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VOLUME 38 NUMBER 9 DECEMBER 1998

More light on Cherenkov effect

DESY DIRECTIONS
The German laboratory's HERMES experiment is poised to reveal new insights into what carries proton spin

IT'S A GEM
The gas electron multiplier developed at CERN promises better performance for major new physics experiments

AUSTRON INVITATION
Austria is seeking international partners for a pulsed high-flux neutron spallation source in central Europe

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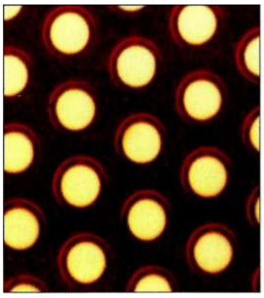

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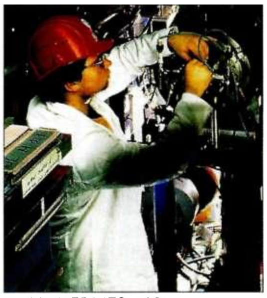

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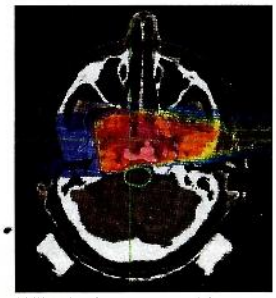

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Cover: First photograph of the Cherenkov radiation from a high-energy lead-ion beam at CERN, p7.

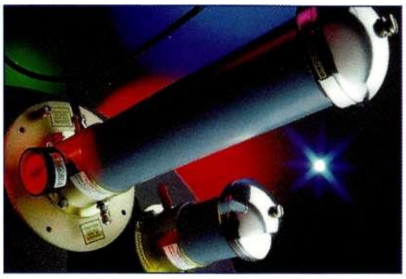
HV SOURCE

Space saving power supplies from Glassman pack more punch *- Full story below*

Glassman launches MORE new products to celebrate 21 years at top

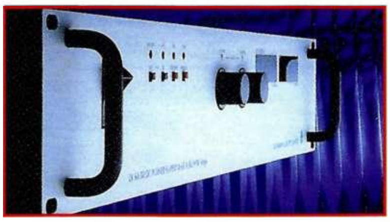
High Performance Dividers

Ross compact and lightweight base-mounted HV dividers handle maximum operating voltages from 3kV to 1000kV DC or PK AC, or up to 1350kV impulse.
Offering high accuracy and bandwidths to over 20MHz, models are available in compensated resistance-capacitance types or uncompensated resistive or capacitive types, for indoor and outdoor use.



High Power, Low Profile

The new LV series high-voltage power supply from Glassman provides high efficiency and high power in a compact enclosure.
Available in 1kW (0 to 600V) or 3kW (0 to 300V) supplies, all units are standard 19" rack mounting. 1kW models are only 1.75" high, and 3kW models 3.5" high.
Overvoltage protection and thermal shutdown are standard. Units carry a full three-year parts and labour warranty.



SLIMLINE

The NEW Series FC from GLASSMAN

- 120W
- 1.75" Panel Height
- Up to 60kV
- Air Dielectric
- CE Approved

Glassman's new FC series regulated high voltage DC power supplies offer 120W performance in a unit with half the panel height of competing 100W devices. There are 16 output ranges from 1kV to 60kV.
The compact, lightweight package has a panel height of only 1.75", and like other models in the Glassman range, it uses air as the primary dielectric medium for easy serviceability.
Automatic crossover from constant-voltage to constant-current regulation provides protection against overloads, arcs and short circuits. All models in the FC series are fully CE compliant. Advantages include low ripple, low stored energy and excellent voltage/current regulation performance.A full three year parts and labour warranty is included as standard.

AC Supplies from DC Specialists

High-specification Chroma 6400 series AC power supplies offer full frequency programmability from 45 to 500Hz - including the 400Hz standard for aerospace applications.
Now available from Glassman, the 6400 series includes five models, offering 375VA, 800VA, 1500VA, 2000VA and 3000VA output power, for optimum versatility over a broad applications range. Features include optional GPIB, RS232C and analogue programming interfaces.

