. Since a Λ cannot bind to a nucleon, photoproduction leads to a break-up process. However, before the hyperon leaves the nucleon, both particles interact strongly. Thus, a phenomenological description of this process requires information on the hyperon–nucleon (YN) potential; or in other words, this process paves the way for investigating the YN potential via electromagnetic processes.

Contrary to the case of the nucleon–nucleon (NN) potential, the properties of the hyperon–nucleon interaction are still somewhat uncertain. In the case of NN forces, one has the rich set of NN scattering data at one's disposal to adjust NN force parameters. This set is essentially absent in the case of the YN system, since performing YN scattering experiments is very difficult. Kaon photoproduction off the deuteron is therefore well suited to tackle this problem by testing various available models for the YN potential. Such a study has been performed by Hisahiko Yamamura and colleagues (Yamamura *et al.* 2000). By using the modern Nijmegen soft-core YN potential, they found sizeable final-state effects caused by this potential near $K^+\Lambda N$ and $K^+\Sigma N$ thresholds.

If kaon photoproduction is performed off a helium nucleus (a helion), then a hypertriton is formed in the final state (see figure 4b). The electromagnetic production of the hypertriton is a clean mechanism for studying this lightest hypernucleus. The production is expected to act as a complementary tool for investigating hypernuclear spectra. In a study using realistic ^{3}He and hypertriton wave functions, obtained as solutions of Faddeev equations, we have found that Fermi motions in the nucleus play a significant role in this process and the cross-section is of the order of several nanobarns (Mart *et al.* 1998). By extending these investigations to heavier nuclei, we could eventually cover the hypernuclear chart.

Equation 1

$$\kappa_N^2 = -\frac{m_N^2}{2\pi^2\alpha}\int_0^\infty \frac{d\nu}{\nu}\,[\sigma_{1/2}(\nu)-\sigma_{3/2}(\nu)]$$

$$= \frac{m_N^2}{\pi^2\alpha}\int_0^\infty \frac{d\nu}{\nu}\,\sigma_{TT'}\,,$$

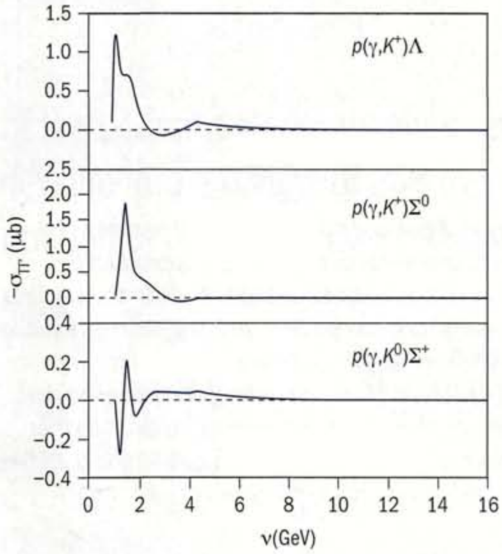

Fig. 5. Predictions for transverse–transverse cross-sections in all three proton channels (Mart and Wijaya 2003) for estimating the contributions of kaon–hyperon final states to the GDH sum rule.

Inside the nucleon

The internal structure of the nucleon is responsible for its ground-state properties, such as hadronic and electromagnetic form factors and the anomalous magnetic moment, while at higher energies this finite internal structure creates a series of resonances in the mass region of 1–2 GeV, as shown in figure 2. The ground-state properties and the resonance spectra are not all independent phenomena, however; they are related by a number of sum rules. One of these is the Gerasimov–Drell–Hearn (GDH) sum rule (see equation 1, left), which connects the magnetic moments of the nucleons and their helicity structures in the resonance region. The derivation of this sum rule is based on general principles: Lorentz and gauge invariance, crossing symmetry, causality and unitarity. The only assumption in deriving equation 1 is that the scattering amplitude goes to zero in the limit, photon energy $\nu \rightarrow \infty$, thus there is no subtraction hypothesis.

Although the GDH sum rule was proposed more than 30 years ago, no direct experiment has been performed to investigate whether or not the sum rule converges. However, with the advent of the new high-intensity and continuous-electron-beam accelerators, accurate measurements of the right-hand side of equation 1, as well as contributions from individual final states, are now possible.

The contribution from kaon–hyperon final states is of particular interest because strange quarks are explicitly present in the final states. Using the elementary operator obtained from figure 1, calculations of the contribution for photon energy up to 2.2 GeV show that about 3.5% of the nucleon magnetic moment comes from the strange quark contribution (Sumowidagdo and Mart 1999). Very recently, a refined calculation up to about 16 GeV (see figure 5) has yielded a relatively smaller value of 1.25%, which is due to the oscillating behaviour of the cross-section (Mart and Wijaya 2003). Despite these small values, however, the calculations indicate that contributions from strangeness to the magnetic moment of proton is obviously significant. It is a challenge to the experimenters to confront the prediction shown in figure 5 with their future data. There is still much of interest to study in kaon photoproduction.

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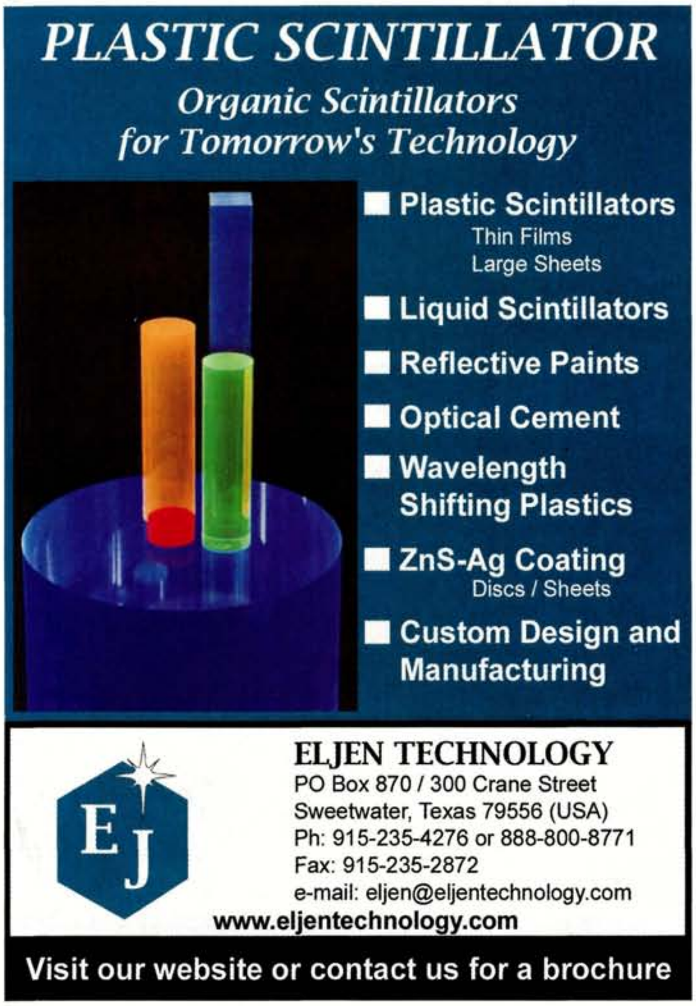
Terry Mart, *Jurusan Fisika, FMIPA, Universitas Indonesia.*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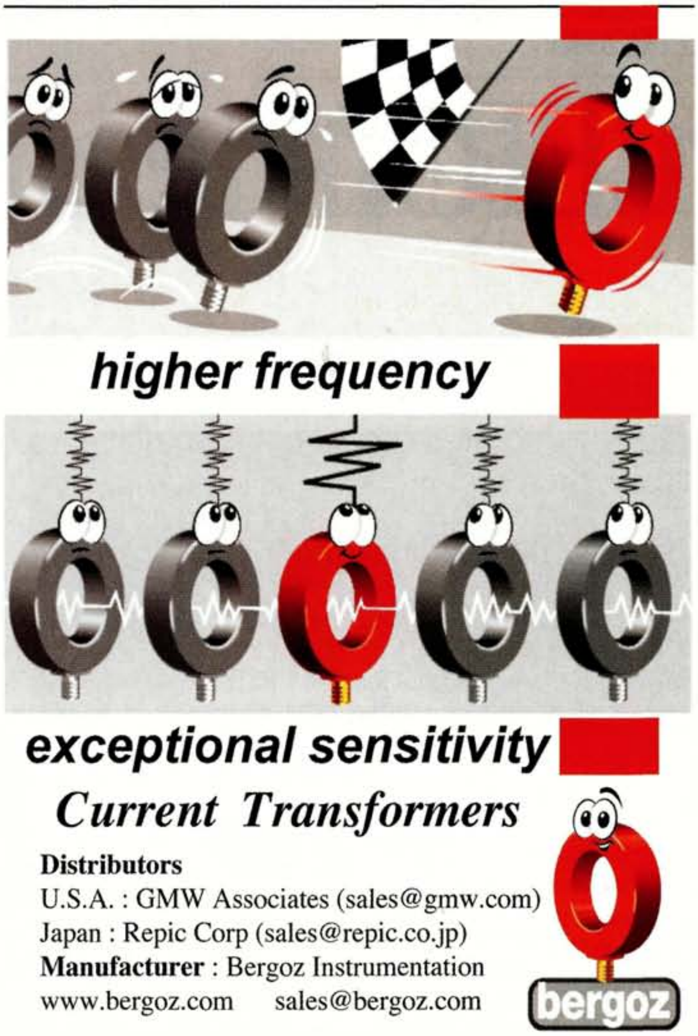
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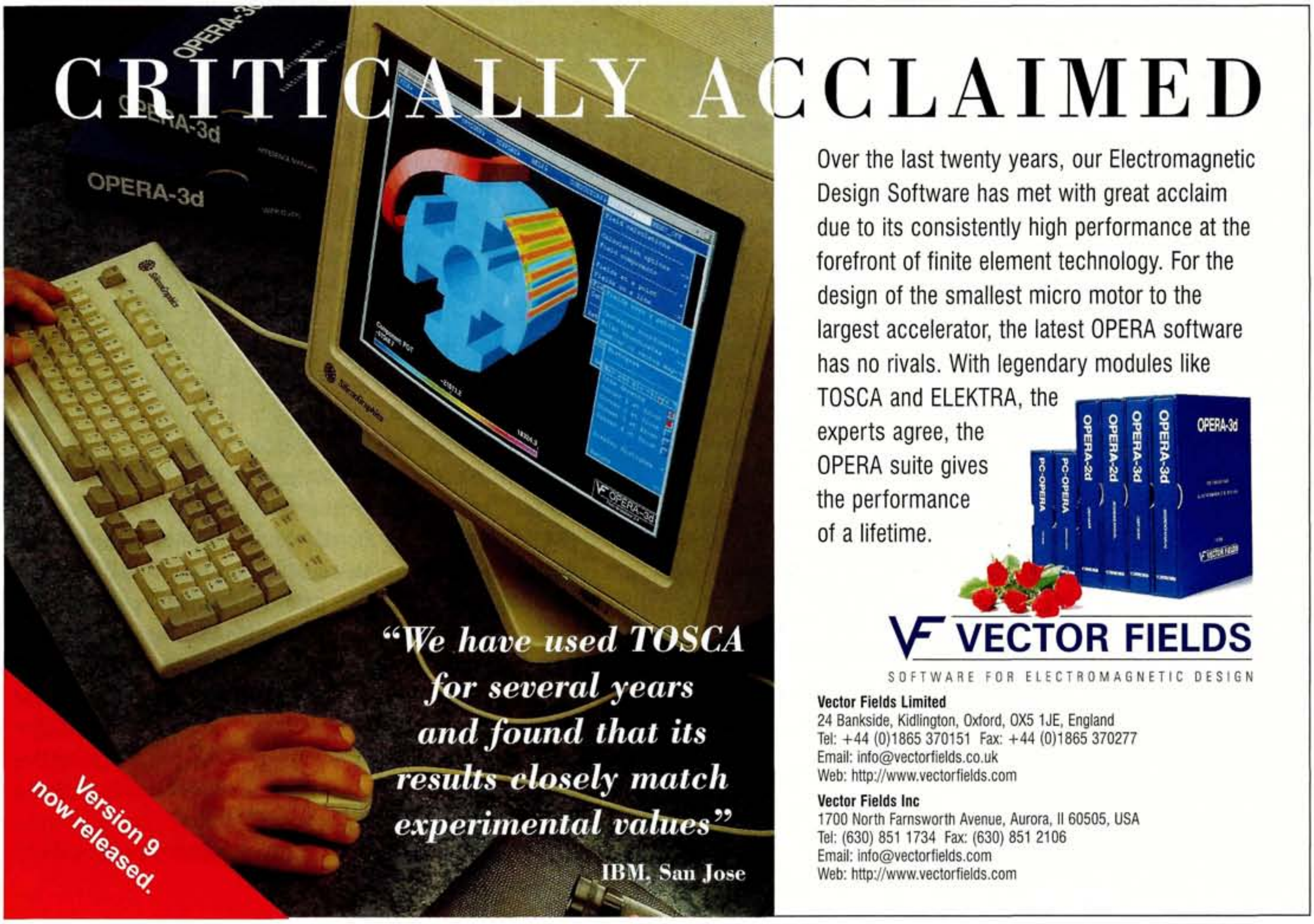
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CERN's teachers' program

