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CERN COURIER

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

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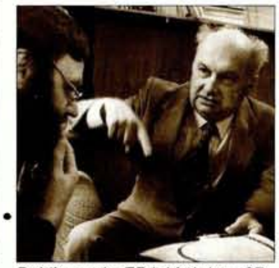
New results from Brookhaven p4

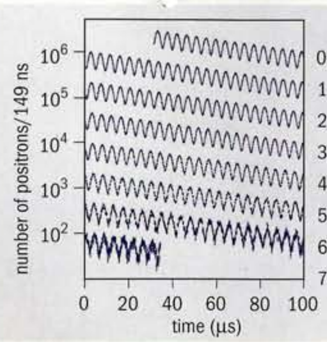

Advances in radio detection p26


Baldin marks 75th birthday p37

Cover: The 70 m radiotelescope in Goldstone, California, used to search for electromagnetic pulses from ultra-high energy particles.

US

Microeffect in muon magnetism



Above: precision masterpiece – the superconducting storage ring at Brookhaven used to measure the muon's magnetism. Right, top (left to right): Georges Charpak, Antonino Zichichi, Hans Sens, Francis Farley and Francis Müller, who performed a pioneer precision measurement of the muon's magnetism at CERN in 1961. Farley is one of the collaborators on the new Brookhaven experiment. Right, bottom: the microsecond wobbles in the spectrum of positrons from muon decay in Brookhaven's storage ring.

A new precision measurement of the muon's magnetism during an experiment at Brookhaven has shown a tiny unexplained discrepancy.

The experiment is one of the few in particle physics that does not study particle scattering. A team of physicists from Germany, Japan, Russia and the US injects 3.09 GeV polarized (spin-oriented) positively charged muons from Brookhaven's Alternating Gradient Synchrotron into a superconducting storage ring with a circumference of 14.2 m. As they circulate round the ring, the stored muons decay into positrons, which can be detected, and neutrinos, which cannot, over periods measured in microseconds.

A muon spins round an internal axis. A spinning charged particle acts like a tiny magnet, and the positrons emitted as the muons decay inside the ring reflect the magnetic behaviour of the parent particle.

Classical Dirac quantum theory of spin 1/2 particles shows that the "gyromagnetic ratio" (g) of the magnetic moment of a charged particle, such as the muon, to its spin angular momentum is exactly two. However, additional small effects can creep in to change this value, so that g–2 is not zero. Such precision magnetism measurements are collectively known as "g–2" experiments.

The additional effects mean that the muon magnets do not line up in exactly the direction of the magnetic field in the storage ring. Instead, each muon wobbles (precesses) as it circulates round the ring, and the observed positron pattern reflects these wobbles.

What are these additional magnetic effects? First, the muon's magnetism is affected by its attendant electromagnetic cloud. The muon behaves like a heavy cousin of the electron, and the discovery in 1947 by Polycarp Kusch and Henry Foley that the electron's g–2 is not zero provided some of the first experimental evidence for the then new theory of quantum electrodynamics. This describes the way in which charged particles like electrons and muons are surrounded by tiny clouds of additional electromagnetic effects. Quantum electrodynamics predicted exactly what the electron's g–2 should be, and the agreement with experimental results was an impressive confirmation of the new theory.

In the 1960s and 1970s a series of precision experiments at CERN measured g–2, this time for muons, to a few parts per million. These were among the most precise particle physics results ever obtained at that time. This pioneered the idea of a storage ring in which the muons could decay.

Unlike the earlier experiments at CERN, the Brookhaven g–2 experiment injects muons into the ring. The CERN studies injected pions, which then decayed in orbit. Muon injection was suggested by the late g–2 pioneer Fred Combley.

As well as interacting electromagnetically, the muon is also affected by weak interactions. In addition, the photon – the carrier of the electromagnetic force – has a minute quark-gluon component, which is affected by the strong nuclear force. This has a further effect on the muon's g–2.

Taking all of these effects into account, the experimental measurement at Brookhaven (to a precision of about one part per million) and the theoretical prediction differ by 2.6 times the estimated error of the measurement.

This result from Brookhaven is based on 2.9 billion muon decays carefully accumulated during 1999. Analysis of the experiment's 2000 data sample has not yet been completed.

With such a precise result apparently differing from the theoretical prediction, those involved in the experiment may indulge in the luxury of speculation. Is additional physics being seen for the first time? Only with more g–2 information will we know.

B PHYSICS

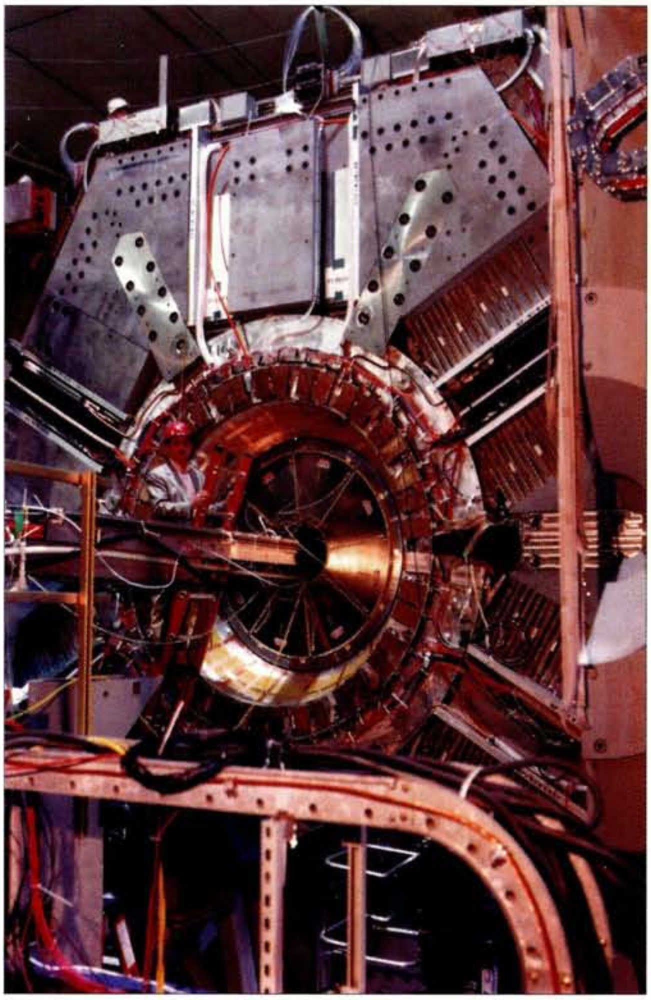
How CP violation came to B

Two major new experiments have provided the first strong indications of the delicate CP violation effect in a totally new domain – the decays of B mesons (containing the fifth or "b" quark). Exploring this still unexplained phenomenon under these conditions could provide fresh insights.

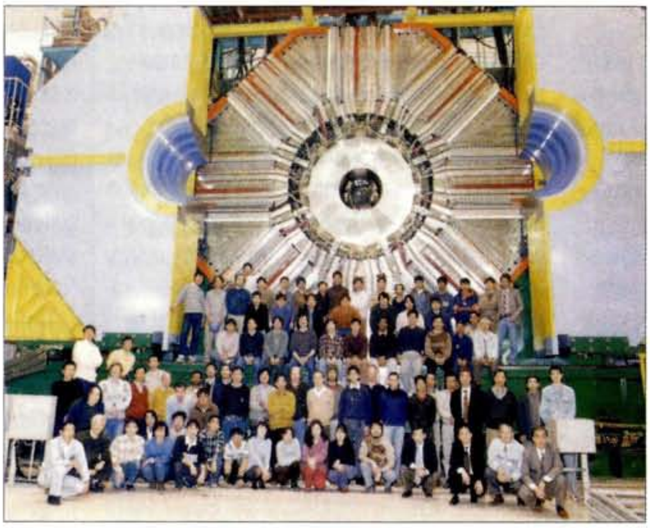
The phenomenon that physicists call CP violation ultimately distinguishes matter from antimatter. In CP (charge/parity) symmetry, the physics of left-handed particles is the same as that of right-handed antiparticles – a natural enough assumption after physicists had been shocked in 1956 to discover that nuclear beta decay is spectacularly left-right asymmetric (P-violating). However, in 1964 new experiments found that CP symmetry is also flawed.

Until recently, the only way to explore CP violation was via the study of the neutral kaon, where CP violation was originally discovered in 1964. However, a new generation of experiments at the PEP-II and KEKB electron-positron colliders at SLAC, Stanford, and Tsukuba, Japan, tuned to produce copious supplies of B-mesons, has opened up a new phase of CP violation research.

These "B factory" machines achieve unprecedented collision rates for electron-positron machines (luminosities well over $10^{33}/cm^2/s$). At SLAC, the BaBar detector has studied 23 million B pairs produced by PEP-II tuned to the upsilon 4S resonance. At KEK, with KEKB tuned to the same energy, the Belle detector has investigated 11.1 million B pairs. The experiments look for CP-violating B decays, mainly into a J/psi particle and a short-lived kaon. When comparing the decays of the neutral B meson and its antiparticle, CP appears as a time-dependent asymmetry in the decays to a specific CP state.



Above: the BaBar detector at the PEP-II B Factory, SLAC, Stanford. Below: the Belle detector at the KEKB B factory, Japan.



The quark transitions responsible for CP violation are conventionally described by a 3×3 matrix – the Cabibbo/Kobayashi/Maskawa (CKM) matrix – the rows and columns of which correspond to the six types of quark. For the B meson system, the relevant parts of this matrix are conveniently represented by a triangle, the angles of which can be measured via CP violation effects.

One of these angles, ß, or rather sin2 ß, has been measured by the new experiments. The BaBar result is sin2 ß = 0.34 ±0.20 ±0.05, while that of Belle is 0.58 + 0.32 - 0.34 + 0.09 - 0.10. (For historical reasons, the Japanese prefer to label the angle as Φ_1.)

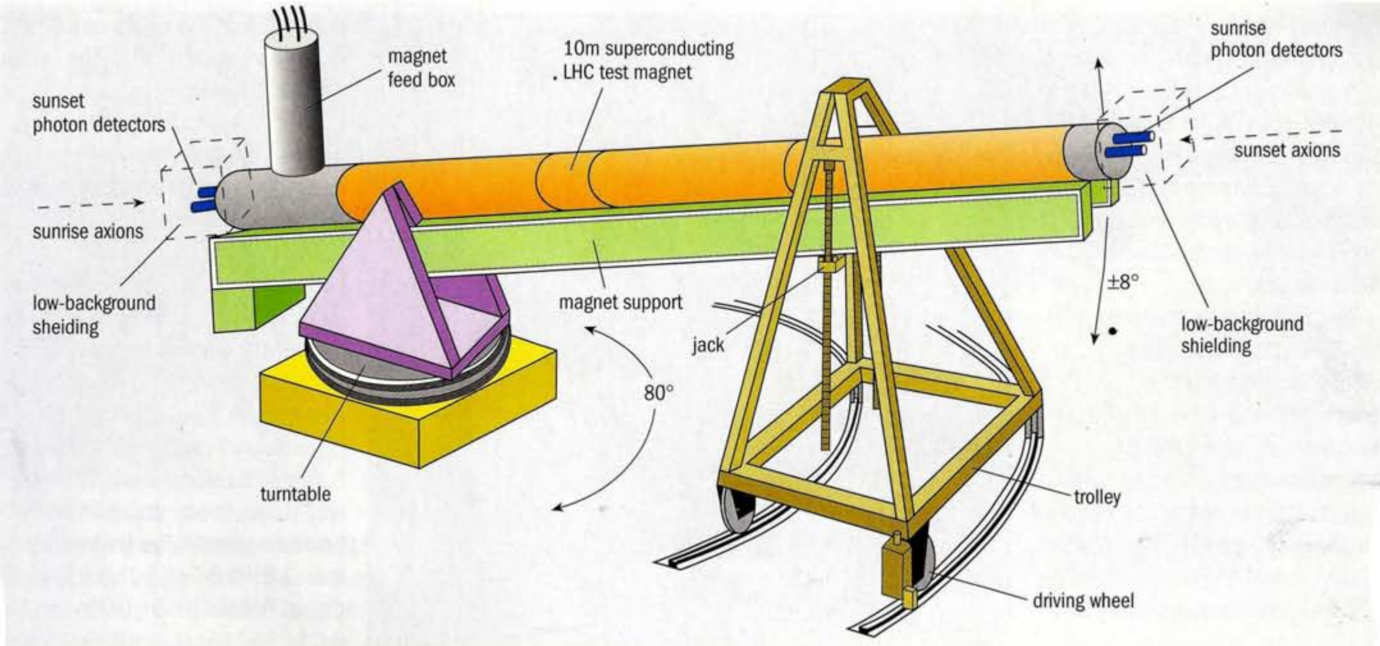
Combined with results from other experiments, including a measurement by the CDF detector at Fermilab's Tevatron, the world average sin2 ß = 0.49 ±0.16, which pretty much rules out (3 standard deviations) the possibility of no CP violation at all.

In reporting this development, *CERN Courier* has an apology to make. First indications of these B-decay CP violation measurements were announced at last year's International High Energy Physics Conference in Osaka. These initial measurements still had rather large errors, which meant that the provisional result was still compatible (just) with no CP violation at all. *CERN Courier*'s report of this meeting (September 2000 p5) jumped the gun when it alleged that CP violation had been "seen" in B decays. "It is only a 1-sigma effect," objected the physicists, who are still stopping short of announcing a discovery.

For an appraisal of these latest results, see p13.

CERN

Solar telescope CASTs the net for solar axions



Looking for axions – an artist's impression of the CAST experiment.

The CERN Solar Axion Telescope, CAST, aims to shed light on a 30-year-old riddle of particle physics by detecting axions originating from the15 million degree plasma in the Sun's core. Axions were proposed as an extension to the Standard Model of particle physics to explain why CP violation – a phenomenon linked to the dominance of matter over antimatter in the universe – is observed in weak but not strong interactions – the so-called strong-CP problem.

One of the most striking consequences of this is the neutron electric dipole moment, which, due to a CP-violating term in the standard equations, is calculated to be ten orders of magnitude larger than its measured upper limit. This can be overcome by introducing a further symmetry, the spontaneous breaking of which yields the axion – a neutral pion-like particle that interacts very feebly. Owing to their potential abundance in the early universe, axions are also leading candidates for the invisible dark matter of the universe.

Searches for solar axions began a decade ago when the US Brookhaven Laboratory first pointed an axion telescope at the Sun – a highly useful source of weakly interacting particles for fundamental research, as the solar neutrino anomaly amply demonstrates. Axions would be produced in the Sun through the scattering of photons from electric charges – the Primakoff effect – and their numbers could equal those of solar neutrinos. The idea behind the Brookhaven experiment, first proposed by Pierre Sikivie, was to put the Primakoff effect to work in reverse, using a magnetic field to catalyse the conversion of solar axions back into X-ray photons of a few kilo-electronvolts.

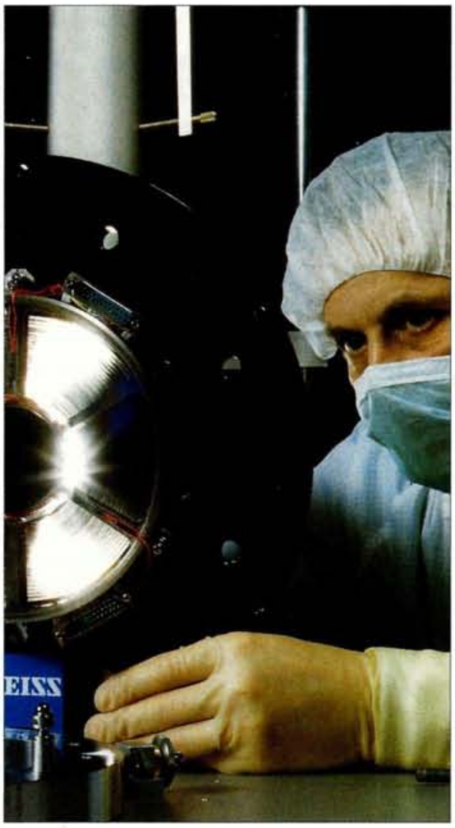
The Brookhaven telescope was later joined by another in Tokyo, while other experiments continued the search in different ways. Experiments at Brookhaven, the Lawrence Livermore Laboratory and Kyoto, for example, search for relic axions from the early universe. CERN's NOMAD experiment joined the hunt, looking for axion production in a neutrino beam. Searches based on axion Bragg scattering have been performed by the SOLAX collaboration using a 1 kg single crystal of germanium in an underground laboratory in Argentina, while optical detection techniques are employed by Italy's INFN experiment, PVLAS.

This list is not complete, but, taken together, earlier experiments have scanned the kinetic energy range from 10^{-11} eV up to 10^{11} eV, so far without success. CAST, however, could make a difference because of the length and strength of the magnetic field that it will have available by using a prototype magnet for CERN's LHC collider.

The conversion efficiency for axions increases as the square of the product of the transverse magnetic field component and its length. This makes a 9 tesla, 10 m LHC prototype dipole magnet with straight beam pipes ideal for the task, giving a conversion efficiency exceeding that of the two earlier telescopes by a factor of almost 100.

CAST's LHC magnet will be mounted on a moving platform with X-ray detectors on either end, allowing it to observe the Sun for half an hour at sunrise and half an hour at sunset. The rest of the day will be devoted to background measurements and, through the Earth's motion, observations of a large portion of the sky. CAST's X-ray detectors are under development, with the collaboration looking at gas-filled and solid-state options. A chamber using the "micromegas" principle has been tested.

The aperture of the LHC magnet's beam pipes is around five times the predicted solar axion source size, so its X-ray detectors must be correspondingly large, implying a high level of noise. To overcome this problem, the CAST collaboration is considering using X-ray lenses to focus the converted X-rays emerging



Additional axion optics – a spare X-ray lens module constructed for the ABRIXAS orbiting X-ray telescope. (Carl ZEISS/ Oberkochen-Germany.)

parallel from the 50 mm magnet aperture to a submillimetre spot. This will bring a vast signal-to-noise improvement over the original CAST proposal and the earlier solar axion telescopes. An option to recover mirrors constructed for the German orbiting X-ray telescope ABRIXAS is being pursued.

CAST is a new departure for CERN, relying not on the lab's expertise in accelerators but on its know-how in X-ray detection, magnets and cryogenics. With a discovery potential for axions extending beyond that dictated by astrophysical considerations, the experiment leaves room for surprises and could open up a new field of terrestrial axion astrophysics. CAST should be ready to begin its search this autumn.

Konstantin Zioutas, Thessaloniki.

Further reading

G G Raffelt 1996 *Stars as Laboratories for Fundamental Physics* (University of Chicago Press, Chicago & London).
The CAST Web page is at "http://axnd02.cern.ch/CAST/".

CERN

End-cap toroids for ATLAS experiment are ready to roll

The first part of the end-cap toroid system for the mighty ATLAS experiment, which is under preparation for CERN's Large Hadron Collider (LHC), will soon be on the road to CERN. The experiment's two end-cap toroids, each weighing 340 tonnes, will be installed at the outer ends of the ATLAS detector and used to determine precisely the momenta of highly energetic muons emerging from the LHC's proton–proton collisions.

The main components of the end-cap toroids are being built by Dutch companies under the guidance of NIKHEF in the Netherlands and the Rutherford Appleton Laboratory in the UK, which has design responsibility for the complete end-cap toroid system. Their construction forms an in-kind contribution to ATLAS from NIKHEF, amounting to roughly €5 million of the €8 million manufacturing cost. Smaller contributions to the toroids will come from several other countries in the ATLAS collaboration.

Each of the toroids consists of eight superconducting coils inside an insulating vacuum vessel that is 10.7 m in diameter and 5 m wide. The resulting magnetic field has circular field lines perpendicular to the beams and will deflect the muons in a plane defined by their track and the beam line, allowing much more precise momentum determination than with the inner detector alone.

The first part to be shipped to CERN will be a vacuum vessel, which is scheduled to leave the Netherlands in June. Owing to its size and weight (about 80 tonnes), the move will not be trivial. Split into two halves, the vessel will be shipped from the Netherlands to Strasbourg via the Rhine, and on to Geneva by road.

Manufactured by Schelde-Exotech in Vlissingen, the vessel was machined to a precision better than 1 mm at Machine Fabriek Amersfoort in Ijsselstein (near Utrecht) before being taken back to Vlissingen, where the two halves are now being combined. Once the vessel has been assembled, its mechanical construction and vacuum tightness will be tested, after which it will be split again for transport to CERN.

A half-shell of an ATLAS end-cap toroid arrives at Amersfoort for machining (Machine Fabriek Amersfoort).

In the meantime another firm, HMA Power Systems in Ridderkerk, has started production of the superconducting coils and their support structures. The eight coils in each vessel will be tightly fixed between eight aluminium keystone boxes, which will keep the coils in place when the field is switched on, exerting radial forces of up to 550 tonnes per coil. Thermal insulation will be provided by the vacuum, a radiation heat shield made by Hatehof in Israel and multilayer superinsulation blankets made by Austrian Aerospace.

To complete the cosmopolitan whole, the 26 km of conductor for the toroids is being supplied as in-kind contributions from Italy (Europa Metalli), Switzerland (ETH/Nexans) and Germany (Vacuum Schmelze). All components of the end-cap toroids are scheduled to be at CERN by the end of 2002 for integration, surface testing and installation underground in the ATLAS experimental hall.

MEDICINE

NIKOS makes coronary tests comfortable

A new method for the radiography of coronary blood vessels (known as angiography) promises to make examinations much easier for patients. The NIKOS intravenous angiography technique, which produces an X-ray image of coronary arteries, was developed by the DESY laboratory, Hamburg, in collaboration with doctors from the University Hospital Hamburg-Eppendorf and the Bevensen Heart Centre, and physicists from the University of Siegen. DESY has examined a total of 379 patients from all over Germany and abroad with extremely satisfactory results.

With the successful conclusion of these trials at DESY's HASYLAB synchrotron radiation centre, a door opens for routine application of the new technique. However, this would have to be at a specially equipped clinic, with a compact source of monochromatic X-rays. An initial design for such a source, based on a storage ring, has already been made at DESY.