GLASSMAN europe

Next Issue...
NEW ML Series HV Power Supply launch

For more HV News: Tel: 01256 883007, Fax: 01256 883017

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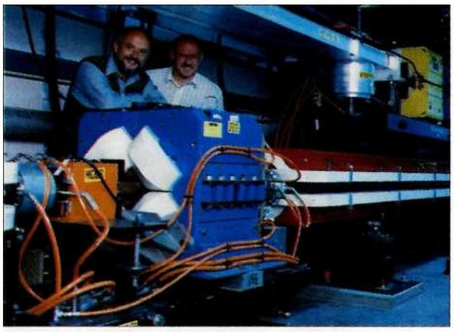
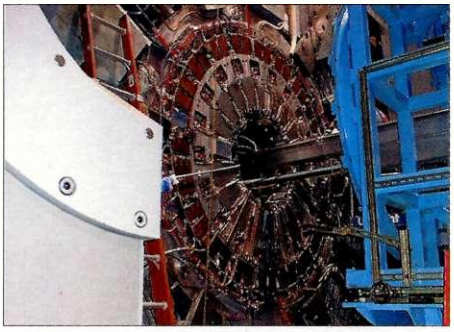
SLAC B Factory makes progress



Pier Oddone (left), Deputy Director of the Lawrence Berkeley US National Laboratory, with Jonathan Dorfan, Associate Director of the Stanford Linear Accelerator Center (SLAC), at the new PEP-II B Factory. Oddone made the original suggestion for such an electron–positron collider with unequal beam energies. Dorfan is the Project Director of the three-laboratory team (Berkeley/Livermore/SLAC) that built it, on schedule and on budget. Electrons circulate from right to left in the lower ring (red and blue magnets), while positrons circulate in the opposite direction in the ring above.



The forward end of BaBar with the endcap crystal calorimeter and the superconducting solenoid, the barrel instrumented flux return and in the foreground a partial view of the instrumented doors.

US Department of Energy Secretary Bill Richardson symbolically initiates operation of the new PEP-II B Factory. Seated in the front row are (left to right): Martha Krebs, Director of the DOE's Office of Science; US Representatives Zoe Lofgren and Anna Eshoo; Stanford University Provost Condoleezza Rice; and SLAC Director Burton Richter. Seated in the second row are: Jim Turner, Director of the DOE's Oakland Operations Office; Bruce Tarter, Director of the Lawrence Livermore National Laboratory; Peter Rosen, Director of the DOE's Office of High Energy and Nuclear Physics; Charles Shank, Director of the Lawrence Berkeley National Laboratory (LBNL); and Michael Witherell, Chairman of the High Energy Physics Advisory Panel. Standing behind Rosen and Tarter is LBNL Deputy Director Pier Oddone.

After achieving its first electron–positron collisions this summer (September, page 17), the PEP-II B Factory at the Stanford Linear Accelerator Center (SLAC) was formally dedicated on 23 October.

And major advances towards the operation of the BaBar detector are being made. Having installed the instrumented flux return and the superconducting solenoid early this year, the first step of the detector's integration has been completed by adding the barrel crystal calorimeter and the central drift chamber. Finally, the particle identification system and the forward endcap calorimeter were installed this autumn.

BaBar is now in a scheduled cosmic-ray run which will be concluded early next year with the addition of the silicon vertex tracker and when BaBar will roll into the B Factory's colliding electron and positron beams.

Brookhaven completes magnet production

A recent celebration in the assembly area at Brookhaven's RHIC Magnet Facility marked the completion of magnet production for the laboratory's RHIC Relativistic Heavy Ion Collider. Among those noting the successful achievement of a milestone within two weeks of a schedule set three years earlier were: RHIC Project Director Satoshi Ozaki; Brookhaven Director John Marburger; Martha Krebs, Director of the Office of Science of the US Department of Energy (DOE); and Acting Director of DOE's Division of Nuclear Physics Dennis Kovar.

In total, some 1800 RHIC magnets have been assembled and/or tested at the Magnet Facility. These contained over 21 million metres of superconducting wire and required over 900 000 technician hours for manufacture. Installation of the magnets is scheduled to be complete by the end of the year. This will be followed by subsystem tests beginning in January 1999, and beam tests in March. Following partial installation of RHIC detectors, a low intensity engineering run is scheduled for July, when the first collisions in RHIC are expected. After a long and arduous preparation, RHIC will take its place at the forefront of world physics.