The High School Teachers' programme at CERN celebrated the completion of its sixth session in July, with 40 teachers participating, not only from all over Europe, but also from China, Mongolia and the US.

The idea of the High School Teachers' (HST) programme originally emerged from discussions within CERN's Academic Training Committee, and was inspired by similar initiatives in the US. The primary goals of the programme are: to promote the teaching of particle physics to high-school students, to promote the exchange of knowledge between cultures, to expose teachers to the world of research, to help stimulate the popularization of physics in the classroom, to create links between European schools, and to promote co-operation between CERN and existing programmes in the European Union.

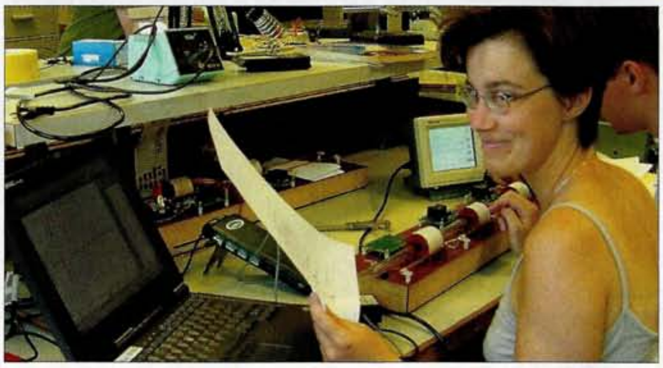
The first HST programme was held in 1998, and since then has continued under the direction of Michelangelo Mangano and Mick Storr from CERN. In addition, Gron Jones from the University of Birmingham in the UK lectures on bubble chambers each year and is a workgroup director.

The increasing interest and success of the programme has helped to expand the number of participants from nine teachers in 1998 to 40 this year. Altogether, 170 teachers from 29 countries have participated over the six years. The programme is advertised by word of mouth, through national organizations and via CERN's teachers' website (see "Further reading"). During the past year, a total of 110 teachers applied to participate in the 2003 programme, with applications coming from CERN member states and from Algeria, Bahrain, China, India, Japan, Mongolia, Pakistan, Slovenia and the US. Among the non-member states, teachers from China, Mongolia, Slovenia and the US were then invited to attend HST 2003.

All of the applicants are high-school physics teachers who are selected on the basis of their English-language competency, their activity in scientific organizations and publications, and their skills in the use of a PC. They are selected by a committee, which also looks for a diversity of cultures, teaching experience and educational backgrounds in the screening process.

During the past five years of the HST programme, a group from the US has also joined as part of the Research and Education for Teachers (RET) initiative, sponsored by Northeastern University in Boston. The RET initiative was founded in 1999 by Steve Reucroft at Northeastern and is funded by the US National Science Foundation. The teachers participating under the RET initiative spend additional time with a researcher at CERN to learn about a specific project. This year six teachers attended, not only from the Boston area, but

Shared experiences



"Participating in the HST programme was a great experience. Being the only physics teacher at my school, I normally don't have the opportunity to exchange all kinds of information concerning physics. Suddenly, I had the chance to share my experiences with more than 35 physics teachers from more than 20 nationalities!"

Vanessa van Engelen (HST 2002 and HST 2003) – seen here working on a demonstration model of a linear accelerator – teaches physics and mathematics at K A Schoten in Belgium. She also worked at the University of Antwerp for two years on a programme called "Brugproject".

Broadening horizons

"My experience at CERN as a participant in HST 2001 has been, without doubt, one of the most important and memorable of my life! I am still processing the educational, scientific and cultural ramifications of those seven weeks, and probably will for years to come. For my own personal enjoyment and enrichment, the friendships made with people from other countries, and the opportunity to travel during free time, broadened my cultural horizons as much as the work at CERN itself expanded my view of major research enterprises."

Alan Kaufman (HST 2001 and RET 2001) – seen here on the far right in the 2001 group photo – teaches at Malden Catholic High School in Malden, Massachusetts, US.

me celebrates its sixth year

A unique opportunity

"Remarkable. That is the best description I can give to the CERN HST programme. I have been exposed to the most advanced physics laboratory in the world. The opportunity of being lectured by outstanding researchers in the field of particle physics is an experience that I will always tell my students in the years to come. I knew that this workshop would be a unique opportunity for me, but it has, in many ways, exceeded my expectations."

Jesus Hernandez (HST 2003) – seen here during the workshop on building accelerator demonstration models – is a physics teacher at Lawrence High School, Lawrence, Massachusetts, US. Born in Venezuela, he has been living in the US for 12 years, and has a Masters degree in Physical Chemistry of Polymers. He decided to become a teacher when he learned about the Massachusetts Institute for New Teachers programme.

Transferring knowledge

"My feeling about the HST programme is that it must continue to be mainly addressed to young or inexperienced teachers, for three main reasons. It is a powerful way of transferring knowledge as it puts secondary school teachers and scientists in direct contact in real research surroundings; it addresses the most modern areas of physics, which are extremely interesting and challenging for everyone, and above all for youngsters of the 21st century; and it is a clever way of motivating teachers to transmit their knowledge and enthusiasm to their students."

Anabela Bastos Tibúrcio Martins (HST 2003) from Portugal – seen here, on the left, with Margarita Lorenzo Cimadevila from Spain – has a PhD in Science Education, with In-service Science Teacher Training, at the Royal Danish School of Educational Studies, Copenhagen, Denmark.

also from Texas and Washington State, and they "shadowed" researchers during the week following the programme.

This year's programme, HST 2003, included attending lectures hosted by CERN's summer student programme, special lectures specifically for the HST participants, projects created in small working groups, presentations of completed projects, site visits and cultural interchange events, the highlight of which was a final gathering featuring native culinary dishes.

A "hands on" workgroup was introduced for the first time this year, in which participants built demonstration accelerator models for the classroom. A second group helped in the organization of CERN's "Ask an expert" website, and two other groups worked on organizing the materials produced by former HST groups and on producing formal lesson plans.

An additional feature in this year's programme was the Alumni working group. Participants from previous years were invited to CERN and were asked to conduct a survey among their HST colleagues on the usefulness of the programme in their teaching and other related work. From the results of this survey, and from information provided by the returning workgroup members, suggestions were then made to the directors for improvements and for the future direction of the programme.

The HST programme has now ended for another year, but the results, like any teaching endeavour, will only be seen in time. This investment in the future by CERN and by the HST participants has the potential not only to sway popular opinion toward scientific endeavour, but also to sow the seeds for the development of some great future scientists.

Further reading

For more information, see http://teachers.cern.ch.

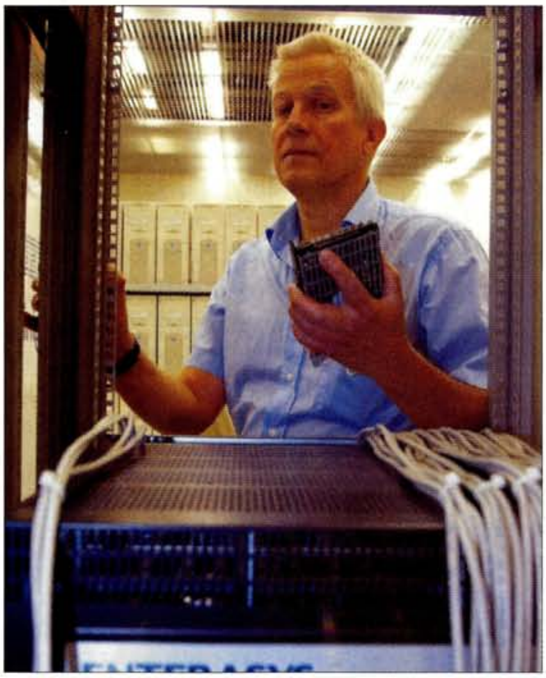
Gary Shetler, *Silver Lake Regional High School, Kingston, Massachusetts, US. HST 2001 and HST 2003.*

The CERN openlab: a novel testbed for the Grid

A new model for partnership between CERN and industry is both integrating and testing emerging computer technologies for the LHC Computing Grid.

Grid computing is the computer buzzword of the decade. Not since the World Wide Web was developed at CERN more than 10 years ago has a new networking technology held so much promise for both science and society. The philosophy of the Grid is to provide vast amounts of computer power at the click of a mouse, by linking geographically distributed computers and developing "middleware" to run the computers as though they were an integrated resource. Whereas the Web gives access to distributed information, the Grid does the same for distributed processing power and storage capacity.

There are many varieties of Grid technology. In the commercial arena, Grids that harness the combined power of many workstations within a single organization are already common. But CERN's objective is altogether more ambitious: to store petabytes of data from the Large Hadron Collider (LHC) experiments in a distributed fashion and make the data easily accessible to thousands of scientists around the world. This requires much more than just spare PC capacity – a network of major computer centres around the world must provide their resources in a seamless way.



Sverre Jarp, chief technology officer of the CERN openlab, with equipment from Enterasys Networks.

CERN and a range of academic partners have launched several major projects in order to achieve this objective. In the European arena, CERN is leading the European DataGrid (EDG) project, which addresses the needs of several scientific communities, including high-energy particle physics. The EDG has already developed the middleware necessary to run a Grid testbed involving more than 20 sites. CERN is also leading a follow-on project funded by the European Union, EGEE (Enabling Grids for E-Science in Europe), which aims to provide a reliable Grid service to European science (see p9). Last year, the LHC Computing Grid (LCG) project was launched by CERN and partners to deploy a global Grid dedicated to LHC needs, drawing on the experience of the EDG and other international efforts. This project has started running a global Grid, called LCG-1 (see p9).