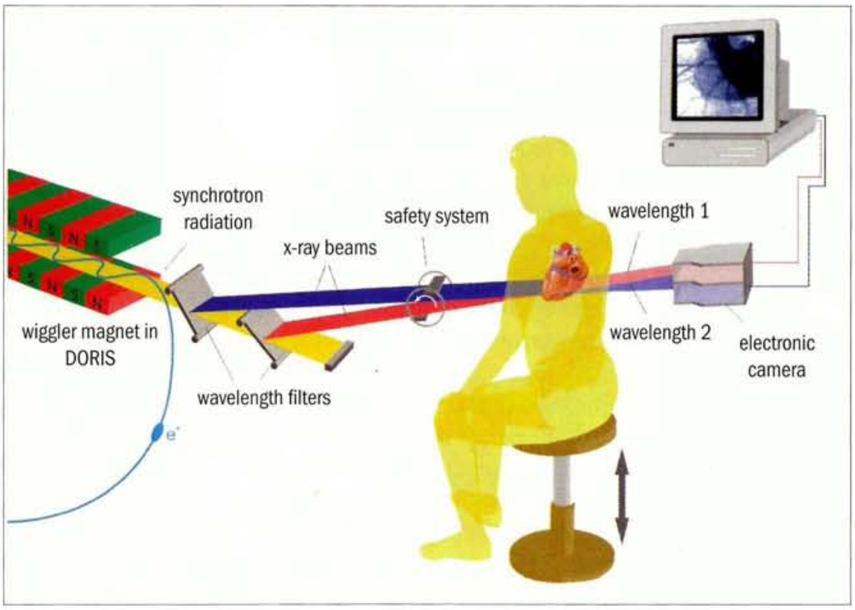
The coronary arteries surround the heart and supply it with blood. If they become constricted, a heart attack can result. To look for these life-threatening constrictions (stenoses), doctors normally insert a long catheter into the coronary vessels via the groin and the aorta. They then inject a contrast medium containing iodine through the catheter and make an X-ray. Such invasive examinations can be an unpleasant experience for patients.

The NIKOS technique eliminates the need for surgical procedures. Instead, the iodine is injected intravenously. Greatly diluted on its journey through the circulatory system, the iodine concentration is so low by the time it reaches the coronary arteries that conventional X-ray tubes cannot produce a clear image. The HASYLAB scientists use intense monochromatic X-rays from the DORIS electron ring as well as a special "two-colour" method to reveal the coronary arteries.

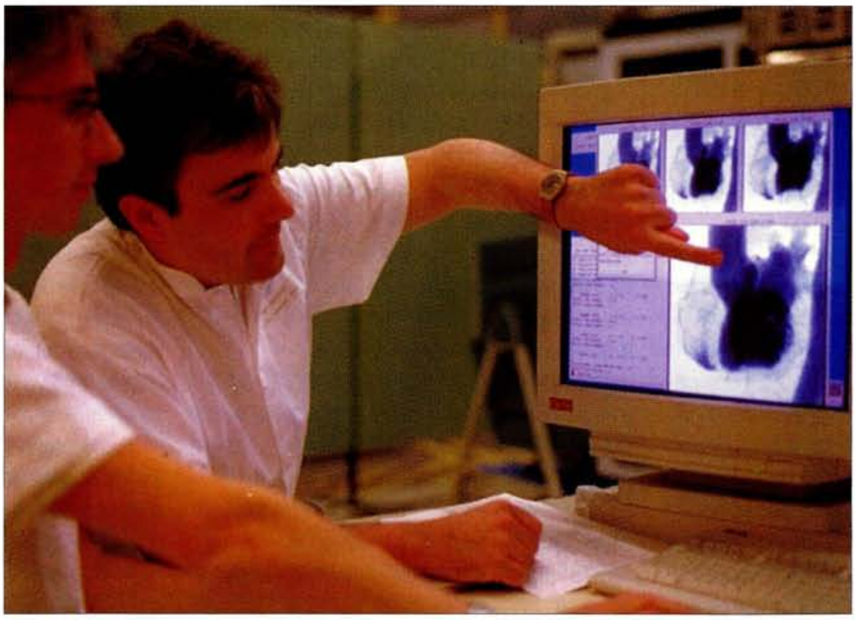
Of the 379 patients examined at DESY using the new technique, 60 underwent a subsequent diagnosis based on conventional X-ray exposure. The diagnoses displayed good agreement.

There are other non-invasive and minimally invasive procedures for imaging the coronary vessels – magnetic resonance imaging (MRI) and electron beam computed tomography (EBCT). However, compared with these methods, the NIKOS technique claims to provide the best image quality. Its output resolution is also better and, unlike MRI, metallic implants do not degrade image quality. However, none of these methods will be capable of replacing conventional coronary angiography in the long term. This is because the conventional method also allows for surgery during the examination, such as repair (angioplasty) or tube implantation (stent).

NIKOS allows the imaging of bypasses and stents in check-ups and postoperative examinations. Further improvements to the system and its associated techniques could increase image quality and therefore the value of the diagnosis.



Schematic of the new NIKOS scheme for the radiography of coronary arteries (angiography). The method needs a powerful source of monochromatic X-rays.



Doctors can view the NIKOS image immediately after the examination.

ACCELERATORS

PCs gain greater importance in particle accelerator control

Personal computers are steadily making inroads into some specialist and very impersonal fields. One example is particle accelerators, and the impact of PCs was described in the Third International Workshop on PCs and Particle Accelerator Controls (PCaPAC), which was held recently at DESY.

From its inception in 1996, PCaPAC has specifically targeted the use of PCs in accelerator controls and has shown itself to be a valuable workshop in giving participants a chance to exchange ideas and experience in PC-related technologies, where trends can change rapidly. Participation in PCaPAC 2000 reached an all-time high of 93 contributions and 127 registered attendees from 43 different institutes and 17 countries.

At PCaPAC 2000, many running accelerators, the control-system infrastructure of which was based either entirely or in part on PCs, were presented. Among these were small systems built and maintained by a few people (e.g. the storage rings ASTRID and ELISA of the ISA Storage Ring Facilities at University of Aarhus in Denmark), medium-scale systems (e.g. the ANKA synchrotron light source in Karlsruhe, and accelereators at KEK in Japan) and the, probably, largest PC-based control systems for the HERA, PETRA and DORIS storage rings and their injectors at DESY in Hamburg.

Industrial solutions were also presented, covering complete packages, such as Supervisory Controls and Data Acquisition (SCADA) systems, as well as control systems based on Common Object Request Broker Architecture (CORBA) or Distributed Component Object Model (DCOM). In this vein, a joint venture between KEK and IT-Industry was presented, where a new Component Oriented Accelerator Control Kernel (COACK) was demonstrated.

In several cases, strategies to convert from legacy systems to modern ones and/or to integrate different platforms were presented. The distributed nature of PC control systems is manifest in the important role that is played by system administration. Also discussed were the needs and wishes of the accelerator operators regarding the control system as well as different approaches to supplying the optimal console profile to different and roaming users.

PCs for particle accelerators – some of the attendees at the DESY workshop.

There were three special "tutorials". First, a representative from CISCO described networking trends in the next three years of campus networks. Another covered "SCADA – current state and perspective", when participants could get a real feel for both SCADA systems and trends in the field. Finally, as interest in such modern innovations as Java and CORBA remains high, whereas the number and variety of associated buzzwords make these subjects daunting for the uninitiated, a tutorial on these topics was also included.

While there is significant overlap in topics with the much larger ICALEPCS conference (May 2000 p26), PCaPAC has nonetheless found its niche as a biennial workshop, alternating with ICAPLEPCS. The pace at which computer hardware and software as well as the Internet evolve is fast, so an event such as PCaPAC, where topics, trends and problems can be discussed in a workshop atmosphere, has been seen to be not only worthwhile but enthusiastically accepted by the controls community. For instance, in the category of Future Trends and Technologies, participants saw their first glimpse of data exchange via SOAP (Simple Object Access Protocol) and XML (extensible markup language).

The Fourth International Workshop on PCs and Particle Accelerator Controls will be held in the autumn of 2002, in Asia or Italy.

Reinhard Bacher, DESY MST.

Edited by Emma Sanders

Uranium dating suggests new age of universe

The first measurement of uranium outside our solar system suggests that the universe is at least 12.5 billion years old. Just as the radioactive decay of carbon-14 is used for dating archaeological remains, astronomers are using the decay of uranium-238, which has a half-life of 4.5 billion years, to estimate the age of the universe.

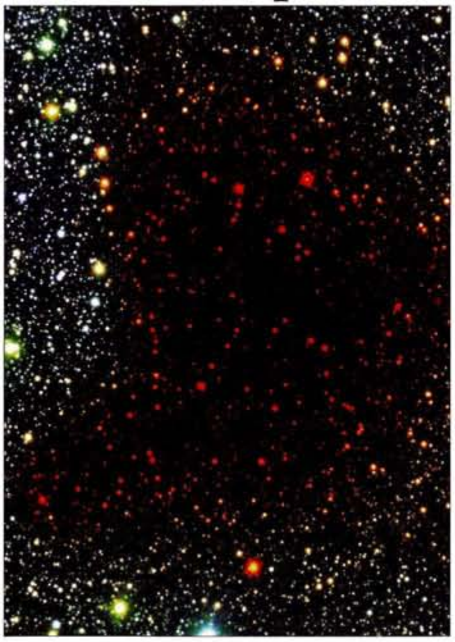
By measuring the uranium line in the spectrum of a star and comparing it to the amount of other stable elements, it is possible to calculate the age of the star. This benchmark is interesting to astronomers because it is independent of models of stellar evolution.

In the past, this method has not been possible because the amount of uranium in stars is tiny and its spectral lines are hidden by emission from more abundant elements.

Now, ESO's Very Large Telescope in Chile has sufficient collecting power and resolution to measure the uranium abundance in an old Milky Way star. The results give an age of 12.5 billion years and, because the universe must be older than the star, a constraint on the age of the universe.

Unusually, the error in the measurement (±1.5 billion years) does not have astronomical origins. The largest contribution comes from errors in the knowledge of how strengths of spectral emission lines are related to element abundances. Astronomers are therefore confident that in a few years a much more accurate result will be possible.

Antu telescope reveals secrets of the stars



Opening up the mysteries of star formation – seeing through the dark cloud B68. (ESO.)

Observations using the European Southern Observatories' Antu telescope in Chile are helping to shed light on the mystery of star formation. Stars form from interstellar clouds of gas and dust that gradually contract and heat up until nuclear synthesis starts in their centre. These central dark clouds are opaque and their structure has until now been a mystery – a missing link in theories of star formation.

Using the infrared camera on Antu, astronomers observed the reddening of the light of background stars as it was absorbed and scattered by dust in the dark cloud B68. This cloud is particularly interesting because it is on the verge of becoming instable and starting its collapse into a star. Measuring the reddening of the different background stars gave detailed information about the internal structure, composition and density of the cloud. Only large telescopes and very sensitive instruments can observe a sufficient number of stars to produce significant results.

Black holes show up in early galaxies

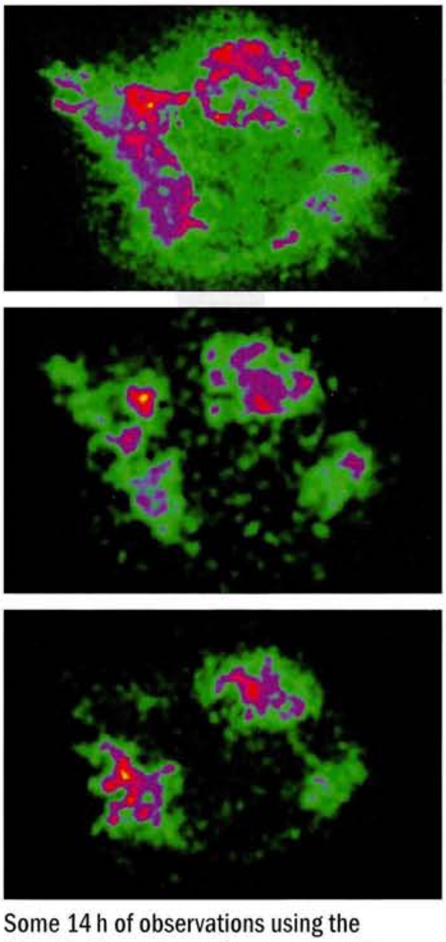
Radio observations have shown the presence of black holes in the centre of early galaxies. The new results support the theory that supermassive black holes played a crucial role in the formation of galaxies in the early universe.

Back in 1996 the Hubble Space Telescope Science Institute released images of what became known as the Hubble Deep Field – the deepest view of the universe ever taken. The images revealed more than 1500 galaxies in the process of formation over 10 billion years ago. Today's radio images are three times as sharp.

The big surprise is that the radio source at the centre of the early galaxies observed is so small – less than 600 light-years across. The emission is so concentrated that it has to come from material orbiting a supermassive black hole. Previously the radio emission was thought to come from the remnants of short-lived massive stars.

The observations were made using the upgraded European Very Long Base-line Interferometry network. The data from nine radiotelescopes across Europe were combined to make one giant telescope of continental dimensions.

Pictures of the month



Some 14 h of observations using the Chandra X-ray observatory produced these maps of the heavy elements ejected from a supernova explosion. These images of the supernova remnant Cassiopeia A show (top to bottom) the distribution of silicon, calcium and iron in the matter thrown out from the exploded star. The shell is about 10 light-years in diameter and has a temperature of about 50 million degrees.

PHYSICSWATCH

Edited by Archana Sharma

Except where otherwise stated, these news items are taken from the Institute of Physics Publishing's news service, which is available at "http://physicsweb.org".

Photons are persuaded to stop and take a light siesta

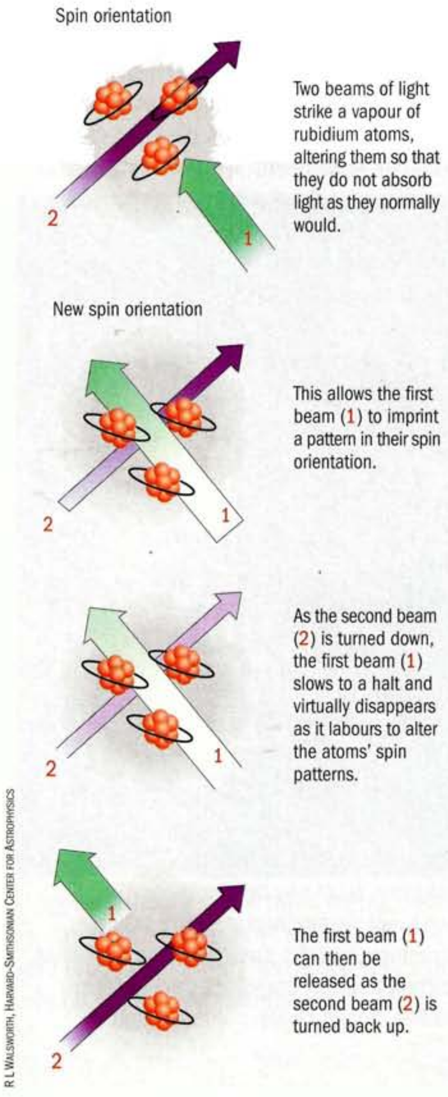
In a groundbreaking feat by two independent research teams (Harvard-Smithsonian and Cambridge), visible photons have been slowed to a dead stop for a period in which they would otherwise have travelled some 200 km.

A cluster of supercooled (1 μK) atoms exploits a phenomenon known as electromagnetically induced transparency. In this cooled ground state, atoms readily absorb light from a probe laser, the frequency of which corresponds to any of its excited energy states, thus becoming opaque at those frequencies. Light in the vapour interacts with atoms changing their spin states coherently and forms an atom–photon system (polariton).

To obtain an unusual quantum superposition of the ground and excited states, another (coupling) laser that is carefully tuned to two hyperfine energy levels in the atom is shot in. The probe laser tuned to the original energy level can no longer be absorbed, thereby stimulating the stopped beam, which emerges with its initial properties intact – opening a new vista for "light storage" and transmission.

This experimental landmark promises a step forward in quantum communication and computation, which in turn could be used to connect ultrafast computers in a large network, comparable to the Internet.

In another development (Kocharavskaya *et al.* 2001 *Phys. Lett.* 22 January) a novel technique for making light not only stop moving, but reverse its direction has been discussed, albeit theoretically. (Phillips *et al.* 2001 *Phys. Rev. Lett.* 29 January.)



Japanese find alternative superconductor

Magnesium diboride, a cheap, "off-the-shelf" chemical compound, can be made into a superconductor, according to reports from Japanese researchers. Below a certain critical temperature, superconductors lose their resistance to electrical current flow, but a major limitation is that the elusive superconducting properties only occur either at extravagantly low temperatures or in complex and expensive materials.

Magnesium diboride becomes superconducting at –234 °C (39K) – much higher than previously observed in relatively simple and readily available compounds. Magnesium diboride may have a bright future as an affordable superconducting compound.

Silicon lasers to work with microchips?

Storing zeros with photons? The dream of processing signals encoded with light, so that photonic technology replaces electronics, could revolutionize communications.

Driven by tiny, cheap microlasers integrated into a microchip, the fantasy is drawing closer to becoming reality. The problem is that there is a lack of light emission from silicon.

While microelectronics uses transistors dedicated to silicon components, light-based information processing requires microlasers. Silicon, rather than gallium arsenide (GaAs) lasers are needed, but matching the GaAs crystal lattice to that of silicon to build a miniature laser has turned out to be a challenging and expensive task.

It has been shown that compounds grown on silicon (cerium silicate) glow when stimulated by another laser. Silicon etched into tiny quantum wires emits yellow, green and blue light (depending on the thickness of the wire) when a current passes through it.

A number of groups are contributing to the development of silicon microlasers. An MIT team has created "virtual materials" with exactly the right lattice match and infrared emission using sophisticated computer modelling. An Italian team has fashioned "quantum dots" of silicon that emit red light, and stimulated emission has been observed. At PSI in Switzerland an unconventional quantum cascade laser has been made using polysilanes – silicon and hydrogen polymers with chain-like molecules – thus avoiding the lattice match problem. Meanwhile a team at Queen Mary and Westfield College, London, has succeeded in making a two-layer diode by using two different non-crystalline materials. The first carries current from the silicon base to the infrared light-emitting second layer which is made of molecules with an erbium atom at their core.

Although as yet they are far from being efficient and practical optoelectronics devices, such developments hold promises of a quantum jump for information technology.

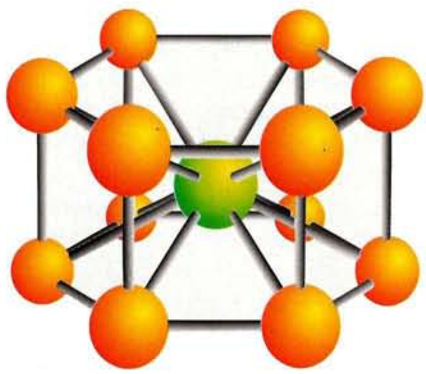
SQUIDs are multiplexed for low-temperature sensors

Superconducting quantum interference devices (SQUIDs) have already shown their worth, but a new development suggests a way to link these useful devices together.

Looking for a "cool" sensor? Take a superconducting loop, interrupt it at two points with a thin insulator gap (permitting electron "Cooper" pairs to pass through) and maintain a current flow. The result is a working SQUID. Any magnetic flux threading the circuit will cause a voltage increase across the gap, and tiny changes can be detected. Thus a SQUID operates as a flux-to-voltage converter for measuring magnetic fields, and it can also be used to read small currents.

A SQUID-based multiplexer that can simultaneously interrogate arrays of many such low-temperature sensors has been developed by physicists at UC Berkeley. These find applications in sensors for the detection of ultraviolet light and x-rays. Magneto-encephalography – mapping of the magnetic fields from brain activity – also uses SQUIDs, as do arrays of several thousands of voltage-biased superconducting bolometers, employing tens of multiplexers.

Tungsten is confined in a silicon trap

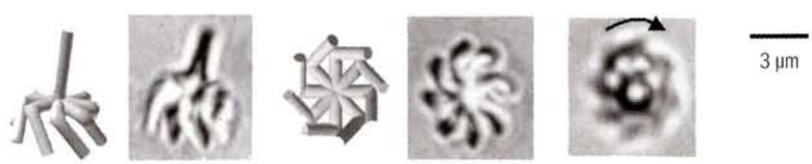


After weaving a web with 12 silicon atoms, a tungsten atom has been trapped by Japanese researchers, forming stable structures just like carbon fullerenes. Unlike carbon atoms, pure silicon cannot form stable, closed cages, but new research reveals that silicon can gather around a central metal atom and settle into basket-like arrangements called silicon cage clusters.

A particularly low-energy, and therefore stable, configuration consists of 12 silicon atoms forming a regular hexagonal cage that surrounds a tungsten atom. The choice of a central metal atom affects the chemical behaviour of cage clusters, thus enabling the tailoring of the clusters to create novel nanodevices and catalysts.

Clusters efficiently isolate their guest metal atoms from the surrounding environment – a feature that could permit a cluster to act as a dynamic "qubit" in a quantum computer by storing a single bit of information in the spin state of the trapped metal atom. (H Hiura *et al*. 2001 *Phys. Rev. Lett.* 26 February.)

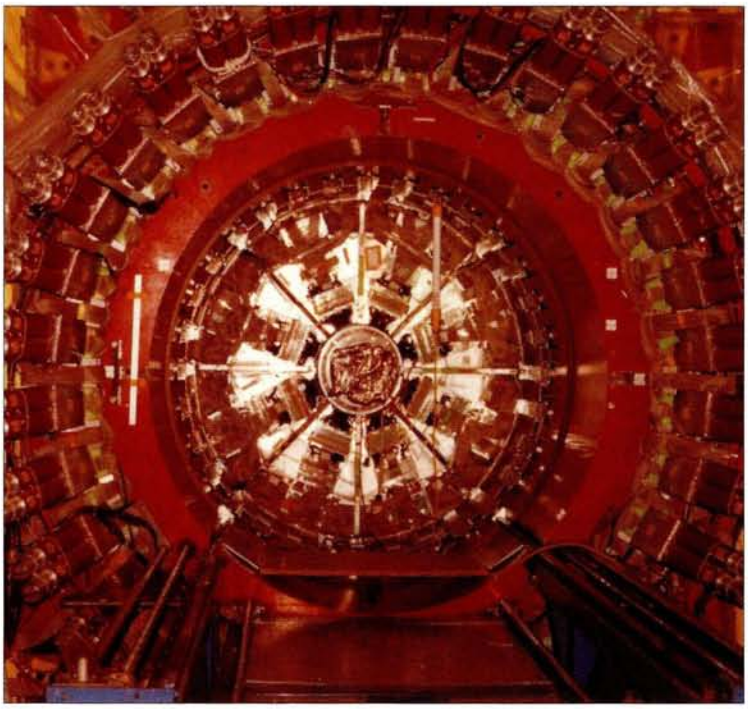
Micromachines – the optical windmill?



Illuminated by a laser beam, a 5 μm wide resin structure, shaped like a propeller, rotates merrily in the optical wind. Micromechanical systems (MEMS) could one day be powered by tiny rotors like this, which could in turn be used to twist molecules, giving a measure of their mechanical properties.