• Brookhaven's venerable AGS Alternating Gradient Synchrotron, commissioned in 1960, recently reached a record intensity of 6.82×10^{13} protons/pulse. The AGS will soon take on a new role, supplying beams of ions to feed RHIC.

NESTOR approved

On 10 August, the Greek government formally approved the establishment of a national NESTOR Institute for Deep Sea Research, Technology and Neutrino Astroparticle Physics. Its headquarters are at Pylos in Navarino bay, 300 km south of Athens.

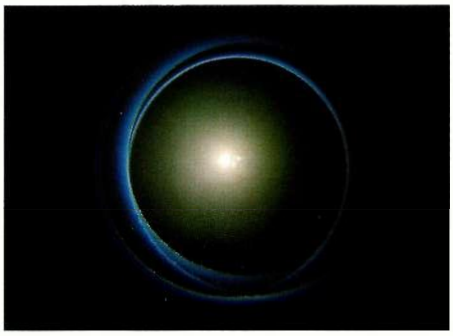
Supported by local, regional and national governments and under the interim directorship of Leo Resvanis, NESTOR's goal is to build a large underwater neutrino detector for deployment nearby. Development work has been under way for some time (October 1997, page 17).

More light on the Cherenkov effect

Cherenkov radiation is one of the main techniques for particle identification, but details of the underlying theory are still under debate. A group of researchers from Comenius University, Bratislava, CERN and JINR recently carried out measurements using CERN's high-energy beam of lead ions. With the assistance of the NA49 experiment, they used air, helium and various crystals as media.

The photo shows the result of passing the beam through a biaxial crystal of triglycine sulphate. The circle is the image of the Cherenkov radiation via the focusing lens, and the two elliptical bands are the Cherenkov radiation (the crystal has two different refractive indices). The light is also not uniform due to the alignment of the optical axis of the crystal.

Cherenkov radiation derives its name from Pavel Cherenkov, who as a young PhD student at Moscow's Lebedev Institute in the early 1930s, was assigned by Sergei Vavilov the task of investigating what happens to the radiation from a piece of radium when it is immersed in a fluid. Such radioactive materials give off an eerie blue light, such as that seen in a "swimming pool" nuclear reactor.



Ring the changes – first photograph of the Cherenkov radiation from a high-energy lead-ion beam at CERN.

Initially, this was thought to be fluorescence, similar to that seen when X-rays strike a screen, but Vavilov and Cherenkov were not convinced. After heroic investigations, where Cherenkov would typically prepare for a working day by staying in a totally dark room for one hour, he found that the radiation was produced by electrons and was essentially independent of the liquid used, thereby ruling out fluorescence.

The explanation for the effect came in 1937 from Ilya Frank and Igor Tamm, who explained that the radiation is a shock wave resulting from a charged particle moving through a material faster than the velocity of light in the material – the optical equivalent of the sonic boom produced by an aircraft as it accelerates beyond the speed of sound.

The "Cherenkov" radiation propagates as a cone whose opening angle depends on the particle velocity. When this cone hits a flat surface, a characteristic ring is seen.

Further elucidation came in the 1950s when Cherenkov rings were photographed by Valentin Zrelov using proton beams at the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow. In 1958, Cherenkov, Frank and Tamm shared the Nobel prize for their work. Vavilov had died earlier.

Web tool LIGHTs up code

CERN's Information and Programming Technology (IPT) group has exploited the World Wide Web to make it easier to keep track of masses of computer code. Lifecycle Global Hypertext (LIGHT) was so successful when applied to the ALEPH experiment that it is now being taken up around the world.

The software for a big particle physics experiment can run to tens of thousands of lines of code, organized into hundreds of routines written by dozens of people in many institutions, and often has code from independent program libraries folded in too. It can have a lifetime of over a decade during which it is constantly evolving. No wonder newcomers to an experiment can find it daunting.