Enter the openlab

The CERN openlab for DataGrid applications fits into CERN's portfolio of Grid activities by addressing a key issue, namely the impact on the LCG of cutting-edge IT technologies that are currently emerging from industry. Peering into the technological crystal ball in this way can only be done in close collaboration with leading industrial partners. The benefits are mutual: through generous sponsorship of state-of-the-art equipment from the partners, CERN acquires early access to valuable technology that is still several years from the commodity computing market the LCG will be based on.

In return, CERN provides demanding data challenges, which push these new technologies to their limits – this is the "lab" part of the openlab. CERN also provides a neutral environment for integrating solutions from different partners, to test their interoperability. This is a vital role in an age where open standards (the "open" part of openlab) are increasingly guiding the development of the IT industry.

The CERN openlab for DataGrid applications was launched in 2001 by Manuel Delfino, then the IT Division leader at CERN. After a hiatus, during which the IT industry was rocked by the telecoms crash, the partnership took off in September 2002, when HP joined founding members Intel and Enterasys Networks, and integration of technologies from all three led to the CERN opencluster project.

At present, the CERN opencluster consists of 32 Linux-based HP rack-mounted servers, each equipped with two 1 GHz Intel Itanium 2 processors. Itanium uses 64-bit processor technology, which is anticipated to displace today's 32-bit technology over the next few years. As part of the agreement with the CERN openlab partners, this cluster is planned to double in size during 2003, and double again in 2004, making it an extremely high-performance computing engine. In April this year, IBM joined the CERN openlab, contributing advanced storage technology that will be combined ▷

IBM joins CERN openlab to tackle the petabyte challenge


Rainer Többicke of CERN with the 28 terabyte storage system sponsored by IBM.

The LHC will generate more than 10 petabytes of data per year, the equivalent of a stack of CD ROMs 20 km high. There is no obvious way to extend conventional data-storage technology to this scale, so new solutions must be considered. IBM was therefore keen to join the CERN openlab in April 2003, in order to establish a research collaboration aimed at creating a massive data-management system built on Grid computing, which will use innovative storage virtualization and file-management technology.

IBM has been a strong supporter of Grid computing, from its sponsorship of the first Global Grid Forum in Amsterdam in 2001 to its participation in the European DataGrid project. The company sees Grid computing as an important technological realization of the vision of "computing on demand", and expects that as Grid computing moves from exclusive use in the scientific and technical world into commercial applications, it will indeed be the foundation for the first wave of e-business on demand.

The technology that IBM brings to the CERN openlab partnership is called Storage Tank. Conceived in IBM Research, the new technology is designed to provide scalable, high-performance and highly available management of huge amounts of data using a single file namespace, regardless of where or on what operating system the data reside. (Recently, IBM announced that the commercial version will be named IBM TotalStorage SAN File System.) IBM and CERN will work together to extend Storage Tank's capabilities so it can manage the LHC data and provide access to it from any location worldwide.

Brian E Carpenter, IBM Systems Group, and Jai Menon, IBM Research.

with the CERN opencluster (see box above).

For high-speed data transfer challenges, Intel has delivered 10 Gbps Ethernet Network Interface Cards (NICs), which have been installed on the HP computers, and Enterasys Networks has delivered three switches equipped to operate at 10 gigabits per second (Gbps), with additional port capacity for 1 Gbps.

Over the next few months, the CERN opencluster will be linked to the EDG testbed to see how these new technologies perform in a Grid environment. The results will be closely monitored by the LCG project to determine the potential impact of the technologies involved. Already at this stage, however, much has been learned that has implications for the LCG.

For example, thanks to the preinstalled management cards in each node of the cluster, automation has been developed to allow remote system restart and remote power control. This development confirmed the notion that – for a modest hardware investment – large clusters can be controlled with no operator present. This is highly relevant to the LCG, which will need to deploy such automation on a large scale.

Several major physics software packages have been successfully ported and tested on the 64-bit environment of the CERN opencluster, in collaboration with the groups responsible for maintaining the various packages. Benchmarking of the physics packages has begun and the first results are promising. For example, PROOF (Parallel ROOT Facility) is a version of the popular CERN-developed software ROOT for data analysis, which is being developed for interactive analysis of very large ROOT data files on a cluster of computers. The CERN opencluster has shown that the amount of data that can be handled by PROOF scales linearly with cluster size – on one cluster node it takes 325 s to analyse a certain amount of data, and only 12 s when all 32 nodes are used.

Data challenges galore

One of the major challenges of the CERN opencluster project is to take maximum advantage of the partners' 10 Gbps technology. In April, a first series of tests was conducted between two of the nodes in the cluster, which were directly connected (via a "back-to-back" connection) through 10 Gbps Ethernet NICs. The transfer reached a data rate of 755 megabytes per second (MB/s), a record, and double the maximum rate obtained with 32-bit processors. The transfer took place over a 10 km fibre and used very big frames (16 kB) in a single stream, as well as the regular suite of Linux Kernel protocols (TCP/IP).

The best results through the Enterasys switches were obtained when aggregating the 1 Gbps bi-directional traffic involving 10 nodes in each group. The peak traffic between the switches was then

One of the nodes in the high-performance CERN opencluster.

CERN fellow Andreas Hirstius with the opencluster.

measured to be 8.2 Gbps. The next stages of this data challenge will include evaluating the next version of the Intel processors.

In May, CERN announced the successful completion of a major data challenge aimed at pushing the limits of data storage to tape. This involved, in a critical way, several components of the CERN opencluster. Using 45 newly installed StorageTek tape drives, capable of writing to tape at 30 MB/s, storage-to-tape rates of 1.1 GB/s were achieved for periods of several hours, with peaks of 1.2 GB/s – roughly equivalent to storing a whole movie on DVD every four seconds. The average sustained over a three-day period was of 920 MB/s. Previous best results by other research labs were typically less than 850 MB/s.

The significance of this result, and the purpose of the data challenge, was to show that CERN's IT Division is on track to cope with the enormous data rates expected from the LHC. One experiment alone, ALICE, is expected to produce data at rates of 1.25 GB/s.

In order to simulate the LHC data acquisition procedure, an equivalent stream of artificial data was generated using 40 computer servers. These data were stored temporarily to 60 disk servers, which included the CERN opencluster servers, before being transferred to the tape servers. A key contributing factor to the success of the data challenge was a high-performance switched network from Enterasys Networks with 10 Gbps Ethernet capability, which routed the data from PC to disk and from disk to tape.

An open dialogue

While many of the benefits of the CERN openlab for the industrial partners stem from such data challenges, there is also a strong emphasis in openlab's mission on the opportunities that this novel partnership provides for enhanced communication and cross-fertilization between CERN and the partners, and between the partners themselves. Top engineers from the partner companies collaborate closely with the CERN openlab team in CERN's IT Division, so that the inevitable technical challenges that arise when dealing with new technologies are dealt with rapidly and efficiently. Furthermore, as part of their sponsorship, HP is funding two CERN fellows to work on the CERN opencluster. The CERN openlab team also organizes thematic workshops on specific topics of interest, bringing together leading technical experts from the partner companies, as well as public "First Tuesday" events on general technology issues related to the openlab agenda, which attract hundreds of participants from the industrial and investor communities.

A CERN openlab student programme has also been created, bringing together teams of students from different European universities to work on applications of Grid technology. And the CERN openlab is actively supporting the establishment of a Grid café for the CERN Microcosm exhibition – a Web café for the general public with a focus on Grid technologies, including a dedicated website that will link to instructive Grid demos.

Efforts are ongoing in the CERN openlab to evaluate other possible areas of technological collaboration with current or future partners. The concept is certainly proving popular, with other major IT companies expressing an interest in joining. This could occur by using complementary technologies to provide added functionality and performance to the existing opencluster. Or it could involve launching new projects that deal with other aspects of Grid technology relevant to the LCG, such as Grid security and mobile access to the Grid.

In conclusion, the CERN openlab puts a new twist on an activity – collaboration with leading IT companies – that has been going on at CERN for decades. Whereas traditionally such collaboration was bilateral and focused on "here-and-now" solutions, the CERN openlab brings a multilateral long-term perspective into play. This may be a useful prototype for future industrial partnerships in other high-tech areas, where CERN and a range of partners can spread their risks and increase their potential for success by working on long-term development projects together.

Further reading

For more information about CERN openlab, see the website at www.cern.ch/openlab.

François Grey, *CERN openlab for DataGrid applications.*

APPOINTMENTS

Turner takes over at the NSF

On 1 October 2003 the astrophysicist Michael Turner, from the University of Chicago in the US, took over as assistant director for mathematical and physical sciences at the US National Science Foundation (NSF). This $1 billion directorate supports research in mathematics, physics, chemistry, materials and astronomy, as well as multidisciplinary and educational programmes. Turner recently chaired the US National Research Council's Committee on the Physics of the Universe, which earlier this year produced a comprehensive report entitled: "Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century". This report contributed to the current US administration's science planning agenda. Turner, who will serve at the NSF for a two-year term, replaces Robert Eisenstein, who was recently appointed as president of the Santa Fe Institute in New Mexico (see *CERN Courier* June 2003 p29).

Institute of Advanced Study announces its next director

Peter Goddard is to become the new director of the Institute for Advanced Study, Princeton, from 1 January 2004. Goddard, a mathematical physicist, is well known for his work in string theory and conformal field theory, for which he received the ICTP's Dirac prize in 1997, together with David Olive. This work dates back to 1970–1972, when he held a position as a visiting scientist at CERN and began working with others on what was to become string theory. Goddard is currently master of St John's College, Cambridge, UK, and is professor of theoretical physics at the University of Cambridge, where he was instrumental in helping to establish the Isaac Newton Institute for Mathematical Sciences.

Photograph courtesy of the Institute for Advanced Study, Princeton. Photographer: Cliff Moore.

CERN

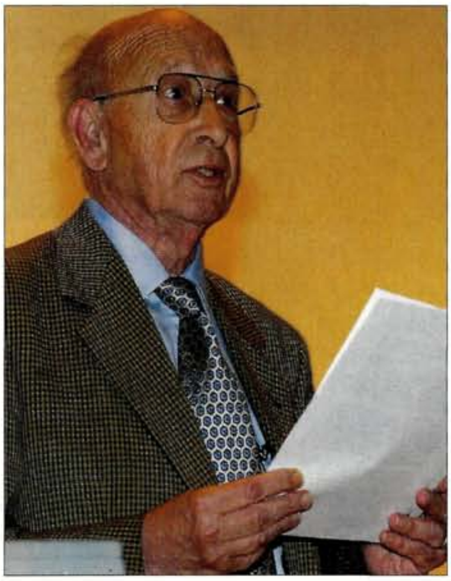
CERN signs a further protocol with Pakistan

CERN Council has approved a protocol to the co-operation agreement between CERN and Pakistan, according to which Pakistan will make a net contribution of up to $5 million to CERN. The protocol was signed on the occasion of the opening of the 28th Nathiagali Summer School in Islamabad. Shown here signing the protocol are Parvez Butt (seated centre), chairman of the Pakistan Atomic Energy Commission (PAEC) and Riazuddin (seated left), director of the National Centre of Physics (NCP). Diether Blechschmidt from CERN (seated right) and members of the PAEC and the NCP (standing behind) look on.