B factories measure an eternal triangle

New results from the "B factories" could help to explain why a universe made of matter emerged from a Big Bang that created equal amounts of matter and antimatter.



Although the B physics spotlight now turns on the experiments at the new B factories, the CLEO detector at Cornell's CESR electron–positron collider helped to pioneer this field and has provided a wealth of valuable B physics information.

As reported on page 5 of News, two major experiments have provided the first observation of the delicate CP violation effect in a totally new domain: the decay of B mesons, which contain the fifth ("b") quark. The obscure phenomenon that physicists call CP violation could have been the mould that formed a universe of matter from the Big Bang's equal mixture of matter and antimatter.

After the shock discovery in 1956 that nuclear beta decay is spectacularly left-right asymmetric (P-violating), the proposition of CP (charge/parity) symmetry, with left-handed particles behaving in the same way as right-handed antiparticles, seemed a natural theoretical handhold for physicists to grasp. However, further experiments carried out in 1964 found that CP symmetry was also flawed. To reach an understanding of why CP violation happens, physicists must first measure exactly how it happens.

The B-route

Until recently the only particle that showed CP violation was the neutral kaon, where CP violation was originally discovered in 1964. However, according to the conventional wisdom of today's Standard Model (SM) of particle physics, CP violation should also be observed in the decays of B particles. Only recently have experiments been able to look into this further.

CP violation has its own language. In this CP-speak, the quark transitions responsible for CP violation are conventionally described by a 3×3 matrix – the Cabibbo/ Kobayashi/ Maskawa (CKM) matrix – the rows and columns of which correspond to transitions involving the six types of quark. For the B meson system, the relevant parts of this matrix are conveniently represented by a Unitarity Triangle (figure 1) the angles of which can be measured via CP violation effects. One of these angles, β, or rather $\sin 2\beta$, is now being probed.

A first shot at this measurement was taken by the Opal and Aleph collaborations at CERN's LEP electron-positron collider. In these experiments the decays of Z particles into b quark-antiquark pairs were harnessed to "tag" B particles, with the decay of neutral B mesons and their antiparticles monitored via their disintegration into J/psi and a short-lived kaon.

LEP results for $\sin 2\beta$ were severely limited by statistics and did not quantitatively test SM predictions. Prior to the advent of the new B factories (PEP-II at SLAC, Stanford, and KEKB at KEK, Japan; p5), the CDF collaboration at Fermilab's Tevatron proton-antiproton collider reported the first real measurement – $\sin 2\beta = 0.79 + 0.41 - 0.44$ – disfavouring negative values for $\sin 2\beta$, which are possible in unorthodox scenarios.

First results from the B factories were reported last summer at the international high-energy conference in Osaka, Japan, and caused quite a stir. In particular, the value reported by the BaBar collaboration at PEP-II – $\sin 2\beta = 0.12 \pm 0.37 \pm 0.09$ – was significantly lower than the SM predictions but was not conclusive due to limited ▷

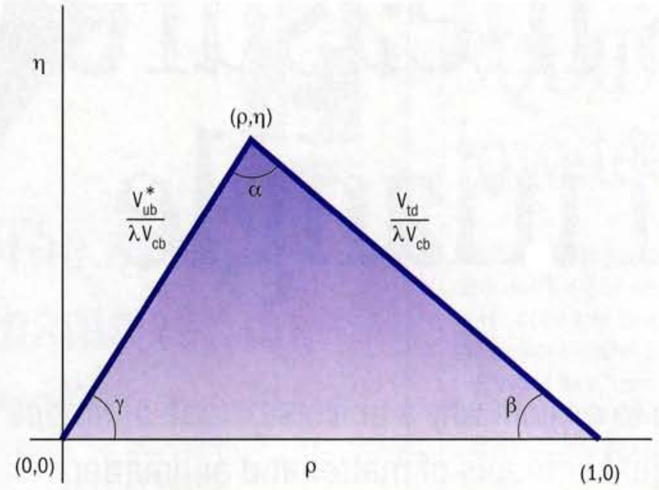


Fig. 1. The unitarity triangle for quark transitions and the various parameters involved. The various V subscripts refer to different kinds of quark transformations – t for top, b for beauty, c for charm, d for down and u for up.

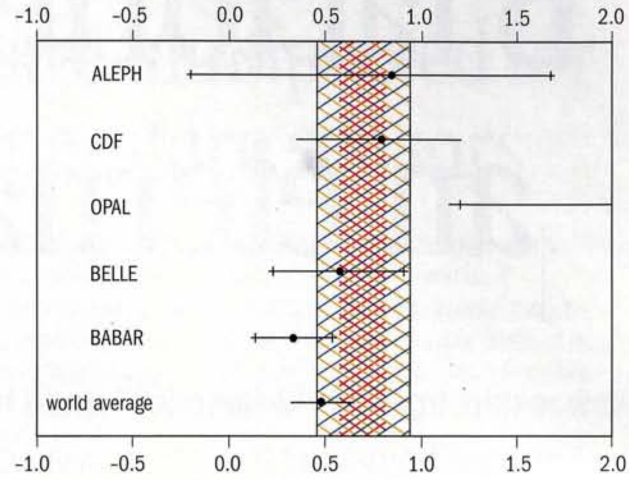


Fig. 2. Current status of measurements of CP violation in the decays of B mesons from different experiments. The band shows estimates based on current SM understanding, with one and two standard deviations. The axis shows the quantity sin2 ß.

statistics (September 2000 p5).

In February the Belle (KEKB) and BaBar collaborations announced their updated results. The BaBar measurement now makes use of 23 million upsilon(4S) decays into B pairs, while the Belle measurement so far corresponds to approximately half of that number. The principal decay modes used are B decays into J/psi and a short-lived kaon; into J/psi and a long-lived kaon; and into psi(2S) and a short-lived kaon. However, a small number of other modes are also reported.

Their measured values sin2ß = 0.58 + 0.32 - 0.34 + 0.09 - 0.1 (Belle) and $0.34 \pm 0.20 \pm 0.05$ (BaBar) are shown together with the earlier results in figure 2. Compared with last summer, the errors from BaBar and Belle have come down considerably, but the reported values of sin2ß are still consistent with no CP violation within two standard deviations.

However, the combined data of all five experiments yields a world average of 0.49 ± 0.16, constituting a measurement at slightly more than three standard deviations. It thus establishes CP violation for the first time in any system other than kaons.

Unitarity triangle

To unravel the CKM matrix fully and understand all quark transitions, physicists need to look beyond B particles. Theoretical input is needed to translate experimental results into CKM parameters.

Much painstaking work has been done, but fixing one side of the unitarity triangle requires knowledge of the decays of the sixth "top" quark into a light "down" quark. This t-d transition is expected to be a rare process, and in addition the difficulty of tagging a d-quark in top quark decays makes direct measurement daunting.

So far only the dominant CKM matrix element involving the top quark - into b quarks - has been measured directly by the CDF collaboration. Hence information on t-d transitions has to be culled from indirect measurements in which the top quark appears as a virtual, intermediate state.

There are three principal means at present to estimate t-d transitions, all based on weak interaction mixings between neutral mesons and their antiparticles. The first method involves measuring the mass difference between neutral B_d mesons (containing a b quark and a d antiquark, or vice versa); the second, the corresponding mass difference in the neutral B_s mesons (containing a b quark and an s antiquark, or vice versa); and the third, CP violation from neutral kaon mixing.

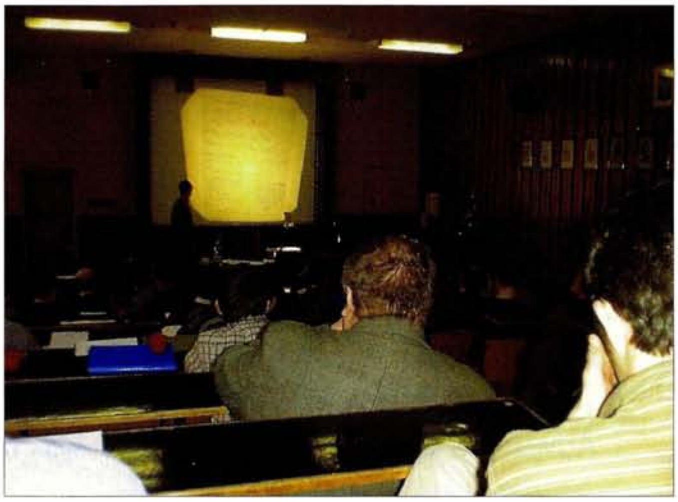
The SM fits, including direct and indirect measurements, yield a value for sin2ß that lies typically in the range 0.58-0.82 at a 68% confidence level, widening to 0.45-0.95 at the 95% confidence level, as shown in figure 2. Thus the present world average, 0.49 ± 0.16, is, within experimental and theoretical errors, in agreement with the SM. This test will become much more incisive with improved accuracy of the sin2ß measurements, and of the other two angles of the triangle in future B factory and hadron collider experiments. Additional valuable input to CKM phenomenology is anticipated from the measurement of mass differences and via the study of rare B and kaon decays.

If new physics is present, the principal way it can enter is via new contributions to the mixing of neutral particles and their antiparticles. Decays, dominated by the exchange of W particles, remain essentially unaffected by new physics. Thus, even with the presence of new physics, those transitions involving charm (c) and b quarks or b and up quarks correspond to their SM values, so that two sides of the unitarity triangle remain unaffected. However, the third side, which depends on top-down quark transitions, is likely to be affected by new physics. Furthermore, the measurements of kaon CP violation and B_s mixing, which provide acdditional constraints, will also be affected.

Therefore, if new physics is present, the allowed unitarity triangle as obtained from current experimental data may not correspond to the SM version. Likewise, if new weak interaction effects are present, they may show themselves by the inadequacy of describing CP violation in terms of the three angles of a triangle. Either of these two scenarios would be clear evidence for new physics.

From **Ahmed Ali**, *DESY, Hamburg*

B physics is surveyed in Cracow



Delegates focus on CP violation at the Epiphany meeting.

A recent meeting in Cracow gave an overview of developments in B physics.

The mysterious phenomenon of CP violation – which ultimately distinguishes matter from antimatter – has kept physicists busy since its experimental discovery in kaon decays some 35 years ago.

In CP (charge/parity) symmetry, the physics of left-handed particles is the same as that of right-handed antiparticles. CP symmetry became popular after physicists were shocked to discover in 1956 that nuclear beta decay, a fundamental weak interaction, is spectacularly left-right asymmetric (P-violating). The confusion grew in 1964 when new experiments found that the CP criterion was not 100% reliable either. Ever since then, physicists have sought to understand how and why this symmetry is flawed.

Today the effects of CP violation are expected to manifest themselves in the decays of B mesons (containing the fifth or "b" quark) as well as in the traditional kaons. This change prompted Cracow physicists from the Institute of Nuclear Physics, the Jagellonian University, and the Faculty of Physics and Nuclear Techniques of the University of Mining and Metallurgy – co-organizers of the annual Cracow Epiphany Conference – to choose B physics and CP violation as the topic of this year's meeting, which was held in Cracow in January.

The past two years have brought a real breakthrough in experimental observations. Participants at the conference heard Bertrand Vallage and Taku Yamanaka describe the latest news from NA48 and KTeV on measuring direct CP violation in neutral kaon decays. The long-awaited measurements of CP violation in B decays by the Belle and BaBar experiments operating at the KEKB and PEP-II B-factories, and from the CDF detector at Fermilab's Tevatron proton–antiproton collider, were presented by Kenkichi Miabayashi, Vasilii Shelkov and Slawek Tkaczyk.

In addition to new results on rare B decays presented in the talks on BaBar and Belle, many interesting B measurements from CLEO were shown by Karl Berkelman – CLEO has been studying B physics for more than 20 years. For ongoing experiments, Wouter Hulsbergen from HERA-B at DESY, Andreas Schopper from LHCb and Maria Smizanska from ATLAS at LHC presented the prospects in the B sector.

Among many activities in the field of kaon decays, the ambitious KAMI project at Fermilab to measure direct CP violation in ultra-rare long-lived neutral kaon decays was presented by Taku Yamanaka. Furthermore, as discussed by Fabrizio Scuri, new precision results in the kaon sector can be expected soon from the KLOE experiment at DAPHNE. Together with the data collected by the CPLEAR and LEP experiments (reviewed by Andreas Schopper, Tadeusz Lesiak and Celso Martinez-Rivero), it is clear that there will be plenty of new experimental information on B physics and CP violation.

Challenging the Standard Model

Understanding all of this experimental data will present a challenge for the theory. With the most popular theoretical description of CP violation also being the one provided by the conventional Standard Model (SM), different ways of testing this picture were presented.

For B meson decays, the extraction of parameters from the data was discussed in some detail by Ahmed Ali. The topic of radiative B decays and radiative transitions of b to strange quarks was reviewed by Mikolaj Misiak. With the b-quark mass being fairly large, theoretical approaches for infinite b mass were presented by Chris Sachrajda, Bennie Ward and Thomas Mannel, while Andre Hoang discussed the issue of b mass and non-relativistic effective quark theory. Jose Bernabeu showed how B decays can probe not only CP- but also T- and CPT-violating effects.

A few theoretical talks looked at CP problems in physics beyond the SM. These included effects in supersymmetry (Leszek Roszkowski) and Higgs boson interactions (Bohdan Grzadkowski). Peter Minkowski gave a talk on the perpetually intriguing subject of neutrinos. The conference was summarized by Roy Aleksan.

The Cracow Epiphany Conference has had a different topic every year since 1995, when the series was initiated by Marek Jezabek, chairman of the conference organizing committee. By bringing in new subjects and inviting new participants every year, each meeting can offer a general forum to discuss the frontiers of physics, while providing the Polish physics community with the opportunity to broaden its horizons and meet internationally acclaimed experts.

The next Epiphany meeting, to be held on 4–6 January 2002, will concentrate on quarks and gluons in extreme conditions.

Maria Rózanska *and* **Piotr Zenczykowski**, *Institute of Nuclear Physics, Cracow, Poland.*

Computing technology sits in the driving seat

Advances in physics go hand in hand with those in experimental techniques, and increasingly so with progress in computing and analysis. A recent workshop at Fermilab surveyed this fast-developing area, which has impact far beyond physics alone.

Fermilab director Mike Witherell, welcoming nearly 200 participants from around the world to the 7th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2000), said: "We have wonderful opportunities awaiting particle physics over the next decade. Two technologies are widely recognized as having driven our field from the beginning – accelerators and particle detectors. But there is also growing recognition that we rely on developments in advanced computing technologies. Innovative scientists often recognize the need for a revolutionary development before the wider world understands what it is good for. Once something becomes available, of course, lots of people know what to do with it, as we have learned over the last decade with the World Wide Web. There is a mutual benefit in collaboration between forefront physics research and computing technology. We rely, all over our laboratory (and our community), on continued innovations in the areas being discussed here at this conference."

Pushpa Bhat and Matthias Kasemann (right) of Fermilab chaired the recent 7th International Workshop on Advanced Computing and Analysis Techniques in Physics Research.

Short history

Reflecting the short history of these techniques, the first workshop in the series was held only 11 years ago in Lyon, France, under the name Artificial Intelligence in High Energy and Nuclear Physics, and was organized by Denis Perret-Gallix (LAPP, Annecy). Following this, the workshop was held in Europe every 18 months or so.

The 7th international workshop was the first to be held in the US with the updated name and with expanded scope. It followed four main tracks: artificial intelligence (neural networks and other multivariate analysis methods); innovative software algorithms and tools; symbolic problem solving; and very large-scale computing. It also covered applications in high-energy physics, astrophysics, accelerator physics and nuclear physics.

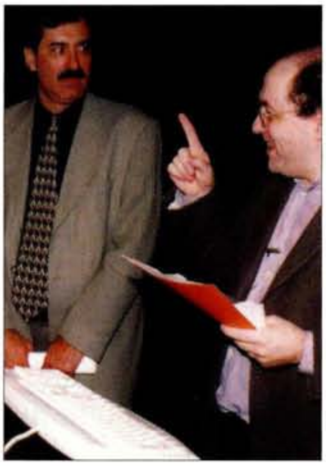
Besides the plenary, parallel and poster sessions, the workshop included working group and panel discussion sessions focusing on particular topics – uses of C++, large-scale simulations, advanced analysis environments and global computing – which allowed informal presentations and extensive discussion sessions.

The keynote talk, entitled "Information technology: transforming our society and our lives", was given by Ruzena Bajcsy of the US National Science Foundation. John Moody, a former particle theorist and now professor of computer science and director of the Computer Finance Program at Oregon Graduate Institute, spoke on "Knowledge discovery through machine learning". Gaston Gonnet from ETH, Institute for Scientific Computation, Zurich, Switzerland, talked about the "Computer algebra system".

A big attraction early in the workshop was C++ inventor and world-renowned computer scientist Bjarne Stroustrup from AT&T Bell Labs. He gave a featured talk entitled "Speaking C++ as a native" and served as a distinguished panellist in discussions on the "Use of C++ in scientific computing". His talk explained, by way of several simple but striking examples, how C++ can be used in a much more expressive manner than one commonly finds. Stroustrup, echoing the comments of Mike Witherell, noted that the world is slow to catch on to new ideas. He also emphasized the need for physicists to be involved in the C++ Standards Committees if they wish to influence the further development of that language.

Another distinguished participant and speaker was Stephen Wolfram, creator of the Mathematica software packages and the winner of a McArthur Foundation Fellowship award in 1981 at the age of 22. Early in his career he worked in high-energy physics, cosmology and quantum field theory. For the last couple of decades he has been developing a general theory of complexity.

Wolfram gave a special colloquium describing his perspective on the development of Mathematica and the establishment of Wolfram Research. His talk gave glimpses of his work on "A new kind of science," which has occupied his attention during the past nine years. Stephen Wolfram has been working on cellular automata and the evolution of complex systems, and he is writing an epic volume (of about 1000 pages) on the subject, which is soon to be published.



Left: Inventor of C++ Bjarne Stroustrup from AT&T Bell Labs. Right: Fermilab and Chicago cosmologist Rocky Kolb (left) with Stephen Wolfram, creator of the Mathematica software packages.

New experiments

High-energy physics experiments and analyses took centre stage halfway through the workshop with plenary talks on "Advanced analysis techniques in HEP" by Pushpa Bhat (Fermilab), "Statistical techniques in HEP" by Louis Lyons (Oxford) and "The H1 neural network trigger project" by Chris Kiesling (MPI). These were followed by "Theoretical computations in electroweak theory" by Georg Weiglein (CERN).

There were vigorous and stimulating discussions in a panel session on Advanced Analysis Environments, with perspectives presented by Rene Brun (CERN), Tony Johnson(SLAC) and Lassi Tuura (CERN and Northeastern).

Fermilab is facing the collider Run II (which began in March) with upgraded CDF and D0 detectors. The advanced computing and analysis techniques discussed at this workshop may be crucial for making major discoveries at the Tevatron experiments.

The new generation of experiments under construction in particle physics, cosmology and astrophysics – CMS and ATLAS at CERN's LHC collider, the Laser Interferometer Gravitational Observatory (LIGO) and the Sloan Digital Sky Survey (SDSS) – will usher in the most comprehensive programme of study ever attempted of the four fundamental forces of nature and the structure of the universe.

The LHC experiments will probe the tera-electronvolt frontier of particle energies to search for new phenomena and improve our understanding of the nature of mass. LIGO hopes eventually to detect and analyse gravitational waves arising from some of nature's most energetic events. SDSS will survey a large fraction of the sky and provide the most comprehensive catalogue of astronomical data ever recorded.

Together, these investigations will involve thousands of scientists from around the world. Mining the scientific treasures from these experiments, over national and intercontinental distances, over the next decade or two, will present new problems in data access, processing and distribution, and remote collaboration on a scale never before encountered in the history of science.

Thus "grid computing" is emerging as one key component of the infrastructure that will connect multiple regional and national computational centres, creating a universal source of pervasive and dependable computing power. Grid computing was therefore the focus for a whole day at the workshop. Various champions of the grid projects GriPhyN, Particle Physics Data Grid (PPDG) and European DataGrid contributed, such as Ian Foster (ANL), Paul Avery (Florida), Harvey Newman (Caltech), Miron Livny (Wisconsin), Luciano Barone (INFN) and Fabrizio Gagliardi (CERN), along with other pioneers of grid and worldwide computing.

In the sphere of very-large-scale computing and simulations, Robert Ryne (Los Alamos) spoke on accelerator physics, Alex Szalay (John Hopkins) on astrophysics, Paul Mackenzie (Fermilab) on lattice calculations and Aiichi Nakano (LSU) on molecular dynamics simulations. A working group on large-scale simulations coordinated by Rajendran Raja (Fermilab) and Rob Rosner (Chicago) featured contributions from particle experiments CDF, D0, CMS and ATLAS, as well as from the muon collider and astrophysics communities.

Technology show

A major event at the workshop was a technology show coordinated by SGI representative Kathy Lawlor, Cisco representative Denis Carroll and Fermilab's Ruth Pordes, Dane Skow and Betsy Schermerhorn.

The show featured the Reality Center for collaborative visualization, IP streaming video, IP Telephony, wireless LAN by SGI and Cisco, and hardware and application software exhibits from Wolfram Research, Platform Computing, Objectivity, Kuck & Associates Inc and Waterloo Maple.

The meeting was organized and co-chaired by Pushpalatha Bhat of Fermilab, who for more than a decade has been a strong advocate of the use of advanced multivariate analysis methods in high-energy physics, and by Matthias Kasemann, head of Fermilab's Computing Division.

The workshop was sponsored by Fermilab, the US Department of Energy and the US National Science Foundation; it was co-sponsored by Silicon Graphics and Cisco Systems; and it was endorsed by the American and European Physical Societies.

- The Web site for the workshop is "http://conferences.fnal.gov/acat2000/". All plenary talks were videostreamed live and can be viewed from the Web page. Presentation slides and papers are also available there. The proceedings of the workshop will be published by the American Institute of Physics.

