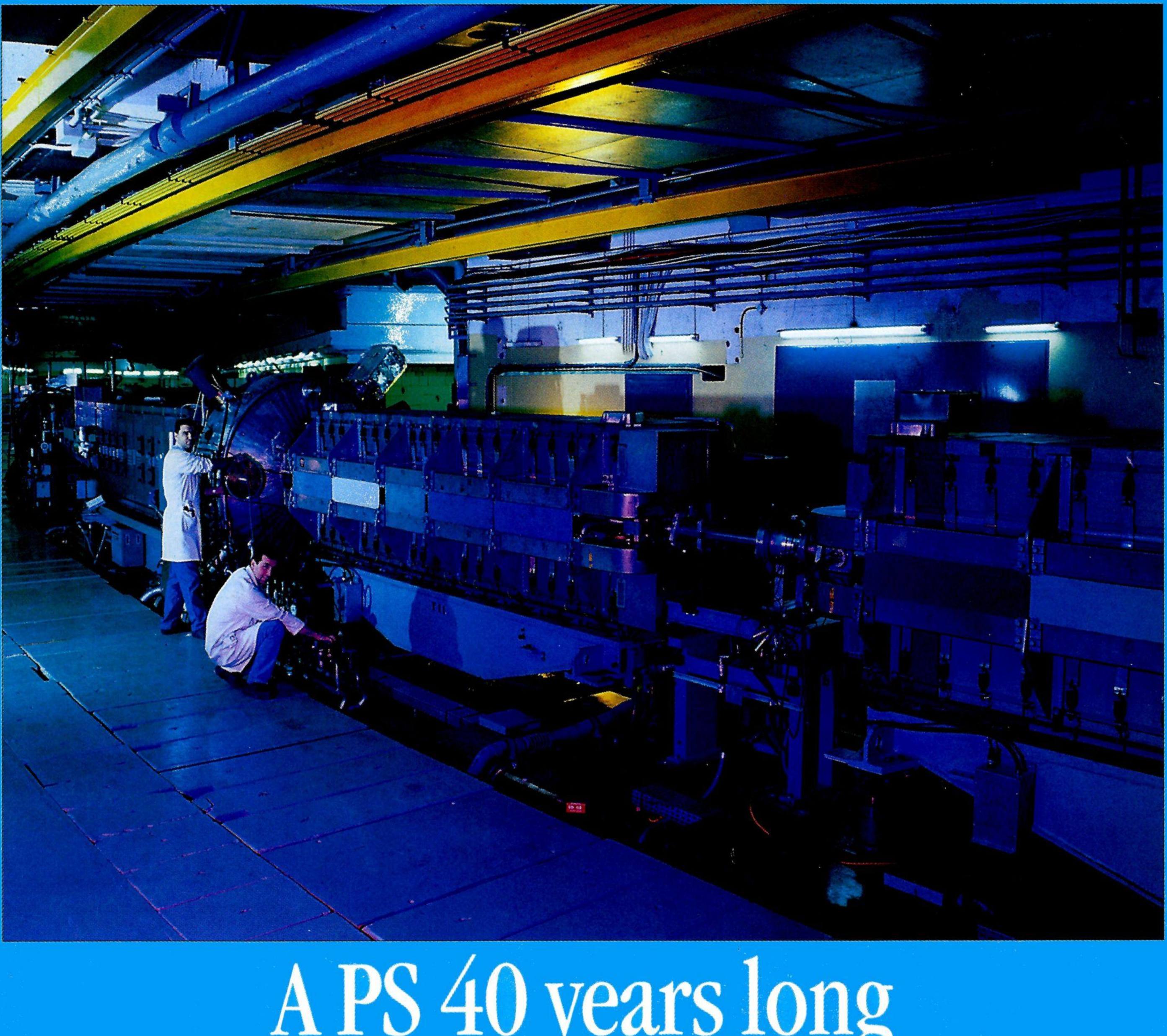
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 39 NUMBER 10 DECEMBER 1999

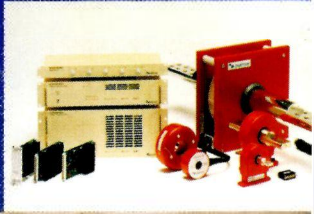


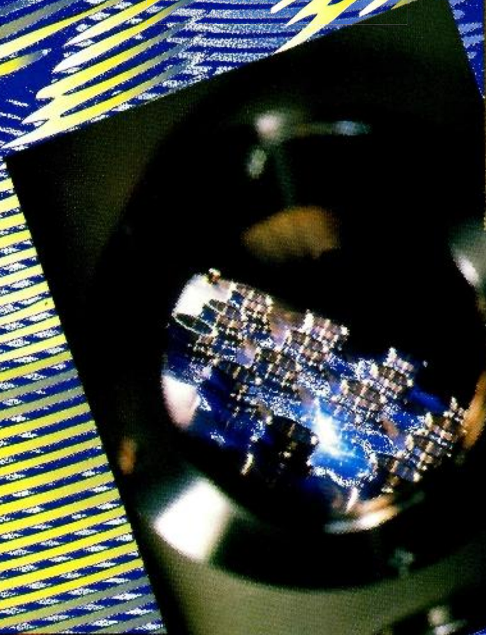
A PS 40 years long

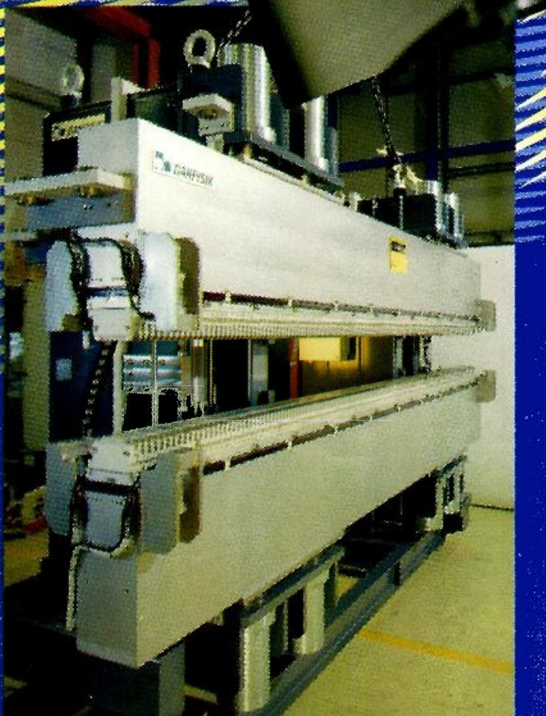
ISOTOPE FACTORY
From nuclear physics to life sciences with radioactive beams p20

WHERE DOES SPIN COME FROM?
New experiments look deeper into the heart of the proton p25

SWISS PRECISION
The Swiss National Laboratory celebrates its 25th anniversary p27



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

CERN Courier is distributed to Member State governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly except January and August, in English and French editions. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by Institute of Physics Publishing Ltd
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Web http://www.iop.org

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USA/Canada: Janice Voss, Creative Mailing Services, P.O. Box 1147, St Charles, Illinois 60174. Tel. 630-377-1589. Fax 630-377-1569

Published by: European Laboratory for Particle Physics, CERN, 1211 Geneva 23, Switzerland. Tel. +41 (22) 767 61 11
Telefax +41 (22) 767 65 55

USA: Controlled Circulation Periodicals postage paid at St Charles, Illinois

Printed by: Warners (Midlands) plc, Bourne, Lincs, UK

ISSN 0304-288X

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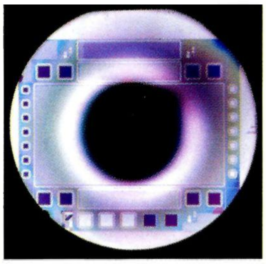
VOLUME 39 NUMBER 10 DECEMBER 1999


A network of telescopes p12


Radioactive ion beams p20


Meritorious detector p29

News 5

ATLAS solenoid coiling is complete. Avalanche photodiodes come of age. Novel X-rays detected at Jefferson. HAPPEX probes "sea" of nucleon strangeness. New data centre is opened at Brookhaven. SAMBA talks detector applications. Siberian searchlight on rare decay. ACCESS intercepts cosmic rays. BEARS deliver radioactive species. New meson physics pushes on in 2000.

Astrowatch 12

Physicswatch 13

Features

40 years of CERN's Proton Synchrotron 15
CERN's stalwart machine looks foward as well as back

Radioactive beams drive physics forward 20
From basic nuclear physics to the life sciences

Handling high-energy spin 25
Where does the proton's spin come from?

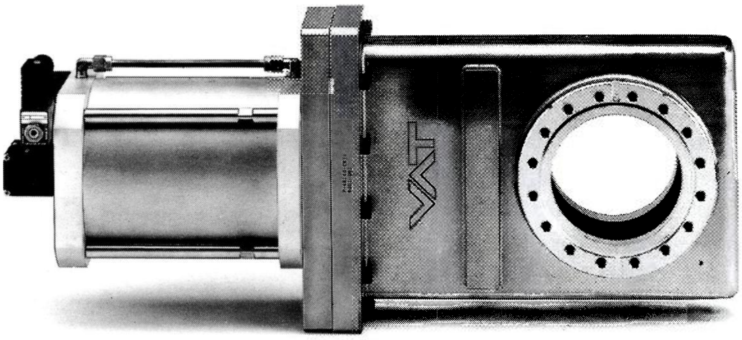
Silver celebration for Swiss pions 27
The Swiss National Laboratory looks back on a productive quarter of a century

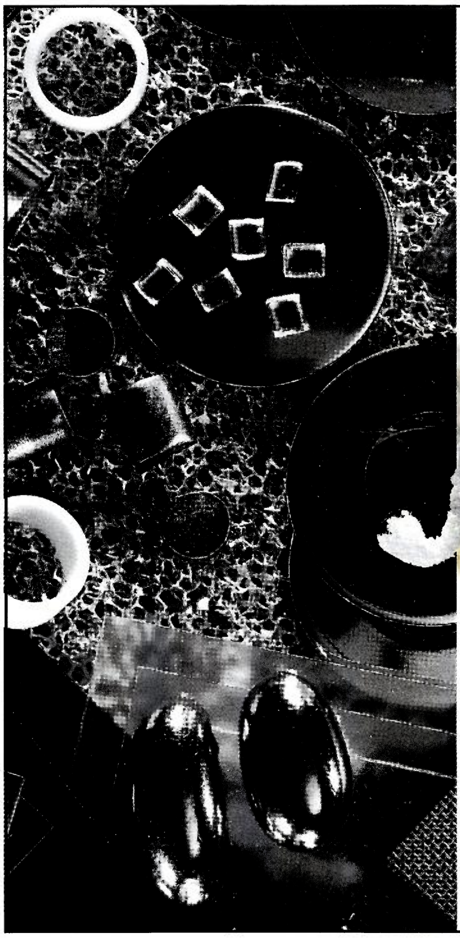
People 29

Recruitment 33

Bookshelf 38

Cover: CERNS's Proton Synchrotron celebrates its 40th birthday. When it first started operation it was the highest-energy proton synchrotron in the world. It has become the hub of an interconnected system of particle beams, unmatched anywhere in the world (p15).



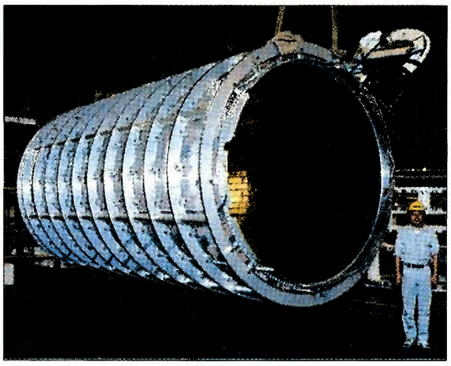


ATLAS solenoid coiling is complete

The coil winding for the central solenoid magnet of the forthcoming ATLAS experiment at CERN's Large Hadron Collider has been completed. It will provide a magnetic field of 2 T at the centre of ATLAS's tracking volume. This superconducting solenoid was designed and developed by Akira Yamamoto and his team at the Japanese KEK Laboratory, as Japan's contribution to the ATLAS magnet system. The project is led by Takahiko Kondo.

Weighing in at 5.5 tons, the coil is 2513 mm in diameter, 5300 mm long and 45 mm thick. Conductors made of high-strength aluminium stabilizer, developed by Furukawa Electric and Hitachi Cables, have been used so that the coil is as thin as possible. Some 8.92 km of conductor is coiled into 1151 turns inside an aluminium cylinder, which was made by Oxford Instruments. The coil winding and curing was carried out by Toshiba in Japan and took four months.

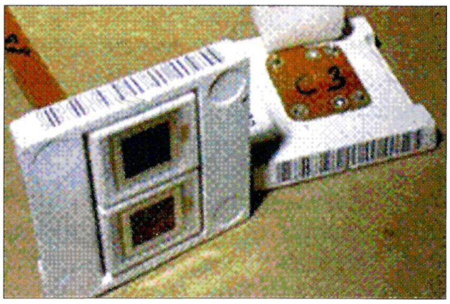
Outer reinforcement rings currently support the solenoid. The rings will be removed early next year when the solenoid is incorporated into the inner cylinder of the cryostat, which is being constructed by the US Brookhaven National Laboratory, where the ATLAS liquid argon barrel calorimeter will be housed. The entire solenoid system will then undergo cooling and excitation tests in Japan before being shipped to CERN along with its associated cryogenics in 2001.



The central solenoid magnet of the forthcoming ATLAS experiment at CERN's Large Hadron Collider was designed and developed at the Japanese KEK Laboratory.

Avalanche photodiodes come of age

A delegation from the CMS experiment was in Japan earlier this year to discuss details of the contract for the delivery of 130 000 avalanche photodiodes from Hamamatsu.



Two avalanche photodiodes, each measuring 5×5 mm, of the type that will be used for the CMS experiment at CERN's Large Hadron Collider.

In the search for optimal performance under difficult conditions, experiments for CERN's LHC are exploiting new technologies. One example is the large-scale use of avalanche photodiodes to read out light signals, which are produced by electromagnetically interacting particles in the CMS detector.

Photodiodes – light-sensitive semiconductors – have long been used in high-energy physics to read out signals from scintillating fibres and light-emitting crystals in calorimeters, because large magnetic fields or space may prevent the use of vacuum devices. One example is a simple p–i–n photodiode with a layer of intrinsic semiconductor sandwiched between the p and n layers.

An advance on this basic configuration is the avalanche photodiode (APD). The applied bias voltage produces a region with a large field (150 kV/cm or more) in which to generate an avalanche of secondary carriers and thereby amplify the signal. This gain depends on both the applied field and the temperature. This technique has the additional advantage of fully amplifying the signal generated by the scintillation light absorbed at the surface, while signals generated within the diode by traversing ionizing particles are not amplified. A further refinement of the avalanche device is a "reverse" structure, first developed at the beginning of the 1990s, in which a thick avalanche region is located behind a thinner photoconversion layer (in contrast with a standard avalanche device in which the photoconversion layer is thicker).

The scintillating crystals, which are used for recording electromagnetic energy, are one of the big spin-off success stories of particle physics. For big detectors, such as CMS at CERN's LHC, lead tungstate facilitates a compact calorimeter design and produces short, fast signals. However, because lead tungstate has a low light yield, the APD read-out's combination of amplification of the light signal and insensitivity to ionizing particles is crucial.

Developing APDs that were able to withstand the high particle intensities of the CMS environment required further research and development with two different specialist suppliers. Using more than 30 different APD prototypes, substantial progress was made and beam tests, using lead tungstate crystals, achieved the design energy resolution of better than 0.5%. The next task was to decide on the relative merits of manufacture, either via epitaxial growth or by diffusion. Last year, CMS chose the epitaxy route, and, after further development work, a contract with Hamamatsu for the supply of 130 000 APDs was signed in Japan by PSI (with ETHZ, Northeastern University and the universities of Minnesota and Split as contributing partners).

Meanwhile a full-scale CMS electromagnetic calorimeter module, with a 400 lead tungstate crystal read-out via 800 APDs, is being constructed at CERN.

Novel X-rays detected at Jefferson

In a recent experiment, Thomson-scattered X-rays from Jefferson Lab's infrared free-electron laser were detected, confirmed and initially characterized. The results suggested a potential new dimension for the laboratory's free-electron laser development programme. Experimenters used specially configured optical devices to extract intense, ultrafast (hundreds of femtoseconds) X-ray pulses in coincidence with the infrared light pulses of the electron-beam-driven free-electron laser.

The X-ray pulses are generated within the free-electron laser (FEL) via the Thomson scattering of infrared light by electrons. The FEL's operating characteristics allowed the production of results in a few days. X-ray pulses manipulated in synchronized combination with infrared pulses enable pulse-probe studies – one input pulses a target system to yield a subpicosecond of special physical conditions for the other input to probe.

In solid-state physics and materials science, pulse-probe applications could include, the temporal dynamics of condensed-matter phase transitions, the ultrafast time-resolved monitoring of structural changes in materials, and heat propagation at submicrometre dimensions. In biology and chemistry, the capability could be applied to studies of short-range order changes in chemical reactions. In accelerator physics it could be used to develop beam diagnostics for next-generation light sources.

The Jefferson Lab is responding to a call for proposals for the development and application of short-pulse X-ray light sources. The lab's development of high-average-power FELs is an application of the superconducting radiofrequency accelerating technology, which is at the heart of the 6 GeV continuous-wave accelerator that serves nuclear physics. In July a kilowatt FEL, built mainly with Navy funds, delivered 3.1 μm wavelength light at an average power of 1.72 kW (*CERN Courier* September 1999 p7). Funding has been allocated for an upgrade that will enable the delivery of 10 kW infrared light and 1 kW ultraviolet light.

HAPPEX probes 'sea' of nucleon strangeness

The proton is not strange. This is the conclusion drawn from the initial results of an experiment at the Jefferson Laboratory, Newport News, Virginia, which cast new light on the deep interior of nuclear particles.

Classically, the proton is understood to contain three "valence" quarks – two "up" and one "down". However, in 1987 the European Muon Collaboration experiment at CERN revealed that only about 30% of the intrinsic angular momentum (spin) of the nucleon is carried by the quarks. Ever since, physicists have been searching for the missing spin-carrying component.

All subnuclear particles contain a skeleton of valence quarks along with a fluid "sea" of transient quarks and antiquarks, and gluons, which transmit information between quarks.

In the case of the proton, the composition of this sea would not necessarily be limited to light up and down quarks but could also contain some of the heavier and more exotic quarks, particularly the "strange" quark, which makes up particles that are not normally found in our world.

One possibility is that this fluid sea contributes to the missing spin of the parent particle. To investigate this, the Hall A Proton Parity Experiment (HAPPEX) was commissioned at the Jefferson Laboratory CEBEF electron accelerator. The idea was to scatter a beam of high-energy polarized (spin-oriented) electrons and look at the spin distribution of the scattered electrons.