The traditional way of finding a way around all this involves the printed word: a bookshelf full of manuals to wade through as well as the source code itself. But help is now at hand thanks to LIGHT, originally developed for CERN's ALEPH experiment and since adopted by many other experiments around the world.

Paolo Palazzi had the idea for LIGHT in 1993 and it was subsequently developed by members of CERN's IPT group. The idea was to make all the necessary information available through a Web interface. A click on a subroutine call in a big program, for example, would take you to that routine's source code, and a click on the code would take you to the documentation. Having built your program from all the different packages available and plugged in your own specific code, you would then be able to submit it through a Web-based template so that your complete analysis could be conducted through the Web.

The ALEPH-specific implementation of LIGHT was ready in 1995, and is now used on all of ALEPH's main off-line software. True to its name, ALEPH LIGHT will manage the software for the lifecycle of the experiment – any new code or updates to old routines appearing automatically at the end of hypertext links.

In 1997 the IPT group decided to make LIGHT available generally, and under Alberto Aimar's co-ordination it was re-engineered and the project was re-organized. Other experiments soon followed ALEPH, with CERN's DELPHI showing what they thought of the system by giving their customized version the name "Delight".

Others to follow are ATLAS at CERN, BaBar at Stanford in California, and KLOE at Italy's Frascati laboratory. With a second version of LIGHT under development, making it easier to add new formats and languages, the product is set to reach a wider range of experiments and projects. The software remains as complex as ever, but with LIGHT all information is just a click away.

See "http://light.cern.ch" for more details.

The broken arrow of time

New results from experiments at Fermilab and at CERN remind us how, in the strange world of the neutral kaon, a fast rewind does not necessarily take you back to where you started. Full story in the next issue.

Correction

The 8-inch phototubes referred to in the caption of the article on the Borexino detector (October, page 12) should have been credited to Electron Tubes and not Thorn EMI.

Edited by Emma Sanders

Explosion forces rethink on stellar collapse

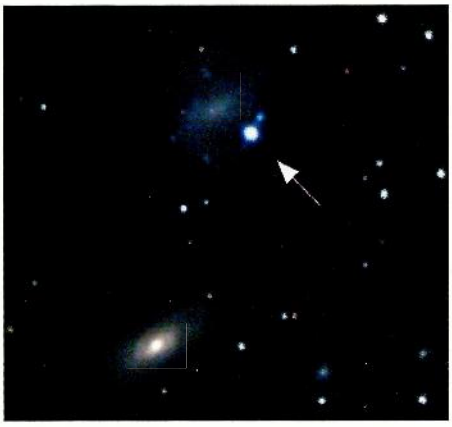
An exceptionally powerful explosion in a nearby galaxy has led astronomers to re-examine their theories of stellar evolution. What is more, the explosion was co-incident with a burst of gamma rays, providing another clue to the origin of these bizarre phenomena.

As a large star reaches the end of its life-time and runs out of nuclear fuel, it becomes unstable. The core collapses inwards forming an extremely dense neutron star or black hole and sending out a shockwave which blasts the rest of the star out into space. For a few weeks, this supernova explosion can be as bright as 100 billion ordinary stars.

Now, a supernova has been seen that is 30 times more powerful than any measured before. Moreover, it is coincident with a gamma ray burst. Trying to explain their observations, astronomers suggest the existence of "hypernovae." These are extremely massive stars that collapse into black holes and send out a very strong shockwave capable of generating the observed gamma rays.

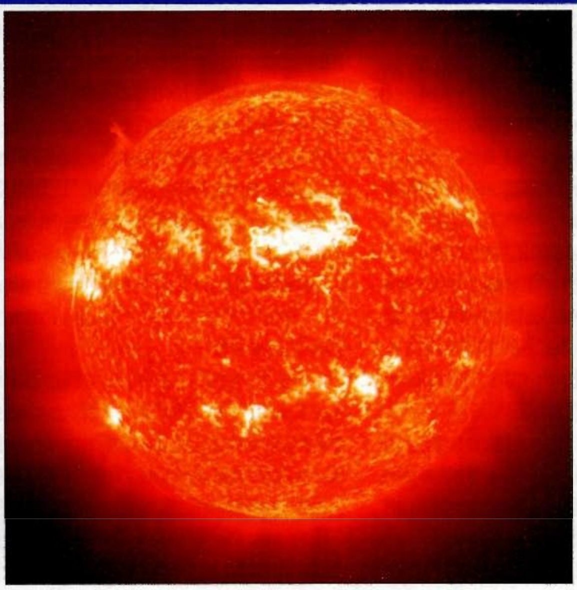
Gamma-ray bursts have remained a mystery for 30 years. Last year, optical and radio observations linked them to galaxies at enormous distances. These new results are important because they connect a gamma-ray burst to an explosion much nearer to home.