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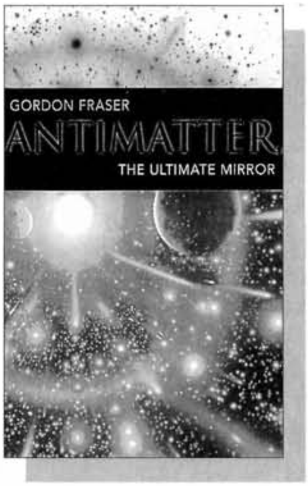

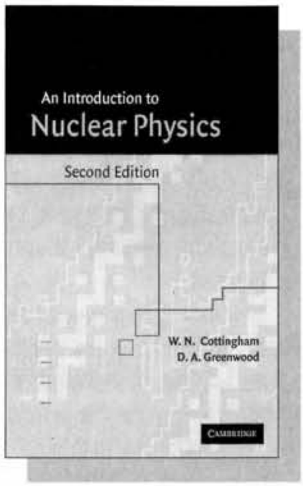

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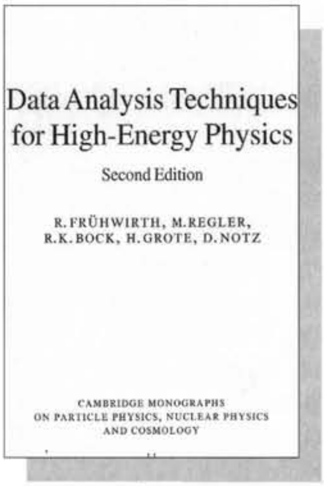

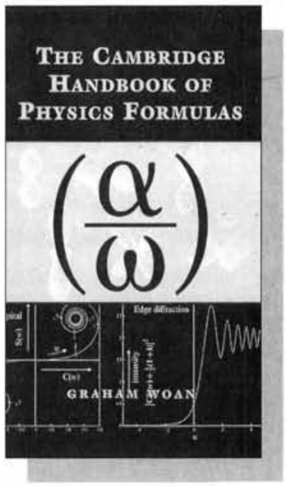

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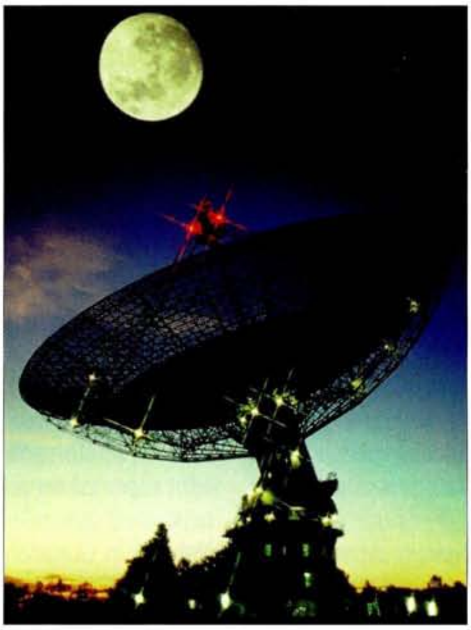
Antennas tune in to high-energy particles

After 40 years of research, physicists met at the First International Workshop on the Radio Detection of High Energy Particles to discuss the detection of high-energy cosmic rays and neutrinos using radio waves. *Peter Gorham* and *David Saltzberg* report.

The highest-energy particles ever observed are also the rarest of all observed cosmic rays – only a few per square kilometre per century reach the Earth. Understanding the origin of these particles, with energies measured up to 300×10^{18} eV (more than 1 million times as much energy as accelerators on Earth) is at the heart of questions posed by particle astrophysicists: Where and how are these particles produced and accelerated? How can they reach the Earth without losing their energy? Are they indicative of as yet unknown physics, such as extremely heavy relics of the Big Bang? In response, physicists and astrophysicists have tried to collect as many of these elusive events as possible. They have proposed and built the largest particle detectors ever considered, with volumes measured in cubic kilometres.



Tuning in – the Parkes 64 m radiotelescope in Australia searches for electromagnetic pulses from ultrahigh-energy particles striking the Moon. (Seth Shostak.)

Coherence from cascades

Since the early 1960s, astrophysicists have recognized that a special property of radio emission from particle cascades, known as coherence, could be the basis of the largest particle detectors. For detectors of visible light, the intensity of light increases in direct proportion to the energy deposited by a particle showering in a material. However, for radio waves having wavelengths several times as large as the size of the shower, each particle produces electromagnetic radiation in phase, coherently, so that the total electric field increases in direct proportion to the shower energy. The resulting quadratic increase of radio emission with particle energy means that radio emission from an ultrahigh-energy cascade will dominate all other forms of secondary radiation. It is this that drew more than 50 physicists and astrophysicists from around the world in November 2000 to the University of California, Los Angeles, to the the First International Workshop on the Radio Detection of High Energy Particles (RADHEP-2000).

The history of theoretical ideas was reviewed by Boris Bolotovskii (LPI, Moscow) and Jon Rosner (Chicago). In the 1960s several mechanisms were identified that would cause the particles to radiate. The Armenian-Russian theorist Gurgen Askaryan from LPI realized that Compton scattering and positron annihilation by the shower particles in matter would result in a 15–25% excess of electrons over positrons that could emit radio Cherenkov radiation. Kahn and Lerche pointed out that the splitting of the electron and positron trajectories in the Earth's magnetic field would cause them to radiate like a relativistic dipole.

Giant spark chamber

Robert Wilson, later the founding director of Fermilab, even considered the possibility that cosmic rays could discharge the atmosphere's electric field gradient like a giant spark chamber. In air, the radiation will be coherent for frequencies of up to about 100 MHz. In dense materials, where the shower is more compact, coherence may be seen up to about 10 GHz. At the workshop banquet, Bolotovskii gave a memorable after-dinner personal reminiscence of Askaryan, whose sharp mind led to many ground-breaking physics ideas as well as to personal and professional struggles. Karo Ispirian (Yerevan, Armenia) translated and recited several of Askaryan's poems.

Trevor Weekes (Harvard-Smithsonian) recounted the story of the first successful radio detection of cosmic rays in 1964 – the result of his PhD work at Jodrell Bank with Neil Porter in an experiment supervised by John Jelley, one of the pioneers of Cherenkov detection techniques. Weekes showed pulses that were probably the first radio emissions detected from extensive air showers induced by cosmic rays with energies of more than 10^{16} eV. The data-acquisition ▷

system consisted of a camera mounted on an oscilloscope triggered by a small array of Geiger counters. The camera recorded the scope trace of the summed voltage output of a large field of dipole antennas. Weekes noted that the number of papers presented at cosmic-ray conferences on radio signals dropped precipitously in the mid-1970s, leading A A Watson to remark: "It appears that experimental work on radio signals has been terminated everywhere."

Yet from 1979 to 1992, the period when few groups were working with radio techniques, the Gauhati University Cosmic-Ray Group collected a large sample of atmospheric events in India. The latest results and implications for production models were transmitted to the workshop in absentia by Kalpana Sinha (Assam Institute, India). Rosner summarized the team's work as well as from others in Japan and the former Soviet Union in a variety of measurements ranging from 2 to 200 MHz. Rosner also described his own air-shower work at the Dugway Proving Grounds in Utah.

Augmenting Auger array

Using a simple antenna and recording system, they are approaching the sensitivity to electric fields in the 20-250 MHz range necessary to detect coincidences. This work is proceeding with an eye towards augmenting the giant Pierre Auger array under construction in Argentina with a complementary radio detector. Rosner's talk will probably be a useful resource for future students of the field, because he has collected a large number of useful scaling laws and common experimental details in one place.

Upward-going showers in a large volume of solid material is one of the classic signatures that is sought to identify neutrino-induced events, which could give birth to high-energy neutrino astronomy. Steve Barwick (Irvine) and Francis Halzen (Wisconsin) reported on current and future experiments - Amanda and Icecube - which search for optical Cherenkov radiation from the showers produced by such events.

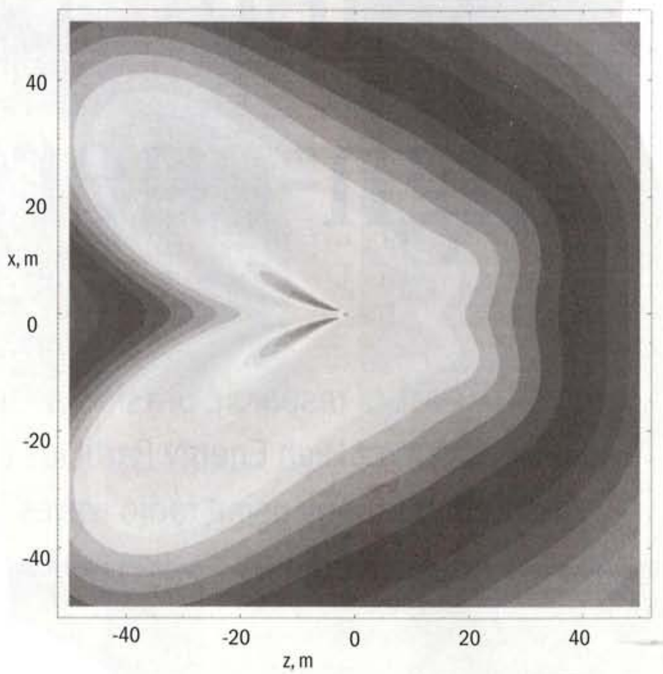
Radio searches for upward-going events began in earnest in the 1980s when various groups began to bury dipoles in deep Antarctic ice, which is so pure that it has been measured to be transparent to radio and microwaves for hundreds, even thousands, of metres. Dave Besson (Kansas) reported on the status of the largest and longest-running of these, the Radio Ice Cherenkov Experiment (RICE). This collaboration has submerged radio dipoles at the South Pole on the strings used by the Amanda experiment for placing its phototubes 2 km below the surface. It placed a limit on the neutrino flux, although there are a few intriguing events and more data to be analysed.

Masami Chiba (Tokyo Metropolitan) discussed his measurements of nearly lossless propagation in another ultrapure material - salt. He described how natural geological salt formations may be of sufficient purity and size to provide a complementary material to Antarctic ice with more than twice the density.

Askaryan was the first to note that the outer few metres of the Moon's surface, known as the regolith, would be a sufficiently transparent medium for detecting microwaves from the charge excess in particle showers. The radio transparency of the regolith has since been confirmed by the Apollo missions.

In the late 1980s Igor Zheleznykh (INR, Moscow) and Rustam Dagkesamanskii (LPI, Puschino), who both participated in RADHEP, predicted that radiotelescopes on Earth would be sensitive to such microwave pulses and might discover a flux of cosmic neutrinos with energies of more than 10^{19} eV. Tim Hankins (New Mexico Tech) reported on the first such search in 1996 using the 64 m diameter Parkes radiotelescope in Australia. Peter Gorham (Jet Propulsion Lab) reported on a current search using two large and physically separated radiotelescopes in coincidence at NASA's Deep Space Network in Goldstone, California. Requiring coincident microwave pulses at both antennas all but eliminates triggers due to terrestrial radio interference. (The day after the workshop, many of the participants joined an excursion to the Mojave Desert, where NASA sponsored a tour of the Deep Space Network radio antennas.) Dagkesamanskii described his plans for a search using the Kalyazin and Bear-Lake Radio Telescopes in Russia.

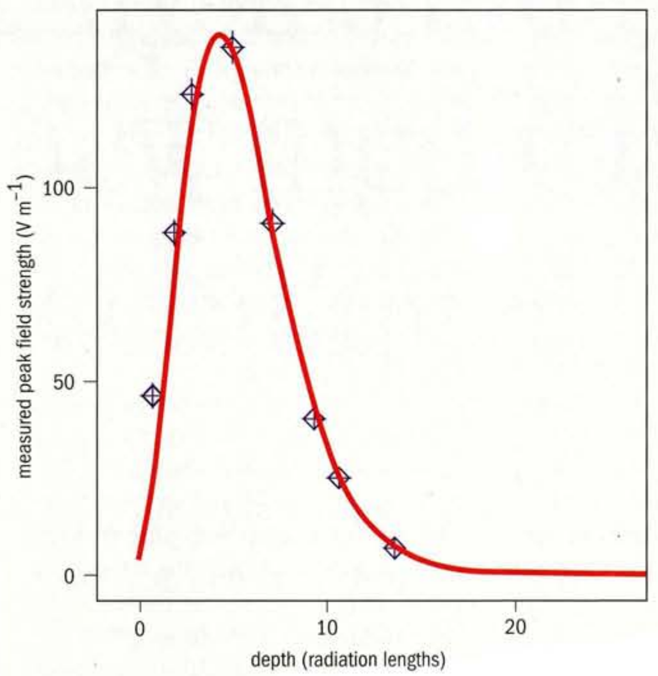
Particle theorists who dared to predict the electric field intensities from particles showering in solids were faced with developing an interface between large shower Monte Carlo programs and Maxwell's equations.



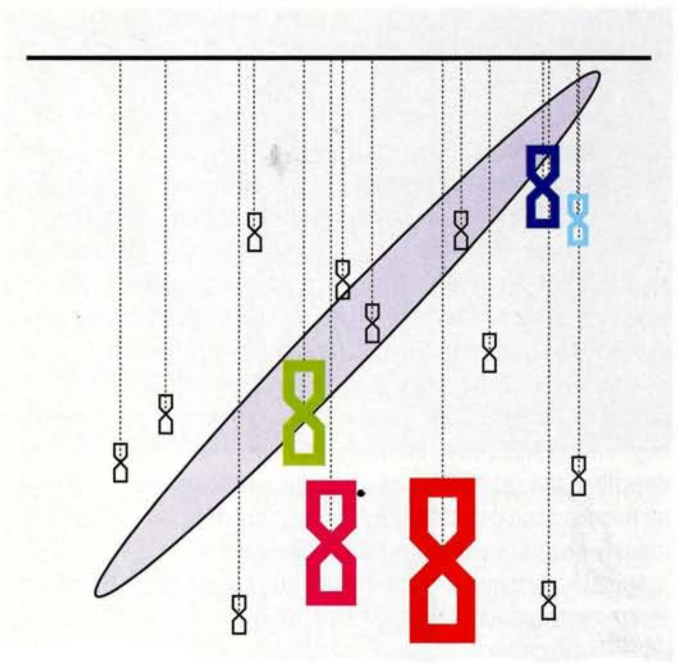
Buniy's simulation of the radio shock wave (lines of constant phase for the total electric field) produced by an electromagnetic shower moving at near light speed through pure ice.

Modest controversy

Enrique Zas (Santiago de Compostela, Spain) summarized the pioneering work by Halzen, Zas, Stanev and Alvarez-Muñiz with detailed particle showers and models for radiation that improved Askaryan's early work. Soeb Razzaque (Kansas) described his new work using the modern GEANT Monte Carlo package. Some disagreement with the other simulations point to a modest controversy. Roman Buniy (Kansas) warned all concerned to be careful with lengthscales, such as the Fresnel versus Fraunhofer limits. Buniy showed some beautiful graphical visualizations from his calculations of field intensities



Simulating extraterrestrial effects – the measurement of the peak electric field versus shower depth produced by a photon beam at SLAC, Stanford, dumped into a sand target (1.7–2.6 GHz). The solid curve is proportional to the expected number of charged particles for these showers.



An event detected by the RICE dipole array in the Antarctic ice at the South Pole. The size and colour of the dipoles denote the size and timing of the pulses fit to a Cherenkov radiation cone.

and phases that show the "richness of structure" imposed by the different lengthscales. Jaime Alvarez-Muñiz (Bartol), with a major effort in three-dimensional geometry, applied some of the theoretical results to the lunar experiments, describing how parameters could be varied to optimize the detection of neutrinos versus other high-energy particles.

Terrestrial simulation

Although the prediction of the intense radio pulse in solids depends only on well known physics processes, such as Compton scattering and Maxwell's equations, some members of the larger cosmic-ray community have been sceptical. David Saltzberg (UCLA) presented new results from SLAC's Final Focus Testbeam. The group directed an intense giga-electronvolt photon beam into a 4 tonne sand target to produce electromagnetic showers in a solid dielectric. Antennas picked up the strong electromagnetic radiation with its predicted intensity, spectrum and polarization, leaving no doubt that the effect predicted by Askaryan is real.

Zheleznykh long ago predicted that similar signals from transition radiation (TR) from showers traversing interfaces could also be useful for cosmic-ray detection. John Ralston (Kansas) recalled early accelerator work and proposed a new comprehensive test beam, using a detector with carefully chosen and symmetric boundary conditions, for detailed studies of electromagnetic radiation produced by both hadronic and electromagnetic showers.

Saltzberg showed data from an electron beam at the Argonne Wakefield Accelerator, demonstrating that transition radiation signals are indeed sufficiently strong. Ispirian gave further interpretation of accelerator measurements of transition radiation and described future accelerator tests of TR, which are to be undertaken at the Yerevan accelerator. He also did many a service by translating a paper on coherent TR from clouds from Russian into English.

Several speakers reminded the audience that radio detectors need not be passive and that particle showers could be probed using radar and related techniques. Peter Gorham discussed early radar measurements that may have been due to reflections from extensive air shower ionization, and he described analogous measurements on meteor ionization trails. He discussed the potential for adding a triggered radar system to existing cosmic-ray detectors. Alfred Wong (UCLA) reported that a network of antennas distributed across Alaska have sufficient phase sensitivity (0.1°) to detect a change in effective path length due to ionization. Tanya Vinogradova (Jet Propulsion Lab) described a proposal to use a strong transmitter, 1.5 Mwatt at 50 MHz, and an array of more than 18 000 dipoles available in Jicamarca, Peru, to search for transient events due to cosmic rays.

Acoustic showers

The "A" in RADHEP may well have stood for "acoustic", which, like radio techniques, relies on the coherence of the acoustic pressure field induced in water by a shower. Yet again this idea is due to Askaryan. John Learned (Hawaii) described how a high-energy neutrino-induced shower could cause a pressure wave to propagate in the ocean where long clear channels for non-dispersive, low-loss transmission are available and could be detected by hyrdophones. He also described accelerator measurements in the mid-1980s at Brookhaven and the Harvard cyclotron, which successfully reproduced the effect. Learned remarked that the new interest in the ▷

highest-energy cosmic rays is fortuitous because it is at these energies that this technique works best.

Zheleznykh described an experiment called Sea Acoustic Detection of Cosmic Objects that uses a hydrophone array off the coast of Kamchatcka that is sensitive to neutrinos with energy 10^{20}–10^{22} eV. He also pointed out the possibility of lowering the energy threshold with acoustic antennas used on submarines.

David Seckel (Bartol) and Peter Gorham gave their views on future large-scale radio detection projects. Meanwhile, several other participants addressed achieving large samples of high-energy cosmic rays with the next generation of proposed optical detectors. Halzen gave an overview of physics at various scales and how the currently proposed Icecube project would have high sensitivity to the ultra-high-energy neutrinos. Similarly, Zas and Pierre Sokolsky (Utah) described the capabilities of the Auger air shower array and Hi-Res air fluorescence detectors, respectively, including their possibility to identify neutrinos using inclined showers.

Masahiro Teshima (Tokyo) showed that there may be clustering of high-energy events in the existing AGASA air shower array dataset, which is indicative of possible point sources. A future Earth-orbiting optical detector, EUSO, described by Katsushi Arisaka (UCLA), would observe incredibly large volumes of atmosphere, beyond even the largest radio detectors considered.

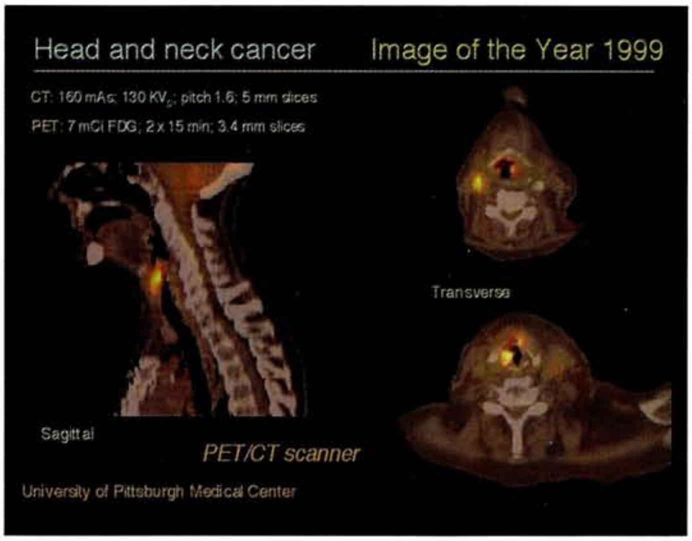
Although radio and acoustic experiments and simulations are challenging, several RADHEP participants described the potentially large rewards. Vadim Kuzmin (INR, Moscow) spoke of how the highest-energy cosmic rays may be due to the decay of superheavy particles in the universe. Marieke Postma (UCLA) described a novel neutrino signature for the decays of such particles in the early universe. Stuart Wick (Vanderbilt) proposed that the radio techniques may discover a flux of magnetic monopoles. Tom Weiler (Vanderbilt) discussed why the highest-energy events might actually be due to the scattering of high-energy neutrinos on Big-Bang-relic neutrinos. Guenter Sigl (IAP, Paris) examined numerous scenarios, including one where the highest-energy cosmic rays may signal an increase in the neutrino reaction cross-sections due to possible large extra dimensions associated with string theories.

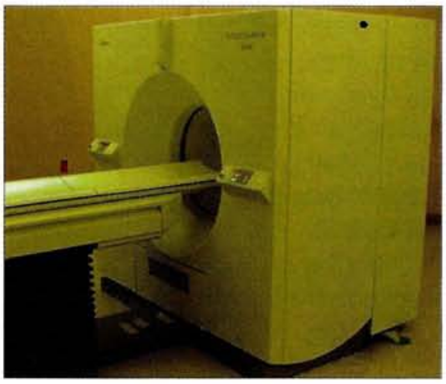
This workshop was in many ways indebted to two outstanding 20th-century physicists, both of whom recently passed away – Gurgen Askaryan, the remarkable theorist, and John Jelley, the consummate experimentalist. Their ideas and methods have now resonated for nearly 40 years, sometimes with great strength and other times without much notice. However, from the enthusiasm and creativity evident at this meeting, it appears that the seeds planted by these physicists a generation ago are now bearing fruit.

- Copies of the talks are available at the RADHEP Web page "www.physics.ucla.edu/~moonemp/radhep/workshop.html" and proceedings will be published by the American Institute of Physics.

Peter Gorham, *Jet Propulsion Lab, and* **David Saltzberg**, *UCLA.*

Physics aids new medical techniques




Above: an example of what the combined PET/CT scanner can reveal. Left: this prototype combined PET/CT unit is currently undergoing clinical evaluation at the University of Pittsburgh.

Since the discovery of X-rays, fundamental physics has been a source of ideas for radiography and medical imaging. A new imaging method firmly rooted in particle physics was chosen by *Time* magazine as one of its "Inventions of the Year 2000".

These days, innovation is flourishing in every industry. The variety of ideas currently being generated was illustrated last year by the news magazine *Time,* when it selected three specialist areas - consumer technology, medical science, and basic industry - in which to put new developments to the vote as "Inventions of the Year".

The award-winning invention in the medical science category was a scanner that combined the advantages of computer tomography with positron emission tomography (PET). The use of these techniques, which depend on detecting and analysing electromagnetic radiation (X-rays or gamma rays respectively), show that detection techniques from particle physics have made, and continue to make, essential contributions to medical science.