When electrons "bounce" off protons in this way, the bounce can be mediated either by an electromagnetic photon, or by the neutral Z carrier of the weak force. The delicate interference of these two effects depends on the way in which the electrons interact with the quarks in the proton. This produces a characteristic left-right asymmetry in the scattered beam. In particular, any strange quarks should contribute to this asymmetry in a different way from the more prominent up and down quarks.

HAPPEX used a 100 μA continuous beam of 3.356 GeV polarized electrons, which were derived from a laser-driven semiconductor photocathode. To measure the asymmetries – expected to be at the level of parts per million – any correlation between the beam's spin alignment and intensity was avoided by using a sophisticated feedback system.

The asymmetry measured by HAPPEX is -14.5 ± 2.2 ppm, which does not indicate a significant contribution from strange quarks. However, to reach a definitive conclusion, more data are needed to isolate the charge and magnetic contributions to the asymmetry.

HAPPEX completed a new run last summer that will decrease the present experimental uncertainty by a factor of two. The experimenters say that the success of this experiment bodes well for the future use of these techniques as an incisive probe of subtle effects in nucleon and nuclear structure. The high intensity, together with the high polarization of the electron beam (up to 70%), is a major achievement.

New data centre is opened at Brookhaven

Brookhaven and the State University of New York at Stony Brook have established a new centre for data-intensive computing at Brookhaven. James Gliman, Professor of Applied Mathematics and Statistics at the State University of New York, is director.

When Brookhaven's new Relativistic Heavy Ion Collider begins physics research, the large number of particles that will be produced per collision will generate a huge volume of data. Brookhaven is also one of the US national data centres for the ATLAS experiment at CERN's LHC proton collider, which is scheduled to begin operation in 2005.

In other areas of science, Brookhaven, site of the US National Synchrotron Light Source, is becoming increasingly involved in determining the structures of proteins.

SAMBA talks detector applications

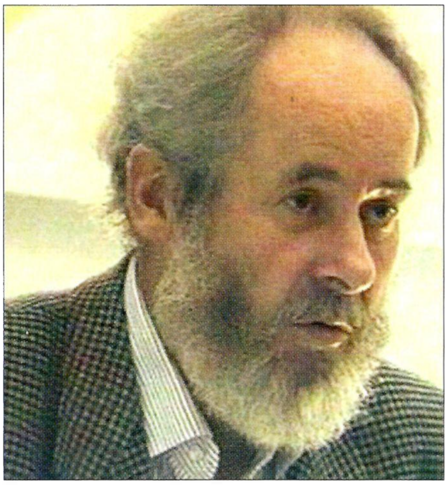
High-energy physicists are proud that their instrumentation, which was developed for their research, has widespread applications in other fields. A recent symposium Special Applications of Particle Detectors in Medicine, Biology and Astrophysics (SAMBA), proved that this was not just wishful thinking.

The meeting, in Siegen, Germany, on 6–8 October, was highly cross-disciplinary, to the extent that it was sponsored by the Siegen Research Institute for Social Science and Humanities. The meeting highlighted the contribution of applied physics to our culture and to social prosperity.

After the formal opening by Siegen mayor Ulf Stötzel, Amos Breskin (Weizmann Institute, Israel) surveyed novel, large-area gas avalanche imaging photomultipliers for applications in the assessment of radiation damage to DNA, digital mammography and in the early detection of cancer. These aspects were underlined by Fulvia Arfelli (Trieste) who reported on the demanding diagnostic problems faced to reveal microcalcifications as possible indicators of breast cancer.

The prospects for macromolecular crystallography, particularly for proteins, using synchrotron facilities were presented by Peter Laggner (Graz, Austria). The development of multiwavelength anomalous dispersion techniques has transformed the method from an academic specialist's playground into a large-scale, high-throughput industry. The importance of time-resolved measurements in X-ray structure analysis was emphasized for small- and wide-angle diffractive scattering experiments on non-crystalline materials.

The jump-relaxation technique opens up time domains down to microseconds, where supramolecular structure processes, induced by a change of parameters such as pressure, temperature or chemical environment, can be analysed. This kind of experiment calls for the development of new, fast, high-resolution and high-rate detectors so that the brilliance of the powerful synchrotron radiation sources, today and in the near future, can be exploited fully. With such experimental facilities designed as multipurpose, multi-user instruments, requirements emerge for new integrated approaches to measurement and detector control, fast data compactification, and artificial intelligence in the evaluation of multiframe results.


Gerhard Kraft from GSI Darmstadt described the impressive successes of tumour therapy with carbon ions.

Commercial imaging systems for medical applications were reviewed by Detlef Mattern (Siemens/Erlangen). Despite ongoing attempts to switch to directly converting detectors, scintillators are still widely used for medical imaging. In radiography, computer tomography and nuclear medicine, a variety of scintillating devices are the workhorses in today's clinical practice.

For radiography, flat X-ray detectors with evaporated scintillation layers are not far away. However, X-ray image intensifier tubes are competitive, and have features like speed and dynamic range that are still hard to beat. Although X-ray image intensifier tubes have disadvantages like size and weight, they give more robust image quality and have become cheaper over the decades. Detectors in computer tomography have evolved from scintillators into gaseous direct converters and back to scintillators again. Extreme timing requirements and detector modularity have ruled out designs that would rank as high performance in other fields.

The domain of nuclear medicine is a good example of how difficult it is to replace cheap and reliable technology. For many years, direct converters like cadmium telluride have been proposed as replacements for NaI(Tl) scintillation counters. However, for cost it is difficult to beat this light, high-output scintillator when used in combination with the practically noiseless photomultiplier. New ultracompact multianode photomultiplier designs could even make gamma cameras more compact without using directly converting detectors.

A highlight of the meeting was the talk by Gerhard Kraft (GSI Darmstadt, Germany) on the instrumentation for tumour therapy, which uses heavy-ion beams. Taking advantage of the Bragg peak at the end of the range of charged particles and the nonlinear biological sensitivity to the energy deposit, the small difference in destructive efficiency between healthy cells and cancer cells becomes sufficient to destroy well localized tumours accurately. Short-lived beta emitters, formed by carbon-12 beam fragmentation, are used to monitor the results via PET imaging.

High-granularity pixel counters, such as those being prepared for experiments at CERN's LHC, are also used as focal detectors for X-ray astronomy. Lothar Strüder (Max Planck Institute for Extraterrestrial Physics, Munich) described the results of the ROSAT and Chandra missions, where radiation damage of semiconductor counters, caused by the Earth's radiation belts, has to be taken into account. Similar problems concerning radiation hardness also have to be mastered for LHC detectors.

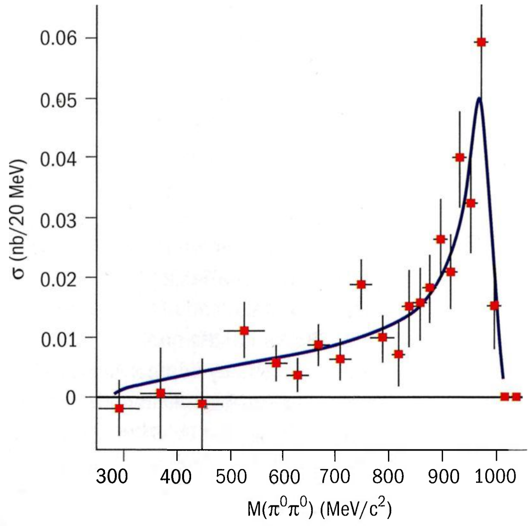
Allan Hallgren (Uppsala) concentrated on particle detectors for astrophysics. He described the virtues of neutrino astronomy using the Antarctic ice as Cherenkov medium. The search for dark matter, using cryogenic detectors, was covered by Klaus Pretzl (Bern). These cryogenic systems are also promising candidates for a new generation of particle trackers to be used in future accelerator experiments.

A public lecture by Claus Grupen (Siegen) entitled "Applications of particle detectors in astrophysics" attracted a good audience.

The meeting was organized jointly by H J Besch, C Grupen, N A Pavel, A Taune and A H Walenta. The proceedings will be published in a special volume of *Nuclear Instruments and Methods*.

Participants requested a follow-up meeting in this interdisciplinary field of detector applications. More information can be found at "http://www.physik.uni-siegen.de/samba/".

Siberian searchlight on rare decay



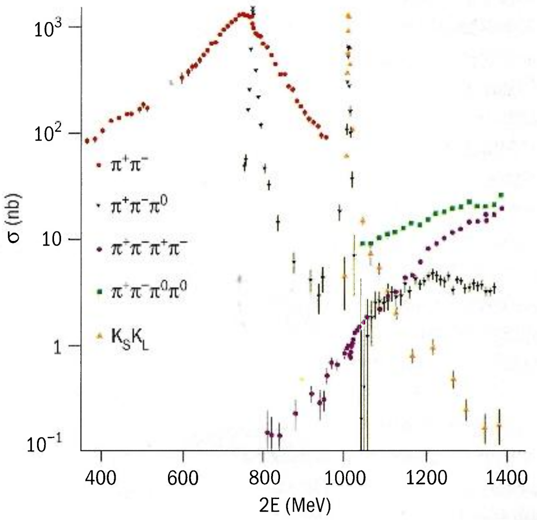


Fig. 1 (left): The first observation of the electric dipole transition to $f_0(980)$ and a photon at Novosibirsk's VEPP-2M electron–positron collider.

Fig. 2 (right): The energy dependence of the major processes that contribute to electron–positron annihilation into hadrons at VEPP-2M.

The VEPP-2M electron–positron collider, which has been running at the Budker Institute of Nuclear Physics, Novosibirsk since 1974, amassed more than 4×10^7 phi mesons before the start of the new Italian DAFNE phi factory. With a fairly high luminosity of 3×10^{30} cm^{-2}/s at the phi meson (1.02 GeV), VEPP-2M's flexible magnetic lattice allowed operation in the pion production threshold to 1.4 GeV collision range.

Two detectors were installed for a series of experiments that started in 1992: CMD-2 (cryogenic magnetic detector) – a general purpose detector with a drift chamber inside a 1 ton superconducting solenoid, barrel caesium iodide, and endcap bismuth germanate electromagnetic calorimeters; and SND (spherical neutral detector) – a non-magnetic detector with an almost complete angular coverage sodium iodide calorimeter.

These detectors have been successfully complementing each other in their quest for rare decay modes of the rho, omega and phi mesons as well as high-precision measurements of hadronic reaction rates.

Among numerous accurate measurements of various phi decay modes is the first observation of the electric dipole transition to $f_0(980)$/photon (figure 1) and to $a_0(980)$/photon. A high branching ratio of about 10^{-4} may indicate an exotic four-quark structure of these enigmatic scalar particles.

Another radiative phi decay, to eta/photon, observed by both detectors, is the missing link in a long chain of magnetic dipole transitions among the vector and pseudoscalar mesons, which consist of light quarks. Also of interest to theorists are doubly suppressed decays, to two charged pions, to an omega/neutral pion and to four charged pions.

In addition to the search for rare decay modes of the vector mesons, low-energy measurements of the total electron–positron annihilation cross-section R will allow the precise calculation of the hadronic vacuum polarization, which is currently a limiting factor in other precision analyses. The goal is to measure R to an accuracy greater than 1%.

The dominant contribution below 1 GeV comes from the simplest hadronic reaction, which produces charged pion pairs. Of more than 2 million pion pair events detected by CMD-2, about 150 000 have been analysed in the rho meson energy range (610–960 MeV). Thorough analysis of possible systematic effects allowed the final cross-section to be measured with a systematic uncertainty of only 0.6%.

Other achievements include the measurement of three- and four-pion production above the phi meson. The cross-section for annihilation into three pions (two charged) determined by SND agrees with the previous measurement, but it is more precise and shows peculiar behaviour that is consistent with the existence of the omega at 1200 MeV rather than 1420 MeV as recommended by previous interpretations. Analysis of this channel by CMD-2 is still in progress.

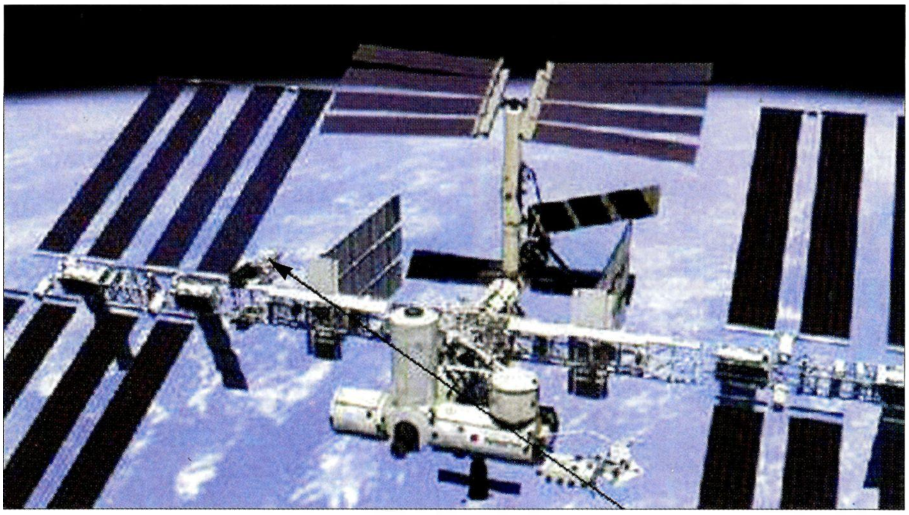
Both groups measured two possible final states of the four-pion production with consistent results. The elegant analysis at CMD-2 of intermediate mechanisms leading to the four-pion final state is also important. While for two charged and two neutral pions the omega/neutral pion and $a_1(1260)$/pion channels contribute, it is the latter that saturates the final state with four charged pions.

High luminosity allows the measurement of much smaller cross-sections, at the level of 0.5 nb and below. This is important for the precise determination of R. Figure 2 gives a general impression of the energy dependence of the major contributing processes.

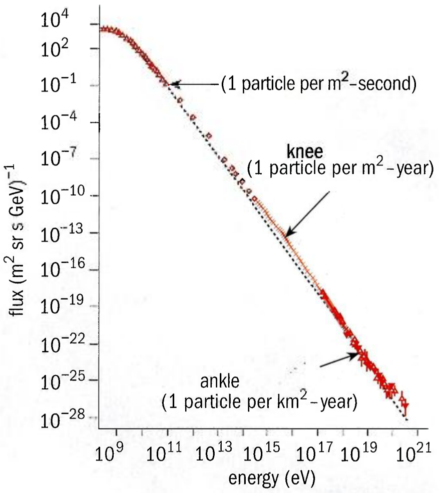
However, VEPP-2M is probably facing its last season. The Budker Institute recently proposed revamping the collider by implementing "round beams" as well as superconducting magnets to increase luminosity and energy. The design foresees flexible operation in the threshold to 2 GeV broad collision energy range, with a maximum luminosity of about 10^{32}, which covers vector meson recurrences and gives a dominant contribution to the uncertainty of important hadronic corrections.

Construction of the new collider as well as the planned upgrade of both detectors should start in 2000, thus justifying the tentative name of the new machine – VEPP-2000.

ACCESS intercepts cosmic rays



The ACCESS cosmic-ray experiment will be mounted on the International Space Station.



The cosmic-ray energy distribution shows remarkable uniformity over 10 orders of magnitude. However, there are two kinks. The ACCESS experiment is designed to investigate "the knee" (near 10^{15} eV).

NASA's Goddard Space Flight Center is coordinating a study, by an international collaboration, of a high-energy cosmic-ray instrument for the International Space Station. The Advanced Cosmic-Ray Composition Experiment for the Space Station will study cosmic-ray nuclei at around 10^{15} eV in energy to understand better the mechanisms by which particles in the galaxy are accelerated to such high energies.

The Advanced Cosmic-Ray Composition Experiment for the Space Station (ACCESS) will complement terrestrial cosmic-ray air-shower arrays and balloon-borne experiments. It will have the advantage, however, of being able to intercept the incident cosmic rays in space directly rather than observing the showers that they produce when they interact with the atmosphere. This will allow ACCESS to determine the chemical composition of the high-energy cosmic rays directly and should lead to a better understanding of how particles are accelerated in the galaxy. A flight is planned for 2006.

The cosmic-ray energy distribution shows a remarkably uniform slope over many orders of magnitude. There are, however, two kinks in the distribution. One – the "knee" – occurs near 10^{15} eV. The second – the "ankle" – is below 10^{19} eV. Near both energies, cosmic rays have attracted considerable interest. Above about 5×10^{19} eV, cosmic rays should not exist. If they originate from a distant source, then their energy should have degraded through interaction with the cosmic-microwave background radiation. If they originate nearby, then it would be surprising if we had not already detected the accelerating source. Thus their origin remains a mystery.

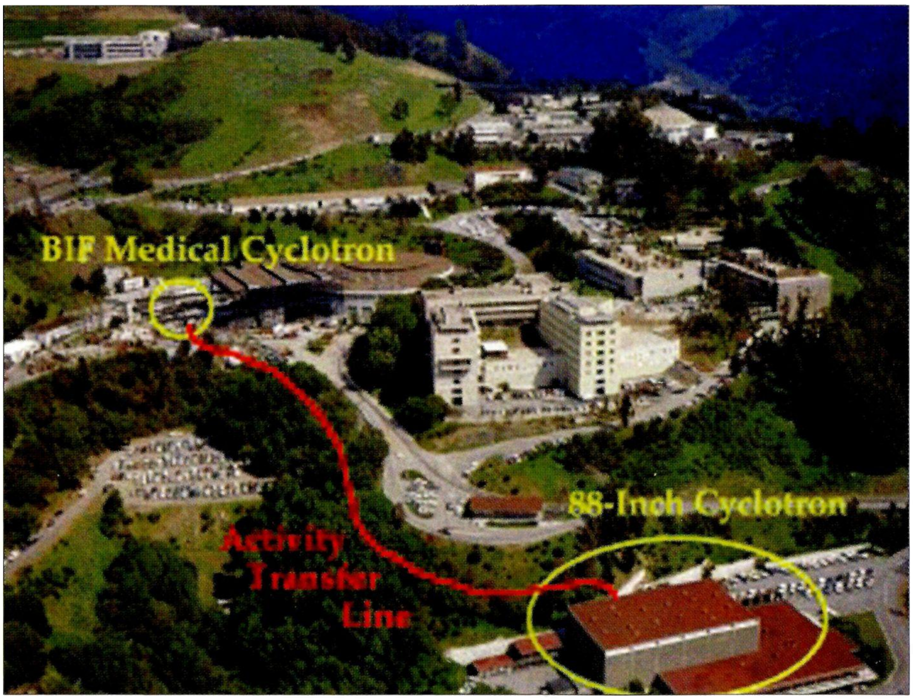
Studying such events is hampered by the extremely low frequency of the cosmic rays; above 10^{20} eV around $1/km^2$ per century is detected. However, at the knee, where ACCESS will concentrate its efforts, the rate is about a billion times as high and theories exist for an acceleration mechanism. The most popular theory involves shock waves from supernovae. These will accelerate not only particles blown out in the supernova explosion but also any particles that they encounter as they spread throughout space.