The gamma rays were detected by the Italian-Dutch BeppoSAX satellite and optical observations were made using the European Southern Observatories telescopes in La Silla. The supernova was also observed by the Australian compact array radio telescopes.



An unusually bright supernova explosion. (European Southern Observatories.)

Picture of the month



The Sun, pictured by the Extreme Ultraviolet Imaging Telescope onboard the Solar and Heliospheric Observatory (SOHO). The NASA/ESA satellite is making a full recovery since it span out of control last summer (October, page 9). All instruments have now been switched back on. SOHO is very popular with astronomers and has had many successes. In the past, helioseismological data from the spacecraft has given independent support for solar models, adding confidence to their predictions for solar neutrino flux. (NASA/ESA.)

Infrared reveals early universe

Observations using the Infrared Space Observatory (ISO) show that the first galaxies to form were far brighter than astronomers thought. The results were presented at a meeting in Paris.

Infrared telescopes reach parts of the sky other telescopes can't see. Large dusty clouds absorb the radiation emitted by the stars they hide. The heated dust glows in the infrared, revealing what is behind.

ISO has surveyed the faintest and furthest infrared objects, revealing a new population of luminous galaxies. "Two to three times more stars are being formed than the rate inferred originally from optical surveys," said Michael Rowan-Robinson of Imperial College, London.

Results are confirmed by the detection of the first-ever infrared bright gravitational arcs. These are images of distant galaxies magnified by up to 10 times by gravitational lensing, allowing astronomers to see objects that would otherwise be too faint and too small. All the galaxies detected this way have much higher rates of star formation than predicted.

Greenwich's time has come

Britain's Royal Greenwich Observatory (RGO) has closed due to funding cuts. Founded in 1675, it was home to the first Astronomer Royal, John Flamsteed, and was the country's oldest scientific institution. The original observatory marked the zero degree meridian line.

Most of the RGO's research was devoted to providing fundamental astrometric measures and almanacs for use by navigators and surveyors. In the 20th century the RGO's activities broadened to include research on stellar structure and evolution, galaxy dynamics, active galactic nuclei and the large-scale structure of the universe, as well as being home to a technology group devoted to telescope and instrument design. In the 1950s the observatory was moved out of London, and from 1990 was located in Cambridge, near to the University's Institute of Astronomy.

Some of the RGO's work will be continued by the Astronomy Technology Centre in Edinburgh.

HERMES heralds insi

In which direction do quarks point? The HERMES experiment using DESY's HERA electron ring and an ingenious system to control the spin of the electron beam is poised to reveal new insights into the puzzle of what carries the proton's spin.

In 1987 CERN's European Muon Collaboration (EMC) revealed a puzzle that has been intriguing particle physicists ever since. The EMC measurements implied that the constituent quarks accounted for only some 30% of the nucleon spin. If the nucleon spin is not carried by quarks, where does it come from?

Several subsequent experiments at CERN and SLAC (Stanford) have given a more precise fix of this total quark contribution to the spin, but without being able to find where or what the missing spin is.

This is where HERMES comes in, a second-generation experiment at DESY's HERA electron-proton collider which aims to study the origin of nucleon spin via electron-nucleon scattering in which both the beam and target particles are spin-oriented (polarized). HERMES does not use HERA in its usual collider mode. It uses instead HERA's electron (or positron) beams with a specially-designed target, and does not use the HERA proton beam.

Now well into its fourth year of data-taking, HERMES has demonstrated the validity and potential of its new approach and is now taking its first steps towards a solution of the spin puzzle by presenting a preliminary separation of the contributions of the individual quark flavours to the nucleon spin.