Tracers and tomography

Soon after their discovery by Roentgen in 1895, X-rays were being used for monitoring bones, teeth and other dense organic matter, thereby revolutionizing medical diagnostics and introducing a new science - radiography.

Then came nuclear medicine. George de Hevesy was awarded the 1943 Nobel Prize for Chemistry for his invention of radioactive tracers, in which small doses of radioactive material are administered to patients to follow the metabolic functioning of organs such as the kidneys or thyroid gland. The impact of the technique was so great that the supply of suitable radioactive isotopes went on to become an industry in its own right.

Although they provided valuable new information, these techniques, like conventional X-ray photographs, could only reveal a two-dimensional image of a three-dimensional body, and interpretation could therefore be difficult.

The imaging capabilities of X-rays were dramatically boosted by the 1972 invention of the computer-assisted tomography (CT) scanner, in which a fan-like beam of X-rays rotates round a patient, providing a two-dimensional picture of a "slice" of their body. A complete three-dimensional image can be built up by scanning the body slice by slice. Tomography can be combined with nuclear medicine, for example in single-photon emission computed tomography (SPECT), which maps the internal distribution of the tracer.

The birth of PET

Many artificial isotopes emit positrons, the antiparticles of electrons. In the early 1950s it was discovered that these isotopes offered new possibilities for nuclear medicine.

A positron, once it has been produced, is quickly snapped up by a neighbouring matter particle - usually an electron. This annihilation of the positron and the electron produces a characteristic fingerprint - two 511 keV photons (gamma rays) shooting out in exactly opposite directions. By picking up these pairs it is possible to pinpoint where the positron annihilations occurred. The new science of PET was born, in which the annihilation signals track a patient's metabolism, revealing, for example, the way in which the brain reacts to stimuli.

Since its inception, PET technology has profited from new developments in radiation detection, first using sodium iodide crystals, then using materials such as bismuth germanate (BGO), which offered better performance, and more recently lutetium oxyorthosilicate, which is faster and gives more light output than BGO. ▷

Specialists from particle physics have also applied new high-speed computing solutions (transputers) to speed up the imaging process.

Dedication's what you need

Developing these techniques is time-consuming and requires a great deal of motivation as well as resources. In a pure science laboratory like CERN, which focuses on major experiments in particle physics, such spin-off research and development work has sometimes had to take a back seat, and several enthusiasts have left for new pastures.

Among them is physicist David Townsend, who worked at CERN in 1970–1978 before concentrating on PET developments in the US and Europe and finally transferring to the University of Pittsburgh. He is one of the masterminds behind the development honoured by *Time*. The other is engineer Ronald Nutt, senior vice-president and director of research and development at CTI PET Systems – the leading supplier of PET technology – in Knoxville, Tennessee.

Another physicist, Alan Jeavons, who worked at CERN with Townsend in the 1980s to develop the high-density avalanche chamber (HIDAC) PET camera, left physics research to form his own company, Oxford Positron Systems, and he has landed his first major contract to supply advanced PET systems.

Time *magazine's inventors of the year 2000 – David Townsend (top) and Ronald Nutt (bottom).*

Imaging techniques in tandem

Non-invasive technologies that image different aspects of disease can, and should, be viewed as complementary rather than competitive.

Often the sensitivity and specificity of using one technique for the diagnosis of a particular disease is compared with that of another technique, to demonstrate that one of the two is superior when applied to that disease. One example is when a primarily anatomical imaging approach, such as CT or magnetic resonance (MR), is compared with functional imaging, such as PET or SPECT. In practice, such comparisons are of little real value because anatomical and functional imaging have different space, time and contrast resolution, and the images reflect different aspects of the disease process. CT and MR are used primarily for imaging anatomical changes associated with an underlying pathology, whereas the molecular imaging techniques of PET and SPECT capture functional and metabolic changes.

To identify a change in function without knowing accurately where it is localized, or, equivalently, to know there is an anatomical change without understanding the nature of the underlying cause, compromises the diagnosis.

More important, a functional change may precede an anatomical one, so there may be no identifiable anatomical analogue of the molecular transformation.

Patients often undergo a number of different imaging studies. The resulting images are usually reviewed separately on different viewing stations. Image datasets, however, can be combined and presented as fused images.

Image fusion has been successful for brain studies, mainly because the brain is a rigid organ fixed within the skull. Abdominal organs can move significantly between scans and subsequent correlation becomes more difficult.

Dual imaging

Historically, one of the first dual imaging approaches was a combination of CT and SPECT. Pioneer work in the early 1990s combined anatomical (CT) and functional (SPECT) imaging using a single material – high-purity germanium – as the detector for both techniques.

However, the difficulty of achieving an adequate level of performance for both SPECT and CT with the same detector material led to the combination of SPECT and CT using different, dedicated imaging systems – a clinical SPECT camera in tandem with a clinical CT scanner. The results showed improved correlation between the two sets of images.

PET has emerged as a major imaging tool for a range of clinical applications, primarily in oncology (cancer studies). The first rotating partial ring PET scanner was assembled at CERN in 1990 by Townsend, who worked in collaboration with CTI PET Systems in Knoxville, and funded by the Swiss government. The PET device was clinically tested at the Cantonal Hospital in Geneva from 1991.

Combining PET with MR is technologically challenging in view of the extensive restrictions placed on imaging by the strong magnetic field. However, several developments are being used to study brain function and tumour development.

Combining PET with CT, on the other hand, is less challenging, and one such device – a combined PET/CT scanner – has recently been developed. It comprises a clinical CT scanner and a clinical PET scanner to ensure fully diagnostic anatomical and functional imaging capability, and to avoid any compromise in quality. After an initial CT scan, the patient's bed is shifted into the PET scanner.

The CT used is a third-generation Somatom helical scanner. Helical CT acquires its successive-slice information via the continuous movement of the patient's bed. PET is supplied by a rotating partial ring tomograph consisting of dual arrays of 11 × 3 BGO blocks. It rotates at 30 rpm to collect the full projection data for three-dimensional reconstruction.

The combined PET/CT scanner has been undergoing clinical evaluation at the University of Pittsburgh PET Facility since June 1998. It has been used to study more than 250 patients, covering a range of cancers, including head and neck, melanoma, lymphoma, lung, colorectal and ovarian. It was this development, headed jointly by Townsend and Nutt, that was selected by *Time* magazine as its "Medical Invention of the Year 2000".

A small PET

Until recently, PET analysis was limited to humans and large animals because of the spatial resolution of commercial cameras. Now new PET developments extend non-invasive PET imaging to smaller specimens.

Manufactured by Alan Jeavons' firm, Oxford Positron Systems, HIDAC is one of the first commercial PET cameras developed for this purpose. It uses a quadratic configuration of 16 planar detector modules, with four modules stacked on each side. The distance between opposite modules is 170 mm and the modules are 280 mm deep, providing a cylindrical field of view with corresponding diameter and length.

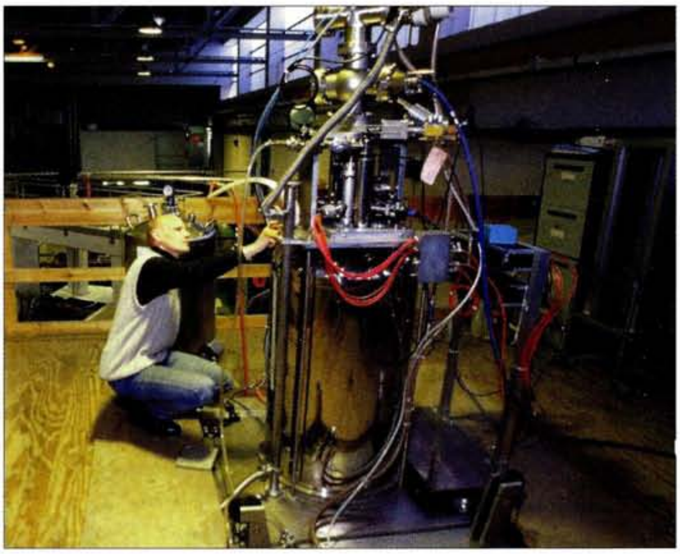
Each detector consists of a multiwire proportional chamber combined with laminated plates of interleaved lead and insulating sheets drilled with a dense matrix of small holes. An electric field focuses electrons onto the centres of the holes, 0.4 mm in diameter and 0.5 mm in pitch, yielding intrinsic submillimetre resolution. To ensure uniform data acquisition, the detector bank continuously rotates 180 ° backwards and forwards every 6 s.

A HIDAC camera – the second such model to be built – was delivered to the Swiss PSI laboratory in December, following a prototype and an initial commercial model, which was used at London's Hammersmith Hospital. Acceptance tests at Hammersmith demonstrated a resolution of 1.2 mm – twice as good as that obtainable with PET cameras using crystal detectors.

In the past, such fruitful spin-offs have taken root despite CERN's natural focus on particle physics priorities. However, an increasing awareness of the need for, and benefits of, the transfer of such technology now means that CERN's current portfolio (which includes new crystals for PET detectors) should find much more fertile ground. □

Spectrometry provides

Extremely accurate experiments can be conducted when particles and nuclei are delicately guided using electric and magnetic fields. A recent conference surveyed the range of such research under way around the world.



The ISOLTRAP Penning trap spectrometer at CERN's ISOLDE on-line isotope separator explores a range of physics.

The various techniques of mass spectrometry now provide atomic and nuclear mass measurements of such precision that, as well as enabling theoretical nuclear models to be stringently tested, they also allow the testing of higher-order effects in quantum electrodynamics (QED) – the most precise theory in existence.

Progress in the field was highlighted by the Atomic Physics at Accelerators (APAC) 2000 conference on mass spectrometry held at the Institut d'Etudes Scientifiques de Cargèse, Corsica. APAC2000 was the second of a series of three Euroconferences on atomic physics at accelerators. Completing the triad begun by APAC99 (held near Mainz), which covered laser spectroscopy, will be APAC2001 (to be held in Aarhus), which will cover spectroscopy with highly charged ions. The APAC conferences were initiated by Heinz-Jürgen Kluge, director of the Atomic Physics Division of the GSI Laboratory, Darmstadt, and they are interdisciplinary, linking the study of the nucleus with its influence on the atomic electron cloud.

Commitment to atomic masses

Atomic mass data are systematically evaluated because their impact on neighboring masses via reaction and decay energies can be considerable. This important job has long been carried out by Aaldert H Wapstra, now retired from NIKHEF, and Georges Audi (CSNSM-Orsay), who together periodically produce the benchmark Atomic Mass Evaluation publication.

A large part of the funding for APAC2000 was secured for the training and mobility of young European students and researchers, so a tutorial session of six lectures was included. It marked the 78th birthday of Aaldert Wapstra, honouring his unwavering commitment to the field of atomic masses.

The first lecture covered the evaluation of atomic masses (Georges Audi, CSNSM-Orsay), and was followed by an overview of the experimental techniques for such measurements (Alinka Lépine-Szily, Sao Paulo). Penning traps – magnetic storage devices that confine charged particles and determine their mass by making them "dance" at their cyclotron frequency – now dominate the field in precision measurement.

Atomic mass provides important information about nuclear structure via the binding energy. The correct treatment of the nucleon–nucleon interaction is required to make a correct calculation. Unfortunately, masses can still be measured with more than 100 times the accuracy that calculations can provide. Some of the reasons were explained by Michael Pearson (Montreal), who described the quest for a microscopic nuclear mass formula. Measurements are even accurate enough to warrant the inclusion of the atomic binding energy, thus requiring theorists to look beyond QED (Gerhard Soff, Dresden). The role of nuclear masses in explosive nucleosynthesis (Stéphane Goriely, UL Brussels) is critical, and the fact that most of the nuclides involved cannot be produced in the laboratory forces a dependence on nuclear models.

Accurate mass measurements also provide stringent probes of the underlying fundamental interactions – a domain that was once solely the concern of those conducting experiments with the world's largest particle accelerators. The energy of a certain type of beta-decay (super-allowed) is sensitive to up–down quark transitions, and accurate measurements provide important constraints (John Hardy, Texas A&M).

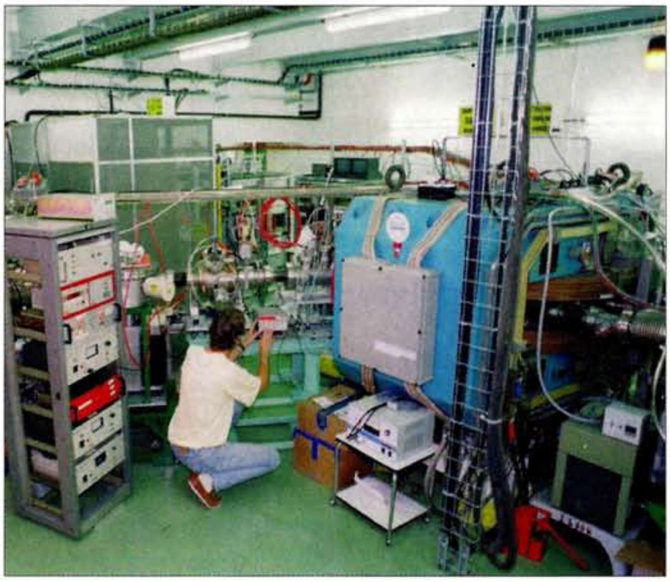
The tutorial session was concluded by Aaldert Wapstra, who shared some of his memories of a long career dedicated to studying atomic masses.

Worldwide effort

Review talks from the numerous groups involved in mass measurement worldwide – all of whom were represented – revealed not only a variety of techniques but also a rich harvest of new results.

In Europe, several groups are pursuing mass measurements for nuclear physics: at GANIL in France the energy-loss spectrometer SPEG (Hervé Savajols, GANIL-Caen) is being used to study the

precision for the masses



Measuring short-lived isotopes – the MISTRAL radiofrequency spectrometer at CERN's ISOLDE.

Cargèse, Corsica – not an accelerator in sight.

weakening of shell structure far from stability (Fred Sarazin, Edinburgh), and the CSS2 and CIME cyclotrons (Marielle Chartier, Bordeaux) are being used for the study of isospin symmetry in nuclei (Anne-Sophie Lalleman, GANIL-Caen); at GSI in Germany the Experimental Storage Ring (ESR) is being used in both Schottky pick-up mode (Yuri Litvinov, GSI-Darmstadt, and Guenther Loebner, LMU-Munich) and isochronous mode for shorter half-lives (Marc Haussman, GSI-Darmstadt). At ISOLDE-CERN such studies are being made using the radiofrequency spectrometer MISTRAL (Dave Lunney, CSNSM/Paris Sud) and the Penning trap spectrometer ISOLTRAP (Georg Bollen, ex-ISOLDE, now Michigan State), where a variety of physics themes are explored, notably isospin symmetry and the weak interaction (Frank Herfurth, GSI).

Sophisticated calculations

SMILETRAP in Stockholm (p28) uses a Penning trap for measuring masses of highly charged stable nuclides (Tomas Fritioff, Stockholm) to test sophisticated atomic binding energy calculations for various atomic charge states. Another key SMILETRAP goal is a fundamental test concerning neutrinoless double beta-decay, where an accurate mass difference can help in determining whether neutrinos are their own antiparticles or not. At the GSI on-line facility, masses come as a by-product of extensive nuclear spectroscopy studies (Ernst Roeckl), and similarly at the Swedish Studsvik reactor facility (Konstantine Mezilev, NPI-Gatchina).

Mass-yielding spectroscopy is very important for short-lived isotopes that are inaccessible by other techniques, as shown by a report (Mark Huyse, KU Leuven) on neutron-deficient polonium isotopes measured at SHIP-GSI and at RITU-JYFL in Finland. Although some nuclides are known to be "schizophrenic", these measurements indicate that some species may have not just two but three shape "personalities".

In North America, masses are also included in large data harvests of alpha-particle and proton emission from Argonne (Cary Davids) where these nuclides are formed offshore of the island of nuclear stability, then shedding protons to beach themselves and decay along the valley of stability.

Similarly, beta-particle endpoint measurements at Yale's Wright Laboratory (Daeg Brenner, Clark) provide masses of proton-rich nuclides of importance to the astrophysical rapid proton capture process (Ani Aprahamian, Notre Dame). Argonne will soon initiate an ambitious programme for studying nuclides of interest for testing the fundamental properties of weak interactions, using the Canadian Penning Trap (Guy Savard, Argonne).

An important aspect of using mass values for the better definition of physical constants is pursued at the University of Washington in Seattle (Robert Van Dyck) and at MIT (Simon Rainville). These groups give mass measurements of record accuracy – parts per trillion. A Harvard group working at CERN has used the excellent environment of Penning traps for an ultra-precise comparison of the proton and antiproton masses – an appetizer for the imminent synthesis and study of antihydrogen (Gerald Gabrielse).

A further high-precision Penning trap result, on bound-electron magnetism (Guenther Werth, Mainz), puts the ball back in the court of Penning trappers measuring masses, because the electron mass uncertainty now dominates the error of this measurement. Complementing the masses of these fundamental particles was that of the pion (Guenther Borchert, IKP-Julich), which is of importance for cosmology.

New standards

The very mass unit itself, the kilogram – the last fundamental standard defined by an artefact – was the subject of a prizewinning presentation (Annette Paul, PTB-Braunschweig) on the AVOGADRO project to redefine the kilogram using silicon atoms counted in a lattice.

Atomic masses can also be determined via nuclear reactions with heavy ions (Yuri Penionzhkevich, JINR-Dubna) and with neutrons ▷

Don't run over time! Ingmar Bergström, emeritus professor from the Manne Siegbahn Laboratory in Stockholm (see following article), demonstrates his speaker cut-off mechanism.

(Cyriel Wagemans, Gent). New schemes were presented for measurement techniques using tabletop storage rings (Hermann Wollnik, Giessen) and small cyclotrons (Oleg Kozlov, JINR-Dubna).

The sessions on measurements and techniques were complemented by reports on advances in theory. On the atomic physics side, higher-order QED corrections to atomic binding energies dominate the overall errors. These calculations are among the most precise possible (Vladimir Shabaev, St Petersburg; Eva Lindroth, Stockholm; and Paul Indelicato, LKB-Paris). On the nuclear physics side, more affordable computing power opens up the scope and validity of mass predictions. Recent advances on the nuclear theory front include mean-field calculations (Paul-Henri Heenen, UL Brussels), including a separable monopole Hamiltonian (Jirina Rikovska, Oxford), the Monte Carlo shell model for light nuclides (Takaharu Otsuka, Tokyo) and semi-empirical shell model calculations for superheavy nuclides (Nissan Zeldes, Jerusalem).

Future projects

The conference ended with a look to future projects – all involving ion traps – for the DRIBS facility (Nicolai Tarantin, JINR-Dubna) and GSI's new HITRAP for atomic physics (Wolfgang Quint) and SHIPTRAP for nuclear physics (Gerrit Marx). Some of these are covered by European Research and Training networks, notably EUROTRAPS and EXOTRAPS (Ari Jokinen, Jyvaskyla), and have begun to yield promising results.

The concluding speaker, Catherine Thibault (CSNSM-Orsay), was one of the pioneers of direct on-line mass measurements via mass spectrometry. She lauded the tremendous progress made in recent years, notably thanks to Penning traps.

Abstracts of the conference presentations, as well as all of the posters, are available at the conference Web site: "http://csnwww.in2p3.fr/amdc/apac2000". The conference proceedings will be published this year in the journal *Hyperfine Interactions*.

APAC2000 was funded by the EU Program for Training and Mobility of Young Researchers. Additional support came from the French Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), from the German GSI heavy ion laboratory and from the French host institute, Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, at the Université de Paris Sud, Orsay.

David Lunney, *APAC2000 conference chairman, CSNSM-Université de Paris Sud.*

Nuclear masses hang in the balance

A CERN-inspired development at the Manne Siegbahn Laboratory, Stockholm, has produced physics results of impressive accuracy. *Ingmar Bergström* reports.

From time to time, people ask whether particle physics at CERN and other large laboratories produces applications for other sectors of society. Usually they are pointed towards the use of detector technology in medicine and the development of information technology. Everyone knows that the World Wide Web was born at CERN, but even earlier than that the very creation of the laboratory was one of the first demonstrations of how effective European co-operation can be.

Less frequently discussed is how CERN has become such a rich source of scientific and technical knowledge from specialists from all over the world. Visitors at CERN exposed to this enormous pool of knowledge and expertise are often inspired with new ideas to implement when they return to their home labs. The impact of large international labs such as CERN is thus boosted by related activities at the smaller home labs.

CERN collaboration case-study

For more than two decades, Stockholm's Manne Siegbahn Laboratory was one of the collaborators in the study of exotic atoms, first at CERN's PS and later at LEAR. (In exotic atoms, the orbital electrons of everyday atoms are replaced by other, heavier particles, such as muons, kaons and antiprotons.)

However, we were often motivated to try to transfer some of CERN's impressive technological achievements to our own home lab, within a necessarily limited budget. Therefore, sabbatical years for scientists and leave of absence for skilled technicians working with CERN accelerator groups, the vacuum group and in the electronics sector were organized systematically.

From this came the idea to build a storage ring where particles did not make head-on collisions as in particle physics but merged in a soft collision. Though stored ions could have energies of tens of mega-electronvolts per nucleon, and, for example, be merged with electrons in the kilo-electronvolt region, the collision energies, surprisingly, could be as small as fractions of a milli-electronvolt.

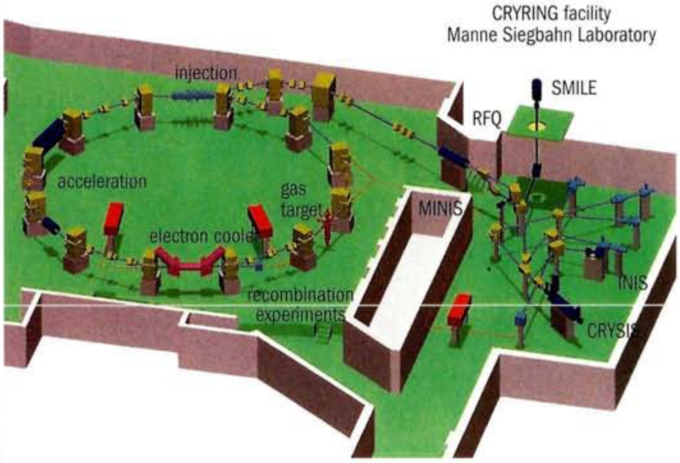


Fig. 1. The CRYRING storage ring at the Manne Siegbahn Laboratory, Stockholm.

Stockholm's CRYRING storage ring was to a great extent based on the design and experience of CERN's low-energy antiproton ring (LEAR), although the size is somewhat smaller (circumference 54 m compared with 80 m for LEAR). Figure 1 shows the CRYRING layout with its ion injectors and low-energy experiments.