AWARDS

Royal Society elections recognize research in particles and waves

Research in particle physics and gravitational waves has been recognized in the 2003 elections to the Royal Society. Valentine Telegdi, who is professor of physics at the Eidgenössiche Technische Hochshule, Zurich, has been elected as a foreign member. The Royal Society's citation observes that Telegdi has measured every property of the muon, namely: parity violation in the $\pi \rightarrow \mu \rightarrow e$ decay chain; the muon mass; the positron spectrum from polarized μ-decay; μ-capture rates; the muon-neutrino helicity; and the RF spectroscopy of muonium, and all were done with great simplicity and elegance. His study, with a group from Argonne, of the asymmetries in polarized neutron decay is described as perhaps "his most informative work yet, directly yielding the structure of the β-decay coupling".



Valentine Telegdi: elected as a foreign member of the Royal Society.

Peter Dornan, head of high-energy physics research at Imperial College, London, and James Hough, director of the Institute for Gravitational Wave Research at the University of Glasgow, have both been elected members of the Royal Society. Dornan is recognized for his role in suggesting the possibility of searching for charm decays using the SLAC rapid cycling bubble chamber and initiating an imaginative scheme to provide the necessary trigger. He later led the Imperial College group into the ALEPH collaboration at CERN, developing the experiment's very precise inner tracking chamber in order to study heavy flavour physics. Hough, for his part, has brought the UK to the forefront of research in the detection of gravitational waves, with the development of innovative and practical laboratory techniques. Aspects of these techniques have been successfully transferred to other fields and to industry.

Turbulence pioneers Kraichnan and Zakharov awarded 2003 Dirac Medal

Robert H Kraichnan and Vladimir E Zakharov, two pioneer physicists in the field of turbulence, have been awarded the 2003 Dirac Medal of the Abdus Salam International Centre for Theoretical Physics.

Robert Kraichnan, who was one of Albert Einstein's last assistants at the Institute for Advanced Study in Princeton, has had a long career as a consultant in a variety of governmental organizations and private firms, including MIT, the National Science Foundation and the US Department of Energy. He has conducted pioneering research on field-theoretic approaches to turbulence and other non-equilibrium systems. Most noteworthy are his insights into the inverse cascade for two-dimensional turbulence.

Vladimir Zakharov, who is director and professor of physics at the Landau Institute for Theoretical Physics in Moscow, is an expert in the mathematical physics of nonlinear phenomena. Zakharov's work has proven to be instrumental to our basic understanding of plasma physics, hydrodynamics, magnetism and optics, in particular contributing to a deep understanding of weak wave turbulence.

AWARDS

Prague honours theory and experiment

Medal winners Guenakh Mitselmakher and Frank Wilczek (second and third from left), together with Miroslav Finger of Charles University (left) and Ivan Netuka, dean of the Faculty of Mathematics and Physics at Charles University (right).

The commemorative medal depicting Charles the 4th, Emperor of the Holy Roman Empire and founder of the Charles University.

Frank Wilczek of the Massachusetts Institute of Technology and Guenakh Mitselmakher of the University of Florida have been awarded commemorative medals from the Faculty of Mathematics and Physics of the Charles University in Prague. Wilczek received his medal as "one of the world's most outstanding theoretical physicists", for work including the discovery of "asymptotic freedom" and other results of fundamental importance. The award for Mitselmakher acknowledges his achievements as one of the "world's leading experimental particle physicists". The citation mentions his contributions to experiments at particle colliders as well as his integrating role in international research, including contributions to co-operation between the Charles University and major research centres.

LETTERS

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

Limits on extra dimensions

We enjoyed the informative article "Testing times for strings" by Ignatios Antioniadis in the July/August 2003 edition of *CERN Courier*. The author gave a most accessible report on string theory and associated hidden dimensions. We would like to remedy one apparent oversight in the article regarding the status of current experimental searches for extra dimensions. Such searches are already an ongoing and active part of the physics programme at the Fermilab Tevatron. Both the CDF and D0 collaborations have performed searches sensitive to the anomalous production of dilepton and diphoton final states associated with graviton interactions in extra dimensions.

At the Lepton–Photon Conference at Fermilab in August, the D0 collaboration announced the most stringent limit so far on the scale of large extra dimensions, based on 250 pb^{-1} of data from Tevatron Runs I and II combined. The new limit on the fundamental Planck scale is 1.37 TeV (in the GRW convention). We expect to significantly improve on this sensitivity as more data are collected at the Tevatron.
John Womersley and Jerry Blazey, co-spokespersons, D0 experiment at Fermilab.

Bubble-chamber pioneers

The July/August 2003 issue of *CERN Courier* contains an article entitled "The legacy of the bubble chamber". It is regrettable that the article does not acknowledge the monumental work of Ralph Shutt's bubble-chamber group at Brookhaven National Laboratory. Not only was this group technically and scientifically creative, but they also initiated the social experiment of providing film to outside groups for analysis at their own institutions.
R Ronald Rau (retired), Brookhaven National Laboratory.

NEW PRODUCTS

PI (Physik Instrumente) has announced the arrival of the world's smallest multi-axis, closed-loop, piezoelectric scanning stages for applications in scanning microscopy and nano-manipulation. The stages offer high multi-axis linearity and stability, and are capable of 50 picometres resolution. For further information, e-mail: info@polytecpi.com, or visit the websites: www.pi.ws or www.polytecpi.com.

SPSS Science is now offering an all-inclusive bundle of software for data analysis and graphic presentation. The two components of the new software bundle consist of SigmaStat, which contains the most frequently used statistical procedures, and SigmaPlot, which includes editing functions that enable the creation of publication-quality graphs. For further information about the bundle, see the SPSS website at www.spss.com/science.

ANNIVERSARIES

Helmut Reich – from Booster to books

Helmut Reich, well known as one of the main protagonists of CERN's proton synchrotron (PS) Booster, celebrated his 80th birthday in May. He joined the PS magnet group at CERN in 1955, as a young physicist-engineer, and after a decade of varied responsibilities, his abilities put him in the role for which he is so well remembered. In 1964, Pierre Germain initiated plans for a major PS upgrade. Intensity was limited by space-charge effects, and a higher injection energy would raise that limit. Helmut was given responsibility for a study on how this could best be achieved. A new 200 MeV linac was considered, as was an intermediate accelerator to raise the energy of the protons from the existing 50 MeV linac. However, it was Helmut's systematic assessment, in particular of Werner Hardt's multi-ring injectors, and his dogged insistence, that led to the choice of an 800 MeV slow-cycling booster consisting of four superposed rings.

In this photograph from 1956, showing the members of the magnet group sitting on top of the first unit of the PS magnet, Helmut Reich is in the front row, fifth from the right.

To build the Booster, the Synchrotron Injector (SI) Division was created in 1968, with Giorgio Brianti as leader and Helmut as his deputy. In 1973, the SI Division was integrated into the MPS Division as the Booster Group (BR), with Helmut as its leader. Today, 30 years later, the Booster success story goes on; it provides high intensities for all CERN users, with ISOLDE as a direct customer, and will shape the ultra-high-density proton beam for the LHC.

Apart from accelerators, Helmut had other, perhaps deeper, interests. In 1983 he took early retirement to dedicate himself to research and teaching in psychology at the University of Fribourg, Switzerland. In his new career, he proved to be a prolific researcher and writer. His recent book *Developing the Horizons of Mind* (Cambridge University Press, 2002) summarizes his main post-CERN achievement: the development of Relational and Contextual Reasoning, or RCR. RCR offers solutions in decision-making situations that are seemingly without resolution. It does so by abandoning "oppositional", "binary", logic (true–false, right–wrong, friend–enemy...) in favour of "inclusive" considerations, taking into account the context (wave-particle duality comes to the mind of physicists). Helmut's new logic is the result of empirical studies, in which people were interviewed to probe the mental operations leading to opinions and decisions. CERN's Giuseppe Cocconi, Rolf Hagedorn, and former director-general Vicky Weisskopf, were among the interviewees. RCR has attracted interest as a well-tested theory of the human mind and as a tool for resolving ideological conflicts. Anyone interested in the rationale of decision making should take this book to heart.

Reich today, in his second career as a researcher and writer in psychology.

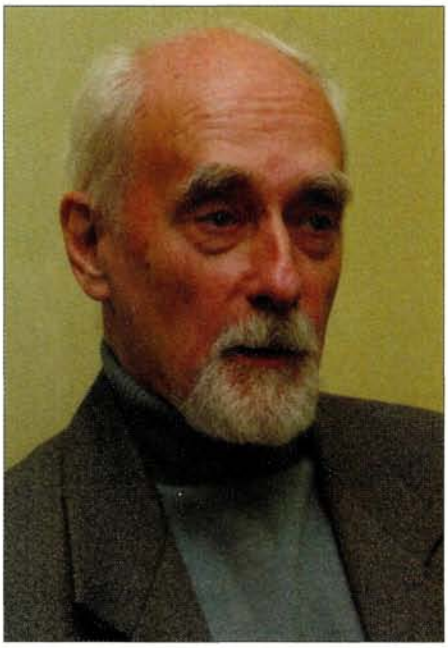
ANNIVERSARIES

Lev Barkov – from submarines to snakes

Lev Barkov, one of the leading physicists of the Budker Institute in Novosibirsk, celebrates his 75th birthday in October.

Barkov's early interests were related to measuring the energy spectra of fission neutrons, as part of a highly classified project to construct uranium–water nuclear reactors for atomic power stations, submarines and icebreakers. When, in 1955, this became de-classified, Barkov reported the work at the first conference on peaceful applications of atomic energy in Geneva. In 1952 he began participating in high-energy physics experiments at the Dubna synchrocyclotron, where he suggested and developed the technology for making diffraction grids on photoemulsion plates – a simple, reliable and very cheap solution, which was characteristic of his style in general.

A new period of activity began in 1967 when Barkov moved to the Institute of Nuclear Physics in Novosibirsk, where he continued studies of hyperons. He was one of those who actively backed the construction of the electron–positron collider VEPP-2M, and for experiments at this collider he suggested a unique detector with a magnetic field created by a superconducting solenoid and an optical spark chamber working at cryogenic temperatures and high pressure. The detector was successfully constructed by his young team, and the institute acquired invaluable experience of operations with liquid helium and in constructing large superconducting devices, which were used later while making the famous Siberian "snakes" – undulators and solenoids.



Budker Institute physicist Lev Barkov is celebrating his 75th birthday this month.

In the 1970s, together with Max Zolotorev, Barkov performed an experiment in which the rotation of the light polarization plane in vapours of atomic bismuth was discovered. This phenomenon indicated the weak interactions of electrons with nucleons caused by neutral currents, and the observation became one of the milestones of the Standard Model. Barkov was also the leader of the team constructing a new general-purpose detector, CMD-2, which combined many modern subsystems. This detector, installed at VEPP-2M in 1991, was successfully used until 2000 to study the properties of vector mesons. The upgrade of the VEPP-2M, to VEPP-2000, is now in progress, and will allow a study of the broader energy range with higher luminosity. A new detector, CMD-3, is also being constructed for experiments at VEPP-2000 by Barkov's pupils, who were fortunate to hear his lectures and work together with an enthusiastic teacher.

• A seminar dedicated to the 75th anniversary of Lev Barkov will be held in Novosibirsk, Russia, on 23–24 October 2003. For further information, see http://cmd.inp.nsk.su/conf/barkov2003.