How to look at a nucleon's spin

At collision energies where contributions due to the weak nuclear force are small enough to be neglected, a polarized electron or positron scatters off a polarized nucleon via the exchange of a virtual photon, which carries polarization from the incoming electron. Due to angular momentum conservation, this photon can interact with a quark in the nucleon only if this is polarized in the opposite direction.

The different spin orientations of beam and target, obtained by flipping the target polarization back and forth, reveal asymmetries in the different reaction rates which eventually yield the spin distributions of the nucleon's constituents.

As well as its three valence quarks, the overall spin of the nucleon has contributions from its accompanying "sea" quarks and antiquarks, the gluons (which hold the quarks together), plus quark and gluon orbital angular momenta.

Up to now, most experiments have focused on measuring "inclusive" polarized lepton-nucleon scattering, where only the scattered lepton (electron or muon) is detected. This gives only an "overall" spin structure of the nucleon – the spin carried by the quarks as a whole, without resolving the individual contributions of each quark.

The great power of HERMES lies in its ability to detect and identify the emerging hadrons in coincidence with the scattered lepton. Since high-energy forward-scattered hadrons are correlated with the struck quark, these hadrons "tag" the flavour of the struck quark. The contributions to the nucleon spin are determined not as a whole, but are separated into the individual quark flavours.

HERMES

HERMES – HERa MEasurement of Spin – is an international collaboration of 200 researchers from 10 countries. It uses an internal gas target of polarized atoms in place of the solid targets of past experiments, and the world's first longitudinally polarized high-current electron beam, circulating in the HERA storage ring.

The electrons pass through the gas target repeatedly, yielding plenty of clean data with minimal background contamination by scattering off other polarized or unpolarized nuclei (as is the case with solid targets).

Approved in 1993, the detector – a forward angle spectrometer of conventional design – was assembled in the HERA East Hall during winter 1994/95 and commissioned in early summer 1995. It uses HERA's 27.5 GeV electron/positron beam, naturally polarized transverse to the beam direction. Up- and downstream of HERMES, a pair of spin rotators turns the spins into the longitudinal and back to the transverse direction at every revolution – a world premiere in a high-energy electron storage ring first achieved in 1994. This was an absolute precondition for the operation of HERMES.

The HERMES target consists of nuclear polarized gas fed into a thin-walled storage cell inside the HERA electron/positron ring. This new technique increases the surface target density by a factor of 100 compared to a free atomic beam, and allows high target polarization levels without dilution from unpolarized nuclei.