An impressive amount of work has been published since CRYRING began running in 1992. From the very beginning, research concentrated on stored highly charged ions produced in an electron-beam ion source (CRYSIS).

CERN asked whether Stockholm could reproduce the seemingly strange LEAR result that the lifetimes of stored lead-208 ions with some even and odd charge states were dramatically different.

CRYRING confirmation

To optimize the beam, the lead ions injected into LEAR were cooled by electrons. This also brings the risk that ions are lost by dielectronic recombination. In such a two-electron resonance process, a cooling electron is captured by the ion and the energy balance is regulated by the excitation of one of the bound electrons. This was studied for 53+ and 54+ charge states by R Schuch and H Danared. Not only were the LEAR results confirmed, but the reason for this deviation was indeed found to be due to dielectron recombination resonances.

In the case of 53+, these occurred at the very low energies of 0.1 and 1 meV. Similar resonances are not present for 54+. From the measurements it is possible to determine the energy splitting between the ground state and the first excited state (4s and 4p levels) with an accuracy of about 1 meV. This is the most accurate determination of such a splitting ever measured in a very highly charged ion. The energy splitting includes large quantum electrodynamic effects.

At the ESR storage ring at the GSI Darmstadt lab, researchers have observed an ordered structure of stored ions when only some 5000 ions are left in the ring – a phenomenon sometimes referred to as one-dimensional ion crystallization. This has also been confirmed at CRYRING by studying the behaviour of stored nickel-17+ ions. Recent work has shown the existence of a one-dimensional lattice of xenon-36+ ions with thousands of stored ions.

In 1985 two experiments using electromagnetic traps were launched at CERN. One, at LEAR (G Gabrielse *et al*), aimed at a precision determination of the ratio of antiproton to proton masses, and it went on to show that they were equal to within a factor of 9×10^{-11}. The other trap experiment (ISOLTRAP) was set up at the ISOLDE on-line ion source for the determination of masses of radioactive nuclei. More than 100 masses of short-lived radioactive atoms have been determined to an accuracy of 10^{-7}.

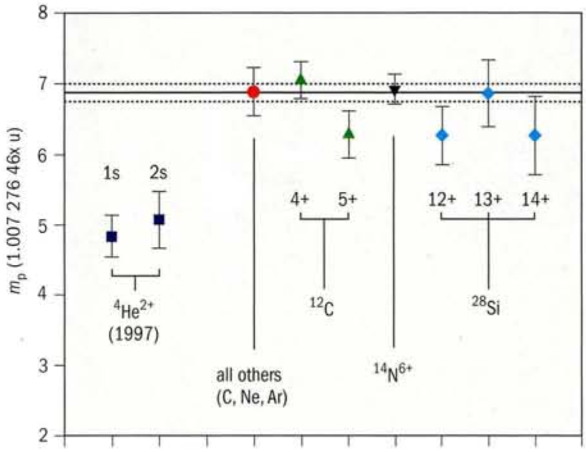


Fig. 2. In the CRYRING SMILETRAP precision proton mass measurements, an ionized hydrogen molecule was used as a proton carrier. This shows the values for the proton mass obtained using light, highly charged ions as mass references. Helium-4 gives a proton mass that deviates from the accepted mass value, calling for a reappraisal.

Having an electron beam ion source in Stockholm, we asked why everybody was using singly charged ions when it was obvious that the precision in mass measurements in a Penning trap increases linearly with the ionic charge. In collaboration with H-J Kluge's group, we built another Penning trap (SMILETRAP) at Mainz, which was subsequently connected to the Stockholm electron beam ion source.

In a Penning trap, the mass of a highly charged ion is determined by measuring its cyclotron frequency and comparing it with the cyclotron frequency of a mass reference ion – often a carbon-12 ion of a suitable charge. The atomic mass is then obtained by correcting for the mass of missing electrons and their electron binding energies.

In addition to carbon ions, we used helium-4, nitrogen-14, neon-20, silicon-28 and argon-40 ions with various high charges as mass references. Their masses are known to an accuracy of about 10^{-10}. Ionized hydrogen molecules were used as carriers for the proton. The ratio between the hydrogen molecule ion and the proton mass is known to better than 0.05 ppb.

Puzzling deviation

The results are shown in figure 2. The proton mass value obtained (1.007 276 466 72(16)(86)) is close to the currently most accurate value (1.007 276 466 89(13)), except for the mass calculated from helium-4. This deviation seemed puzzling because the listed mass claimed an uncertainty of 0.25 ppb.

We therefore remeasured the helium-3, helium-4 and tritium masses using the hydrogen molecule ion as a mass reference. Figure 3 shows the results. The masses of these three light atoms are heavier than previously reported. It is thought that the relatively large ▷

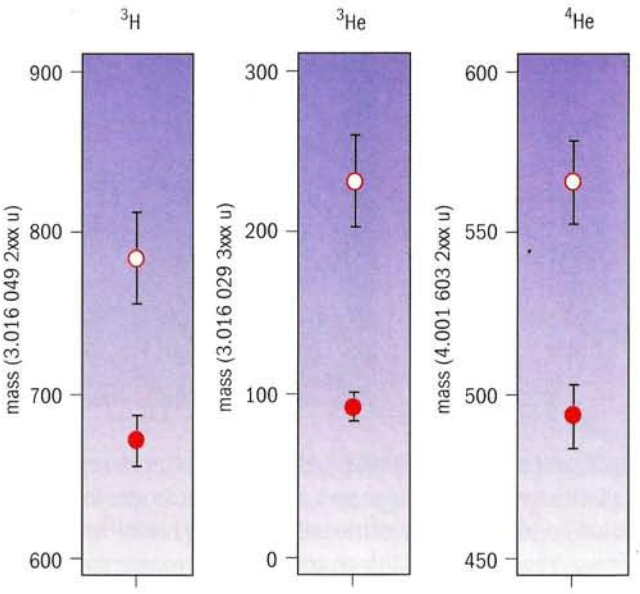


Fig. 3. The masses of helium-3, helium-4 and tritium. The upper points are the recent Stockholm results, while the lower points are the accepted values. The mass difference between tritium and helium-3 could be used in future analyses of tritium beta decay to set an even lower limit on the electron antineutrino mass.

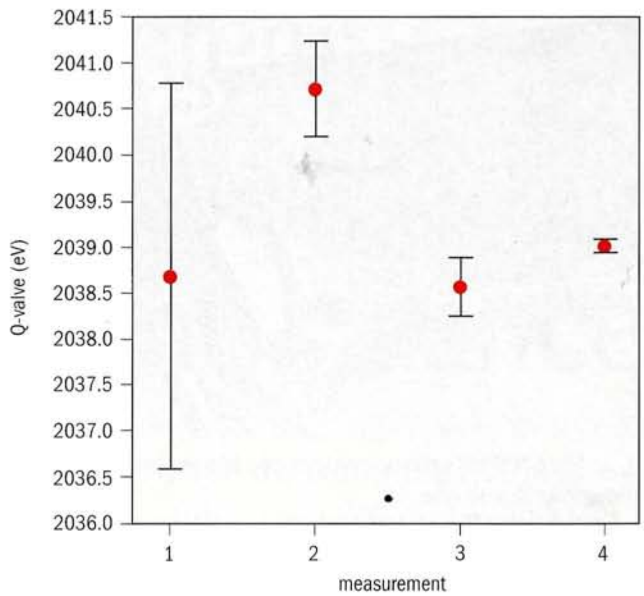


Fig. 4. Measurement 1 represents the nuclear decay energy equivalent (Q-value) of germanium-76 double-beta decay from 1995 accepted masses; 2 is the first direct Q-value measurement by the Manitoba group in 1985; 3 is a revised value from the same group in 1991; and 4 is the value derived from germanium-76 and selenium-76 masses measured in Stockholm in 2000.

mass discrepancy may be due to a day/night variation in the magnetic field that was unknown at the time of the earlier measurements.

This emphasizes how important it is in precision physics to obtain results from a number of different groups, preferably each employing a different technique. Our interest therefore focused on the neutrinoless double beta decay of germanium-76 – a process that, if observed, would signal some unexpected physics.

The most promising results come from the Heidelberg–Moscow experiment in the Grand Sasso underground laboratory (January 2000 p8). The masses of germanium-76 and selenium-76 were measured with an uncertainty of 1 ppb. However, for mass difference measurements, the systematic uncertainties cancel and the decay energy equivalent (Q-value) becomes very accurate (Q = 2 039 006(50) eV). Our Q-value is so accurate that its uncertainty represents only a few per cent of the half-width of the expected electron peak in the semiconductor detectors used.

This value may thus seem exaggerated, but it should be pointed out that the mass uncertainty reported from measurements with conventional mass spectrometers often has large underestimated systematic uncertainties. In this particular case, however, we have confirmed the latest reported Q-value (figure 4), and with an accuracy seven times as good.

Through contact with CERN, a number of scientists and technicians at Stockholm have been able to establish a unique facility for advanced in-beam atomic and molecular physics. Other laboratories could produce similar measurements. Our choice of experiments has often been influenced by current problems in particle and accelerator physics – no doubt as a direct result of our contact with CERN.

Ingmar Bergström, *Manne Siegbahn Laboratory, Stockholm.*

CERN experience benefits students and specialists

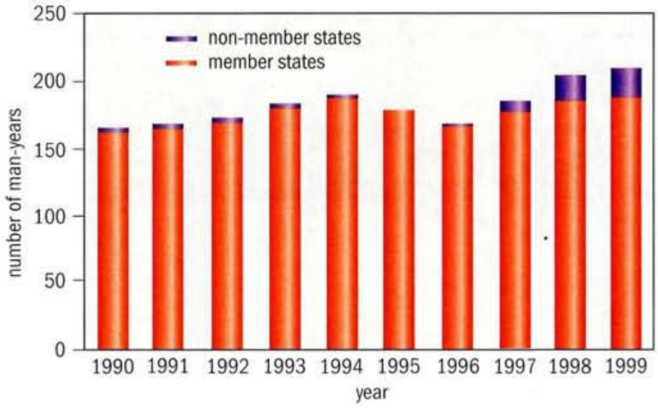
Every year, several hundred talented specialists, most of them young, experience working in CERN's unique atmosphere. What they learn during this time provides a springboard for their careers, as well as furthering science and promoting technology exchange throughout Europe and further afield.

CERN's popular summer student programme has a tradition that goes back to the early years of the organization. Each year some 150 selected students participate in CERN's research programme under the supervision of CERN scientists and attend a series of specially arranged lectures. The student summer programme is just one of a number of items on CERN's menu.

CERN's major contributions to culture range wider than the discovery of the neutral current of the weak interaction, or the carriers of the weak nuclear force. CERN has shown how international collaboration in science works. Different national attitudes complement and reinforce each other, but this needs to be experienced first.

The vitality of the more than 7000 researchers using CERN's facilities creates a continuous exchange of ideas and people from all over the world. In addition to the advances in frontier science, the technology needed to carry out this research is often years ahead of what industry can provide.

Every year more than 600 new students, scientists and engineers participate in the various schemes over periods ranging from three months to three years. They all benefit from their experience of working in an international collaboration at the forefront of science ▷



Numbers in CERN's fellowship programme, showing the increasing contribution from non-member states.

and/or technology. Returning to their home institutes, they provide a seedbed for new developments.

A significant fraction (about 10%) of CERN's personnel budget is spent on various fellow, associate and student programmes. As well as promoting the exchange of knowledge between scientists and engineers from all over the world, these programmes are vital elements in the high-level research and technology training of scientists from CERN's 20 European member states and, to a lesser extent, from other nations too.

The programmes are popular and there are many applications from eager candidates. Their success is largely due to the strict criteria applied in the selection procedures.

The fellowship programme aims to provide advanced training to young CERN member state university-level postgraduates (mostly with doctorates) in a research or technical domain.

Catering for a different need is the associates programme, which offers opportunities for established scientists and engineers from both member states and elsewhere to spend some time – typically a year – at CERN, on leave from their research, teaching, managerial or administrative duties. During their stay at CERN, associates are on detachment from their home institute.

Students and trainees

Fulfilling another requirement are the various student programmes (summer students, technical students and doctoral students) for undergraduates and postgraduates in CERN member states. Doctoral and technical student programmes are currently restricted to candidates from applied sciences and engineering, but there is a move to extend this.

In the popular summer student programme, with a tradition going back to CERN's early years, some 150 students selected each year from many times that number of applications participate in CERN's research programme under the supervision of CERN scientists, and they also attend a series of specially arranged lectures. Many leading scientists have benefited from this scheme early in their careers.

The trainee programme is new. Numerous member states have shown a very strong interest in using CERN as a training ground in a wide area of hi-tech activities. In the past five years there has been a rapid development of special programmes that are based on bilateral co-operation agreements.

Member states Austria, Denmark, Finland, Norway and Sweden provide additional funds for the student programmes, while Israel, a CERN observer state, contributes to the associate programme. For another observer state, Japan, since 1996 part of the interest in the nation's financial contribution to the construction of the new LHC accelerator has been used to help to fund a few fellows and short-term associates.

Member states Spain and Portugal provide grants that cover the insurance and living costs of the young people specializing in engineering and technology. An additional CERN contribution offsets the relatively high cost of living in the Geneva area.

At a regional level, about 25 young engineers and technicians spend some time at CERN within the framework of a special French Rhone-Alps Region programme. A few graduates and postgraduates from the Italian Piedmont are funded by the regional Association for the Development of Science and Technology. It is hoped that these special programmes will be integrated into the wider schemes and expanded.

Together, the various student and short-term visitor schemes transfer specialized knowledge and expertise, and make CERN's mission and work in particle physics and further afield known to a wider public.

● For more information, see "http://cern.web.cern.ch/CERN/Divisions/PE/HRS/Recruitment/".

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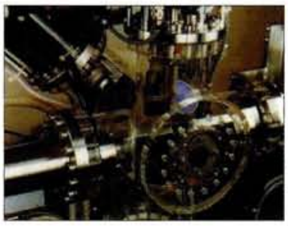

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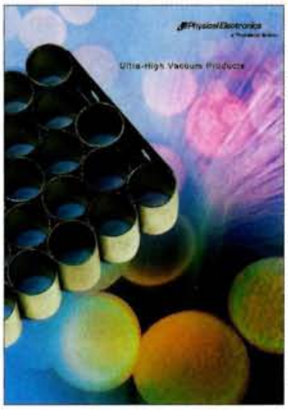

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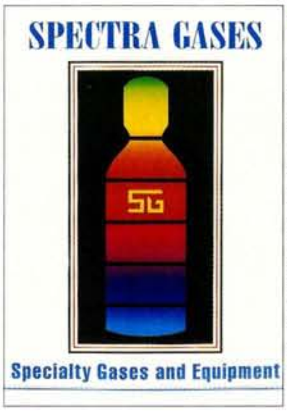

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APPOINTMENTS & AWARDS

EPS introduces new Lise Meitner prize

The Nuclear Physics Board of the European Physical Society has created a new prize – called the Lise Meitner prize – for nuclear science with sponsorship from the company Eurisys Mesures. The award consists of a medal, a diploma and €5000 in cash.

The first recipients, for the year 2000, are Peter Armbruster and Gottfried Muenzenberg of GSI in Darmstadt and Yuri Ts Oganessian of the Flerov Laboratory of Nuclear Reactions in Dubna for their unique work over a long period on the synthesis of heavy elements, which has led to the discovery of elements in the nuclear charge region 102 to 105 (dubnium), as well as bohrium (107), hassium (108) and meitnerium (109).

These discoveries involved extensive developments of experimental techniques and the use of a specific reaction mechanism – the "cold" fusion of two heavy nuclei. Measurements of these elements provide an important cornerstone to the concept of deformed shells in nuclei, the existence of which is responsible for the increased stability of the new nuclei.

The prize was given to Peter Armbruster at the XXXIX International Winter Meeting on Nuclear Physics in Bormio in January. The other two laureates will be honoured at the Europhysics meeting on East-West Collaboration in Nuclear Science in Sandanski, Bulgaria, in May.

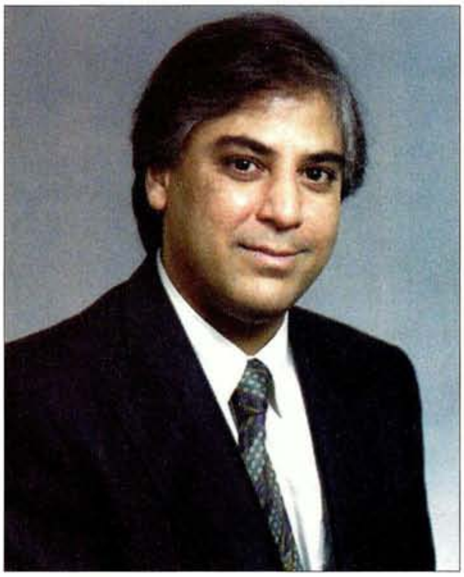
See "http://fidabs.ing.unibs.it/eps-npb/" and "http://www.eurisysmesures.com/".

The European Physical Society's new Lise Meitner Prize for Nuclear Science goes to (left to right) Peter Armbruster (GSI, Darmstadt), Gottfried Muenzenberg (GSI, Darmstadt) and Yuri Ts Oganessian (Flerov Laboratory of Nuclear Reactions, Dubna) for their synthesis of new heavy elements.

Willis Lamb of Arizona, who shared the 1955 Nobel Prize for Physics with Polycarp Kusch for their precision measurements of, respectively, hydrogen spectroscopy and the electron's magnetic moment, receives the US National Medal of Science 2000 "for his towering contributions to classical and quantum theories of laser radiation and quantum optics". These measurements showed the first indications of the tiny effects due to quantum electrodynamics.

Alain Connes of the Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, and the Collége de France, Paris, is awarded the prestigious Crafoord prize, which is administered by the Royal Swedish Academy of Sciences, for "his penetrating work on the theory of operator algebras and for having been a founder of non-commutative geometry". This has provided powerful methods for theoretical physics. The prize will be presented by the King of Sweden on 26 September.

Swapan Chattopadhyay, previously head of Berkeley's Center for Beam Physics, becomes Associate Director of the Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia.



Swapan Chattopadhyay, previously head of Berkeley's Center for Beam Physics, becomes Associate Director of the Jefferson Lab, Newport News, Virginia.

Chattopadhyay came to Berkeley in 1974 as a graduate student. After receiving his PhD in 1982, he spent two years at CERN before returning to Berkeley, where he made major contributions to national and international projects. In 1987 he became leader of Berkeley Laboratory's Accelerator and Fusion Research Division's Exploratory Studies Group, establishing the Center for Beam Physics in December 1991. Under his leadership, CBP researchers have been at the forefront of such technological breakthroughs as femtosecond X-ray generation and laser plasma beam acceleration.

At Jefferson Lab, Chattopadhyay will oversee research and development as well as operations of the main continuous electron beam accelerator facility (CEBAF), plus the lab's free electron laser facility, light sources programme, applied superconductivity and superconducting radiofrequency R&D centre, and its cryogenics and engineering programmes. He will also hold an appointment as the Governor's Distinguished CEBAF Professor of SURA (Southeastern Universities Research Association).

Super-awards

The Council of Superconductivity of the influential Institute of Electrical and Electronics Engineers (IEEE) has recently established an IEEE award for continuing and significant contributions in the field of applied superconductivity for contributions "to the field...over more than 20 years, based on novel and innovative concepts".

The current recipients are:

David Larbalestier, Wisconsin, "For significant and continuing contributions in the field of superconductive materials: leading to the identification of microstructural features that resulted in dramatic increases in the superconducting critical current density: in particular, for the identification and optimization of magnetic flux pinning centres and the identification and minimization of deleterious defects in superconducting wires and tapes".

Martin Nisenoff, retired, formerly US Naval Research Laboratory, "For long and continuous service to the superconductivity community as a scientist, program manager, activist and statesman; elected three times to Applied Superconductivity Conference board, long-standing member of IEEE's Committee on Superconductivity; three-decade career spanning activities in Josephson junctions, SQUID applications, HTS filters and cryocoolers".

Arnold Silver, retired, formerly TRW, "For significant and continuing contributions in the field of superconductive electronics, both as a researcher and as an R&D manager, including the invention of the superconductive Quantum Interference Device (SQUID), which resulted in the development of ultrasensitive magnetic sensors and is the basic building block for superconductive digital technology, for inventing numerous other superconducting analogue and digital circuits and subsystems, and for outstanding insight in promoting the use of superconducting electronics in scientific, military and commercial applications".

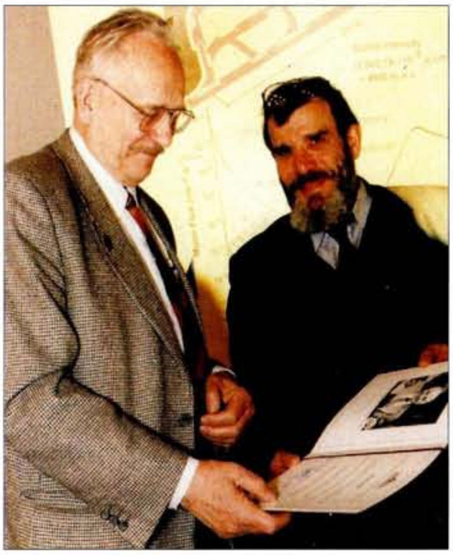
John Stekly, retired, formerly Intermagnetics General Corporation, "For significant and continuing contributions in the field of superconducting magnet systems, and devices, in particular the pioneering work in understanding, quantifying and applying the engineering thermal stability requirements of superconducting magnets operating in boiling liquid helium, known as the Stekly Criterion".

Kyoji Tachikawa, Tokai, "For significant and continuing contributions in the field of superconducting materials: in particular, the pioneering research in innovative and intelligent materials processing techniques for the formation of superconducting wires and tapes, leading to the development of new high-field superconductors that incorporate useful intermetallic compounds".

Theodore Van Duzer, Berkeley, "For significant and continuing contributions in the field of superconducting electronics as a researcher, educator and mentor, in particular for directing numerous innovative research projects in superconductive device and circuit concepts, for mentoring many students who have become the core of the US activity in superconductive electronics, for his co-authorship of the standard textbook on superconductive devices, for serving as the founding editor-in-chief of the IEEE *Transactions on Applied Superconductivity* and for his enthusiastic support to establishing, and frequently chairing, various conferences, workshops and study groups promoting the growth of the superconductive electronics technology".