Shock-wave acceleration can account for the cosmic-ray spectrum out to about 10^{14} eV but has difficulty in going much further. Two possible explanations have been suggested to explain the observation of cosmic rays at higher energies, and ACCESS will be able to distinguish between them. The first assumes that the supernova shock-wave model is essentially correct. This would accelerate protons to 10^{14} eV and heavier elements up to higher energies. Iron, for example, would reach 3×10^{15} eV. Another, unknown, mechanism must then be invoked to explain the spectrum at higher energies, with the kink in the distribution being due to overlap between the two mechanisms and the progressive change in chemical composition as the knee is approached. Candidates for the mechanism include rotating compact magnetic objects, such as neutron stars, or black holes.

The second potential explanation postulates a smooth energy distribution up to the highest cosmic-ray energies with some, as yet unknown, loss mechanism beginning to take effect at about 10^{15} eV and giving rise to the observed kink. By measuring the chemical composition of the cosmic rays at 10^{15} eV, ACCESS will be able to put the first explanation to the test.

ACCESS is an experiment at the overlap between terrestrial particle physics and astrophysics. The particle detector technologies originate in particle physics experiments but are being pushed to their limits by the volume and weight constraints of a space-borne experiment. The ACCESS team recently tested potential designs for its calorimeter and Transition Radiation Detector in test beams at CERN. The final ACCESS detectors will be calibrated in CERN beams before launching the instrument into space, where it will measure cosmic rays at energies more than 1000 times as great as current accelerators can deliver.

BEARS deliver radioactive species



The BEARS project has delivered its first radioactive beam. It includes a specially built 300 m long, 15 cm diameter transfer line.

Understanding how the strong force binds nucleons together to form light nuclei and how stars synthesize heavier nuclei is fundamental to our comprehension of the universe. The study of stable and unstable nuclei leads to an improved knowledge of nuclear structure, the limits of nuclear stability and the nature of interactions between protons and neutrons. Accelerator-produced radioactive species will provide a critical source of proton- and neutron-rich nuclei to further these studies.

Lawrence Berkeley National Laboratory's Berkeley experiments with accelerated radioactive species (BEARS) project has achieved a major goal with the delivery of its first radioactive beam – 1–2 × 10^8 ions/s of 110 MeV carbon-11 onto a gold target for a period of 4 h – for a study of the yields of astatine isotopes. BEARS is led by Joseph Cerny, Professor of Chemistry at the University of California and LBNL Nuclear Science Division, with other researchers from the Nuclear Science Division, the Life Sciences Division of LBNL and from the Brookhaven National Laboratory. The project produces radioactive beams, for use in nuclear studies, at a modest cost by using existing cyclotrons. Efforts are focused on this coupled cyclotron approach, which uses one cyclotron to produce a radioactive isotope and a second one to accelerate it.

The group began proof-of-principle experiments using carbon-11 with a half-life of 20 min. The carbon-11 is made at Berkeley's 88 inch cyclotron by bombarding nitrogen-14 with protons. The carbon-11 combines with a small amount of oxygen to form CO_2. This was transported by gas jet to a reservoir near the electron cyclotron resonance ion source (ECR) and cryotrapped with liquid nitrogen while the carrier gas was pumped away. The trap was then warmed up and the carbon-11 was fed into the ECR to test the efficiency of the ion extraction. The ions were extracted. However, the efficiency was low.

The next step was to produce batches of carbon-11 at the Biomedical Isotope Facility cyclotron, which is an 11 MeV, 30 μA proton machine. Higher yields were achieved using a high-pressure gas target and the higher beam currents available. The carbon-11 (as CO_2) was trapped in a coiled stainless steel tube submerged in liquid nitrogen and brought by truck to the 88 inch cyclotron. The liquid-nitrogen trap was warmed and the carbon-11 was fed into the advanced ECR (AECR) source, ionized and extracted, with 10% efficiency, as a 4^+ charge beam of ions. The carbon-11 was injected into the 88 inch cyclotron and the beam was tuned using 8^+ neon-22. After the beam optics had been completed with neon, the cyclotron's radiofrequency was shifted a few kilohertz to bring carbon-11 into resonance. A foil before a key bending magnet completely stripped the ions of electrons. This allowed the separation of contamination from the ECR source. The typical extracted beam speed was 3 × 10^7 ions/s.

With the success of these experiments, the construction of a 300 m transfer line between the two cyclotrons was begun. Previous tests had shown that the transfer time over this distance was 20 s. A 150 mm rigid outer pipe was installed between the cyclotrons about 1 m off the ground with access boxes every 30 m. Then a 50 mm vacuum hose was pulled through the pipe. Finally, a bundle of capillaries, varying in size from 3 to 10 mm in diameter, was pulled through the 50 mm hose. The pressure in the hose was maintained at 1 Torr. The integrity of the system was monitored for pressure loss, continuity and radiation levels. This system exceeds stringent laboratory safety requirements. The BEARS group also worked closely with the Environmental Health and Safety Division. Close co-operation among all three divisions was instrumental in the project's success.

On completion of the transfer line, a successful commissioning run used carbon-11 in the form of CO_2, which was produced at the Biomedical Cyclotron and released in batches of 3 × 10^{13} molecules down the transfer line at 5 min intervals. At the 88 inch cyclotron the CO_2 was caught in a cryotrap and slowly released into the AECR. The entire process was automated and was controlled and monitored by computer. Between 1 and 2 × 10^8 ions of 11 C/s were available on target.

Future plans will envolve the development of other short-lived radioactive beams, which will include nitrogen-13, oxygen-14, and fluorine-17 and -18 for nuclear physics and nuclear astrophysics experiments.

New meson physics pushes on in 2000

The CLEO collaboration in front of its detector at Cornell's CESR electron–positron collider. CLEO has undergone several facelifts in its 20 year history.

On 9–10 December a symposium at Cornell University, Ithaca, New York, will mark the 20th anniversary of the Cornell Electron Storage Ring, the CLEO particle detector and the Cornell High-Energy Synchrotron Source. It will also herald the beginning of a new era of B meson physics and a new generation of synchrotron radiation beamlines.

The Cornell Electron Storage Ring (CESR) is now completing a major upgrade with the goal of producing more than 15 million B meson pairs per year. Simultaneously the CLEO detector is installing a new silicon vertex detector, drift chamber and ring-imaging Cherenkov counter. Accelerator commissioning has begun, and data collection is expected to begin in early 2000. The CESR and CLEO upgrades will open the door to studies of CP violation, rare B decays and precision measurements of quark mixing. Cornell is a major player in this new physics push (*CERN Courier* October p22).

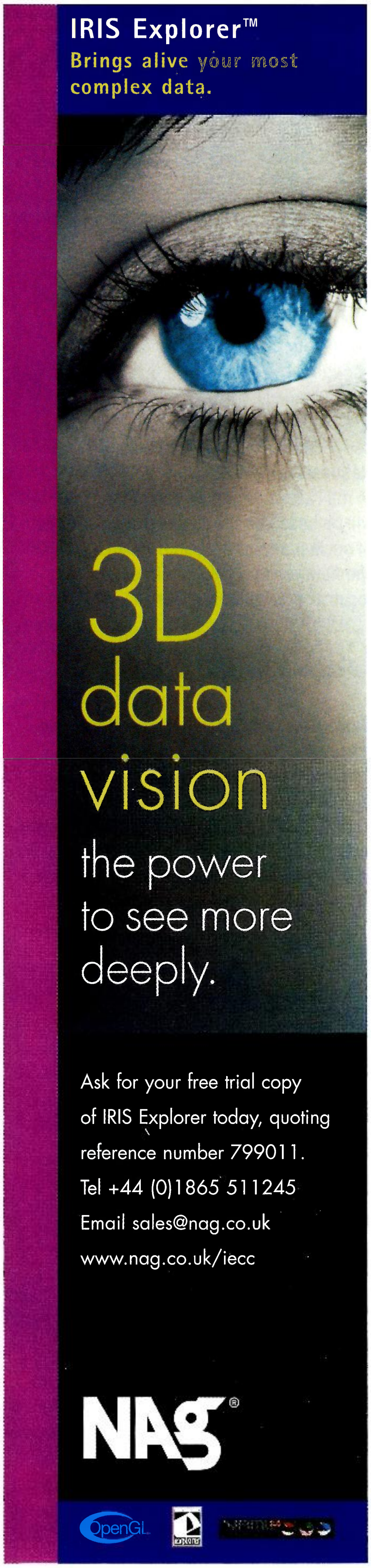
In parallel with the CESR/CLEO upgrade, the Cornell High-Energy Synchrotron Source (CHESS) is upgrading its X-ray optics. Construction of a building to house three new, ultrahigh flux X-ray stations is well under way.

In the past 20 years, CESR and CLEO have provided much of the world's knowledge on heavy quark and lepton physics. Highlights have been the discoveries of the B meson (CLEO, CUSB 1979–1980), the first observation of transitions between the bottom and up quarks (CLEO, 1990) and the first direct sighting of "penguin" decays (CLEO, 1993).

More information can be found at "http://www.lns.cornell.edu/symposium.html".

Correction

We regret that the Polish group from Lodz was omitted from the article "WASA meson detector inaugurated" (*CERN Courier* October p8). This group is responsible for the build-up and maintenance of the light pulser monitoring system, to which it has contributed at all stages of the CELSIUS/WASA programme.



ASTROWATCH: ITALY

Edited by Emma Sanders

Astrowatch turns its gaze to Italy, a country where astronomy research has been growing in popularity remarkably fast.

Italian astronomy enters new era

Astronomers in Italy will soon have a new coordinating body – the National Institute of Astrophysics – to regroup the 12 national observatories and strengthen ties with university astronomy departments and the 8 astronomical research institutes of the National Research Council.

The National Institute of Astrophysics (INAF) will be based on the successful organization of nuclear physics research within the INFN. The new administration looks set to bring together new collaborations.

"Any individual establishment was not really in a position to have dialogue with the INFN," said Franco Pacini (director of the Arcetri observatory and president-elect of the International Astronomical Union), who is very much in favour of the new arrangement. "Both communities will now profit."

Pacini identified instrumentation as one of the areas where collaboration could be beneficial. "Although classical astrophysics, with all kinds of instruments, is still providing the main ground for understanding the universe [the existence of dark matter was proven by observational astronomers], gravitational waves and particle astrophysics will become very important in the coming decades. Astronomers know better what's around us; physicists are much more sophisticated in their experiments. With more interactions and joint ventures, INAF and INFN will benefit from each other."

The INAF president and board will be selected before the end of the year and will become operational within about six months.

Galileo telescope

Galileo, the new 3.5 m Italian national telescope, will soon be open to astronomers. Situated on the Roque de los Muchachos Observatory in the Canary Islands at an altitude of 2400 m, its prestigious neighbours include the UK-Dutch Isaac Newton telescopes and the Nordic Optical telescope. Galileo saw first light in 1998. Operational problems with its controls are now resolved.

Picture of the month

Italy has two 32 m radio telescopes, this one in Noto, Sicily, and another in Medicina. They will form part of the worldwide Very Long Baseline Interferometry network of radio telescopes. A 64 m radio telescope is planned for Sardinia. (IRA, Noto.)

VIRGO advances at Pisa

When Galileo dropped cannon balls from the top of the leaning tower of Pisa early in the 17th century, he demonstrated that all bodies fall with equal acceleration. It is fitting, therefore, that Pisa will be the home of a remarkable new gravity experiment – VIRGO.

Einstein predicted the existence of gravitational waves, which are generated by perturbations in space–time. Examples of strong sources of gravitational waves include supernova explosions, binary star systems, interacting black holes and even the Big Bang. The weakness of the force of gravity makes it extremely difficult to detect gravitational waves. Astronomers only have indirect proof of their existence from observations of orbiting neutron stars.

VIRGO will attempt to make direct measurements of these gravitational waves. The experiment will consist of a laser interferometer with two 3 km perpendicular arms. As gravitational waves distort space–time along perpendicular directions, the waves will either lengthen or shorten the arms of the interferometer and this will show up when the laser beams are recombined.

Incredible accuracy is required; VIRGO will use the first of a new generation of ultrastable lasers and the mirror surfaces will be accurate to one hundredth of a micrometre. The mirrors will be suspended on a system of five pendula to eliminate seismic noise.

VIRGO is a collaboration between France and Italy. The facility is due to open in 2001. A similar project, called LIGO, is being built in the US, and other groups are working on cryogenic resonant bar detectors for gravitational waves (*CERN Courier* March p10).

Double vision aids high resolution

The largest telescope in the northern hemisphere will be the Large Binocular Telescope (an optical infrared interferometer) at Mount Graham in Arizona. It will have two 8.4 m primary mirrors (mounted on the same support structure), which will give a light-collecting area equivalent to that of a 12 m telescope. The design is different from other large telescopes and astronomers are looking forward to interesting high-resolution studies.

The European Southern Observatories' Very Large Telescope (VLT) is an interferometer with four telescopes (*CERN Courier* April p11). Its resolution will be 5 times as great as that of the Large Binocular Telescope (LBT). However, more signal will be lost through the complicated VLT optics, so the LBT will be able to observe much fainter objects.

The mechanical structures of both telescopes are being built in Italy by Ansaldo. The US and Germany are collaborating in the LBT project. Commissioning should finish by 2003.

Edited by Alison Wright

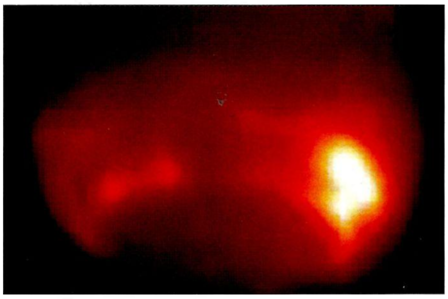
Except where otherwise stated, these news items are taken from the Institute of Physics Publishing's news service, which is available at "http://physicsweb.org".

Chilled-out mirrors give a sharper image

The quality of images that are obtained from ground-based telescopes has been revolutionized by the advent of adaptive optics. In this system, parts of the telescope mirror are continuously adjusted to compensate for the effect of atmospheric turbulence on the incoming signals. Researchers in Paris have proposed a similar adaptive system to cool the thermal motion of mirrors used in interferometers, such as the gravity wave hunters LIGO and VIRGO.

Researchers shone laser light onto a mirror and detected phase shifts in the reflected light, which were caused by the thermal motion of the mirror. By feeding this signal back into the system, the laser could be adjusted such that its radiation pressure cancelled the mirror's Brownian motion.

This cooling mechanism can reduce thermal noise by a factor of 20. This implies a spatial sensitivity of around 10^{-19} m for interferometer mirrors. *AIP*



A cloud the size of Europe can be seen in this infrared image of Neptune. The picture was taken with the Palomar High Angular Resolution Observer camera, which is mounted on the Hale telescope in California. The adaptive optics system includes a computer-controlled mirror adjusted up to 500 times per second to compensate for distortions caused by turbulence in the Earth's atmosphere.

Memories of light

Today, computers use electrons travelling in metal wires to process and store information. In the optical computers of the future, these tasks will be performed by photons travelling in optical fibres or thin films. However, one of the toughest challenges yet to be faced is building high-speed optical memory. Now Japanese researchers have discovered a possible solution.

A powder sample of samarium-doped ZnS nanocrystals (3 nm in diameter) was irradiated with laser light and the resulting excitation spectrum revealed a hole, which matched the wavelength of the irradiating laser. This "hole burning" effect has been observed before.

The sample was then rotated with respect to the incoming radiation. When the sample was moved through only a few tenths of a degree, the original hole in the excitation spectrum vanished. By making holes at various wavelengths and differing angles, it was demonstrated that the "data" (wavelength and incoming angle) were being stored with high resolution.

The scientists suggest that what is recorded are the interference patterns of multiple-scattered light in the sample, and this could eventually be used for effective three-dimensional data storage in optical systems.

Buckyballs generate waves

The interference pattern formed by particles passing through a grating is a distinctive signature of the duality of quantum particle and wave behaviour. Electrons, neutrons and even small molecules produce such patterns, and now scientists in Vienna have moved up an order of magnitude with the observation of the first interference patterns for carbon-60 molecules (buckyballs).

The team directed a collimated beam of carbon-60 molecules through a silicon nitride grating with 50 nm slits and a period of 100 nm. With a velocity of 220 ms^{-1}, the de Broglie wavelength for the molecules was 2.5 pm – which is 400 times less than their diameter. Allowing for van der Waals effects between the grating and the carbon-60 molecules, the researchers saw a pattern with a central maximum and first-order diffraction peaks that matched predictions for a carbon-60 molecule interfering as a wave.

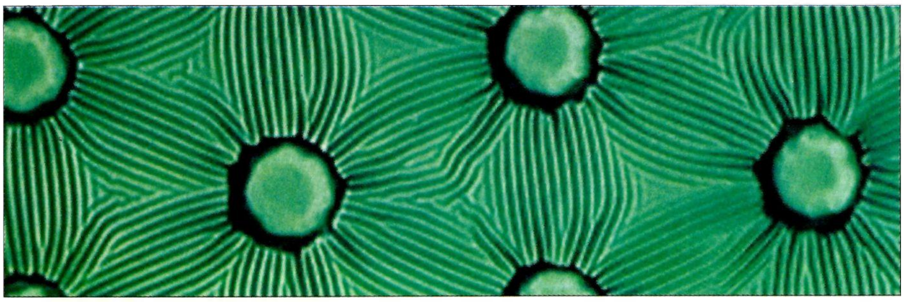
Now the team plans to repeat the experiment, using larger molecules or even viruses, to investigate at what scale classical physics takes over from the quantum duality of wave and particle.

SETs raise standards in accuracy

Almost 40 years ago, when the metre was redefined in terms of the wavelength of radiation emitted from a transition in the krypton atom, quantum physics entered the International System of Units. More recently, standards for voltage and resistance have been set by quantum effects (known as the Josephson and quantum Hall effects respectively). Now the US National Institute of Standards and Technology in Colorado has also placed the measurement of capacitance on a quantum basis by exploiting the new technology of single electron transistors.

In a piece of apparatus that is cooled to 40 mK, single quanta of electric charge are able to tunnel through a system of single electron transistor (SET) junctions. These packages of electrical charge are collected on a capacitor. By measuring the resulting voltage change across the capacitor, its capacitance can be determined to an accuracy of 1 ppm without the frequency dependence that has dogged previous standards. The National Institute of Standards and Technology ultimately hopes for an accuracy of 0.01 ppm. *AIP*

Undulating microstructures



Micro-upholstery – a silica coating on a heated polymer buckles as it cools to form waves in the surface. A template, like these 30 µm diameter circles on the polymer, causes the waves to form as ordered microstructures.