Milos Lokajicek – interdisciplinary solutions

Milos Lokajicek celebrated his 80th birthday in August. After graduating from Charles University in Prague in 1948, he became a student of Václav Votruba, the founder of Czechoslovak elementary particle physics. In 1953 they published a paper together on generalizing the use of isotopic spin (which had been introduced by Heisenberg for nucleons) to other particles and short-lived resonances. Their collaboration was interrupted a year later, however, when the communist regime sentenced Lokajicek to seven years in jail when he refused to agree with the condemnation to death of the Czech politician Milada Horakova. Although freed after three and a half years, he was not allowed to continue to work in physics for a further 15 years.

Milos Lokajicek, who was 80 in August.

Only in 1968 did Lokajicek return to physics, to work in the elementary particle-physics division of the Institute of Physics of the Academy of Sciences, in the fields of phenomenology of elementary particle physics (diffractive scattering), radiobiology, hadron therapy, axiomatics of quantum theory, philosophy of natural sciences, etc. Lokajicek's scientific activity can be characterized by three features: rapid finding of the crucial unsolved problems, the original contribution to their solution based on an interdisciplinary approach, and the transferring of methods developed in one branch of science to another. He still gives lectures on radiobiology at Charles University.

OBITUARIES

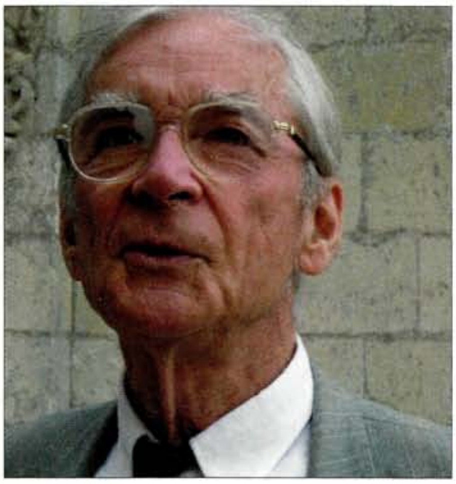
Lucien Montanet 1930–2003

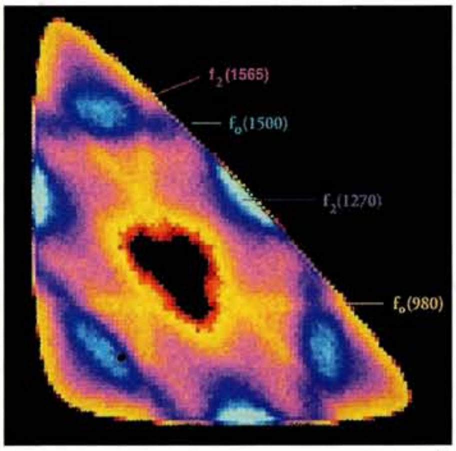
It was with great sadness that we heard that Lucien Montanet had passed away on 19 June. Until quite recently he had still been here among us at CERN, discussing physics with his usual enthusiasm. A few weeks before he died, he even managed to overcome his exhaustion to pay a warm and eloquent tribute to his friend Charles Peyrou (*CERN Courier* June 2003 p25).

As a very young graduate from France's Arts et Métiers engineering school, Lucien first extended his knowledge of physics at Paris University, before setting out on his physicist's career during his national service at France's ZOE nuclear reactor. In 1957 he was one of the first physicists to take up a position at CERN, which was just starting to be built at the time. To gain experience in particle physics, Lucien went to the Jungfraujoch in Switzerland, where Patrick Blackett from Manchester University had set up a Wilson cloud chamber. There, with other physicists such as Antonino Zichichi and Roberto Salmeron, he analysed cosmic-ray interactions (~100 GeV), the subject of his thesis in 1960.

Lucien then worked on images taken from a propane bubble chamber at CERN's synchro-cyclotron. Shortly afterwards, he began his long career with liquid-hydrogen bubble chambers by working on a 20 cm chamber at Saclay's Saturne accelerator, which supplied a π^- beam between 500 and 1000 MeV. He then teamed up with Peyrou's group to work on CERN's 32 cm liquid-hydrogen chamber, and took part in developing suitable techniques for the analysis of bubble-chamber images. In 1961, together with a number of physicists from CERN and Paris (among them Rafaël Armenteros and myself), Lucien analysed proton–antiproton annihilations on images taken in the 81 cm bubble chamber belonging to Saclay and the Ecole Polytechnique, which had just arrived in the South Hall at the CERN PS. He co-signed the discovery of the first meson resonance found at CERN and in Europe, the E meson (which later became the $\iota(1440)$ and is now known as the $\eta^0(1440)$).

This marked the start of a long career devoted to meson and baryon spectroscopy.





The Dalitz plot from Crystal Barrel for $p\bar{p}\rightarrow 3\pi^0$.

Hard on the heels of the $E/\iota(\eta^0(1440))$ discovery came that of the C ($K_1(1270)$) and D ($f_1(1285)$), all with the 81 cm HBC. Thereafter, the images from CERN's 81 cm and 2 m chambers were used for the analysis of the A_2 into two kaons, the saga of the $E/\iota(\eta^0(1440))$, which is now a glueball candidate, the Q bump, the three-body phase-shift analyses, analysis of the characteristics of numerous resonances produced by π^- at 3.92 GeV and K^- at 4.2 GeV, the mass of the K^0 and the Λ^0, the width of the $\omega^0(782)$, the decay of the K^0, the lifetime of the K^0 short, and evidence for the δ ($a_0(980)$), the "Bouddha" ($b_1(1235)$) and the $f_1(1420)$.

Lucien became an eminent specialist in this field. He played a major role in the construction of the present scheme of elementary particles and was a key member of the Particle Data Group, organizing and leading numerous workshops and conferences on hadron spectroscopy. For many years he was very much in demand as a rapporteur for review talks on these topics.

In his experimental activities, Lucien initiated and co-ordinated several experiments of central importance at CERN. One of the most illustrious was the EHS (European Hybrid Spectrometer), an elaborate set of particle detectors fed by a high-energy beam at the CERN SPS. Lucien was the spokesman of the large (by the standards of the time) collaboration of institutes working on the EHS. The goal of the experiment was to determine, in complex hadronic final states, the dynamic features of strong interactions, and to study the associated weak decays. This spectrometer was the first to measure, with excellent precision, the lifetime of the charmed D meson. Among the most remarkable of the sub-detectors that made up the hybrid spectrometer were a rapid cycling bubble chamber and a holographic high-resolution bubble chamber.

Lucien was adept at attracting young physicists and infusing them with his enthusiasm and experience. In this way, he played a major role in the development of high-energy physics in Spain, which, although not yet a CERN member state, was an important contributor to the EHS.

Lucien played a similar role when, in 1985, he was appointed co-ordinator of the CERN–USSR Committee, which subsequently became the CERN–Russia Committee. The excellent relations between CERN and Russia are largely due to his skill and devotion to the task. In 1990 he became a member of the Scientific Council of the Joint Institute for Nuclear Research (JINR) at Dubna, and played a key role in defining its scientific policy.

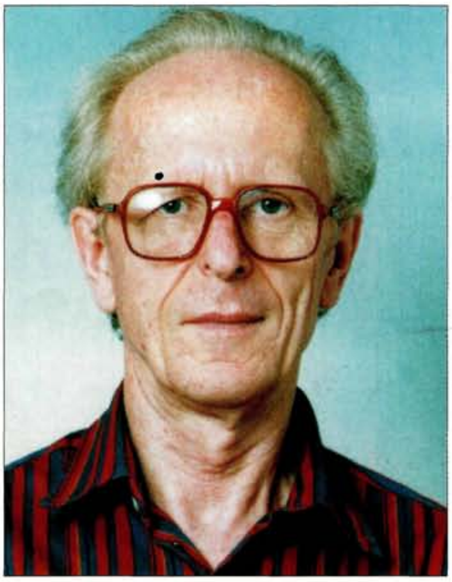
Lucien was also a very influential member of the "Crystal Barrel" experiment, which analysed the γ rays and charged particles produced when the antiprotons from LEAR collided with a liquid hydrogen target. This experiment was known for its precise analyses of the π^0, η and η' final states, its discovery ▷

of the new resonances $\eta_2(1685)$, $\eta_2(1875)$ and the analysis of many resonances in the $3\pi^0$, $\eta\eta\pi^0$, $\eta\pi^0\pi^0$, $\eta\eta'\pi^0$ states and by finding in the $3\pi^0$ channel the f_0 (1500), which associated with the E/ι could make a pair of glueballs. It was one of the glories of an already glittering career. The splendid plots representing the three-body reactions are now a reference and could even be described as works of art.

In 1973 Lucien became the editor of *Physics Letters*, and continued playing this role competently and efficiently even after his retirement in 1995. This enabled him to remain in close contact with the high-energy physics community and made him a well-known figure for younger generations. Most of the publications of CERN and other European laboratories went under the expert and critical scrutiny of Lucien and his partner Klaus Winter. Up to the last moments of his life he performed this task with the same diligence.

In Lucien Montanet, we lose one of the pioneers of modern high-energy physics, an inspired, generous and friendly member of our community and a true lover of science.
Paul Baillon, CERN.

Lev D Soloviev 1934–2003



Lev D Soloviev, an outstanding Russian theoretical physicist and director of the Institute for High Energy Physics (IHEP) in Protvino, Russia, from 1974 to 1993, passed away on 6 July 2003 after a long illness.

Soloviev's scientific career began in 1956 in the Steklov Institute in Moscow, Russia's famous centre of mathematics, after graduating with excellent results from Moscow State University and following a post-graduate course. When his scientific interests became focused on nuclear physics, he began to work at the Joint Institute for Nuclear Research (JINR) in Dubna.

Soloviev then moved to IHEP–Protvino soon after its creation in 1963 to construct the 70 GeV U-70 proton accelerator. This was the world's highest energy facility until CERN's Intersecting Storage Rings and Fermilab began operation in the early 1970s. At IHEP he continued his theoretical research, and his notable uses of modern mathematics in high-energy physics soon became recognized in the scientific world. These included the theory of low-energy photoproduction and electroproduction, the S-matrix theory of high-energy electromagnetic interactions, and relativistic string theory. Soloviev's name is also connected with the famous finite-energy sum rules, which served as a basis for the creation of the duality concept, and then superstring theory.

Soloviev was a scientist of rare ability. He combined distinguished scientific work with 19 years' service as director of the IHEP, Russia's largest high-energy physics institute. During those years, IHEP was developing both its experimental and accelerator capabilities. Soloviev constantly paid great attention to the further improvement of scientific personnel in what was then the USSR and is now Russia. There were many talented scientists among his students who gained fame both in Russia and abroad. One major factor in this success was the example he set of high scientific and personal standards. His many contributions to the development of science were highly valued by his home country.

After his term as director, Soloviev continued as IHEP's senior scientist. Despite his grave illness, he continued both his well-loved physics research and his teaching as chairman of the Moscow Physical–Technical Institute's branch in Protvino, until almost the last day of his life.

Soloviev was also a leading figure in the international high-energy physics community. He was one of the first young Soviet physicists to make an extended stay at the Niels Bohr Institute in Copenhagen. From 1976 to 1982 he served as a member and then from 1982 to 1984 as chairman of the IUPAP's Commission on Particles and Fields. In 1977 he was a founding member of the International Committee for High Energy Spin Physics Symposia, and became its first Russian honourary member in 2002. Moreover, he chaired the first Russian Spin Physics Symposium, which was held at IHEP–Protvino in 1986. After a long period of strained East–West relations, this historic symposium served as a model for further scientific co-operation. When his directorship ended, Soloviev became a visiting professor at the University of Michigan, where he wrote some significant papers on theoretical spin physics.