Martin Wilson, Oxford Instruments, "For significant and continuing contributions in the field of large-scale superconductive applications, in particular the pioneering research leading to the fundamental principles of superconducting magnet design and execution, for his documentation and explanation of these concepts and calculations pertaining to, for example, magnetization, minimum quench energy, quench development, etc, concisely presented in his book on superconducting magnets, and in recognition of his leadership of outstanding forefront scientific and engineering teams involved in applied superconductivity in research labs and industry, for example, the development of Rutherford cable and the Helios synchrotron X-ray source".

Pontecorvo prize



The Bruno Pontecorvo prize for 2000 is awarded to Academician Georgi Zatsepin and Vladimir Gavrin (both from the Institute for Nuclear Research, Moscow) for their outstanding contributions to solar neutrino research using the gallium germanium method at the Baksan Neutrino Observatory. The prize, administered by the Joint Institute for Nuclear Research, Dubna, near Moscow, was awarded during the January session of JINR Scientific Council. In even-numbered years, the prize is awarded to Russian physicists only.

Bruno Pontecorvo Prize 2000 laureate Vladimir Gavrin (right) with Dmitri Shirkov, jury chairman and honorary director of the Joint Institute for Nuclear Research Bogoliubov Laboratory of Theoretical Physics. (Yu Tumanov.)

Japan and Russia took a historic step on 27 November when **Hirotaka Sugawara**, director-general of Japan's KEK laboratory, and **Vladimir Kadyshevsky**, director of the international Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, signed the first co-operation agreement in physics involving Russia–Japan relations. It places particular emphasis on theory, establishing the Tomonaga–Bogolyubov programme in honour of two of the countries' most famous sons. Wider cultural aspects were not ignored – the agreement promotes broader contacts between the home towns of KEK and JINR – Tsukuba and Dubna respectively. At the signature of the agreement were (left to right) T Inagaki, KEK Particle and Nuclear Studies director S Yamada, KEK director-general H Sugawara, JINR director-general V Kadyshevsky and JINR Nuclear Laboratory deputy director A Kurilin.

At CERN on 19 February, Finnish Minister of Education **Maija-Liisa Rask** (kneeling centre) hears about progress for the giant CMS experiment at the LHC.

MEETINGS

This year's **IEEE Nuclear Science Symposium** and **Medical Imaging Conference**, including the **Symposium on Nuclear Power Systems**, will take place in San Diego, California, on 4–10 November. New this year is the International Workshop on Room-Temperature Semiconductor X- and Gamma-Ray Detectors. The abstract submission deadlines are 20 April (NSS, MIC, SNPS) and 15 June (Workshop). For more details see "http://www.nss-mic.org/".

The **29th SLAC Şummer Institute**, entitled Exploring Electroweak Symmetry Breaking' will take place on 13–24 August at Stanford, California. For more information contact: Maura Chatwell, e-mail "ssi@slac.stanford.edu", tel. +1 650-926-4931.

The **2001 CERN School of Computing**, organized by CERN in collaboration with the Institute of Physics of the University of Cantabria, Spain, will be held on 16–29 September in Santander. It is aimed at post-graduate students and research workers with a few years experience in particle physics, computing or related fields. Special themes this year are computer architecture: software and hardware; fistributed real-time systems; high throughput distributed systems; and principles of distributed databases. For additional information see "http://www.cern.ch/CSC/".

A **Workshop on Gravity and Particle Physics** will be held at DESY, Hamburg, on 9–12 October. It will cover strings and D-branes; large extra dimensions and phenomenology; cosmology and astrophysics; gravitational waves; and new phenomena. It will be organized by D Luest (Humboldt University Berlin). For more information see "http://www.desy.de/desy-th/workshop.01/index.html".

Frontiers in Particle Astrophysics and Cosmology: a EuroConference on Neutrinos in the Universe will take place in Lenggries, near Munich, on 29 September to 4 October. The conference chairman is Georg G Raffelt (MPI für Physik, Munich). The conference is part of the 2001 Euresco Programme. For more details see "http://www.esf.org/euresco/01/pc01142a.htm".

Laboratory directors and other notables at the DESY laboratory, Hamburg, on 8 February gathered for a meeting of the International Committee for Future Accelerators.

The **Second International Workshop on Atomic Collisions and Atomic Spectroscopy with Slow Antiprotons (PBAR01)** will take place on 14–15 September at Aarhus University, Denmark. The aim is to present initial scientific progress at CERN's new antiproton decelerator. The first such meeting was held at Tsurumi, Kanagawa, Japan, in July 1999. The major topics of the workshop will be spectroscopy of antiprotonic atoms; interaction of slow antiprotons with matter – stopping power, channeling, etc; excitation and ionization of atoms, molecules and clusters with slow antiprotons; antihydrogen; and formation processes for antiprotonic atoms. For information see "http://www.ifa.au.dk/pbar01/".

The next **Crimean conference on New Trends in High-Energy Physics**, co-organized by the Bogolyubov Institute for Theoretical Physics in Kiev and the Joint Institute for Nuclear Research in Dubna, will be held near Yalta in Crimea on 22–29 September. The subjects are elastic and diffractive scattering of hadrons and nuclei; deep inelastic scattering and multiparticle dynamics; duality, strings and confinement; collective properties of the strongly interacting matter; astroparticle physics; heavy flavours and hadron spectroscopy; the standard model and beyond; advances in quantum field theory; new physics at future colliders; beam physics; and new detector technique. The preliminary list of lecturers includes V N Bolotov, L D Faddeev, V S Fadin, M I Gorenstein, R Jackiw, L L Jenkovszky, A B Kaidalov, E A Kuraev, L N Lipatov, D V Shirkov, A A Slavnov and H Terazawa. Applications should be sent to "crimea@gluk.org" or Crimea-2001, BITP, Kiev 03143, Ukraine; fax +380 44 2665998; tel. 2669123; "http://www.gluk.org/hadrons/crimea2001".

Croatian Minister of Science and Technology **Hrvoje Kraljeviç** (left) and Deputy Minister for International Cooperation **Davor Butkovic** at CERN on 13 February.

Alexander Baldin celebrates 75 years

At 75 – Alexander Baldin.

On 26 February 2001, Academician Alexander Baldin, the distinguished Russian physicist whose name is widely known to the world scientific community, celebrated his the 75th birthday.

Baldin has contributed greatly to the development of the physics of electromagnetic hadron interactions, the physics of the atomic nucleus and particle physics. He is a pioneer of relativistic nuclear physics, the author of several scientific discoveries, the initiator of the construction of novel superconducting accelerators of charged particles, and the visionary and leader of the wide scientific programme of the accelerator complex of the Joint Institute for Nuclear Research (JINR) in Dubna, near Moscow, including the unique superconducting Nuclotron.

For his numerous scientific achievements, he was awarded the Lenin and State prizes of the USSR. For 30 years he headed the JINR Laboratory of High Energies. He is now scientific supervisor at this laboratory.

Dominique Vautherin 1941–2000

Dominique Vautherin passed away last December at the age of 59. His work, characterized by breadth, clarity and originality, profoundly marked the field of nuclear physics. A brilliant nuclear theorist, he had a major influence on the international community during the past 30 years.

Born in 1941, Vautherin studied at the Ecole Polytechnique in 1961–1963. Admitted to the CNRS in 1964, he obtained his doctorate at Paris-Sud in 1969. He spent most of his career at the Division de Physique Theorique of the Institut de Physique Nucleaire at Orsay, where he was director in 1991–1995. A visiting scientist at MIT in 1970–1972 and at the Lawrence Berkeley Laboratory in 1976–1977, he made frequent visits abroad. In 1976–1991 he had teaching responsibilities as Maitre de Conferences at the Ecole Polytechnique. He received the Prix Langevin and the Grand Prix Jean Ricard of the French Physical Society, and had just received an award from the Alexander von Humboldt-Stiftung. From 1999 he was Chairman of the Board of Directors of the European Centre for Theoretical Studies, Trento.

In 1969–1970, together with David Brink, Vautherin recognized the value of Skyrme's interaction for the description of nuclear properties. He soon extended this approach to deformed nuclei and opened the way to a coherent and unified description of all nuclei, light or heavy, spherical or deformed, stable or unstable. It then became possible to reproduce and to predict, solely from Skyrme's interaction and throughout the periodic table, a large number of nuclear properties, such as binding energies, proton and neutron densities, single-particle spectra, equilibrium deformations and (by application of external fields) binding energies as a function of deformation, fission barriers, etc. While at MIT, Vautherin also developed a density matrix expansion that linked Skyrme's interaction with realistic nucleon-nucleon forces.

Dominique Vautherin 1921–2000.

He extended his approach to dynamical processes and the description of large-amplitude motions. In this way he contributed significantly to the understanding of the relations between individual and collective aspects of nuclear stucture – a recurrent theme of the physics of many-body systems.

His interest in astrophysical problems led him to seminal contributions to the thermodynamics of nuclear matter at high density (neutron stars) and high temperature (supernovae). He made the first calculation of the vaporization temperature of nuclei and studied the influence of the temperature on the nuclear collective excitations.

In recent years he was mainly interested in the properties of the quark-gluon plasma. With his collaborators he elaborated a variational approach, leading to approximate projected solutions of the gauge field equations.

His constant cheerfulness, sense of humour, gentle sarcasm and generosity were proverbial. To all of his French and foreign friends, colleagues and students, it is difficult to imagine that they will no longer benefit from his deep insights and continual enthusiasm.

Marcel Veneroni, IN2P3.

Aleksandr Chudakov 1921–2001

Aleksandr Chudakov, outstanding Russian scientist in the field of cosmic-ray physics, passed away on 25 January at the age of 79.

Chudakov was born on 16 June 1921 and graduated from Moscow State University in 1948. In 1953 he confirmed experimentally the existence of the transition radiation predicted by V L Ginzburg and I M Frank in 1945. In 1955 he predicted the effect of decreasing ionization losses for narrow electron-positron pairs, which was later referred to as the Chudakov effect. Phenomena similar to this effect are now found in quantum chromodynamics.

In the 1950s Chudakov carried out a series of experiments investigating cosmic rays outside the atmosphere with rockets and the first satellites, which resulted in his discovery (in collaboration with S N Vernov) of the Earth's radiation belts during the third Soviet Sputnik flight.

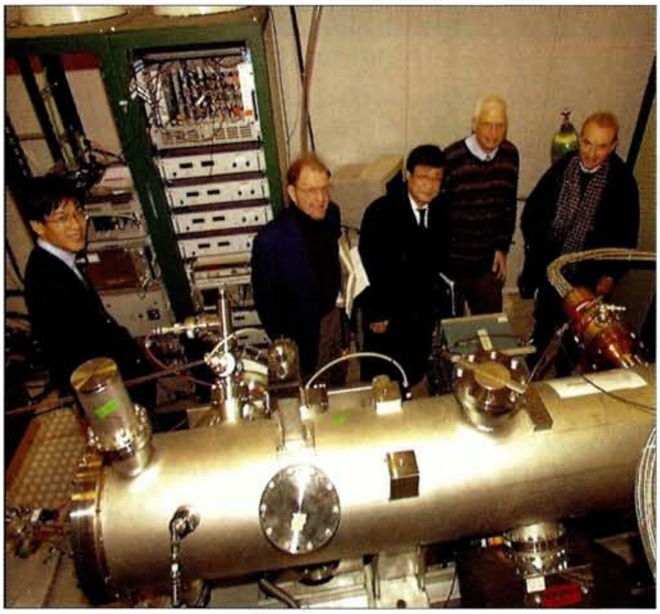
Aleksandr Chudakov 1921–2001.

In 1961, with G T Zatsepin, Chudakov suggested the air Cherenkov method for gamma-ray astronomy and carried out a pioneering experiment at Katsively, Crimea.

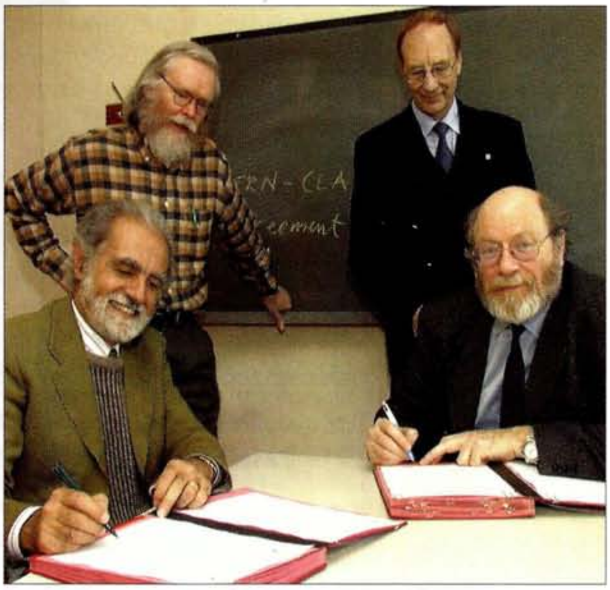
From the mid-1960s he headed the design and construction of the Baksan underground scintillation telescope (one of the first large multipurpose facilities for underground physics, which was put into operation in 1978). First-class results in astroparticle physics and cosmic rays were obtained with this instrument, which is still in operation.

Aleksandr Chudakov was one of the leaders of cosmic-ray science of his time. Being for some time a chairman of the IUPAP Cosmic Ray Commission, he was known and highly respected by the community all over the world. His death is a great loss to his friends and colleagues.

• Distinguished CERN physicist Douglas Morrison died on 25 February. A full tribute will appear in the next issue.

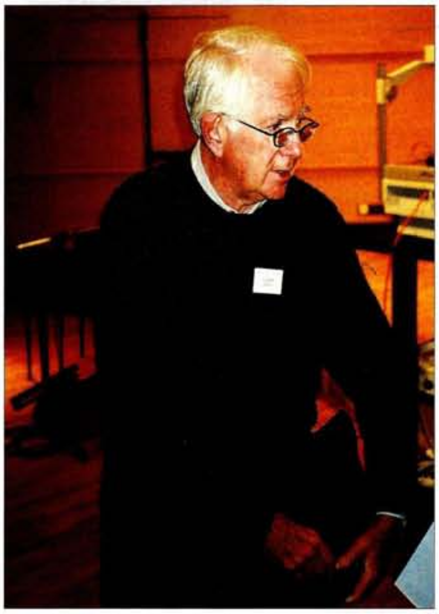


At CERN, admiring the Japanese-financed decelerating radiofrequency quadrupole (RFQD) for the ASACUSA low-energy antiproton experiment, are (left to right) **Masaki Hori** of Tokyo, **John Eades** of CERN, Japanese KEK laboratory director-general **Hirotaka Sugawara**, **Werner Pirkl** of the CERN RFQ team and CERN accelerator director **Kurt Hubner**.



Luis Masperi (left) of Rio de Janiero and director of Centro Latino Americano de Fisica (CLAF) signs an agreement for a programme of CERN–CLAF physics schools in Latin America. Signing the agreement for CERN is research director **Roger Cashmore**, and looking on are CERN advisor for non-member state matters **John Ellis** (left) and CERN physics schools director **Egil Lillestøl**. The inaugural school will take place in Itacuruca, Brazil, in May.

At CERN, en route to a meeting at DESY (see p37), Fermilab director **Michael Witherell** inspects a module of the hadronic calorimeter for the CMS experiment at CERN's LHC. Fermilab is a major staging post for the vital US contributions to the CMS experiment.



Together in Paris to help celebrate the 60th birthday of distinguished theorist John Iliopoulos were the three architects of the famous 1970 Glashow–Iliopoulos–Maiani (GIM) model. Top, left to right: Luciano Maiani (now CERN director-general), John Iliopoulos and (bottom) Sheldon Glashow. Until the GIM model, electroweak unification only worked for weakly interacting particles (leptons). The GIM model showed how it could work also for quarks, provided that there were four of them. However, only three quarks were known at the time. Iliopoulos is also one of the architects of the Bouchiat– Iliopoulos–Meyer (BIM) mechanism for the cancellation of lepton–quark anomalies.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Rates per single column centimetre: mono £36, single colour £38, full colour £40. Please contact us for more information on publication dates and deadlines.

Associate Scientist Position in the Physics Analysis Tools Department

The Computing Division at Fermilab has an opening for an Associate Scientist in the Simulation Group of the Physics Analysis Tools Department. As a member of the Simulation Group, the Associate Scientist will work on the development, maintenance and use of simulation tools for the Tevatron collider experiments and future collider experiments, and for the study of the physics potential of experiments at future accelerators. In addition, the position offers the opportunity to participate part-time in Fermilab's ongoing research program in high energy physics. The successful candidate will have major responsibility in the development of new generators and other computer simulation tools, and will be expected to participate in the development and maintenance of tools used in simulating a wide variety of important high pT physics processes, including channels involving high pT hadronic jets, W and Z bosons, hard photons, and missing transverse energy. The successful candidate will work closely with the experimenters, and with members of the Fermilab Theory Department, to implement strategies for better and more efficient separation of new physics signatures from Standard Model physics and detector backgrounds.

The candidate must have a Ph.D in theoretical high energy physics and significant development experience with multi-purpose Monte Carlo event generators such as Pythia, Herwig, and Isajet, as well as a variety of more specialized parton-level generators. The candidate should have extensive knowledge of the theory of QCD and electroweak physics, and be equally familiar with important new physics areas such as Higgs physics, supersymmetry, and technicolor. Extensive experience in the development of physics software in Fortran 77, C or C++ is required, experience with UNIX, C and C++ recommended.

Applications should include a curriculum vitae, a list of publications and 3 letters of reference and should be sent to **Dr. Matthias Kasemann, Fermi National Accelerator Laboratory, P.O. Box 500, M.S. 120, Batavia, IL 60510, USA.** Application materials and letters of reference should be received by April 30th, 2001.

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Universität Heidelberg

The Faculty of Physics and Astronomy at the Ruprecht-Karls-University Heidelberg extends her activities to integrate computer science. A new interdisciplinary curriculum in physics with emphasize on computer science is currently established that offers a high qualification in both disciplines in addition to the two existing chairs for computer science the faculty has immediate openings for two professorships at the Associate Professor level (German salary scale C3):

Associate Professor Position (C3) Multidimensional Image Processing

The position is located at the Research Group Image Processing at the Interdisciplinary Centre for Scientific Computing (www.iwr.uni-heidelberg.de) and is endowed by the Robert Bosch GmbH, Stuttgart. The successful candidate should show a proven excellent and versatile scientific record in multidimensional image processing. In addition, experience with applications in industry and natural sciences are expected. For further details please contact Prof. B. Jähne (Bernd.Jaehne@iwr.uni-heidelberg.de). The IWR offers a first rate interdisciplinary scientific environment with key applications in natural sciences and – in cooperation with the Robert Bosch GmbH – in industrial image processing.

Associate Professor Position (C3) Technical Computer Science

The position is located in the Research Group Technical Computer Science at the Kirchhoff Institut für Physik (www.ti.uni-hd.de). Possible research directions are among others parallel and distributed computer architecture and applications in natural sciences with emphasis on existing interdisciplinary activities in physics. The successful candidate should show a proven excellent scientific qualification in the area of technical computer science. For further details please contact Prof. V. Lindenstruth (ti@kip.uni-heidelberg.de). The Kirchhoff Institut offers modern laboratory facilities including an excellently equipped ASIC lab.

Teaching obligations in computer science 8 hours per week during the semester. Required background is a "Habilitation" or equivalent evidence of professional proficiency.

Section 1, Paragraph 67 of the *Universitätengesetz* (University law) requires that a candidate without a previous appointment a university professor in the German university system be initially employed on a non-tenured basis. The appointee is not required to reapply for the position if his/her contract is to be extended beyond the initial term. Exceptions to these regulations may be granted if candidates from abroad or from outside the university system refuse to accept an appointment under these conditions.

Applications in written and electronic form including C.V., list of publications and teaching experience, summary of research focus, and outline of planned research activities should be received by the Dekan der Fakultät für Physik und Astronomie der Universität Heidelberg, Albert-Ueberle-Strasse 11, D-69120 Heidelberg, not later than April 23, 2001. – The faculty intends to increase the number of women in teaching and research, women are therefore explicitly invited to apply.

Candidates taken into further consideration are invited to give a talk in a colloquium and an example lecture for students. The colloquium for the C3-professorship Multidimensional Image Processing will take place on May 23, 2001.

Associate Scientist Beams Division

Fermi National Accelerator Laboratory currently seeks an Associate Scientist to work in one of the Beams Division systems groups (Tevatron, Main Injector, Antiproton Source, Proton Source), contributing to machine operation, improvements, and diagnostics. Additional duties will include writing application programs in C, performing shift work during machine commissioning periods and conducting beam studies, coupled with advanced accelerator calculations aimed at improving machine performance and versatility. This role will also entail making accesses into beam enclosures and working in radiation and ODH areas. Some shift work is required during commissioning.

Qualified candidates will possess a PhD in Physics, with a minimum of three years of postdoctoral work and prior experience in experimental beam physics. Exact title and level will depend on the qualifications of the selected candidate.

Qualified applicants should submit a curriculum vitae, publication list and the names of three references to: John Marriner, Head, Beams Division, Fermilab, MS 306, P.O. Box 500, Batavia, IL 60510, USA.

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Staff Scientist Position

at the

LIGO Laboratory,
California Institute of Technology (Caltech)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) Laboratory is seeking to fill a three-year term position for a staff scientist at its Livingston, Louisiana site.

The position may be converted at a later date to a long-term appointment subject to available funding.

The successful candidate will become a member of the observatory staff with primary responsibility to participate locally in the LIGO Laboratory Data and Computing Group activities. Primary responsibilities will include: site support for LIGO Data Analysis System hardware and software and participation in the scientific data analysis for astrophysical signatures from gravitational waves associated with compact relativistic objects.

Skills we are seeking include: Linux/Solaris administration background; MPI-based parallel computational background; training in astronomy, astrophysics, or physics; programming experience in C or C++ and/or tcl/tk; and knowledge of computer hardware systems including the ability to repair, install, and maintain computer equipment.

Letters of interest must include a resume with a minimum of three references listed and where the applicant saw the advertisement and should be sent to: Dr. Albert Lazzarini, California Institute of Technology, LIGO 18-34, Pasadena, CA 91125. Electronic materials may be submitted either as a pdf attachment or as ascii-only text; please no MS WORD documents.

Further information may be obtained from Dr. Lazzarini at lazz@ligo.caltech.edu.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, Minorities, Veterans, and Disabled Persons are encouraged to apply.

Postdoctoral Positions in High-Energy Gamma-Ray Astrophysics

Max-Planck-Institute for Nuclear Physics, Heidelberg

The Max-Planck-Institute for Nuclear Physics in Heidelberg invites applications for postdoctoral positions to work on the H.E.S.S. project in TeV gamma ray astronomy. The H.E.S.S. collaboration is currently constructing a system of large imaging Cherenkov telescopes in Namibia, see www-hfm.mpi-hd.mpg.de/HESS.