Harvard scientists have found a novel way to make micrometre-sized structures.

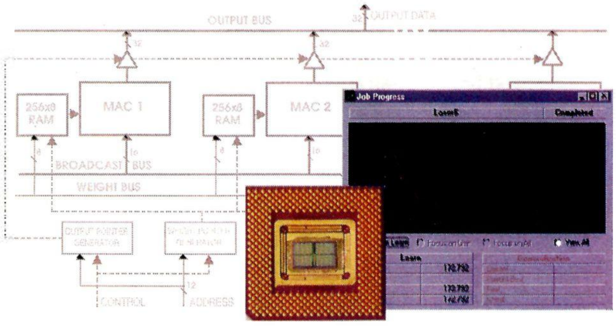
When a film of elastic polydimethylsiloxane (PDMS) on a glass slide is heated to 250 °C and exposed to oxygen, a silicate crust is formed. As the sample cools down, the silicate layer buckles to form waves across the surface. The wave structures can be made with wavelengths as short as 0.5 µm and can be ordered on larger scales by introducing a pattern on the polymer layer to act as a template. Diffraction gratings, and printing and lithographic devices are likely applications of this new technique. The microstructures could also be used as surfaces on which cells could be grown and oriented.

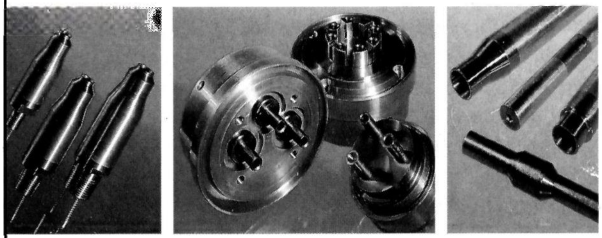
AIP

Core calculation

To build an accurate model of the Earth's interior, a thorough knowledge of the high-pressure thermodynamic properties of iron is required. (Iron is the principal component of the Earth's solid inner core and its liquid outer core.) Physicists working at University College London have devised a way of determining the core temperature as a function of pressure. The calculation is based on density functional theory.

Simulation on a Cray T3E supercomputer predicted temperatures for core pressures of between 50 and 350 GPa. The results matched the existing data from shock experiments well. For the expected pressure of 330 GPa, at the boundary between the inner and outer core, the new calculation gives a temperature of 6670 ± 600 K, which is a useful constraint on models of the core, and is also important in our understanding of the Earth's magnetic field, earthquakes and volcanic activity.





40 years of CERN's Proton Synchrotron

The team that coaxed the protons from CERN's Proton Synchrotron through the "transition energy" and up to 24 GeV on the night of 24 November 1959. Left to right: John Adams, Hans Geibel, Hildred Blewett, Chris Schmelzer, Lloyd Smith, Wolfgang Schnell and Pierre Germain.

CERN's Proton Synchrotron achieved its first high-energy beams 40 years ago. The pioneers at CERN had dared to follow a new, untested route in a bid to become the world's highest energy machine. Now, 40 years later, the valiant Proton Synchrotron remains the ever-resourceful hub of an unrivalled particle beam network.

On 24 November 1959, CERN's new Proton Synchrotron accelerated protons through the dreaded "transition energy" barrier and on to achieve the nominal energy of 24 GeV. Could any of those rejoicing on that historic day have thought that their machine would still be alive and well 40 years later, or that it would be the hub of the world's largest complex of accelerators, at the centre of European high-energy physics? If such thoughts were on their minds, they certainly would not have extended so far in time or in performance.

When operation for physics began in 1960, the Proton Synchrotron (PS) delivered 10^{10} protons per pulse. Since then, 40 years of relentless effort has improved the performance more than a thousandfold. Today the PS delivers 3×10^{13} protons per pulse.

The early history – the decision to build the PS, the courageous step from a weak-focusing to a strong-focusing synchrotron, its design, construction and legendary start-up – has been told before. Instead we look at the evolution that has led to today's PS, the complex that has grown around it and the assured future that awaits it.

History 1959–1999: protons

The performance of the PS has increased, partly through patient optimization and partly owing to specific steps taken to cope with CERN's evolving physics programme. In June 1960 the Parameter List showed a "best performance" of 6×10^{10} protons per pulse and further progress was rapid (figure 2).

Physics quickly benefited from Europe's new high-energy proton source. In the first year of operation, internal targets supplied four

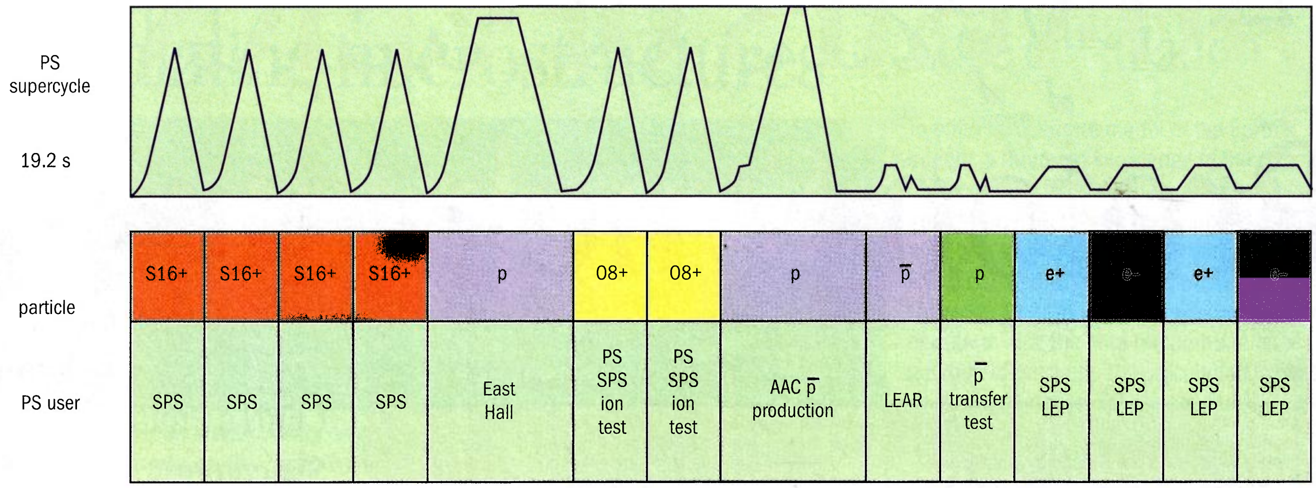


Fig. 1: A great variety of PS cycles are composed into a "supercycle", in which one user after another is served. In a particularly rich case, from August 1990, no less than six different kinds of particle (sulphur ions, protons, oxygen ions, antiprotons, electrons and positrons) were sequentially served to seven different destinations.

experiments in the South Hall with secondary particles for more than 1000 h. More beamlines came into operation in 1961. From 1963, fast and slow extraction supplied primary protons to the East Area. Between 1972 and 1975 they were supplied to the West Area.

Although the intensity had increased a hundredfold by 1964, the many particle-hungry users, and the prospect of having to supply the new ISR proton collider, triggered an improvement programme.

A new main magnet power supply would double the repetition rate. A new Booster – four superimposed synchrotron rings, one quarter of the PS diameter, taking 50 MeV protons from the Linac up to 800 MeV – would raise the PS space-charge limit by a factor of 10, to 10^{13} protons. Construction of the Booster began in 1968 and was completed in 1972. With it came an increase in PS intensity, which was welcomed by the ISR and the Gargamelle bubble chamber. A further increase in intensity came in 1978, when the new Linac 2 replaced the original one. Today the Booster more than triples its design intensity, routinely delivering 3×10^{13} protons per pulse, to the delight of the ISOLDE radioactive-ion beam users.

In striving for higher intensities, several obstacles had to be overcome. One was passing the transition energy in the PS causing the dilution of longitudinal phase-space density. This was remedied in 1970 by the "Q-jump" and then the "gamma-transition jump", in which pulsed quadrupoles make the protons traverse transition much faster. This trick came just in time for the much higher intensities generated by the Booster.

In 1976 the new SPS synchrotron became a welcome client. In 1970, in a deadlock over site selection for the new "300 GeV project", John Adams had proposed attaching it to the existing CERN site and use the PS as the injector, thereby consolidating the future of the machine he had built and of CERN as a whole.

The variety of users and their demands generated a need for the PS to deliver different beams on successive cycles. This was called pulse-to-pulse modulation, with a number of different cycles grouped into a "supercycle" (figure 1). It was a great challenge for the long sequence of ever more powerful controls computers, the first having been a 1967 IBM 1800.

When, in December 1991, the council declared that the LHC was the "right next machine" for CERN, the PS had to prepare for yet another client – a very demanding one. The LHC would need proton beams of unprecedented density. For the Booster and the PS, this entailed a number of drastic changes, the validity of which was tested extensively at the end of 1993.

The radiofrequency systems in the Booster and PS were radically modified for acceleration on new harmonic numbers. Intricate radiofrequency gymnastics for splitting and merging bunches were also introduced (figure 3).

To obtain high transverse beam densities, the blow-up of emittances must be strictly limited. In 1999 the harmful effects of space charge in the PS were reduced by raising the Booster energy to 1.4 GeV. To preserve emittance tightly requires measuring it accurately. Existing diagnostic tools were sharpened and new ones added.

> When operation for physics began in 1960, the Proton Synchrotron delivered 10^{10} protons per pulse. Since then, 40 years of relentless effort has improved the performance more than a thousandfold

Today, automatic beam steering alleviates the burden of optimization and will be an essential tool in meeting the LHC stringent emittance requirements.

Acceleration of ever higher intensities brings higher radiation doses to the machine components. The first radiation damage was recorded as early as 1964, after a total of 1.1×10^{19} protons had been accelerated. Strict measures were taken to reduce losses – figure 4 shows how successful these measures were – otherwise the total of 1.56×10^{21}

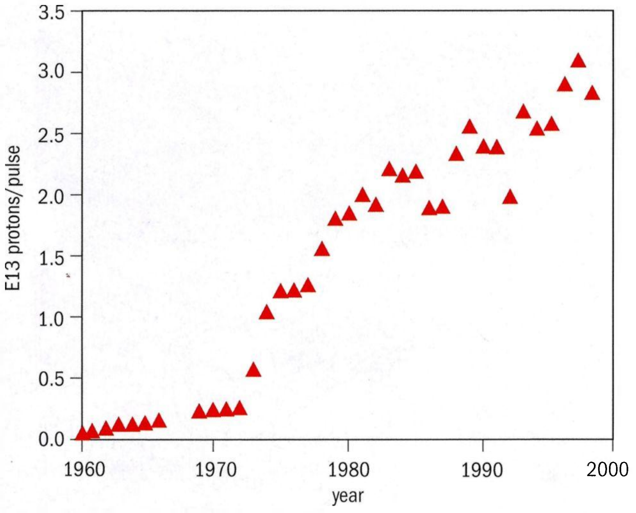


Fig. 2: PS peak intensity in protons per pulse. The linear scale, which was chosen to highlight the evolution since the early 1970s, does not reflect the rapid improvements in the early years. Apparent regressions in some years were caused simply by a lack of demand.

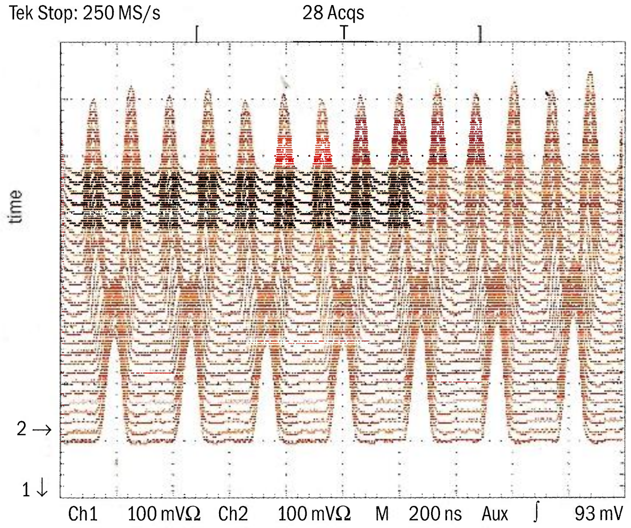


Fig. 3: "Bunch splitting", one of the many kinds of "radio frequency gymnastics" to make the PS beam palatable to the future LHC. At an intermediate stage the eight bunches, which were accelerated to 3.5 GeV/c, are split into 16, by adiabatically reducing the 3.69 MHz accelerating voltage (the 8th harmonic of the revolution frequency) and simultaneously raising the voltage of the 7.38 MHz 16th harmonic. The process lasts about 40 ms.

protons delivered so far would never have been reached. (The rest mass of all of the protons accelerated during 40 years of operation amounts to a mere 2.6 mg.)

Ions

Protons are not the only particles supplied. In 1964 the Linac produced deuterons of 12 MeV/nucleon and the PS accelerated them for a few milliseconds. In 1976 and 1977, deuterons were accelerated and transferred to the ISR for d-d collisions. When Linac 2 came into operation for protons, Linac 1 was left free for more ion studies.

In 1980, alpha particles were provided for the ISR. Heavier ions, oxygen and sulphur, were sent to the SPS. This whetted the physicists' appetite for the really heavy stuff. In 1990, in collaboration with several other European laboratories, the construction of a new Linac 3 for the acceleration of lead ions began. It was completed and running in 1994. In the same year, lead ions were accelerated through the PS and SPS.

In the Low-Energy Antiproton Ring (LEAR), oxygen ions were stored and cooled, using both stochastic and electron cooling. Because, for lead-lead collisions, the LHC requires denser beams than the ion source and Linac 3 can provide, the use of LEAR was proposed. Between 1995 and 1997 extensive tests of a scheme for the accumulation and cooling of lead ions in LEAR gave convincing results.

Physics quickly benefited from Europe's new high-energy proton source. In the first year of operation an internal target supplied four experiments in the South Hall with secondary particles for over 1000 h

Antiprotons

For CERN's antiproton programme, the PS became involved very early as a major contributor to the Initial Cooling Experiment to test stochastic and electron cooling. In 1978, the decision to go ahead with the Antiproton Project brought the Antiproton Accumulator (AA) to the PS. Apart from the construction of the AA, the PS had to prepare intense proton beams for antiproton production.

The AA started up in 1980, and in 1981 antiprotons were sent to the ISR and soon afterwards to the SPS (which was converted into a proton–antiproton collider) leading to the discovery of W and Z bosons. To increase antiproton production by an order of magnitude, an Antiproton Collector (AC) complemented the AA from 1987.

Once the AA was proven, LEAR was launched for completion in 1982. It received antiprotons from the AA via the PS, which were decelerated there to 600 MeV/c. This was a feat of beam handling. LEAR functioned as a "beam stretcher". After storing, cooling, decelerating and then cooling again, its antiprotons were fed to the experiments via "ultraslow extraction". Some 5×10^9 antiprotons were served over periods lasting hours, on average at only one antiproton per revolution.

When antiproton physics finished at the SPS, AC–AA and LEAR continued to provide antiprotons to a rich field of physics until 1996. The AA was dismantled, but the AC is making a comeback as an Antiproton Decelerator (AD). It was first tested with protons in 1998. In 1999 the first antiprotons at 100 MeV/c (5 MeV kinetic energy) are scheduled for new experiments.

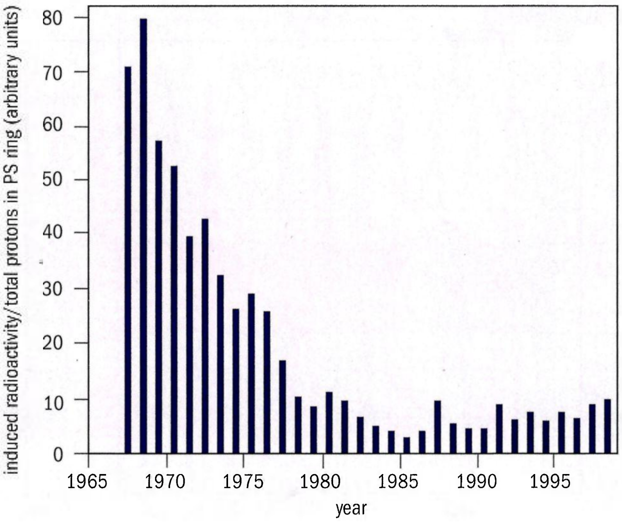
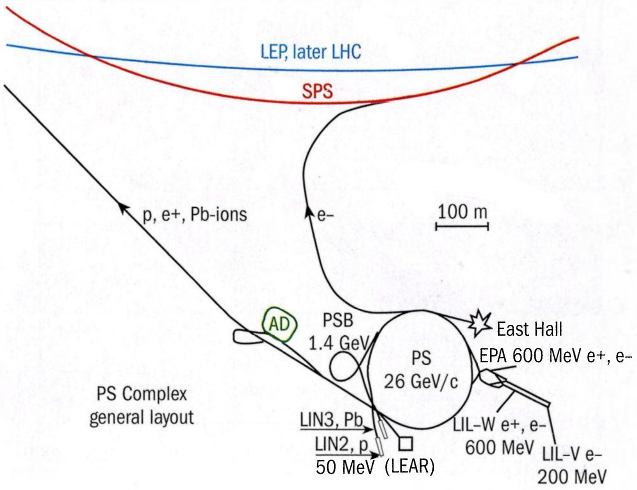


Fig. 4: Unrelenting efforts to limit beam losses radically reduced the radioactivity induced in the PS components, thus permitting ever-increasing intensity. Because beam loss usually rises very steeply near peak performance, it is remarkable that the specific induced radioactivity essentially remained constant since 1978, although in that period the number of protons per pulse more than doubled.



The CERN PS Complex today: eight accelerators and storage rings, with their interconnecting beam and transfer lines to the neighbouring SPS synchrotron.

Electrons and positrons

When CERN's LEP electron–positron collider was conceived, history was repeated. Rather than building new injectors, the PS and SPS could take on the role. More machines had to be added to the PS Complex: a 200 MeV high-intensity electron Linac (to produce positrons from a converter target), a 600 MeV low-intensity electron–positron Linac and an Electron–Positron Accumulator (EPA), from which particles were passed to the PS, accelerated to 3.5 GeV, sent to the SPS for further acceleration and then on to LEP.

For the electron–positron Linacs, expertise and help were sought from LAL, Orsay. Construction began in 1984. By 1987 electron and positron beams were ready. Routine LEP operation began in 1989.

Far-reaching modifications had to be made to the PS – the vacuum chamber was entirely changed, electron and positron transfer lines and injections were added, new 114 MHz cavities and three "wigglers" were added too.

The PS Complex today

As well as being a supplier of protons, antiprotons, electrons, positrons and ions to the SPS, the PS Complex has gathered a number of users of its own – protons supplied to the East Hall feed a major experiment (DIRAC) and a number of smaller ones, mostly to test detectors for the LHC experiments. This is also where key experiments for the Energy Amplifier were recently carried out.