The best memorial for Lev Soloviev will come from the similar work of all those who knew and respected him, and who will try to follow his example.
A A Logunov, N E Tyurin, IHEP, and A D Krisch, University of Michigan.


All you need...
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The Fermi National Accelerator Laboratory (Fermilab) invites applications for:

LEDERMAN FELLOWSHIP — EXPERIMENTAL PARTICLE PHYSICS

Applicants should have demonstrated outstanding ability in research and, in recognition of Leon Lederman's commitment to the teaching of physics at all levels, experience and interest in physics outreach. The successful candidate will have a choice among experiments, which include Tevatron collider experiments, neutrino experiments, other fixed target experiments and non-accelerator projects (dark matter search, cosmic ray observatory), or research on accelerators. See http://www.fnal.gov/ for more information.

Candidates should have obtained a Ph.D. in particle or accelerator physics since Jan 1st 2002. The appointment is normally for three years with an extension possible. Applicants should send a letter including their research and outreach experience and interests, a curriculum vita, publication list and the names of at least four references. One reference should specifically address the outreach experience. ***The deadline for applications is December 6th 2003.*** To apply write to **Dr. Michael Albrow – Experimental Physics Projects Department Head, Fermi National Accelerator Laboratory, MS 122, P. O. Box 500, Batavia, IL 60510-0500. (albrow@fnal.gov)** EOE M/F/D/V

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INFN Istituto Nazionale di Fisica Nucleare

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS

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THEORETICAL PHYSICS (N. 10)
EXPERIMENTAL PHYSICS (N.20)

The INFN Fellowship Programme 2003-2004 offers 30 (thirty) positions for non Italian citizens for research activity in theoretical or experimental physics.

Fellowships are intended for young post-graduates who have not attained 35 years as of November 30, 2003.

Each fellowship, initially, is granted for one year and then, may be extended for a second year.

The annual gross salary is EURO 24,800.00

Round trip travel expenses from home country to the INFN Section or Laboratory will be reimbursed, also lunch tickets will be provided for working days.

Candidates should submit their application form, a statement of their research interests and enclose three reference letters,

Candidates should choose:

- one of the following INFN Laboratories:

Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali del Sud (Catania), Laboratori Nazionali di Frascati (Roma)

- or one INFN Sections in the universities of:

Torino, Milano, Padova, Genova, Bologna, Pisa, Napoli, Catania, Trieste, Firenze, Bari, Pavia, Cagliari, Ferrara, Lece, Perugia, Roma "La Sapienza", Roma "Tor Vergata", "Roma Tre".

The research programs must be focused on the research fields of the Section or Laboratory selected (www.infn.it).

Applications must be sent to the INFN no later than December 31, 2003.

Candidates will be informed by May 2004 about the decisions taken by the INFN selection committee.

Fellowships must start from September to November 2004. Requests of starting earlier accepted.

Information, requests for application forms, and applications should be addressed to

Istituto Nazionale di Fisica Nucleare,
Direzione Affari del Personale,
Ufficio Borse di Studio – Casella Postale
56 – 00044 Frascati (Roma) Italia

Faculty Position

The Physics Department of the Massachusetts Institute of Technology is seeking to make junior faculty appointments in high-energy theory. Candidates will be considered who are working at energy scales from just beyond the Standard Model to the Planck scale, including those working at the interface between particle theory and cosmology. Candidates will be evaluated on the basis of potential contribution to both the research programs carried out in the Center for Theoretical Physics, and to the undergraduate and graduate teaching programs of the Department of Physics. Current faculty in the Center for Theoretical Physics span a broad range of interests, including QCD, electroweak physics, unification, cosmology, and string theory.

Faculty members at MIT teach undergraduate and graduate physics courses, serve as mentors and advisors, and oversee students' research projects. Candidates must show promise in teaching as well as in research. Preference will be given to applicants at the Assistant Professor level. Applicants should submit by regular mail a curriculum vitae (include email address), a publications list, a brief description of research interests and goals, and should have at least three letters of reference sent directly to: **Professor Robert Jaffe, Director, Center for Theoretical Physics, 6-308, 77 Massachusetts Avenue, Cambridge, MA 02139-4307.**

The deadline for applications is December 1, 2003. Women and minority candidates are strongly encouraged to apply.

Massachusetts Institute of Technology

web.mit.edu/hr

ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

The Faculty of Mathematics and Physics invites applications for a Professorship in Experimental Physics (C3)

in the field of experimental physics with emphasis on experimental particle physics. The main research activity should be in the area of data analysis.

Prerequisites are the "Habilitation" or an equivalent scientific qualification. The successful applicant will participate in the general teaching and administrative duties of the department. The university is seeking to increase the number of female faculty members and therefore especially encourages suitably qualified women to apply. Applicants with a physical handicap will be given preference over other candidates when they have equal qualifications.

The professorship is available as a permanent position. In case that this is the first appointment to a professorship the appointment will be in general temporary. Exemptions from this rule are possible. The subsequent appointment to a permanent professorship will not require an additional search committee.

Applications (with a curriculum vitae, copies of certificates, list of publications and teaching records) should be sent by 31 October 2003 to:

Dekan der Fakultät für Mathematik und Physik,
Eckerstr. 1, D-79104 Freiburg, Germany.

Center for Cosmological Physics at the University of Chicago

CfCP Postdoctoral Research Fellowship

The CfCP invites applications for up to two NSF Funded Research Fellowships from young scientists of exceptional ability and promise who will have received a PhD. in Physics, Astrophysics or related fields by September 2004. The appointees are expected to conduct original research in experimental or theoretical cosmology in an interdisciplinary environment. Initial appointments are for one year, renewal annually, for up to three years. Positions have competitive salaries and carry faculty level benefits. Center Postdocs have the freedom to work on any of the efforts in our Center.

Research at the Center for Cosmological Physics (CfCP), based at the University of Chicago, is focused on interdisciplinary topics in cosmological physics: characterizing the Dark Energy, studying the inflationary era, and understanding the highest energy cosmic rays. Studies of the CMB (polarization anisotropies and the Sunyaev-Zel'dovic effect) and Cosmic Infrared Background; analysis of Sloan Digital Survey and other large-scale structure data; high energy astrophysics with photons and cosmic rays, direct detection of Dark Matter particles and numerous topics in theoretical cosmology constitute the current slate of activities. The CfCP also has active visitors, symposia, and education/outreach programs. Information about the CfCP can be found at ***http://cfcp.uchicago.edu/***

An application consisting of a Curriculum Vitae, a statement of research interests, and at least three letters of recommendation should be sent to *centerfellow@cfcp.uchicago.edu* or to Bruce Winstein, Director, Center for Cosmological Physics, Enrico Fermi Institute, 5640 S. Ellis Avenue, Chicago, IL 60637. All qualified applications received for this position will be considered automatically for the DOE Funded Postdoctoral position in theoretical cosmology at the Enrico Fermi Institute unless applicant declines consideration. (For details see: *http://background.uchicago.edu/~whu/postdoc.html*)

The application deadline is December 1, 2003 for positions that will begin in the Summer or Fall of 2004.

The University of Chicago is an Affirmative Action/Equal Opportunity Employer

TIER 1 CANADA RESEARCH CHAIR IN SUBATOMIC PHYSICS

Department of Physics, University of Alberta

The Department of Physics at the University of Alberta **(www.phys.ualberta.ca)** invites applications from outstanding scientists for a senior position (Full Professor) in Subatomic Physics. The successful candidate will be nominated for a senior (Tier 1) Canadian Research Chair **(www.chairs.gc.ca).**

We are especially interested in candidates whose research involves particle physics, but we encourage applications from outstanding candidates in all sub-fields of subatomic physics. Applicants should have established an outstanding research program and be committed to undergraduate and graduate teaching.

The Department has 36 faculty with research interests in subatomic physics, astrophysical sciences, condensed matter physics, and geophysical sciences. Our subatomic physics group includes members with interests in collider physics, particle astrophysics, nuclear astrophysics, neutrino physics, and the standard model (csr.phys.ualberta.ca). We have excellent electronics, mechanical, and computational facilities.

Recent initiatives by the Governments of Alberta and Canada provide exceptional opportunities for additional funding to establish new research programs at the University of Alberta. See, for example,**www.gov.ab.ca/sra, www.icore.ca, www.gov.ab.ca/is/ahfser, and www.innovation.ca**, for further information.

The application should include a curriculum vitae, a research plan, and a description of teaching experience and interests. The applicant must also arrange to have at least three confidential letters of reference sent to the address below, on or before October 15, 2003. Consideration of applications will begin on October 1, 2003; however applications will continue to be accepted as long as the position remains unfilled. The suggested starting date is July 1, 2004.

Subatomic Physics Search and Selection Committee
Dr. John Samson, Chair, Department of Physics
University of Alberta, 412 Avadh Bhatia Physics Lab
Edmonton, Alberta, Canada T6G 2J1
Fax: (780) 492-0714, E-mail: dept@phys.ualberta.ca

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

Canada Research Chairs are open to individuals of any nationality. 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.

Scientific Coordinator – High Energy Physics Computing

University of Toronto

The Experimental High Energy Physics Group at the University of Toronto is seeking a Scientific Coordinator for the Toronto Physics Parallel Computing Centre (TPPCC), a large Beowulf cluster being used primarily for particle physics data analysis and detailed detector simulations. The coordinator would be responsible for coordinating the use of the TPPCC by several particle physics experiments and other users, for coordinating and assisting in the development of GRID and other distributed computing applications to support the scientific computational effort, and for support of experiment-specific application software on the cluster.

Qualified applicants are expected to have an advanced degree in physics or a cognate discipline, experience in large scale computation and data analysis preferably in particle physics, the ability to organize the effective utilization of a facility such as the TPPCC, and excellent inter-personnel and communication skills.

Applications, including a curriculum vitae or resume, and the contact information for three referees should be sent to: **Winnie Kam, Department of Physics, University of Toronto, 60 St. George Street, Toronto, Ontario M5S 1A7, Canada.** Applications will be considered starting 1 October 2003.

The University of Toronto is committed to equity and diversity, and encourages applications from qualified women or men, members of visible minorities, aboriginal peoples and persons with disabilities.

Research Associate Position in BaBar

University of Colorado at Boulder

The experimental high-energy physics group at the University of Colorado at Boulder has an opening for a person with a strong computing background and with a strong interest in experimental High Energy research. The person is to participate in the BaBar experimental program at the Stanford Linear Accelerator Center and on Detector R\&D associated with the Linear Collider project. In BaBar we are working on the Limited Streamer Detector modules associated with the Muon System Upgrade and on various data analysis projects. In the Linear Collider we are working on a novel geometrical design of an electromagnetic and/or hadronic calorimeter. The applicant should have a Ph. D. degree and is expected to have a strong C++ software language background and/or detector development.

Applicants should send a Curriculum Vitae and arrange to have three letters of recommendation sent to **Prof. Uriel Nauenberg, Department of Physics, 390 UCB, University of Colorado, Boulder, CO 80309-0390**. All applications should be received by Dec. 31, 2003. ***You can communicate via e-mail,*** uriel@cuhep.colorado.edu.

The University of Colorado at Boulder is committed to diversity and equality in education and employment.

Experimental and Theoretical Research Associates

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

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

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

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

The deadline for applications is December 1, 2003. Late applicants may still be considered.