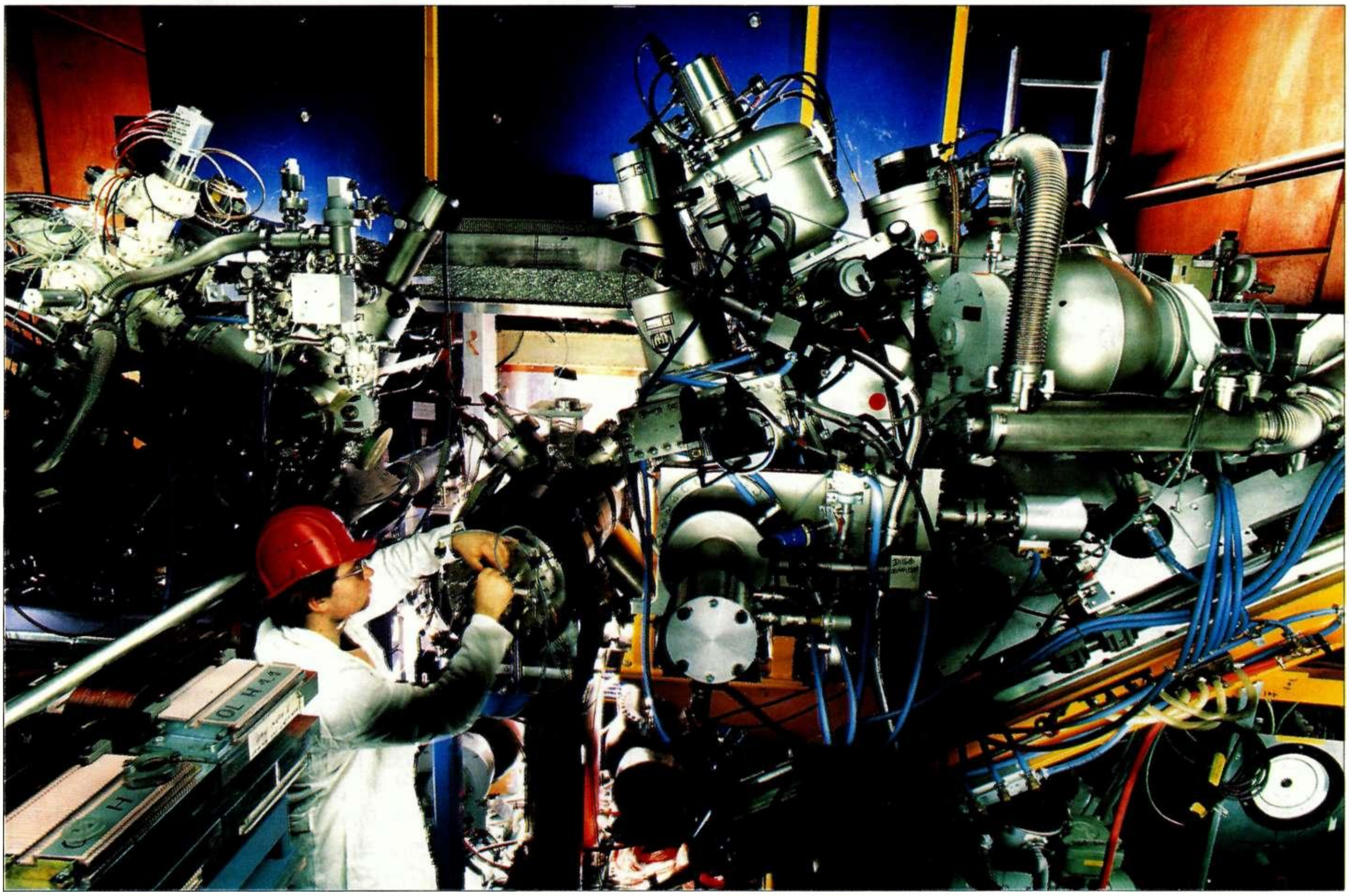
To minimize systematic errors, the target spin orientation is reversed at random intervals. So far, HERMES has been running with polarized helium-3 (1995) and hydrogen targets (1996–97), and deuterium in 1998. The target cell can also be filled with unpolarized gases for the investigation of further nucleon properties unrelated to spin.

First results

During its first four years of operation, the HERMES experiment has lived up to the swiftness of its classical namesake. Primarily a rerun of previous experiments, the first HERMES investigations measured the scattered electron (positron) using targets of polarized helium-3 (1995) and polarized hydrogen (1996–97).

The resulting "overall" spin structure of the neutron and the proton reconfirmed the "spin puzzle". Good agreement with previous data from experiments at CERN and SLAC provided an essential and

ght into nucleon spin



A rare view of the HERMES target area taken from the series "DESY in a special light" by Peter Ginter, showing the hydrogen target cell (centre) with its atomic beam source (right) and a Breit-Rabi polarimeter (left) during assembly work in the winter shutdown 1995/96.

unique cross-check with a completely novel technique.

For a few weeks every year, HERMES has been collecting data from *unpolarized* gases to study further properties such as the quark flavour content of the nucleon sea, an important domain for testing models of nucleon structure. The latest HERMES data give the flavour asymmetry of the light-quark sea, clearly showing an excess of down antiquarks over up antiquarks in the proton sea, in good agreement with data from experiments using a completely different approach at much higher energies.