- ISOLDE moved to the Booster after the closure of the 600 MeV synchrocyclotron in 1990. It is enjoying the higher energy of 1 or 1.4 GeV and intensities of 3×10^{13} protons per pulse.
- Detector development profits from electrons in an experimental area connected to LIL and EPA.
- Experiments around the new AD are being readied for 100 MeV/c antiprotons.
- A new time-of-flight (TOF) facility, using intense proton beams from the PS to produce spallation neutrons, is nearing completion.

The future

For the future, the PS base-load will be the steady delivery of beams to the many clients and maintaining the machines in a good operational state. However, many other tasks are in the offing.

Once the TOF experiment is completed, others, which are using the intense beams from the PS, may follow. The preparation of proton beams to fulfil all of the demands of the LHC requires more effort. There is the conversion of LEAR, for the moment mothballed, to become the Low-Energy Ion Ring, in which lead ions will be accumulated and cooled to the levels required by the LHC. This is a demanding task, which will draw on all the expertise that the PS Division can muster.

The future also means looking beyond the LHC. The vast experience accumulated with a great variety of techniques, machines and beams in the PS Complex is fertile ground. The Compact Linear Collider study has found its home at the PS, with a succession of test facilities (CTF1, CTF2 and now CTF3 is under construction). This will be a major responsibility. A further long-term study has been launched on high-intensity proton accelerators for neutrino factories and, further ahead, a muon collider.

When celebrating a 40th anniversary, it is natural to recall successes and achievements and gloss over thunderstorms, fires, floods and sabotage. Some say that the good old PS should be replaced by something new and better. What is really left of the "good old PS" after all of these upheavals? The astonishing answer is: only the tunnel and 99 of its 100 magnets. Everything else is new, so it really is a "good young" PS. Reserve 24 November 2009 for the PS Golden Jubilee.

The PS Staff, *CERN*.

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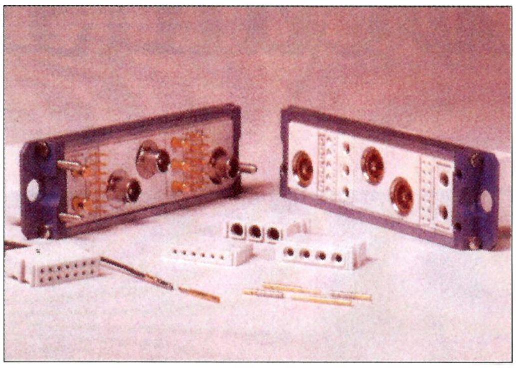

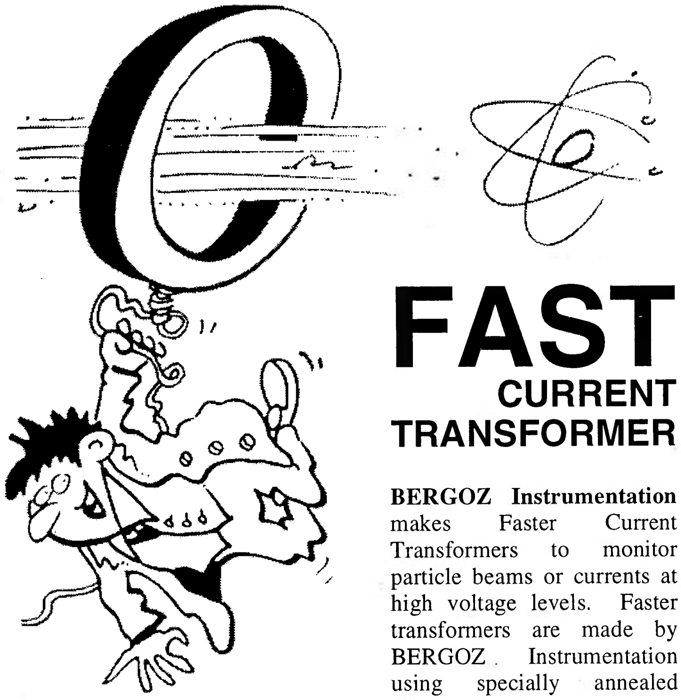

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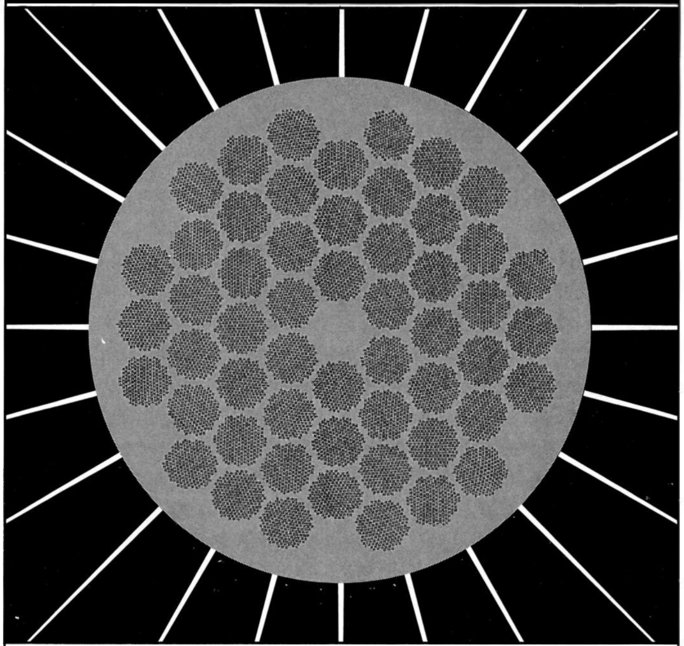

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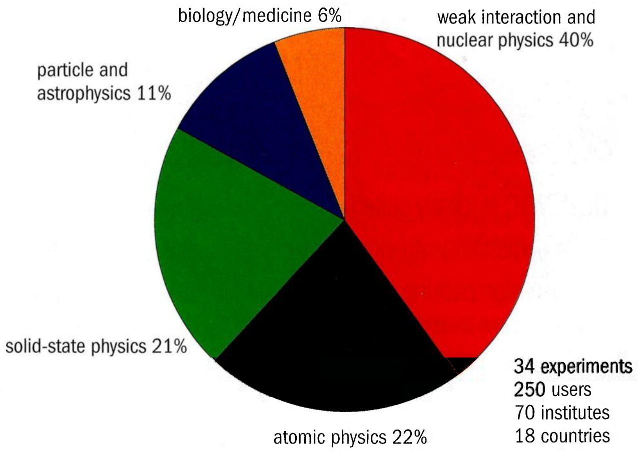
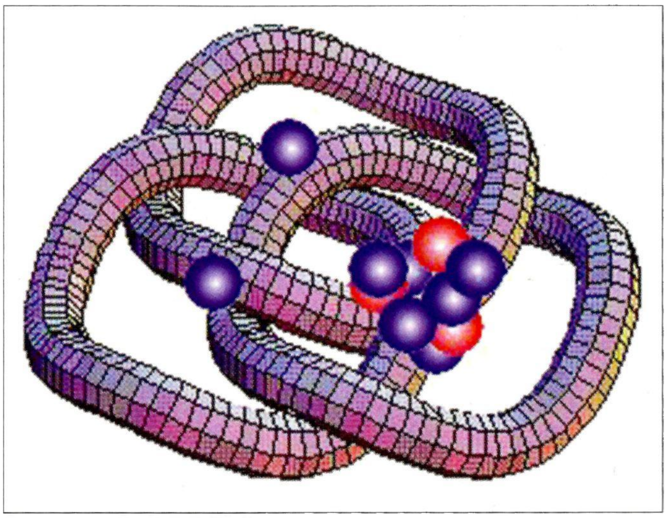
Radioactive beams d

Radioactive ion beams provide access to a variety of research, from basic nuclear physics to the life sciences. *Thomas Nilsson* looks at the varied radioactive ion beam research programme of CERN's veteran, but constantly evolving, ISOLDE facility.



Physics at CERN's ISOLDE ion source covers an impressive range of subjects, of which this article gives only a glimpse.



The lithium-11 nucleus consists of a core lithium-9 nucleus orbited by two neutrons. If any one of the three bodies is removed the remaining two would be unbound, rather like heraldic Borromean rings.

CERN's isotope factory, ISOLDE, has a history stretching back over 30 years. ISOLDE's unique ability to produce some 600 isotopes of 70 elements has ensured it a place at the forefront of low-energy radioactive-beam research and permits a programme that ranges from basic nuclear structure and weak interaction studies to applied fields like solid-state physics and the life sciences. ISOLDE owes its longevity to the ISOLDE team's ability to develop new and more intense isotope beams and to the resourcefulness of the scientists, who design ever-more ingenious experiments for the facility.

The heart of ISOLDE is a target station where a 1 or 1.4 GeV proton beam from CERN's booster accelerator strikes a target to produce a range of isotopes. Those of interest are then extracted, ionized and separated before being delivered to experiments. ISOLDE has always been able to produce extremely pure radioactive beams of a variety of species by combining a range of target materials with efficient and selective ion sources.

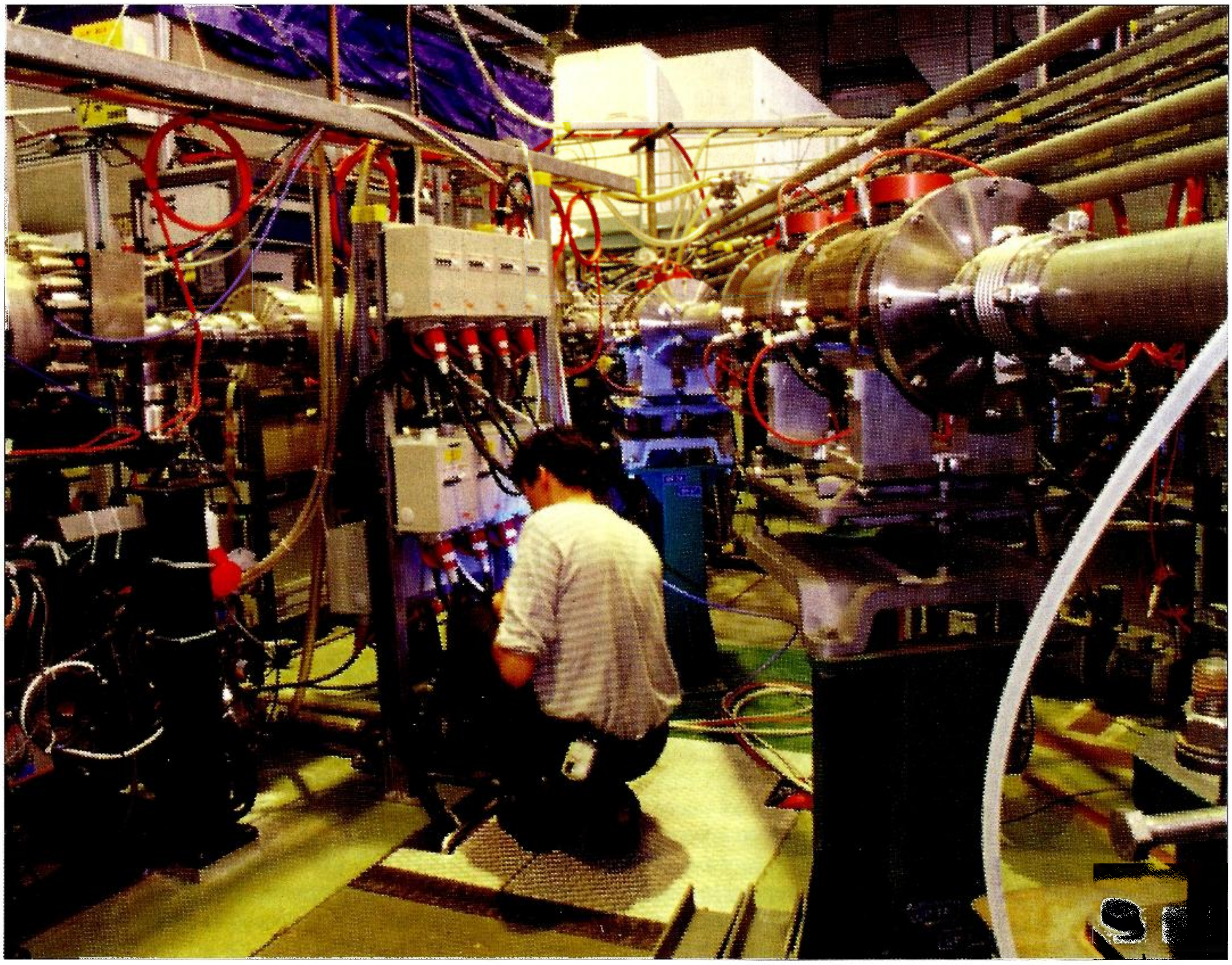
The Laser Ion Source

An important recent development, however, has allowed ISOLDE to improve efficiency and beam purity further. The Laser Ion Source (LIS) works by shining a combination of three laser beams into the cloud of nuclei released from the ISOLDE target. The combination acts like a key in a lock and selectively ionizes the isotopes of interest. This gives an unprecedented combination of both ionization efficiency and selectivity and has already allowed important measurements to be made on key processes that are believed to play a role in supernova nucleosynthesis (*CERN Courier* January 1998 p6).

More recently the LIS has been employed to produce isotopes of beryllium, which opens up a new range of possible experiments. Beryllium-7, for example, holds a key to the solar neutrino problem: the apparent deficit of neutrinos coming from the Sun that has been puzzling researchers for decades. One of the important reactions that gives rise to solar neutrinos is the capture of protons by beryllium-7. A precise knowledge of that isotope's structure is important in understanding the expected flux of beryllium-7 related neutrinos from the Sun. An ISOLDE experiment has recently measured the quadrupole moment of the isotope. Furthermore, an experiment at Israel's Weizmann Institute measures beryllium-7 proton capture using a beryllium-7 target made at ISOLDE.

Other, more esoteric, experiments use beryllium-11 and beryllium-14 to investigate a topic that has attracted much interest in recent years. In the 1980s, experiments on lithium-11 suggested that the nucleus might have a "halo" of two very loosely bound neutrons that surround a core lithium-9 nucleus. The proposed halo structure of lithium-11 has since been well established, both experimentally and theoretically, with much of the experimental work

ive physics forward



Two of the many beamlines in ISOLDE's packed experimental hall.

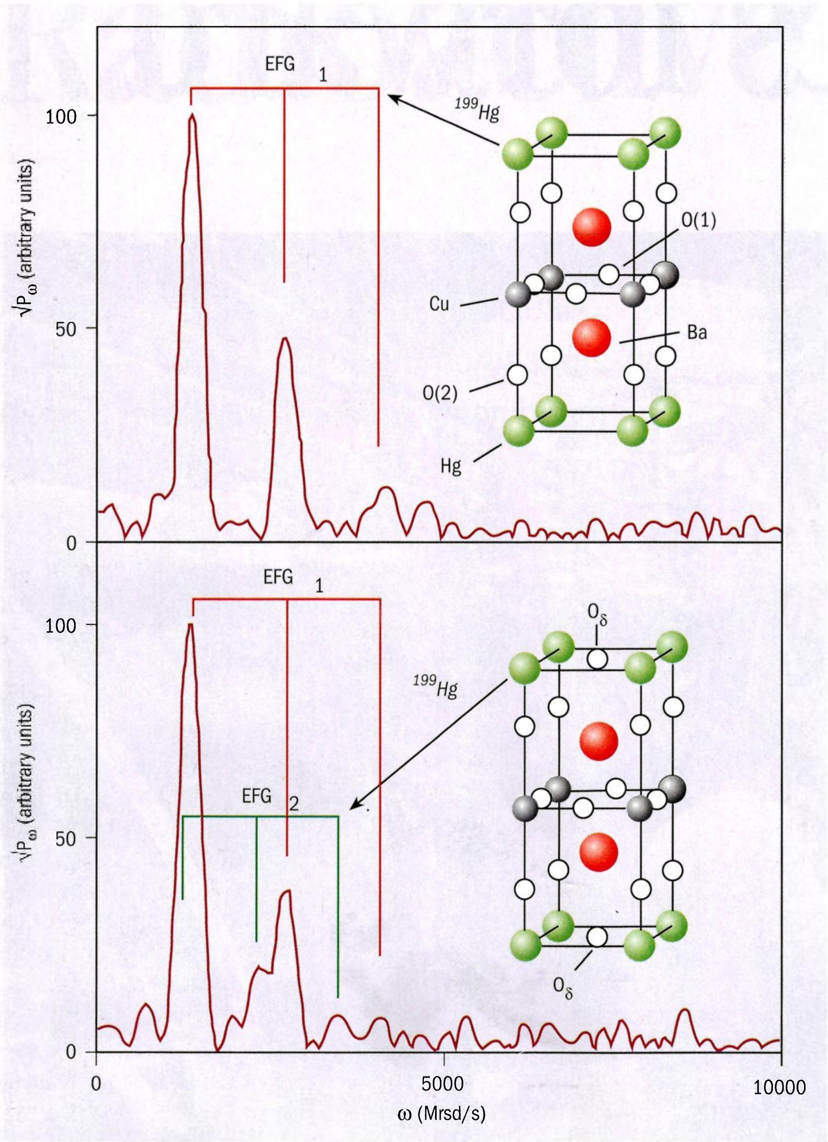
coming from ISOLDE.

Many similar neutron-rich nuclei have since been found and among them were beryllium-11 and beryllium-14. Beryllium-11, which has a single halo neutron, is the most simple halo nucleus. Its halo structure has recently been confirmed by the COLLAPS collaboration at ISOLDE, which has found that the magnetic dipole moment of beryllium-11 is consistent with a halo structure.

Berylium-14 is an altogether more complex object. Like lithium-11 it is a loosely bound three-body structure with two halo neutrons. Such nuclei have been dubbed Borromean because of a characteristic that they share with the heraldic Borromean rings symbol, which also features in mathematical knot theory. Just as a lithium-11 nucleus is a loosely bound state of three bodies, a Borromean ring system is an object composed of three intertwined rings. Whenever one ring is removed the remaining two are no longer bound to each other. The same is true of Borromean nuclei. These are three-body bound states in which any two-body subsystem would not be bound. The di-neutron is not bound, nor is lithium-9 plus a single neutron.

Producing beryllium-14 is particularly difficult because it has a half-life of only 4.3 ms, making it the shortest-lived isotope studied to date at ISOLDE. Few beryllium-14 nuclei survive long enough to escape the target, but a production rate of eight atoms per second has been achieved.

In lithium-11 a number of exotic decay modes involving the emis-



The electric field gradient (EFG1), which interacts with mercury nuclei in certain high-T_C superconductors, is revealed by a set of three frequencies that characterize the mercury lattice site. When doping oxygen merges into the mercury planes, this gradient changes in a characteristic way that is revealed by a different set of frequencies (EFG2), thus providing information about the superconducting mechanism.

sion of tritons, deuterons, or up to three neutrons have been identified. These are associated with the halo structure, and the experimental goal of ISOLDE is to look for similar decay modes in beryllium-14. An early result shows that the probability of one-neutron emission is close to 100%. Further experiments are planned to search for other exotic decay modes.