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CERN COURIER RECRUITMENT BOOKING DEADLINE

November issue:

10 October

Publication date:

13 October

Contact

Reena Gupta

Tel: +44 (0)117 930 1028

Fax: +44 (0)117 930 1178

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ACCELERATOR PHYSICIST

The Lawrence Berkeley National Laboratory's Center for Beam Physics (CBP) is seeking an Accelerator Physicist to support, plan, and design studies and experimental work to meet CBP programmatic needs and R&D goals associated with commissioning and upgrade activities at the Fermilab Tevatron complex. The incumbent will conduct experimental and/or computational research in support of the performance optimization and operation of particle storage rings, such as the Recycler Ring and the Tevatron. He/She will plan, conduct, and analyze experiments on existing Fermilab accelerators, will serve as liaison at Fermilab for LBNL staff working in support of luminosity upgrade activities, and will assist in the development of technical component designs required for the optimization of a storage ring.

A recent PhD or equivalent in Accelerator Physics and experience in major beam physics issues associated with hadron storage rings, such as the choice of working points, beam instabilities, longitudinal and transverse beam dynamics, beam diagnostics, and beam manipulations is required. Experience with commissioning and accelerator physics studies on operational storage rings, including machine optimization studies, is important. This is a one-year term position with the possiblity of renewal.

To apply, please submit your CV, publication list, and list of references via e-mail to gensciemployment@lbl.gov or via U.S. Mail to Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 937-600, Berkeley, CA 94720. Please reference job# AF/016384/JCERN. Berkeley Lab is an EEO/AA employer committed to a diverse workforce.

Please note: This position will be located at Fermilab (Batavia, IL) with occasional trips to Berkeley Lab for consultation and planning.

BERKELEY LAB

LMU
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Ludwig-Maximilians-Universität München

Professur (C 3) für Experimentelle Physik

An der Sektion Physik der Ludwig-Maximilians-Universität München ist zum 1. 2. 2004 eine C1-Stelle einer/eines

Wissenschaftlichen Assistentin/Assistenten

mit Arbeitsgebiet experimentelle Elementarteilchenphysik zu besetzen.

Der/die StelleninhaberIn soll eine tragende Rolle im ATLAS Experiment am LHC übernehmen, insbesondere bei der Inbetriebnahme und Kalibration von Präzisionskammern des ATLAS Myonspektrometers und bei der Vorbereitung der Physikanalyse.

Einstellungsvoraussetzung ist ein abgeschlossenes Hochschulstudium der Physik mit überdurchschnittlicher Promotion. Qualifizierte Wissenschaftlerinnen sind besonders aufgefordert, sich zu bewerben. Schwerbehinderte werden bei gleicher Eignung bevorzugt.

Anfragen für weitere Informationen und Bewerbungen mit den üblichen Unterlagen (Lebenslauf, Zeugnisse und Schriftenverzeichnis) bis zum 1.11. 2003 an Prof. Dr. Dorothee Schaile, LMU München, Sektion Physik, Am Coulombwall 1, 85748 Garching (Dorothee.Schaile@LMU.de)

Institute of Physics
Bhubaneswar 751005, Orissa, India

Faculty Position - Theoretical Nuclear Physics Group

Institute of Physics, Bhubaneswar, an autonomous research institution under Department of Atomic Energy, Government of India invites applications for a faculty position at the level of Senior Lecturer in theoretical nuclear physics in the scale of pay of Rs.10,000-325-15,200 per month plus other allowances. The candidate is expected to work in the area of heavy ion nuclear reactions (theory). A Ph. D. Degree with 2-4 years of experience as a Post-doctoral Fellow is a necessary requisite. Applications may be sent to **Director** in the above address by **31st December, 2003.** Details at **http://www.iopb.res.in**

UNIVERSITY OF OXFORD

Departmental Lecturer or Research Assistant for the ATLAS Experiment

The Sub-department of Particle Physics, University of Oxford, is seeking an outstanding physicist to play a major role in the hardware and software developments for the ATLAS SemiConductor Tracker (SCT).

The high precision of the SCT will be vital for b tagging which is required for many areas of LHC physics such as SUSY and Higgs studies. The Oxford group has two major responsibilties within the ATLAS project, the barrel assembly and the SCT alignment. Three quarters of the ATLAS barrel SCT with about 1,500 silicon detector modules will be assembled at Oxford. A novel laser alignment system based on Frequency Scanning Interferometry (FSI) has been developed in Oxford in order to provide run time information on distortions in the support structure. An X-ray survey system is also being developed at Oxford in order to provide an accurate initial determination of the 3D positions of all 4,088 SCT modules. We anticipate Oxford becoming the centre for the inner detector alignment software. This software activity will lead naturally into ATLAS physics which requires the use of the precision tracker.

A highly qualified successful candidate will be employed by the University of Oxford as a Departmental Lecturer. The Departmental Lecturer post would be for a fixed term of up to 6 years. The Research Assistant appointment is for an initial fixed term of 3 years with some possibility of renewal for one more year.

The application deadline is 15th November 2003. Further particulars about the post and information on how to apply are available at http://www.physics.ox.ac.uk/pnp/jobs/atlas-dl-fp.htm Informal enquiries about the experiment and this post may be made to Dr Tony Weidberg (t.weidberg@physics.ox.ac.uk).

The University is an Equal Opportunities Employer.

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The University of Chicago Enrico Fermi Institute

Is herewith inviting applications for:

2004

THE ENRICO FERMI POSTDOCTORAL RESEARCH FELLOWSHIP AND THE ROBERT R. MCCORMICK POSTDOCTORAL RESEARCH FELLOWSHIP

The Enrico Fermi and the Robert R. McCormick Postdoctoral Research Fellowships are awarded on a competitive basis to recent Ph.D. recipients in physics, astrophysics, geophysics, chemistry, or mathematics. Fellowships are awarded for a two-year term, with a possible renewal for a third year, and carry a salary of $48,000 per annum, faculty-level benefits and an additional allocation of up to $6000 per annum for independent research support. The spirit of these research fellowships is to enable young scientists to work either independently or in close association with the members of the Institute in areas of mutual interest.

The Enrico Fermi Institute is an interdisciplinary research unit within the Physical Sciences Division of The University of Chicago. The Institute's main fields of research include high-energy physics, astronomy and astrophysics, cosmology, general relativity, and related areas. Further details about the Institute and the fellowships can be found at http://efi.uchicago.edu/fellowships.html.

A letter of nomination for each candidate is requested. In addition, in support of her or his nomination for the term starting in the fall of 2004, the candidate is requested to supply the following materials to the: Director of the Enrico Fermi Institute, 5640 South Ellis Avenue, RI-183, Chicago, Illinois 60637 either by US mail or by fax to 773 702-8038. In case of further questions, contact Nanci Carrothers at: n-carrothers@uchicago.edu.

(1) Curriculum Vitae
(2) Bibliography of publications and preprints
(3) Description of research interests to be pursued at the University
(4) The names of two scientists in addition to the nominator whom the candidate has asked to supply letters of recommendation.
(5) You must register on line at the University Job Opportunities website: https://jobopportunities.uchicago.edu where you will be asked to set up an academic profile. No online attachment of additional material is needed.

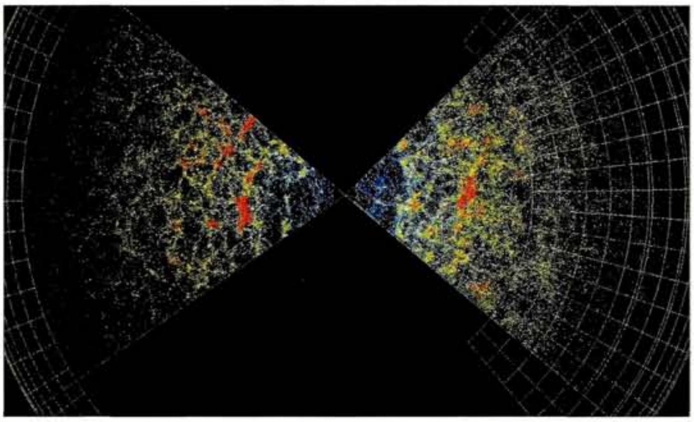
It is the candidate's responsibility to arrange that the two letters of support be sent to The Enrico Fermi Institute at the above address **no later than November 14, 2003.**

The University of Chicago is an Affirmative Action/Equal Opportunity employer. It also participates in the Exchange Visitor Program and will facilitate the granting of visas to foreign applicants.

BOOKSHELF

Modern Cosmology by Scott Dodelson, Academic Press. ISBN 0122191412, £39.95 ($70).

Particle Astrophysics by Donald Perkins, Oxford University Press. Hardback ISBN 0198509510, £44.95 ($74.50). Paperback ISBN 0198509529, £22.95 ($39.50).



Precision cosmology: image showing the distribution of galaxies in the Two Degree Field Galaxy Redshift Survey (2dFGRS). The survey included 221 000 galaxies that covered 5% of the sky and reached a redshift value of 0.3.

It is widely and justifiably stated that we are in a golden age for cosmology. Certainly, in just the past five years our knowledge of the universe has increased in leaps and bounds by virtue of new data concerning the cosmic microwave background (CMB), the study of very distant Type-1a supernovae (SNe1a), and surveys of large-scale structure (LSS). Cosmic parameters that five years ago were uncertain by a factor of two, are now known to a few per cent. The cosmic concordance of the three data sets for CMB, SNe1a and LSS leads us to our present understanding of the universe as flat with a total energy very close to the critical density, and containing (with quite small errors) 4% baryonic material, 23% nonbaryonic dark matter and 73% dark energy.

Other areas of fundamental theoretical physics have also made progress. In particular, again in the past five years, the Standard Model of particle phenomenology has been shown to be inadequate by the experimental demonstration of neutrino masses. Particle phenomenology and theoretical cosmology have become even more closely intertwined. String theory, though not yet supported by any experimental test, is a constant source of ideas concerning both particle phenomenology and the principal issues of theoretical cosmology. It is an interesting question whether the first support for string theory will come from the very small or the very large.

If we go back further, say 20 years, cosmological data were so inaccurate that the field was treated with some condescension by particle theorists who were accustomed to reproducible precision data from the large accelerators. This situation gradually changed due to the heroic efforts of people like the late Dave Schramm. Now, with the release by NASA of the WMAP data on CMB in February 2003, we have entered what can be called, without hesitation, the era of precision cosmology. In a book on precision cosmology, after the necessary introduction to the mathematics of an expanding space–time, the topics that could very reasonably be included are: 1. cosmic microwave background, 2. nucleosynthesis, 3. inflation, 4. dark matter, 5. dark energy, 6. structure formation, and 7. black holes and other extreme events such as supernovae and, what may be a subset, gamma-ray bursters. It is with this preconceived menu in mind that I review these two books.

Modern Cosmology by Scott Dodelson is intended for beginning graduate students. This book is very up to date and gives excellent treatments of structure formation, and especially of the CMB, including its polarization and details of its statistical analysis. This provides what is the most complete such description in any textbook. The topic of weak gravitational lensing is also handled well. The young author is an active researcher in theoretical cosmology whose enthusiasm for the subject is evident throughout, and whose selection of topics reflects his areas of greatest expertise. The inclusion of many worked examples will make this book a very good choice for a graduate course.

For researchers, the treatment of data analysis will be particularly valuable. For both CMB, from WMAP and the future more data intensive Planck mission, and for LSS from the Sloan Digital Sky and 2dF surveys, as well as even larger galaxy surveys in the future, the quality and quantity of the raw data set are such that straightforward algorithms are too slow even with the fastest available computers. Thus considerable creativity and intelligence are needed to optimize such an analysis. It is interesting that a similar situation must exist for raw data from high-energy particle colliders such as from the Tevatron at Fermilab and the future LHC collider at CERN. It is therefore very welcome that, for both CMB and galaxy surveys, Dodelson leads us masterfully through the likelihood function and sophisticated mathematical techniques for its evaluation.