Our institute is centrally involved in almost all aspects of the project. We seek persons with a Ph.D in particle physics, nuclear physics, or astrophysics, with a strong experimental background, and interests to participate in the commissioning of the telescopes and in particular in the data processing and data analysis.

For further information, contact **Werner.Hofmann@mpi-hd.mpg.de.**

Applicants should send a CV, and arrange for three letters of reference to be sent to **Personalverwaltung Max-Planck-Institut für Kernphysik Heidelberg, Postfach 10 39 80, D-69029 Heidelberg.**

The Max-Planck-Gesellschaft especially encourages women to apply.

When a disabled candidate and a non-disabled candidate are equally qualified, the disabled candidate will be chosen.

The **Deutsche Elektronen-Synchrotron DESY** in Hamburg, member of the association of national research centers Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren, is a national center of basic research in physics with approx. 1,400 employees and more than 3,000 scientific guests from Germany and foreign countries per year. The accelerators in operation are dedicated to particle physics and research with synchrotron radiation.

We are looking for a

Physicist or Computing Scientist (m/f)

as head of the IT-group in Hamburg

starting as soon as possible.

The tasks concerning the central information technology of DESY are carried out by the IT-groups in Hamburg and Zeuthen in close co-operation with the teams of the large experiments at the electron-proton collider HERA, of the synchrotron radiation laboratory and of the accelerator facilities. At DESY we are working at the frontier of IT technology. There exist close co-operations with the IT-groups of other centres of particle physics like Fermilab or CERN.

The central IT-group in Hamburg with approx. 60 employees is responsible for the operation and further development of the basic services like networking, computing platforms (mainly Unix, Linux and Windows) and for the efficient management of the physics data (several hundred Tbyte) for several thousand users.

The essential tasks are:

heading the IT-group in Hamburg; organisation of the operation of the central data processing coordination with the IT group in Zeuthen; strategic development of the IT at DESY in close co-operation with the users and with other laboratories; consulting of the DESY-directorate; outside representation of DESY in IT issues.

Candidates should have a degree in one of the a.m. subject areas, appropriate experience in information technology and profound ability to direct scientific and technical personnel. Candidates (m/f) with several years of experience in data processing, particularly in particle physics, will be given preference. Applicants should be conversant with German and English both in speech and writing.

The salary and social benefits correspond to those of the public services (BAT Ia/I).

Deadline for applications: April 20, 2001

Job No.: 79/2000

Handicapped persons will be given preference to other equally qualified applicants.

DESY supports the careers of women and therefore encourages especially women to apply.

In case of questions concerning the described function and qualification, please feel free to contact Dr. Hans von der Schmitt (+49-40-89983200) or Dr. Jan Hendrik Peters (+49-40-89982583). Please send your application documents to:

DESY
Personalabteilung
Notkestraße 85, D-22607 Hamburg
www.desy.de

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MICHIGAN STATE UNIVERSITY

ISIS NEUTRON FACILITY POSTDOCTORAL POSITION

The Department of Physics and Astronomy at Michigan State University is looking to fill a postdoctoral research associate position in the local-structure-property relationship of complex oxides.

The successful candidate will be located predominantly at the ISIS pulsed neutron facility at the Rutherford Appleton Laboratory in the UK. The research involves using neutron diffraction, including Pair Distribution Function analysis, and scattering to study the relationship of structure and local structure to the properties of such materials as colossal magnetoresistant manganites and high-temperature superconductors.

Candidates must have Ph.D. in Physics, Chemistry, Materials Science or related subject. Experience in neutron scattering or diffraction and computer analysis/programming is preferred.

Deadline for applications is April 16, 2001 or until the position is filled. Please send applications, including a vita, statement of research, and at least two letters of recommendation, to

Prof. Simon J.L. Billinge, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824-1116 USA (www.pa.msu.edu/cmp/billinge-group).
Further information can also be obtained from Dr. Paolo Radaelli (p.g.radaelli@rl.ac.uk).

Michigan State University is an affirmative action/equal opportunity institution. Women and minorities are especially encouraged to apply

Staff Physicist – Accelerator Physics

Stanford Linear Accelerator Center is seeking an outstanding individual for a staff physicist position in the Accelerator Research Department - A. SLAC has a world-leading research program of accelerator physics. Interests cover a wide range of accelerator physics and advanced technology research as applied to next-generation linear colliders, storage rings, and synchrotron radiation and free electron laser devices. Successful candidate is expected to propose and lead research, and to participate in team collaborations. The individual must have completed post-doctoral research or equivalent. Broad knowledge of accelerator physics is expected. Level of the position is flexible with the aim of finding the most qualified individual.

Interested parties should send an application letter, brief summary of accomplishments, curriculum vitae, and list of publications to either **Prof. Alex Chao or Prof. Ron Ruth, Mail Stop 26, Stanford Linear Accelerator Center, P.O. Box 4349, Stanford, CA 94309, USA.** Also send at least three letters of recommendation. E-mail inquiries can be sent to **achao@slac.stanford.edu**

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May issue: 11 April

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Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

The Experimental Physics Division invites applicants for a long term position of a

PHYSICIST

in experimental particle physics research.

Candidates are expected to have a PhD in particle physics and an excellent record of successful work with typically 5-10 years of post-doctoral experience in this field. Further requirements include; a high capacity for innovation and leadership; competence in detection techniques and in the use of on-line and off-line software; potential for making a significant medium to long-term contribution to the scientific programme of the Organization. Very good communication skills and an aptitude for team work.

The position is of a long term nature and offers a competitive remuneration package and excellent career prospects.

The selected candidate will take a leading role in all aspects of particle physics experiments, involving the conception and design of experiments, the development and operation of detectors and the analysis of data. He/she will also co-ordinate or make important contributions to studies, projects or committee work and represent the Organization at conferences, workshops, or in other research laboratories and institutions.

Interested candidates are asked to send an application letter, a CV including the names of three referees and a brief description of research interests as well as a list of publications to Professor G. GOGGI, EP Division Leader, CERN< CH 1211 Geneva 23, e-mail: Giorgio.Goggi@cern.ch, by 11 May 2001.

Preference will be given to nationals of CERN Member States*.

This position is also published under reference EP-DI-2001-43-FT, which can be consulted at www.cern.ch/jobs/.

CERN is an equal opportunity employer and encourages both men and women with the relevant qualifications to apply.

* AT, BE, BG, CH, CZ, DE, DK, ES, FI, FR, GR, HU, IT, NL, NO, PL,P T, SE, SK, UK

Uni Bonn

RHEINISCHE FRIEDRICH - WILHELMS - UNIVERSITÄT BONN

The Physics and Astronomy Department of the Mathematics and Science Faculty of the University of Bonn
has an opening in the Physics Department for a
Professorship (C4) in Theoretical Physics
starting fall 2001.

We are seeking a scientifically outstanding candidate in the field of Theoretical Elementary Particle Physics with additional experience in the area of Cosmology and Astrophysics. The candidate should play an important role in the initiation of a research center in Particle-Astro-Physics at the University of Bonn.

The position carries with it the usual teaching duties.

The conditions of employment are described in § 46 HG (NRW). The University of Bonn is determined to increase the percentage of women employed. Applications by women are thus particularly encouraged. Given the same suitability, qualification and scientific achievement, preferential consideration will be given to women.

Disabled applicants with the same qualifications as other candidates are preferably employed.

Please send applications containing the usual documents to Vorsitzenden der Fachgruppe Physik-Astronomie, Endenicher Allee 11-13, D-53115 Bonn, Germany.

The deadline for applications is April 15, 2001.

BOOK OF THE MONTH

Selected Papers of Richard Feynman (with commentary), edited by Laurie M Brown, World Scientific Series in 20th Century Physics, Vol. 27, ISBN 981 02 4130 5 hbk ISBN 981 02 4131 3 pbk.

After *A Quantum Legacy*, the selected papers of Julian Schwinger (edited by Milton, December 2000 p44), it is fitting that the next volume in this carefully selected series covers the work of Richard Feynman.

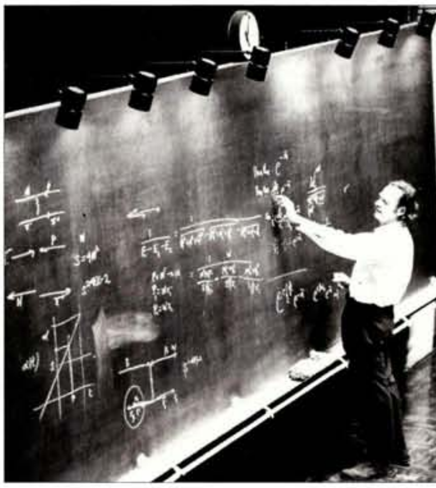
Now a cult figure, Feynman is fast becoming one of the most prolifically documented physicists of the past century. As well as his own popular work (*You Must Be Joking, What Do You Care What Other People Think?*) and his various lectures, there are biographies or biographical material by Gleick, Brown and Rigden, Mehra, Schweber, Sykes, and Gribbin and Gribbin.

Anecdotes about such a flamboyant character are easy to find, but the man's reputation ultimately rests on his major contributions to science, which this book amply documents. Chapters, of various lengths, deal with his work in quantum chemistry, classical and quantum electrodynamics, path integrals and operator calculus, liquid helium, the physics of elementary particles, quantum gravity and computer theory. Each has its own commentary.

As a foretaste of things to come, the first chapter serves up just a single paper – "Forces in molecules" – written by Feynman at the age of 21, in his final year as an undergraduate at MIT. This result – the Hellmann-Feynman theorem – has played an important role in theoretical chemistry and condensed matter physics.

Chapter 2 begins with Feynman's 1965 Nobel Lecture, goes on to include work with John Wheeler at Princeton, which explored the underlying assumptions about the interaction of radiation and matter, and concludes with the classic 1949 papers that presented his revolutionary approach to quantum electrodynamics.

The Nobel Lecture alone is worth reading – clearly a major early source of Feynman anecdote, such as the Slotnick episode. One is struck by Feynman's ambivalent attitudes – his enormous regard for father figures such as Wheeler and Bethe on the one hand, and his clear disdain for many contemporaries on the other. Another good read in this chapter is Feynman's paper presented at the 1961 Solvay meeting, and the ensuing discussion.



Richard Feynman at CERN in 1965.

Chapter 3 deals with the detailed presentation of the path integral approach, which enabled Feynman to dissect electrodynamics and look at it from a fresh, uncluttered viewpoint.

From 1953 to 1958, Feynman looked for fresh pasture and produced a series of seminal papers on the atomic theory of superfluid helium, which is presented in Chapter 4.

Chapter 5 is split into two parts. The first, on weak interactions, includes the classic 1957 paper with Gell-Mann and some lecture notes from the 1960s exploring the consequences of SU3 symmetry for weak interactions. The second part – by far the largest section of the book – deals with his approach to partons, quarks and gluons. Feyman began thinking about describing hadrons simply as an assembly of smaller parts – his partons – just when experiments were beginning to probe this inner structure. This is a good example of how Feynman, arriving at a fresh interest, would invariably strip problems down to their essential parts before reassembling them in a way that he, and many other people too, understood better.

Feynman's interest in numerical computation went back to his time at Los Alamos, when he had to model the behaviour of explosions using only the mechanical calculators of the time. Coming back to the subject in the 1980s, he went on to pioneer the idea of quantum computers. Apart from the prophetic papers published here, this aspect of his work has been well documented in *The Feynman Lectures on Computing* (ed. A J G Hey and R W Allen, Perseus).

Selected Papers of Richard Feynman concludes with a full bibliography. Even without the burgeoning Feynman cult, such a selection of key papers is a useful reference. However, with almost 1000 pages, the book could perhaps have been better signposted. The selected papers are not listed in the initial contents and the pages have no running heads to indicate how the chapters fall.
Gordon Fraser, CERN.

Calorimetry: Energy Measurement in Particle Physics, by Richard Wigmans, Oxford University Press, ISBN 019 850296 6, 726pp, £85.

The role of calorimetry in high-energy physics has become increasingly important during the last 20 years. This is due to the increase in energy of the particle beams available at the major accelerators and to the need for hermetic detectors. The 1980s, in particular the second half of the decade, saw an important breakthrough in the understanding of the mechanisms underlying the development of hadronic cascades and their energy loss.

The theme around which this breakthrough took place is "compensation": for a compensating calorimeter $e/h = 1$, where e represents the response to an electromagnetic and h the response to a non-electromagnetic,that is purely hadronic, shower of the same energy. For compensating calorimeters the energy measurement of electrons and hadrons of the same energy yields the same average response for all energies, at the same time leading to optimal hadronic energy resolution. It is also a prerequisite for linearity of the hadronic energy measurement.

In practice, very few compensating calorimeters have been built for major experiments (one example is the calorimeter of the ZEUS experiment at HERA, discussed in the book), probably because, in practice, achieving compensation means making a concession to the electromagnetic energy resolution. None of the experiments planned at the Large Hadron Collider, for example, will employ a compensating calorimeter. The importance of the research into compensation is nevertheless very large in that it led to a much better understanding of calorimetry in general. The author of the book has made original and essential contributions to this field through his own research.

The book reflects the deep and encyclopedic knowledge that the author has of the subject. This makes the book a rich source of information that will be useful for those designing calorimeters and for those analysing calorimeter data, for a long time to come. At the same time the book is not always successful in finding a way of organizing and conveying all of this knowledge in a clearly structured and efficient way. Parts of the book are rather narrative and long-winded.

The most important chapters are those on Shower Development, Energy Response, Fluctuations and Calibration. Also, that on Instrumental Aspects contains essential information. The chapters on generic studies and on existing (or meanwhile dismantled) and planned calorimeter systems, are interesting but less necessary parts of a textbook. Moreover, the author does not always keep to the subject - calorimetry - leading to unnecessary excursions and, what is worse, outdated material. It would, on the other hand, be interesting if the author, in his description of the calorimeters under construction for the Atlas experiment, had been a bit more explicit on what, in the light of the ideas developed earlier in the book, the optimal approach would be to (inter)calibrating this very complex calorimeter system.The chapter on Calibration is probably the most essential part of the book, bringing together many of the fundamental issues on shower development, signal generation and detection. Reading this chapter, one gets the impression that in fact it is impossible to calibrate calorimeters, but the style chosen by the author is only to

In practice, achieving compensation means making a concession to the electromagnetic energy resolution.

emphasize that the issue is subtle and great care must be taken. The chapter contains information that is extremely worthy of consideration, culminating in the recommendation that, in the case of non-compensating calorimeters, individual (longitudinal) calorimeter sections should be calibrated by the same particles generating fully contained showers in each section, a recommendation that, in practice, cannot always be satisfied. In his ardour to emphasize the importance of the (inter)calibration of longitudinal calorimeter segments, the author even invokes decays, such as that of the neutral rho into two neutral pions, that do not exist in nature - we get the point and forgive him. It is, however, true that there are more places where the book would have profited from a critical, final edit.

Calorimetry is a book that describes the essential physics of calorimetry. It also contains a wealth of information and practical advice. It is written by a leading expert in the field. The fact that the discussions sometimes do not follow the shortest path to the conclusion and that perhaps the "textbook part" of this work should have been accommodated in a separate volume does not make the book less important: it will be amply used by those trying to familiarize themselves with calorimetry and in particular by those analysing the data of the very complex calorimeter systems of future experiments, such as at LHC.
Jos Engelen, *NIKHEF, University of Amsterdam.*

Quarks and Gluons: a Century of Particle Charges by M Y Han (Duke), World Scientific Publishing, 168pp, ISBN 981 02 3704 9 hbk $34/£21, ISBN 981 02 3745 6 pbk) $16/£10.

This is a readable little book on particle physics and is aimed at those with no previous exposure to the subject. It starts with the discovery of the electron in 1897 and works its way more or less historically up to the present. That means, of course, that it contains a lot about leptons and photons as well as the quarks and gluons of the title.

The guiding theme is the discovery of different kinds of conserved charges - first electric charge, then baryon number and the lepton numbers, and finally the more subtle kind of charges that are the source of the colour force between the quarks.

Like Stephen Hawking, the author manages to avoid all equations, except $E = mc^2$. The style is chatty and colloquial (American), which will have some non-native English readers running for their phrase books. For example, correct predictions are "right on the money", and when the terminology seems comical the reader is exhorted to "get a grip on yourself". Nevertheless, as one would expect from a leading contributor to the field, Han takes care to get things right even when using simple language, as for example in his discussion of spin.

The jacket says that the book will be "both accessible to the layperson and of value to the expert". I imagine that the latter refers to its value in helping us to communicate with non-experts.

Like Stephen Hawking, the author manages to avoid all equations, except $E = mc^2$.

I have some misgivings about this book, mainly because its insistence on discussing only those charges that are (within current limits) absolutely conserved leaves the reader with the impression that nothing much is understood about the weak interaction. The author even says that the weak charges have yet to be identified. All of the beautiful developments of electroweak unification are omitted. Also, there is no mention of the exciting possibilities that lie in the near future. This makes the subject seem a bit moribund and musty. For example, we are told that the discovery of the pion in 1947 was "one of the last hurrahs" of cosmic-ray physics, whereas in fact that field continues to show astonishing vitality, with neutrino studies, ultrahigh-energy primaries and other fascinating phenomena promising a rich future.
Bryan Webber, Cambridge.

Anomalies in Quantum Field Theory by R A Bertlmann, Oxford University Press, ISBN 01 850762 3, pbk £29.95.

Field theory "anomalies" constitute a long-standing source of physics and mathematics. They have remained fascinating for physicists and mathematicians, as ongoing developments in string and brane theory show.

This book gives a comprehensive description of the many facets of this subject that were known before the mid-1980s. It is essentially self-contained and thus deserves to be called a textbook. Both mathematicians and physicists can learn from this volume.

With a modest knowledge of quantum mechanics, a mathematician can read about the history of the subject: the puzzle of the decay of the neutral pion into two gamma-ray photons; the inconsistencies of the perturbative treatment of gauge theories ▷

related to the occurrence of anomalies; the original Feynman graph calculations; and the theoretical constructions that introduced relationships with topology, up to the elementary versions of the index theorem for families.

The physicist will find all of the necessary equipment in elementary topology and differential geometry combined in constructions that are familiar to professional mathematicians. S/he will find thorough descriptions of the algebraic aspects that emerged from perturbation theory, both in the case of gauge theories and in the case of gravity, and an introduction to the way in which they tie up with index theory for elliptic operators and families thereof.

The book reads fluently and is written so clearly that one not only gets an overview of the subject, but also can learn it at an elementary level.

The bibliography is a rather faithful reflection of the physics literature and includes a few basic mathematical references, which give the reader the opportunity to learn more in whichever direction s/he chooses.

With a modest knowledge of quantum mechanics, a mathematician can read about the history of the subject.

As mentioned, the subject is still developing in the direction of new mathematics and, possibly, new physics in the context of strings and branes. One may therefore regret that the book stops around the developments that took place in the mid-1980s.

The book is already more than 500 pages. Since it is essentially self-contained and every topic that is dealt with is described in sufficient detail to allow a non-specialist to get acquainted with it, at least at an elementary level, the mathematical techniques do not go beyond elements of differential geometry, as well as of homology, cohomology and homotopy theory. Generalized cohomology theories, including K-theory, only appear in a phenomenological disguise, in connection with the description of the index theorem for families, in the particular case relevant to gauge theories, but not as mathematical prerequisites.

As a consequence of the principle of maximal perversity, one may expect that physics will exhibit subtle effects describable in terms of the above-mentioned constructions. In such an event, there remains the hope for a corresponding textbook as understandable as this one, possibly written by the same author.

Raymond Stora, *LAPP, Annecy.*

A Modern Introduction to Particle Physics
by Fayyazuddin and Riazuddin, 2nd edn, World Scientific ISBN 9810238762 hbk, ISBN 9810238770 pbk.

The first edition of this book by the talented twins from Pakistan, which appeared in 1992 has been updated, with the chapters on neutrino physics, particle mixing and CP violation, and weak decays of heavy flavours having been rewritten. Heavy quark effective field theory and introductory material on supersymmetry and strings are also included.

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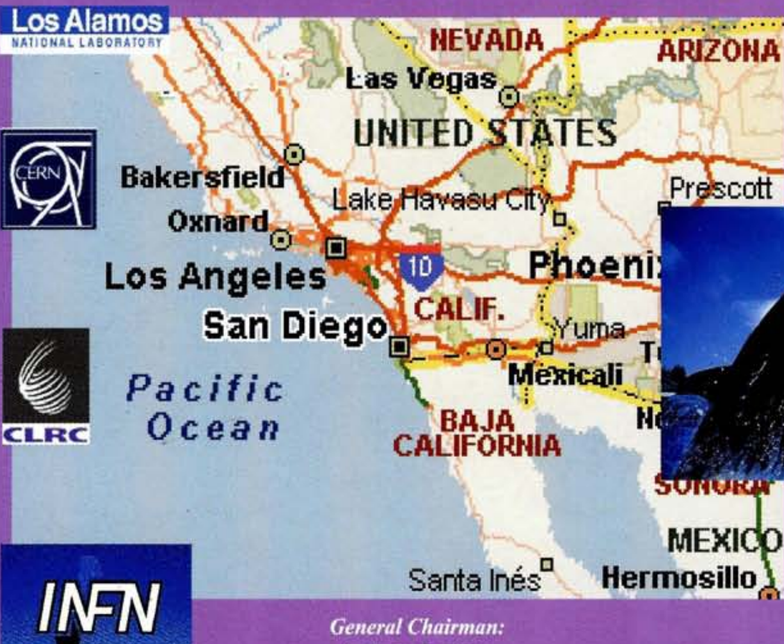

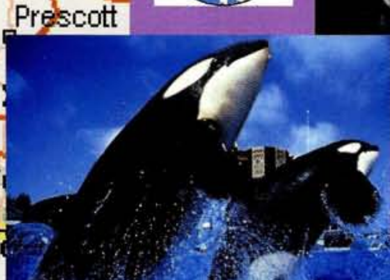

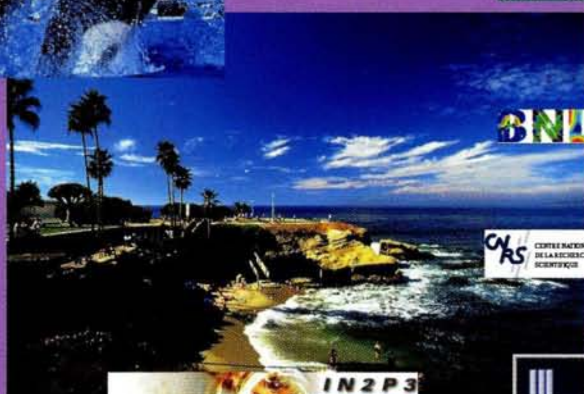

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