Solid-state physics and life sciences

Radioactive nuclei are also used as powerful probes in solid-state physics (*CERN Courier* October 1998 p17) and life sciences. One range of experiments studies the effect of hydrogen in semiconductors such as indium phosphide (InP), gallium arsenide (GaAs) and indium arsenide (InAs). Hydrogen can enter a semiconductor at many stages during production, causing passivation of intentionally introduced dopants by the formation of hydrogen-dopant complexes.

This is investigated at ISOLDE by implanting radioactive silver-117, which decays into cadmium-117. Cadmium-hydrogen pairs then form and, when the cadmium itself decays, the hydrogen is free to diffuse within the semiconductor. Information about the diffusion of hydrogen in the semiconductor can be gleaned by studying the gamma-ray distribution from the cadmium decay.

Another emerging area in which ISOLDE scientists are active is high-T_C superconductors. Among the many that have been found, certain mercury-based materials achieve the highest critical temperature, of 135 K, at ambient pressure. These materials have a simple tetragonal lattice structure in which oxygen regulates the superconducting charge carriers and increases or decreases T_C. ISOLDE researchers are able to extract information about the oxygen's behaviour and concentration at the mercury lattice planes by measuring the electric field gradient that is caused by the charge distribution around implanted radioactive mercury probe nuclei.

In the life sciences, ISOLDE's radionuclides are very suitable for use in biomedical research. One of the most interesting applications is cancer research. Certain modern techniques of systemic cancer therapy make use of "intelligent" molecules, which seek out specific binding sites in cancer cells with high selectivity. Such molecules can be used as vehicles to carry radioactive isotopes, produced at facilities such as ISOLDE, into the cancer tissue where they kill cancer cells. ISOLDE research into such novel forms of cancer therapy is guided by the Division of Nuclear Medicine at Geneva's University Hospital.

Mass measurements

The mass of a nucleus is a fundamental quantity with importance in fields as diverse as nuclear physics and cosmology. This is particularly true of short-lived radioactive isotopes, for which ISOLDE has a long-standing tradition in high-precision mass measurements. The ISOLTRAP experiment, which is a combination of a recently added radiofrequency quadrupole cooler and two consecutive Penning traps, has mapped the nuclear mass surface over a sizable part of the nuclear chart with a resolution of 10^{-7}.

ISOLTRAP will continue to be one of the major ISOLDE experiments for many years. However, it is limited to nuclei with half-lives of around 1 s and longer. This limitation is overcome in a complementary mass-measuring experiment called MISTRAL (*CERN Courier* September 1997 p20), which has measured the masses of 15 radioactive isotopes, 3 of which have half-lives of less than 50 ms, with a mass resolution better than 10^{-5}. These results are now providing valuable input to nuclear structure calculations.

Search for physics beyond the Standard Model

Radioactive nuclei are not only highly interesting systems in their own right but can also yield information regarding fundamental interactions, which is complementary to the results from high-energy physics. Nuclear beta decay, for example, is mediated by the exchange of W bosons having only certain (vector and axial-vector) couplings according to the Standard Model. However, theories beyond the Standard Model predict other weak couplings in nuclear beta decay. These could manifest themselves in electron–neutrino correlations in super-allowed beta decays. The detection of the neutrino in the decay is practically impossible, so this correlation must be deduced from the velocity of the recoiling daughter nucleus.

This is an extremely delicate task because the velocities involved are very small and the movement of the daughter nucleus is affected by the surrounding material. In an experiment at ISOLDE, this last problem was partly circumvented by studying the decay of argon-32, which decays by beta-delayed proton emission. The energy peaks of the protons are then Doppler-broadened by the movement of the emitting daughter nucleus. Subsequently this broadening can be traced back to the electron–neutrino correlation. The results were consistent with the Standard Model and have led to improved constraints on the scalar weak interaction.

Another quest for new physics is the search for right-handed currents in nuclear beta decay. This can be studied via the polarization of positrons that are emitted from a polarized radioactive source. Such an experiment has recently started taking data at ISOLDE.

REX–ISOLDE

In the past, ISOLDE has concentrated its efforts on the study of radioactive nuclei at very low energies – less than 60 keV. The new REX–ISOLDE experiment is set to change this dramatically. A novel scheme for beam cooling, bunching, charge state breeding and subsequent acceleration will launch almost any isotope that is currently produced at ISOLDE into the 0.8–2.2 MeV per nucleon energy range. This opens up a completely new field of experiments with radioactive ion beams.

By combining a variety of target materials with efficient and selective ion sources, ISOLDE has always been able to produce extremely pure radioactive beams of a variety of species

To convert a singly charged beam from the ISOLDE separator into a multiple-charged pulsed beam, which is suitable for acceleration, without losing too large a fraction of the painfully created radioactive nuclei, requires advanced techniques. Initially the ISOLDE beam is trapped, cooled and bunched in a linear Penning trap. The bunched beam is then transported to an electron beam ion source, where it is confined while being bombarded with a strong electron current in order to reach higher charge states. The ions are then re-accelerated and separated according to charge state before reaching a Linac. The overall efficiency is estimated to be 10%.

The REX–ISOLDE experiment aims to find out whether or not the magic numbers 20 and 28 are conserved when going to very neutron-rich nuclei. Other experiments have hinted at a weakening of the nuclear shell structure in the region of magnesium-32 (the most commonly occurring isotope is magnesium-24) and below calcium-48 (calcium-40 is the most commonly occurring isotope) with deduced sizable deformations.

The main detector system to be used for these experiments is the state-of-the-art gamma-detector array, MINIBALL, which is being constructed by a large European collaboration. Once REX–ISOLDE is ready, however, a large number of other experiments are also expected to make use of this powerful new instrument. Two more experiments are already approved. Both are concerned with investigating the unbound subsystems of halo nuclei like lithium-10. In the near future, other experiments that will take place concern the structure of unstable, medium-heavy (mass numbers between 50 and 100) nuclei with approximately the same number of neutrons and protons, proton radioactivity and nuclear astrophysics. The installation of the REX post-accelerator is well under way and the first post-accelerated radioactive beams are expected during 2000.

Outlook

With a well established physics programme, ISOLDE would be able to continue operation for many years to come with the current and foreseeable techniques, in particular with the REX–ISOLDE, including a possible energy upgrade to above 5 MeV per nucleon. However, the path towards new physics often relies on the availability of new or more intense radioactive beams, so the proton beam intensity delivered by the booster will become a limiting factor.

A number of new or upgraded facilities are currently being planned, built or commissioned worldwide. These will complement ISOLDE but they will still be first-generation facilities. There is considerable interest around the world in building a second-generation radioactive ion beam facility. In Europe this is spearheaded by the Nuclear Physics European Collaboration Committee (*CERN Courier* May p23) and in the US by the Department of Energy. Both have independently recommended the construction of a second-generation facility based on the ISOLDE principle, where radioactive beam intensities around 100 times higher than at the current facilities can be produced.

ISOLDE is well placed for further advances before such a facility comes along. ISOLDE currently uses about half of the number of protons delivered by the booster, but its target could easily withstand beam intensities more than an order of magnitude higher. ISOLDE physicists are currently studying the possibility of using a 2 GeV high-current proton Linac, which might form part of CERN's LHC injector complex, to upgrade the facility further in years to come. A small part of the then available protons would be used by the driver beam, which would propel the ISOLDE to new scientific heights.

Thomas Nilsson *is the current co-ordinator of the ISOLDE physics programme at CERN.*

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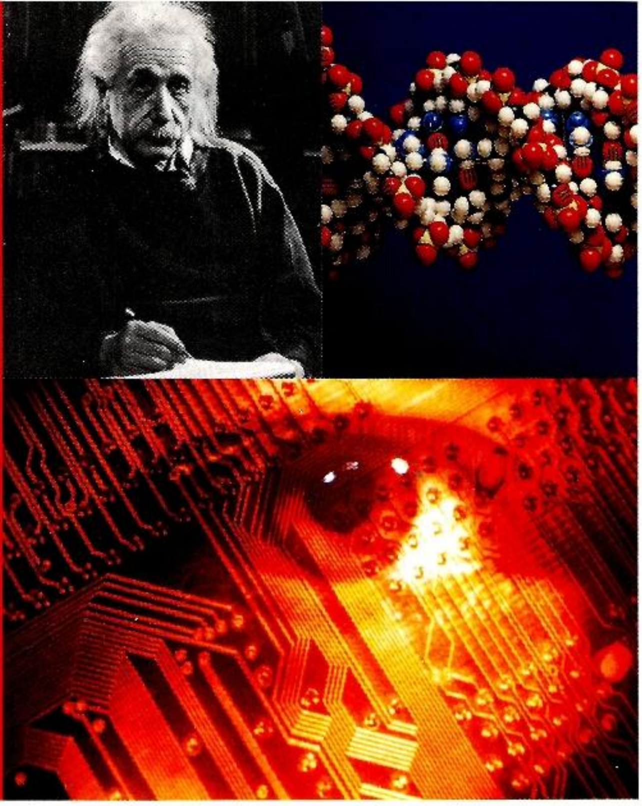

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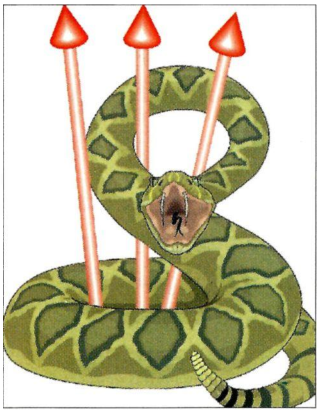
Handling high-energy spin

The discovery of spin was a surprise, and the subsequent history of spin physics has lived up to this reputation. With plenty of spin puzzles still around, physicists have to look at how to handle spin at the highest energies.

More than 10 years after the European Muon Collaboration at CERN discovered that the proton's quarks account for only a fraction of the particle's spin, physicists have been trying to find the "missing" component. This means exploring spin structure and content under higher-energy conditions.

The production of high-energy polarized proton beams and their subsequent long-term storage is one of the greatest challenges facing accelerator physicists. This was high on the agenda at a workshop on Polarized Protons at High Energies – Accelerator Challenges and Physics Opportunities, which was held at the DESY Laboratory in Hamburg earlier this year. Over 100 experts on the machine aspects of polarized proton beam acceleration and storage, spin physics and polarimetry were brought together.



Siberian snake – the logo of the workshop on the handling of polarized protons.

Emphasis was placed on the polarized proton option for Brookhaven's RHIC collider, which is expected to be commissioned next year, and the possible future storage of polarized protons in DESY's HERA collider, in addition to the electrons and positrons that are already polarized.

The case for a fully polarized proton–electron HERA collider has been explored in two previous DESY workshops. Measurements at HERA include the structure functions g_1 (the sum of the polarized quark and antiquark distributions) at low x (the quark momentum fraction) and g_5 (the difference between the polarized quark and antiquark distributions), and polarized photoproduction measurements. The ability of HERA and RHIC to measure – for example, via jet or prompt photon production – the polarized gluon distribution, which is a likely source of spin, again underlined a measurement that is pivotal in understanding the spin structure of nucleons.

Previous studies have been updated, by using detailed detector simulation, for example, and several new channels have been proposed. New ideas were also presented for the HERA-N option in which the polarized proton beam would collide with a polarized, fixed target. The complementarity of the possible future physics programme at HERA and the programme at RHIC was emphasized.

Resonant depolarization during acceleration to high energy can be strongly suppressed using "Siberian snake" spin rotators. However, the snake schemes must be chosen carefully. High-intensity polarized sources, as well as high-quality polarization measurements, are needed at each step in the acceleration cycle.

Subjects for discussion included the necessary modifications to the HERA acceleration chain; the results of long-term spin-orbit tracking simulations for HERA and RHIC; progress on high-performance polarized sources; ideas for realistic snake layouts, which include plans for RHIC; experience at low-energy rings; various aspects of the theory of spin-orbit motion; and the description of helical magnetic fields. Significant advances were reported on all fronts. However, it remains clear that, to reach very high energy in HERA, a cooled beam would be desirable and that new means are needed to overcome the effects of closed-orbit distortion.

E Gabathuler, an opening plenary speaker, recalled the contribution of high-energy polarized scattering to our understanding of the structure of matter, and the surprises that emerged along the way. R Jaffe, A Deshpande and W Nowak reviewed the main aspects of the physics programme for polarized RHIC and HERA colliders. A Krisch recalled the efforts to achieve polarized proton beams at Brookhaven, and the commissioning of the Siberian snake at the IUCF ring in Indiana.

Siberian snakes for the polarized RHIC option are being constructed and will be commissioned in the near future for polarized proton collisions at an collision energy of 200 GeV. The experience that the Brookhaven Lab has in the acceleration and storage of polarized protons will be of vital use in the polarized HERA project.

The current position of the the RHIC spin option was detailed by T Roser. G Hoffstätter presented the status of the ongoing machine physics studies at DESY for HERA. The challenges in measuring the polarization of the high-energy proton beam were reviewed by G Bunce and K Kurita. Polarized ion sources, and the current spectacular developments in this field, were covered by L Anderson.

The future expectations of HERA, which has been running with polarized electron and positron beams for the HERMES experiment, were addressed by E Gianfelice-Wendt. Finally, the results, which will become available in the near future, from DESY (HERMES), CERN (COMPASS) and Jefferson (CEBAF) were reviewed by E Kinney.

A plenary session on polarimetry merited three summary talks. These were on machine aspects (A Chao), spin physics (T Gehrmann) and the general outlook (V Hughes).

A similar meeting, which will probably be held in the US, is planned for 2001, when the exciting results of RHIC will be available.

D P Barber, *DESY and* **A De Roeck**, *CERN.*

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Silver celebration for Swiss pions

This year marks the 25th anniversary of the first particle beams at the former Swiss Institute for Nuclear Research, now better known as the Paul Scherrer Institute.

In 1974 the first protons were accelerated in the ring accelerator and the first pions were produced at, what was then known as the Swiss Institute for Nuclear Research. Some 25 years later, Switzerland's National User Laboratory for Nuclear and Particle Physics has grown into the Paul Scherrer Institute – a multipurpose facility.

In the beginning

The story of the first Swiss pions started in earnest on 17 January 1974. This was a few days after protons had been successfully extracted from the 72 MeV Philips Injector Cyclotron and accelerated via a few turns to 92 MeV in the in-house-designed 590 MeV Isochronous Ring Cyclotron.

Despite vacuum problems, which meant running on only three of the four accelerating cavities, on 18 January the beam dynamics group was able to accelerate protons from 100 to 540 MeV in just 30 min. Thus it created a new world record for the rate of gain of energy achieved by an isochronous cyclotron.

Acceleration to the extraction energy of 590 MeV took a bit more effort. However, shortly before the filament of the ion source burned out, 4 nA of protons were extracted and hit an external copper beam dump. This was the first time that any accelerator had reached truly relativistic energies with a 100% macroscopic duty cycle.

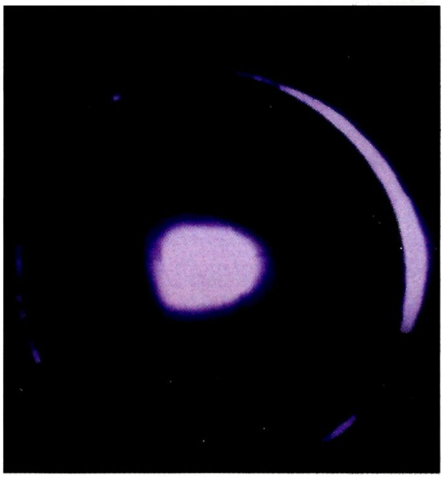
The then director, Jean-Pierre Blaser, and the late Hans Willax, the designer of the ring cyclotron concept, were seen with "silent glows" on their faces. Many years of considerable effort had finally been rewarded with success.

The "big run", which was dedicated to the production of the first pions on the external target station, started in the early afternoon of 23 February 1974. Again, difficulties were encountered, which necessitated running on only three acceleration cavities in the main ring. However, the machine crew took up the challenge, and between 0.1 and 0.2 μA of protons soon reached the extraction radius.

The highlight came just after midnight on 24 February, when the first extracted protons were seen as a bright spot on a glass scintillation screen at the thin target station. A few minutes later the eagerly waiting physicists had their moment of truth: the first pions were detected at the end of the πM3 channel (which was tuned for positive particles of 300 ± 3 MeV/c).

The characteristic signature of protons and pions was seen on the oscilloscope and was confirmed via pulse-height spectra from a scintillator-Cherenkov counter telescope. The first results yielded some 3000 positive pions per second for a proton current of 30 nA. It was a moment for celebration.

Today, 25 years later, the main Ring Accelerator is routinely running at more than 1.5 mA (15 times as great as the design current) with an increase to 2 mA planned. With the present 1 MW proton beam power, PSI has the most intense pion and muon beams in the world. This has yielded numerous first-class results over the years. These include:



Swiss protons – 1974 proton beam spot at the thin target station. The spot was approximately 1 cm in diameter and the beam current was 30 nA.

- the most precise values of the masses of the muon and the charged and neutral pion, in addition to the best "laboratory limit" on the mass of the muon neutrino;
- in the rare and forbidden decay sector, which continues to be a specialist area of research at the facility, the most precise values have been established for the branching ratios of the pion into an electron and a neutrino; and into a muon a neutrino and a photon; and a muon into three electrons and two neutrinos;
- the first observation of a pion decaying into three electrons and a neutrino, and hence the determination of the vector and the two axial-vector form factors of the pion;
- in the search for lepton-flavoured violating processes, the most sensitive limits have been achieved for a muon decaying into three electrons (less than 10^{-12}), for muon to electron conversion in nuclei (less than 6.1×10^{-13}) and for muonium-antimuonium conversion (less than 8.2×10^{-11});
- other precision measurements, one of which is the measurement of the longitudinal polarization of positrons in muon decay, which together with the results from inverse muon decay, demonstrated that the V–A structure of the weak interaction follows on as a natural consequence; also, the helicity of the muon neutrino was determined for the first time;
- in the hadronic sector, the most accurate measurements of the

Accelerator control room elation in the early hours of the morning on 24 February 1974.

delta (1232)** and delta (1232)^0 masses and widths and the determination of the magnetic moment of the delta (1232)** have been made. Measurements in pionic hydrogen have yielded the strong interaction shift and width to unprecedented precision, from which the pion-nucleon scattering lengths at threshold could be determined.

Special symposium

The anniversary was marked by a special symposium as part of the laboratory's traditional half-yearly Accelerator Users Meeting.

The opening address was given by deputy director Ralph Eichler, who set the scene and outlined the present range of experiments at the Ring Accelerator, with the continuing trend towards larger and longer types of precision measurements.