A comparison of Dodelson's book according to my menu of topics, reveals that topics 1 and 6 are thoroughly treated, while items 2, 3, 4, 5 and 7 are only relatively briefly described. Thus the treatment is very strong in only some of the areas. To be fair, the author is well aware of this and provides copious and generous references to other books, which should fill in the gaps.

One minor complaint is that the typesetting is not adequately checked, for example the headings of subsections 7.2.2 and 7.3.2 are at the foot of the previous page. But this is nitpicking and I liked this book and believe that it, together with the other referenced publications, could form the basis for a very interesting postgraduate course in cosmology, as well as being useful for active researchers to have in their personal library.

Donald Perkins' *Particle Astrophysics* is intended for the different audience of advanced undergraduates. The author is a senior high-energy experimentalist, and two of the seven chapters are on topics in particle theory. This book contains elementary discussions of expanding space–time, dark matter, dark energy and structure formation. There is also a chapter each on cosmic rays, the author's forte, and stellar evolution. One attractive feature of Perkins' book is that each chapter ends with a concise summary of its most important items. Perkins writes exceptionally clearly and includes a significant number of worked examples, making this an ideal textbook for use in a junior or senior course that introduces particle theory and cosmology and their strong interrelationship.
Paul H Frampton, University of North Carolina at Chapel Hill.

Facts and Mysteries in Elementary Particle Physics by Martinus Veltman, World Scientific. Hardback ISBN 9812381481, £33 ($48). Paperback ISBN 981238149X, £13 ($19).

I greatly enjoyed finally reading a book that goes into the details I always wanted. Not being a physicist myself, I have often attempted, in vain, to find a reasonably deep explanation of the current state of physics. Most books simply re-hash what the curious layperson already knows: relativity and quantum mechanics are weird, there are quarks in everything. They stop short of telling you how and why nature is strange. Veltman, however, has the courage to try a deeper level about what we understand and what is simply fact. He stubbornly and rightfully sticks to what has been experimentally verified. In his words: "space–time and the laws of quantum mechanics are like the decor, the setting of a play. The elementary particles are the actors, and physics is what they do. A door we see on stage is not a door until we see an actor go through it. Else it might be fake, just painted on." For that reason, you should not expect anything on string theory or supersymmetry. Veltman ends his book with the remark "they are [so far] figments of the theoretical mind." They are doors we have not seen used.

The narrative of the book suffers from bad English in many places, with irritating errors like "than" instead of "then" and awkward phrasing. There are some paragraph breaks missing and other indications of the impatience of the author. An attempt at explaining how "quadratic implies approximately doubling for percentage increases" completely fails, even though I do understand it.

More worrying are places where Veltman may confuse the reader by omitting forward references. On page 69 we are told that there are three quark colours and three anti-colours. That should make for nine corresponding gluons, which I immediately pictured in a square matrix of nine cells, but then he puzzles me by stating that "the white one" does not exist. On page 77 I find a reference to "diagonal gluons" (ah, my mental picture of the gluon matrix was perhaps not entirely wrong!), but it is only on page 114 that the white gluons are explained through mixing. My copy is now full of notes such as "see also page n".

However, the amount explained in this book is truly impressive. To show how much effort went into discovering how nature works at the fundamental level, Veltman gives short biographical notes from a number of scientists. They appear in interesting vignettes, printed in a different colour, each on a full page. There are no fewer than 86 names. Veltman has a nice way of setting the historical record straight, tells amusing stories of his encounters with the personalities involved, and makes you smile at the vignette about Ernest Stückelberg.

Martinus Veltman: "The elementary particles are the actors, and physics is what they do."

Even if you have read books popularizing physics before, you have to read this one slowly. There is some maths (fortunately!), but nothing beyond high-school level, and there are many precise colour diagrams. Veltman often repeats what he explained before, and actually dares to say "forget about it" or "that's the way it is". This is refreshing as other accounts of physics are always vague about what can be explained in terms of more detailed theory and what we should accept as fact.

I have still not understood spin and attractive forces, but one should leave room for the second edition.

Robert Cailliau, CERN.

An Introduction to a Realistic Quantum Mechanics by Giuliano Preparata, World Scientific. IBSN 9812381767 £16 ($24).

In this small book, Giuliano Preparata claims that all the conceptual difficulties of quantum mechanics are eliminated if one takes the broader framework of quantum field theory. I am not sure I agree with him completely. I belong to those who, following John Bell, sometimes feel uneasy about quantum mechanics but realize that absolutely no substitute works, in spite of the courageous efforts of people like S M Roy and others. I am not like Roland Omnès, who thinks that if one asks the right kind of question there is no problem. However, I agree completely with Preparata when he says that going to field theory eliminates a lot of problems and constitutes a considerable improvement. For instance, the transition between states with a fixed number of particles and coherent states is much clearer, and the structure of the vacuum easier to elucidate.

I find this book, published two years after Preparata's death, constitutes a beautiful demonstration of the deep knowledge of quantum physics that Giuliano had. Sometimes during his life he took rather extreme positions against the main stream of particle theorists. There is hardly any trace of that in this book, just a demonstration of his immense culture and broadness of view. I am grateful to him for leaving us this document and can only recommend reading it.

André Martin CERN.

Books received

Transverse Spin Physics by Vincenzo Barone and Philip G Ratcliffe, World Scientific. Hardback ISBN 9812381015, £39 ($58).

Devoted to the theory and phenomenology of transverse-spin effects in high-energy hadronic physics, this book aims to assess the state of the art in this field, in which there has been much theoretical work over the past decade. Beginning with polarized deep-inelastic scattering, it covers the transverse spin structure of the proton, QCD and the structure function g_2, Drell–Yan production, and inclusive leptoproduction and hadroproduction.

Applied Partial Differential Equations by John Ockendon *et al.*, Oxford University Press. Hardback ISBN 198527705, £62.50 ($99.50). Paperback ISBN 198527713 £27.50 ($47.50).

This is a revised edition of a book first published in 1999, which sought to present at a first-year graduate level the theory of partial differential equations from an applied perspective. The new edition contains many new sections and exercises on recent applications.

Ontological Aspects of Quantum Field Theory edited by Meinard Kuhlmannm, Holger Lyre and Andrew Wayne, World Scientific. Hardback ISBN 9812381821, £56 ($82).

This anthology on the foundations of quantum field theory (QFT) brings together 15 essays by researchers in physics, the philosophy of physics and analytic philosophy. It includes work on the role of measurement and experimental evidence, corpuscular versus field-theoretic interpretations of QFT, the interpretation of gauge symmetry and localization.

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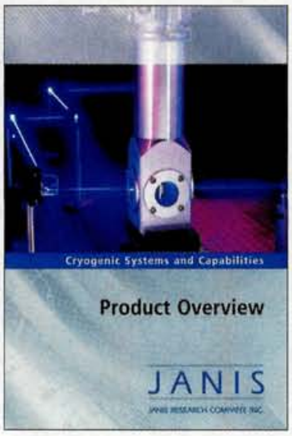

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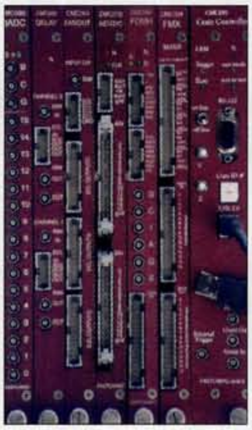

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VIEWPOINT

Training benefits from basic research

Basic research, such as particle physics, not only attracts much needed young people to science, it also provides valuable training, says **Maurice Jacob**.

In 1992–1993, the American Physical society, the European Physical Society and the Japanese Physical Society issued common position papers that were published simultaneously in their respective bulletins. One of the papers dealt with education and expressed concern about the trend observed in all industrialized countries, where fewer students are entering university to study physics as their main subject. This is becoming an increasingly serious problem. How can we obtain new physics knowledge if the number of physicists is sharply decreasing? How can we apply it if there are fewer knowledgeable people to do so? How can we avoid a two-tier society with too few people who know enough to judge the pros and cons of new technologies? This is a real challenge for a knowledge-based economy.

It may be argued that not so many people come to physics because they choose computer science or biology instead. These subjects are also very good at providing new practical knowledge. However, it is the whole of science that is suffering from a decrease in interest. We live in a society where there is nothing better than an MBA. Why suffer through difficult physics studies, as they are claimed to be, if the outcome of the effort does not look so promising?

To investigate the decline, surveys have been made of students who do enter university to study physics, asking them: "How come you chose physics?" The usual answer is: the attraction of mysterious and fundamental objects such as black holes, the Big Bang, quarks and so on.

This gives rise to the notion of "beacon science" – new developments in science that attract young people. It is of course to be hoped, and it is in practice the case, that once young students begin to study physics seriously they discover that there are many exciting things besides black holes and quarks, such as nanotubes and high-temperature superconductivity, and they turn to these topics with enthusiasm. However, black holes and quarks still have a special role to play.

CERN's pure research provides valuable experience for students.

This is important because physics studies at university are not only useful for training professional physicists. Learning how to master abstract concepts to apply them to practical problems, and learning how to appreciate orders of magnitudes and the values and limits of specific approximations are very useful for many activities. Having enough people trained that way is a prerequisite for a dynamic knowledge-based economy.

Consider particle physics. About half of the young people who receive PhDs in particle physics are working in industry within two years of acquiring their degree. The value of the wide range of training provided by such basic research should not be undermined – it is one of the obvious short-term economical returns. Our research with large detectors needs more young people than academia can absorb. Many of them come to research for training and leave it with much appreciated skills.

Indeed, industry does not care much about the research topics of new PhDs. What it appreciates is that people trained in particle physics have worked at the limits of knowledge and technology in large international collaborations, under severe time constraints, often becoming computer wizards in the process. The style of the research matters more than its subject. The great physicist Hendrik Casimir, who was for a long time head of research at Philips, said that: "It is so important to be confronted early in life with research of a greater depth, greater difficulty and greater beauty than one will find later during one's career". He also said: "I have heard statements that the role of academic research in innovation is slight. This is about the most blatant piece of nonsense it has been my fortune to stumble upon."

The value of training through research within a large international research organization like CERN is such that some member states have agreed to also try it for young engineers and have found it very valuable. For several years Spain and Portugal have regularly sent young engineers to CERN so they could acquire valuable training. At the same time, CERN also finds this input of young people very valuable, even if they have to be trained. In 2002, for example, 23 Portuguese and 12 Spanish young engineers joined CERN, many to work on the Grid.

Research domains that make young people wonder and dream should be supported if we are to attract more people to physics and science in general. As Victor Weisskopf said: "We need basic science not only for the solution of practical problems, but also to keep alive the spirit of this great human endeavour. If our students are no longer attracted by the sheer interest and excitement of the subject, we have been delinquent in our duty as teachers." Physics research, and particularly in the case of CERN, basic research, offers wonderful stimulation for innovation but also for the training of highly competent people for many walks of life – prerequisites for a dynamic knowledge-based economy.

● This is the second extract from the closing talk at a special workshop of Marie Curie Fellows on Research and Training in Physics and Technology, held at CERN in 2002. The first extract was in *CERN Courier* June p42.

Maurice Jacob, CERN, former president of the European Physical Society.

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