Former director Blaser recounted the "Origins and Early Days of the Ring Cyclotron" with personal recollections and anecdotes. Then it was the turn of Claude Joseph (Lausanne), a long-standing experimenter at the facility, and Florian Scheck (Mainz), former head of the SIN Theory Group, to summarize physics milestones in the strong interaction and electroweak sectors respectively. This wealth of results is underlined by the number of corresponding entries in the Particle Data Booklet.

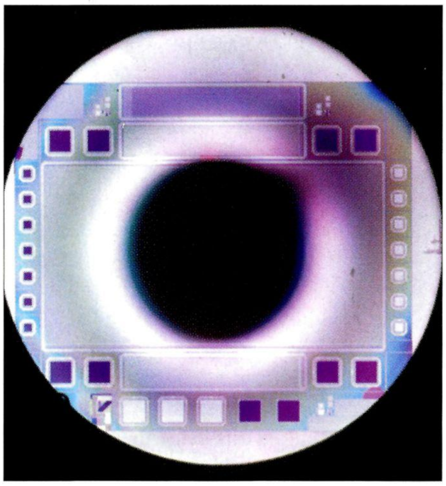
Finally, Jerzy Sromicki (ETHZ) gave a lively overview of the present tests of fundamental symmetries and future particle physics experiments that use neutrons from PSI's spallation neutron source, SINQ, fed by the Ring Accelerator.

As one 25 year period closes, a new one will begin when the Swiss Light Source synchrotron radiation facility is commissioned. ☐

Detectors win 1999 Merit award

The prestigious 1999 Merit award of the Nuclear and Plasma Sciences Society of the Institute of Electrical and Electronics Engineers was presented to Erik Heijne, from CERN, on 26 October. The award was given during the Institute of Electrical and Electronics Engineers Nuclear Science Symposium in Seattle "for vision and leadership in applying silicon technologies to the development of new and important detector systems for high-energy physics".

Heijne has been working at CERN since 1973. Initially he worked on silicon detectors for the neutrino beam monitoring system. In 1980 he introduced the silicon microstrip detector. While the idea of a linearly segmented silicon diode originated in the Philips Research Laboratories in Amsterdam in around 1963 ("checker board" detector), the advances in silicon technology allowed a fresh approach to particle physics. In particular, the use of a miniaturized electronic read-out made it possible to employ systems with thousands of strips.



Meritorious detector – silicon microstrip detector for the ALICE experiment for CERN's LHC collider.

These first microstrip detectors still used surface barrier technology, but soon ion implantation technology became available, thanks to the work of Joseph Kemmer in Munich and owing to its subsequent commercialization by Enertec in Strasbourg, Micron in Southampton and Hamamatsu in Japan. In around 1990, further advances in CMOS chip technology and interconnection techniques allowed the construction of the first silicon micropattern pixel detector for particle tracking.

In the LAA project, Heijne and his group of engineers tested the detector in beams. The first publications appeared at the Institute of Electrical and Electronics Engineers Nuclear Science Symposium in 1989 and 1991. This meeting is widely regarded as the most important annual radiation instrumentation conference. It will be held for the first time in Europe next year, on 15–20 October, in Lyon. The conference chairman is Patrick Le Du from Saclay, who has the help of an extended committee from various radiation instrument communities. Most European countries as well as the US and the Far East will be represented. Further information is available at "http://NSS2000.mi.infn.it/".

Pictured at the opening of the France at CERN trade expo in October are (left to right) the French Minister for National Education Claude Allègre, CERN director-general Luciano Maiani and the Minister for European Affairs, Pierre Moscovici.

France is one of CERN's two host nations – the majority of the 27 km LEP tunnel runs underneath French territory. France is also a major player economically, contributing more than 16% of CERN's budget and making special additional contributions. France at CERN is a regular major event. This year, 44 companies exhibited products and technologies that are related to particle physics. They include cryogenics and vacuum technology, superconductivity, electrical and electronic equipment, and mechanics. The exhibition was organized by the French Committee for Trade Events Abroad.

Bruno Escoubès 1938–1999.

Bruno Escoubès 1938–1999

French physicist Bruno Escoubès died recently while he was preparing for his well earned retirement in Madrid.

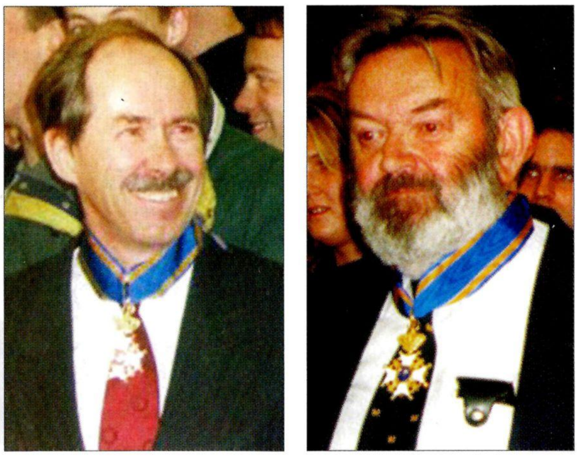
After studying at Orsay, he began his research career with a fellowship at CERN. He worked under Yves Goldschmidt-Clermont and Douglas Morrison on high-energy antiproton interactions using the 80 cm bubble chamber. During this period he met and married Spanish physicist Salomé de Unamuno, who would be his partner for life.

After leaving CERN they moved to Madrid. At that time Spain was a CERN member state and the Junta de Energia Nuclear (now CIEMAT) took great interest in fostering high-energy physics. Escoubès and his wife played an important role in creating an experimental group in Spain and in training younger scientists, including Alvaro de Rújula and Juan Antonio Rubio.

When Spain left CERN in 1968, Escoubès moved to Strasbourg, where he remained until his death (except for a period in the Theoretical Physics Department at the Universidad Autónoma de Madrid). In Strasbourg he worked on kaon and pion interactions, neutrino interactions in Gargamelle and charm production at the ISR. In the last 10 years he turned to cosmic-ray heavy ions and the initial stages of the Pierre Auger Observatory.

Throughout his life he was interested in all problems of science, the communication of scientific discoveries and the role of modern scientists in society. When his battle with ill health restricted his travelling in recent years, he turned to the challenge of scientific communication. In 1984 Escoubès was appointed coordinator of the Boutique de Sciences de Strasbourg, and he recently published several papers on the ethical aspects of science. His friends will remember him as a fighter for all scientific causes.

Alison Wright receives the 1999 Institute of Physics Public Awareness of Science Award. Institute of Physics president, **Sir Gareth Roberts** presented the award at the annual festival of the British Association for the Advancement of Science, held this year in Sheffield. Wright, a CERN fellow on the LHCb experiment, received the award "for her outstanding contributions to the public awareness of physics activities at CERN, using a wide range of methods and facilities, making high-energy physics accessible to many audiences". Alison Wright compiles the Physicswatch page for *CERN Courier*.



Following the announcement of their 1999 Nobel Prize for Physics, **Gerard 't Hooft** (left) and **Martin Veltman** were awarded the prestigious Dutch national order of Commandeur in de orde van de Nederlandse Leeuw. (Ada Molkenboer, Utrecht.)

Former Israeli Prime Minister and now consultant for Israeli telecommunications specialists BATM, **Benjamin Netanyahu** (centre), visited CERN during the international Telecom 99 expo in Geneva. He is seen here with (left) CERN director for Technology Transfer and Scientific Computing **Hans Hoffmann** and **Giora Mikenberg** of the Weizmann Institute.

Hungarian Ambassador **Peter Naray** (left) calls on CERN director-general **Luciano Maiani**.

The Indian Atomic Energy Commission chairman, **R Chidambaram** (centre), was at CERN with the Indian Ambassador to the UN, **Savitri Kunadi**, and (left) **Y Viyogi**, leader of the Calcutta team in the ALICE experiment for CERN's LHC. Viyogi recently presented the experiment's Technical Design Report for a photon multiplicity detector. India has a tradition of contributing to heavy-ion experiments at CERN.

NEW PRODUCTS

Electromagnetic field analysis software

Integrated Engineering Software has released the latest versions of its two-dimentional and three-dimentional electromagnetic CAE tools with many enhancements. The company's suite of electromagnetic software includes MAGNETO & AMPERES 5.1 for 2-D/3-D magnetostatic design, ELECTRO & COULOMB 5.1 for 2-D/3-D electrostatic design, OERSTED & FARADAY 5.1 for 2-D/3-D time-harmonic eddy current design, SINGULA 5.1 for 3-D HF antenna design and LORENTZ 5.1 for 2-D/3-D charged particle design.

The new versions offer significant improvements. Special features include smart, dynamic memory allocation, enhanced parametric analysis capabilities, new post-processing graphing utilities, and new integrations to boost the accuracy and speed of the software.

For more information contact Integrated Engineering Software, 300 Cree Crescent, Winnipeg, Canada R3J 3W9. Tel. 204 632 5636, fax 204 633 7780, e-mail "info@integrated.ca" or visit our Website at "www.integrated.ca".

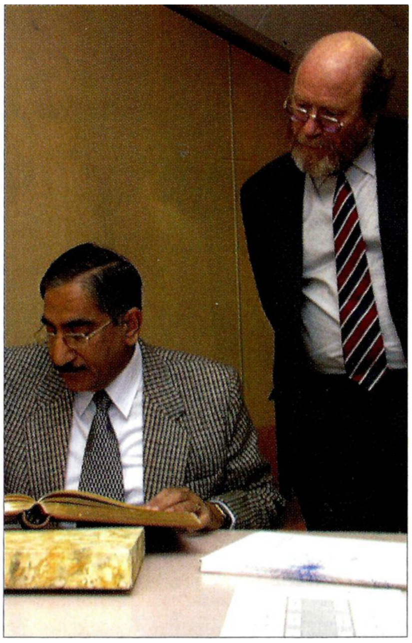
At a meeting in Budapest, CERN director-general **Luciano Maiani** (left) visited the Hungarian National Committee for Technological Development (OMFB), a government agency that aims to promote technological modernization and improve international competitiveness. CERN is seen as a special responsibility. With the director-general are (left to right) OMFB President **Adam Torok**, vice-president **Sandor Bottka**, OMFB advisor and CERN Council member **Barbara Vizkelety**, physicist **Gyorgi Vesztergombi** and OMFB deputy director-general **Pal Koncz**.

MEETINGS

A Workshop on Confidence Limits will be held at CERN on 17–18 January 2000. The workshop will cover topics on how to set confidence limits in difficult cases (small signals, physical boundaries, large backgrounds). Co-convenors will be Louis Lyons (Oxford) and Fred James (CERN). More information is available on the internet at "http://www.cern.ch/CERN/Divisions/EP/Events/CLW/".

The Fourth Workshop on Continuous Advances in QCD has been organized by the Theoretical Physics Institute at the University of Minnesota and will take place on 12–14 May 2000, in Minneapolis. E-mail "QCD@tpi.umn.edu". For more information see "http://www.tpi.umn.edu/QCD00.html".

Città della Scienza – the first Italian science centre – is growing up in the former industrial area of Bagnoli (Naples), in a relic of 19th-century industrial archaeology. In its new role it is designed to appeal to young people. The restoration will be complete in a few years. The most interesting part, from an architectural point of view, will host the museum section of Città della Scienza and will be open to the public from the beginning of 2001. CERN's $E = mc^2$ exhibition recently visited Naples. Under the CERN logo is the founder and president of Città della Scienza, **Vittorio Silvestrini**, from the University of Naples "Federico II".



Technical member of the Pakistan Atomic Energy Commission, **Samar Mubarakmand**, signs the CERN VIP visitors' book watched by the CERN director for Collider Programmes, **Roger Cashmore**.

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please e-mail "cern.courier@cern.ch".

Quantum modelling of the mind

In the article on quantum modelling in the October issue (p10), Tegmark's assertions that there is nothing fundamentally quantum mechanical about the cognitive process in the brain are flawed. He fails to take account of the symmetry of time reversal invariance, in which noise produces an increase in coherence rather than the expected decrease.

Such symmetry is fundamental to quantum-controlled image extraction techniques, used in functional magnetic resonance imaging for medical diagnosis. This gives holographic diffraction patterns – quantum holograms – before conversion into slice images on a screen. The ability to focus on the individual selected slice is known in wave optics as super-resolution.

In super-resolution imaging, as in stochastic resonance, passing the object's image through increasing inhomogeneity increases the quality of the image. In quantum holography it removes classical degeneracy, leading to sharp frequency-adaptive coupling conditions. This produces sharp spectral windows between which there is no crosstalk.

Quantum-secure communications are possible over many kilometres, including transmissions through an atmosphere full of ions and atoms. As the experiments of Rauch show, a loss of quantum coherence is not irreversible (as in time-reversal symmetry).

As for Tegmark's comment that for the neural net community "it's business as usual", the AND Corporation of Toronto already has a working holographic neural technology based on a quantum model which I would assess as substantially outperforming any conventional neural net technology. I would say to the neural net community "watch out!"

Peter Marcer, chairman of the British Computer Society Cybernetic Machine Specialist Group.

Max Tegmark replies:

Dr Marcer lists a series of examples as evidence that decoherence is somehow irrelevant. However, state-of-the-art experiments that demonstrate macroquantum effects owe their spectacular success precisely to the fact that the experimentalists have succeeded in keeping the relevant decoherence rates low. This has been achieved through screening, cooling, etc. Decoherence is a completely uncontroversial quantum effect – indeed, much of the current work in quantum computing is on computing decoherence rates and devising ways of reducing them. In short, the question is not if decoherence is relevant in general, but what the rate is. My calculations probably underestimate the true decoherence rate.

Information processing in the brain takes place in a warm, wet environment which spoils time-reversal invariance and makes decoherence, for all practical purposes, irreversible. It is analogous to the spread of gossip: the information that a neuron is firing spreads to one ion via scattering, then gets passed to a neighbour a femtosecond later though another scattering, and soon everybody knows and it's hopeless to undo.

Max Tegmark, Princeton.

RECRUITMENT

For advertising enquiries contact *CERN Courier* recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel: +44 (0)117 930 1026 Fax +44 (0)117 930 1178
Rates per single column cm: Mono £30, Single colour £34, Full colour £36. Please contact us for more information on publication dates and deadlines.

Duke University

Tenure-Track Faculty Position

Experimental High Energy Physics.

The Duke University Department of Physics has an opening for a tenure-track Assistant Professor position in experimental high-energy physics. The Duke research program focuses primarily on the CDF and ATLAS experiments. The HEP group currently consists of four faculty, one research faculty, five-post-doctoral scientists, plus technical support staff and graduate students. Our activities include data analysis from the CDF experiment, preparations for the CDF detector upgrade, and design and construction of the transition radiation tracker for ATLAS at the LHC with eventual participation in the experiment. Applicants for this position should be capable of taking on major responsibilities in these experiments, and be committed to excellence in undergraduate and graduate teaching at Duke.

The position is available starting September 2000. Applications received by 15 January 2000 will be guaranteed full consideration. Please send a resume, research statement and list of publications and three letters of reference to :

High Energy Physics Search Committee, c/o Ms. Pat Hoyt, (hoyt@hep.phy.duke.edu), Physics Department, Box 90305, Duke University, Durham, NC, 27708-0305, USA.

Duke University is an affirmative action/equal opportunity educator and employer.

RESEARCH SCIENTIST

The Institut Laue-Langevin (ILL) is an international research institute funded by France, Germany and the United Kingdom. Agreements on scientific collaboration have also been signed with Austria, Italy, Spain, Switzerland, the Czech Republic and Russia. The Institute operates the most powerful source of neutrons in the world, a 58 MW reactor.

The Nuclear and Particle Physics Group is looking for a young research scientist who has completed his/her PhD and has gained some experience. The post concerns the high resolution gamma ray facility GAMS used in pure and applied nuclear spectroscopic studies. The successful candidate should have experience in one of the following areas: nuclear structure at low excitation energies, physics of particles and their fundamental interactions, precision measurements using optical interferometers. He/she will work in a group studying radiative decay following thermal neutron capture.

Fixed-term contract (five year) - Competitive salary, benefits (reimbursement of removal expenses, adaptation allowance, etc) - Further information can be obtained by contacting the head of the NPP group (Dr. H. Börner Tel: (33) 4.76.20.73.94; e-mail: borner@ill.fr) or via the World Wide Web (http://www.ill.fr/nfp)

An application with curriculum vitae, a list of publications and the names of two academic referees should be sent, quoting reference 99/20, no later than 15 December 1999 to:

The Associate Director (Science Division)
INSTITUT LAUE LANGEVIN, B.P. 156,
38042 Grenoble Cedex 9 -France

University of Massachusetts at Amherst

FACULTY POSITION

Experimental High Energy Physics

The Department of Physics invites applications to fill a tenure track position in experimental high energy physics to begin September 1, 2000. The hiring is anticipated to be at the assistant professor level, although an appointment at a higher level will be considered for an exceptionally qualified person.

The UMass HEP group (http://www-unix.oit.umass.edu/~blaylock/hepex/) currently participates in the SLAC experimental program, in particular, the physics programs of the SLD and BaBar experiments, as well as the planning stages for the Next Linear Collider.

An interest in the BaBar project for the near term future is desirable. The successful candidate is also expected to be an equal participant in determining the longer range future directions of the group. A Ph.D. in experimental high energy physics and appropriate postdoctoral experience are required.

Applicants should send a curriculum vita, along with a brief description of research and teaching interests, and should arrange to have three letters of recommendation sent to: **Chair of the HEP Search Committee, Department of Physics, 1126 Lederle Graduate Research Tower, University of Massachusetts, Amherst MA 01003.**

Evaluation of applications will begin on February 1, 2000 and continue until the position is filled.

The University of Massachusetts is an Affirmative Action/Equal Opportunity employer.
Women and minority candidates are encouraged to apply

University of California, Santa Barbara

Postdoctoral Position in *High Energy Physics*

The high energy physics group of the University of California at Santa Barbara has one postdoctoral position available for research with the BABAR collaborations on heavy quark physics. A Ph.D. in experimental particle physics is required, with evidence of experience in hardware development and/or data analysis.

Interested candidates should submit a letter of application, statement of research interests, vita, and a list of publications to: **Professor Campagnari, Department of Physics, University of California, Santa Barbara, CA 93106-9530 e-mail :claudio@neutrino.physics.ucsb.edu**

They should also arrange to have at least three letters of recommendation sent to the same address. For primary consideration, applications should be received by January 1, 2000; positions will remain open until filled.

The University of California is an Equal Opportunity/Affirmative Action Employer committed to excellence through diversity.

Faculty Position
In Experimental High Energy Physics
Department of Physics
University of California, Davis

The Department of Physics at the University of California at Davis invites applications for a faculty position in experimental high energy physics. This position has a targeted start date of July 1, 2000, which is negotiable. The appointment will be at the tenure-track Assistant or tenured Associate Professor level as determined by qualifications and experience.

The UC Davis experimental group is primarily focused on the Tevatron and LHC Collider programs. We seek candidates with outstanding research records, strong leadership abilities, and clear potential for impact upon these collider programs. Applicants must have a Ph.D. in physics and the ability to teach effectively at the undergraduate and graduate levels. Demonstrated success in conducting an active research program in experimental high energy physics is essential. The department has recently established a computational physics major program. The potential to contribute to the teaching and research in this area will be taken into consideration.

This position is open until filled; but to assure full consideration, applications should be received by December 29, 1999. To initiate the application process, write an e-mail message to forms@physics.ucdavis.edu and follow the instructions. Those who do not have access to e-mail should send curriculum vitae, publication list, research statement, and the names (including address, e-mail, fax, and phone number) of three or more references to:

Professor Winston Ko, Chair
Department of Physics
University of California, Davis
One Shields Avenue
Davis, CA 95616-8677

Further information about the department may be found on our website at http://www.physics.ucdavis.edu.

The University of California is an affirmative action/equal opportunity employer. The University undertakes affirmative action to assure equal employment opportunity for minorities and women, for persons with disabilities, and for special disabled veterans, Vietnam era veterans, and any other veterans who served on active duty during a war or in a campaign or expedition for which a campaign badge has been authorized.

The particle physics groups at the Universities of Bergen and Oslo in Norway invite applications for a research grant leading to a PhD degree.

The candidate is expected to work on physics topics in one of the following experiments: BaBar (Bergen), HERA-B (Oslo), DELPHI or ATLAS (Bergen or Oslo).

The grant is for three years; with a salary before taxes of NOK 20100 per month.

Applicants should send, postmarked by January 15, 2000, their resume, publications list, and a proposal for a research project to **Department of Physics, University of Oslo, P.O. Box 1048, N-0316 Oslo, Norway.**

DEUTSCHES ELEKTRONEN SYNCHROTRON DESY

DESY is one of the leading laboratories in particle physics and synchrotron radiation research with locations in Hamburg and Zeuthen. In the framework of an international collaboration DESY is coordinating the development of the superconducting electron-positron linear collider project TESLA with integrated free electron laser facility.

The Laboratory in Zeuthen (near Berlin) invites applications for the position of a

POSTDOCTORAL FELLOWSHIP

for R&D work associated with a test facility for a laser driven RF-gun which is under construction at DESY Zeuthen.

It is anticipated that the candidate will play a leading role in this project. Significant contributions to the development, installation and optimisation of the RF-gun are expected. This includes measurements as well as simulations and further developments of theoretical models.

Applicants should have a Ph.D in physics. Substantial knowledge in accelerator physics and electron beam dynamics are required.

The position is limited to a duration of 2 years, with a possible extension for a third year.

The salary will be according to the German civil service BAT-0 IIa.

Handicapped applicants will be given preference to other applicants with the same qualification. DESY encourages especially women to apply.

Interested young scientists should send their letter of application and three names of referees and their addresses by December, 31th, 1999 to:

DESY Zeuthen, Personalabteilung
Platanenallee 6, 15738 Zeuthen.

UNIVERSITY OF CAMBRIDGE

Department of Physics, Cavendish Laboratory

University Lectureship/University Assistant Lectureship in Experimental Particle Physics

Applications are invited from candidates with very strong research records in experimental particle physics or particle astrophysics for a University Lectureship/University Assistant Lectureship in the experimental particle physics group of the Cavendish Laboratory, Cambridge. It is hoped that the successful candidate will take up appointment on, or before, 1st October 2000.

The current group research interests include the CERN-based experiments OPAL at LEP, NA48 (CP-violation) at the SPS, and ATLAS and LHCb at the LHC, together with an active detector development programme. New initiatives in experimental particle physics or particle astrophysics are encouraged.

Further information, including details of the salary scales and tenure conditions, can be obtained from Dr. J. R. Carter (e-mail: jrc1@hep.phy.cam.ac.uk).

Applications (two copies) including a curriculum vitae, publications list, research statement and the full names, addresses, telephone/fax numbers, and e-mail addresses of three academic referees should be sent to Mr. P. Aslin, Secretary of the Appointments Committee, Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA by 7th January 2000.

This post is one of six currently advertised in the Department of Physics. Appointments in the targeted areas depend upon the availability of candidates of sufficient merit.

The University is committed to equality of opportunity and has a policy on arrangements for part-time work.

THEORETICAL ELEMENTARY PARTICLE PHYSICIST

The Physics Division of the **Lawrence Berkeley National Laboratory** is seeking a theoretical elementary particle physicist for a Division Fellow or possibly, in the case of an exceptionally qualified senior candidate, a Senior Physicist position. Division Fellowships are the LBNL equivalent of tenure-track positions: Five-year appointments with a review in the fourth year to determine whether the Fellow will be promoted to a career appointment as a Senior Physicist.

The Division is seeking a candidate to pursue independent research within the theoretical physics group, which currently consists of three LBNL senior physicists and eight U.C. Berkeley faculty. Candidates should have research interests that are broadly related to the Physics Division experimental program, which is focused on understanding the standard model of elementary particle physics and its possible extensions and on the interface between particle physics and cosmology.

Candidates should submit an application with CV (hard copy only) and have four letters of recommendation sent to **Search Committee, c/o Katrina Printup, One Cyclotron Rd., MS 50-4049, Lawrence Berkeley National Lab, Berkeley, CA 94720.** Applications should reference job number **PHTH/011231** and should be postmarked by **01/15/00.** Berkeley Lab is an Affirmative Action/Equal Opportunity Employer, committed to the development of a diverse workforce.

BERKELEY LAB

Post Doctoral Positions in Experimental Particle Physics

The **Fermi National Accelerator Laboratory (Fermilab)** has openings for post doctoral research associates in experimental particle physics. The Fermilab research program includes experiments with the 2 TeV proton – antiproton collider, neutrino oscillation experiments, and fixed target experiments. There are several positions for recent Ph.Ds to join the CDF and DZero collider efforts which have major detector upgrades in progress and are scheduled to begin data taking in early 2001. There are also opportunities to join the upcoming neutrino oscillation experiments MiniBooNE or MINOS, the Cryogenic Dark Matter Search, fixed target experiments for data analysis, as well as detector R&D efforts. Positions associated with these experimental efforts are also available in the Computing Division for candidates interested in modern computing techniques applicable to HEP data acquisition and analysis.

Successful candidates are offered their choice among interested Fermilab experiments. Appointments are normally for three years with one year renewals possible thereafter. Every effort will be made to keep a Fermilab RA until he or she has the opportunity to reach physics results from his or her experiment.

Applications should include a curriculum vita, publication list and the names of three references. Applications and requests for information should be directed to: **Dr. Michael Albrow, Head – Experimental Physics Projects, [Albrow@fnal.gov], Fermi National Accelerator Laboratory, M.S. 122, P.O. Box 500, Batavia, IL 60510-0500.** EOE M/F/D/V

Fermilab

POSTDOCTORAL RESEARCH ASSOCIATE

Rutherford Appleton Laboratory, Oxfordshire

The Rutherford-Appleton Laboratory offers two Research Associate positions in Experimental Particle Physics to work on the Large Hadron Collider Beauty experiment (LHCb) at CERN, designed to make high precision measurements of the CP-violating decay modes of the B meson.

The recently formed LHCb group at RAL will work in close collaboration with other UK Universities and CERN on projects including the design and development of RICH detectors, related software for particle identification and its application to the physics of CP violation. Successful candidates will be expected to make significant contributions to corresponding areas of the R&D programme. The work will be based at RAL but will naturally involve some travel to UK Universities and CERN.

Applicants should have a PhD in Particle Physics or be close to finishing their thesis.

Some knowledge of modern particle detection techniques and proficiency in at least one high level computing language are essential. There will be occasions where overseas travel is required.

The appointments are for a fixed term of up to 3 years but with the possibility of extensions of up to two years.

For an informal discussion about the posts please contact Prof. Ken Peach (+44) 1235 445782, e-mail: k.j.peach@rl.ac.uk

More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

The salary levels are between £17,730 and £26,600 depending on experience. A non-contributory pension scheme, flexible working hours and a generous leave allowance are also offered.

Application forms can be obtained from: Human Resources Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or e-mail: recruit@rl.ac.uk quoting reference VN1878/99.

More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 14th January 2000.

The CCLRC is committed to Equal Opportunities and to achieving the Investors In People standard. A no smoking policy is in operation.

CLRC

COUNCIL FOR THE CENTRAL LABORATORY
OF THE RESEARCH COUNCILS

DESY

DESY is a physics research laboratory with 1400 employees and more than 3000 guests scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of an

Accelerator Physicist or Engineer

The candidate will be responsible coordinator of the DESY II and III Synchrotrons. He is expected to assure successful routine operation and to continously improve the machines.

Applicants should have a degree in physics or engineering and should have profound knowledge of accelerator physics and technology. They should have many years of experience in running accelerators.

The appointment will be indefinit with a salary according to federal tariffs (BAT) depending on experience and ability.

Letters of application including a curriculum vitae, list of publications and the names of three referees should be sent to:

DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg, by January 31th, 2000 Code-No. 110/99

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

RHEINISCHE
FRIEDRICH-WILHELMS-UNIVERSITÄT BONN
PHYSIKALISCHES INSTITUT

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University of Virginia
FACULTY POSITION IN EXPERIMENTAL HIGH ENERGY PHYSICS

The Department of Physics at the University of Virginia invites applications for a tenure-track faculty position in experimental High Energy physics at the assistant professor level. The successful candidate should have Ph.D. degree or equivalent, an outstanding research record and will be expected to expand the range of the activities of the UVa experimental High Energy group by taking a leading role in one of the major High Energy projects planned for the future. The candidate should have a commitment to excellence in undergraduate and graduate education. It may be possible to consider an exceptional candidate at a higher level. The position will be available in September 2000. The deadline for applications to receive full consideration is December 31, 1999. Candidates should submit their curriculum vitae, list of publications, two-page statement of research plans and arrange to have three letters of recommendation sent directly to: **Prof. Michael Fowler, Dept. Chairman, Attn: HEP Search, Department of Physics, University of Virginia, McCormick Road, Charlottesville, CA 22903.**

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Applications should be received by January 31, 2000. Applicants should send a letter of interest, curriculum vitae with a list of publications, and should arrange to have three letters of recommendation sent to:

Professor Katsushi Arisaka,UCLA Department of Physics and Astronomy,
Box 951547, Los Angeles, CA 90095-1547.
E-mail inquiries should be addressed to arisaka@physics.ucla.edu.

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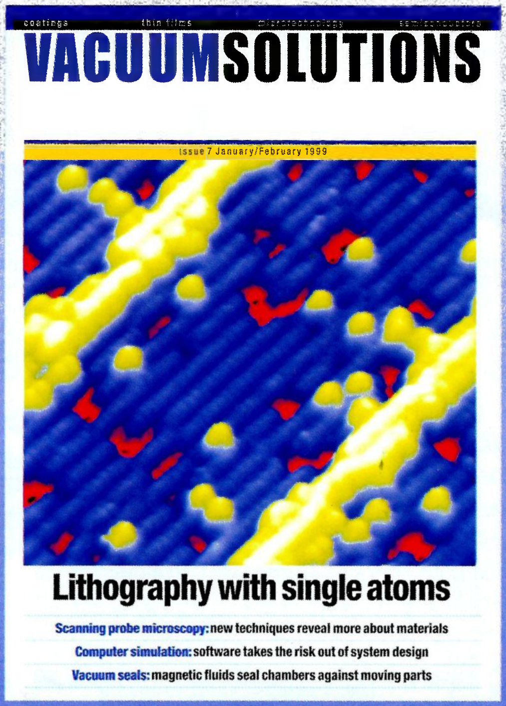

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BOOKSHELF

Heavy Water and the Wartime Race for Nuclear Energy by Per F Dahl, Institute of Physics Publishing 0 7503 0633 5 (£35).

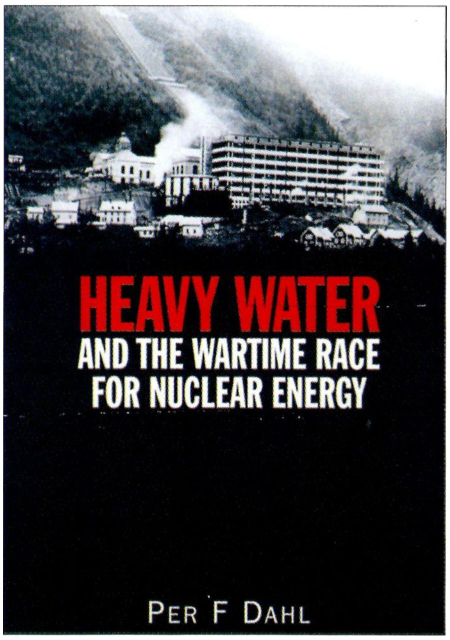
Per Dahl is a physicist who has made significant contributions to the design and development of superconducting magnets for particle accelerators. He also has a burning interest in the history of modern science. It is not surprising that he has already written a book on the history of superconductivity (*1992 Superconductivity: Its Historical Roots and Development from Mercury to the Ceramic Oxides* American Institute of Physics).

Continuing on his history beat, Dahl is also the author of *The Flash of the Cathode Rays* (1997 Institute of Physics Publishing). Advertised as a history of J J Thomson's electron, it is in fact a careful documentation (with nearly 100 pages of footnotes) of many other developments in fundamental physics, from time immemorial up to the early 1930s, where the book stops. Dahl is also the son of CERN pioneer and colourful Norwegian scientific personality Odd Dahl (1898–1994).

In Dahl's new book, heavy water is the hero of a saga that unfolds where Dahl's previous book left off, and it continues up to 1945. In the early 1940s, just after the discovery of nuclear fission, many people were convinced that heavy water was the key to new nuclear physics progress. With little of the substance around, attention was soon focused on Norway, which had an abundance of hydroelectric power for manufacturing processes.

With the outbreak of the Second World War, both sides were eager to get a supply of heavy water and to prevent it from falling into enemy hands. In 1940 the French cornered 185 kg of Norwegian deuterium, which was spirited to Paris via the UK in an elaborately planned operation. With the invasion of France, the heavy water had to be smuggled out again. It eventually found a temporary home in Windsor Castle, England, before being used in wartime Cambridge and then in Montreal, with Lew Kowarski and Hans von Halban playing leading roles.

In 1942 and 1943, allied commando raids and air strikes on the heavy-water plant in occupied Norway attempted to put the factory out of business. This culminated in the famous 1944 Norwegian Resistance operation, which intercepted a ferry carrying tons of deuterium-rich material *en route* to Germany and sank it in Lake Tinnsjø. Eighteen lives were lost. In 1965 the episode was made into a film called *The Heroes of Telemark*, which starred Kirk Douglas.



Dahl manages to combine scientific accuracy with a compelling storyline that keeps the pages turning. Like his cathode-ray book, the volume is meticulously researched, particularly with regards to Norway (although this time the footnotes have been abridged to a mere 57 pages). It is a remarkable read.
Gordon Fraser, CERN.

Handbook of Accelerator Physics and Engineering edited by Alexander Chao and Maury Tigner, World Scientific ISBN 981 02 3500 3 (hbk £58, pbk £32).

World Scientific approached Alex Chao some four years ago and asked if he would be willing to do a book for them. Chao had the idea for some sort of handbook and got in touch with me to ask if I would be interested in joining him. In the course of making that decision we explored many ideas. One approach was that we should write it ourselves. The other route involved trying to convince the real experts in the community to share their wisdom.

It soon became clear that the only economically feasible way of carrying this out was as a community project and a labour of love. No book royalties could possibly repay the kind of effort that would be required of more than 200 authors.

A key feature is that the money goes to the two accelerator schools (at CERN and in the US) for fellowships for students from institutions that are unable to support them. I'm sure this made the difference to many of the authors who toiled after hours and on weekends to meet our strict deadlines.

Having decided to go that way, we compiled a "straw man" table of contents and sent it around to many of those that we hoped would contribute, together with suggestions on which topic(s) we hoped they would write on. To our great joy and surprise, most agreed and we were off.

We tried to be very precise about the level, style and length of articles and, by and large, the authors entered into the spirit of the thing. Even with the best of wills, however, it was impossible for everyone to keep to their space allotment and we had an enormous amount of work to help the authors cut back.

Space was felt to be very important as we insisted that the book should be portable in emulation of previous outstanding examples. Other considerations included uniform notation and style (at which we were only partly successful). The final text is about half the total of the original submissions.

Naturally, now that the work of four years and thousands of person-hours has borne its fruit, we have had many suggestions for improvement. Some of these suggestions and corrections have already appeared on a special Web page.

Maybe someday there will be another edition in which all of these contributed ideas and corrections can be incorporated. At any rate, we profoundly hope that the book will prove useful and stand as an example of the underlying unity of our community and what can be done when there is a will.

See "www.wspc.com.sg/books/physics/3818.html" for more information.
Maury Tigner.

Elementary Particles and the Laws of Physics by Richard P Feynman and Steven Weinberg, Cambridge University Press, ISBN 0 521 658622 4 (110pp, pbk £9.95/$11.95)

The text of the 1986 Dirac Memorial Lectures, long available as a slim hardback, is now available in paperback. Feynman dismantles field theory to find the real reason for the existence of antiparticles, then puts the theory together again. Weinberg's compelling prose "Towards the final laws of physics" examines how quantum physics can be reconciled with gravity. Over a decade later, the messages in these lectures remain fresh.

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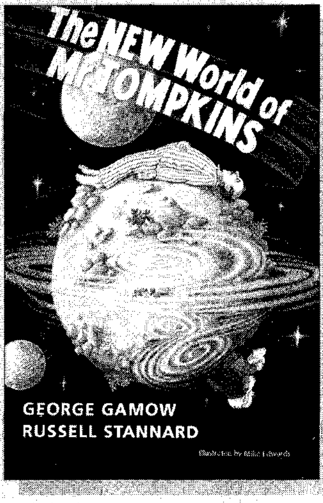

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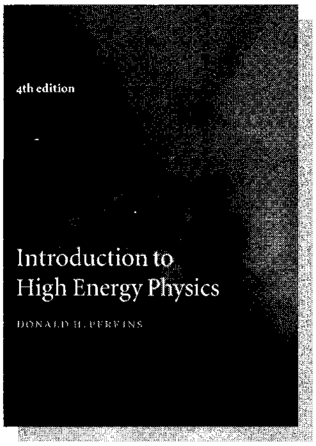

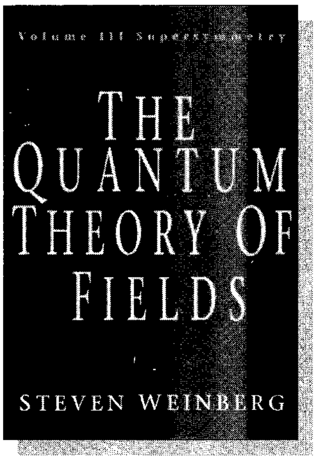

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