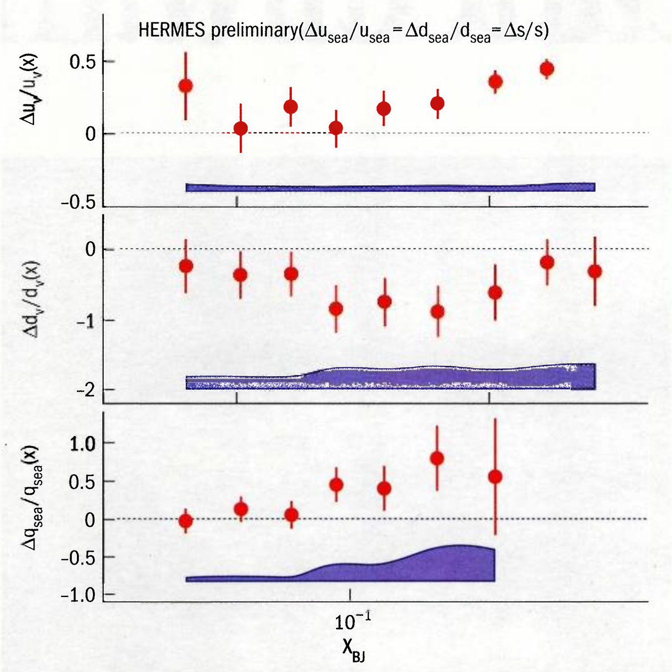
First insights into quark spin

HERMES is now hard on the track of the "missing" spin. Preliminary results present the polarized parton distributions from data taken in 1995 and 1996, with statistics equalling that of the Spin Muon Collaboration (SMC) experiment at CERN, stopped two years ago.

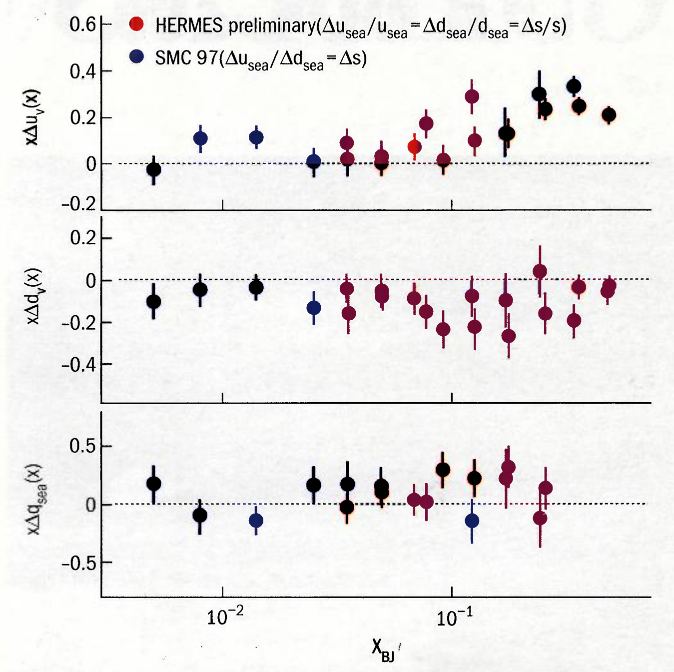
During 1995 and 1996 running, HERMES has measured asymmetries where the struck quark gives a positively or negatively charged hadron recorded by the detector. Three quark polarizations were extracted: the up and down valence quark polarizations, and the average polarization of the quark sea, dominated by up antiquarks.

These preliminary results reveal that the spins of the up valence quarks point in the same direction as the overall proton spin, whereas the down valence quark seems to carry a spin pointing in the opposite direction, the spin contribution increasing with the amount of the proton's momentum carried by the quark. The sea quarks appear to slightly favour alignment with the proton, though the data are still consistent with no dependence on the direction of the proton spin.

The HERMES extraction can be compared with the SMC results. Even though the HERMES definition of flavour independence of the sea polarization varies slightly from that of SMC, the difference was verified to be less than 10%. Both experiments are comparable in their extraction of the up and down valence quark values, with the HERMES data possibly indicating a more positive contribution from the sea quarks than does SMC.



Preliminary polarizations of up (top figure), down (centre) valence and sea (bottom) quarks inside the proton from HERMES 1995 and 1996 data. The bands show the estimated uncertainties of the data. While the spins of the up valence quarks point in the same direction as the overall proton spin, the down valence quark seems to carry a spin pointing in the opposite direction. The sea quarks appear to favour alignment with the proton.



Comparison of HERMES' preliminary polarized quark distributions (red points) with data from the Spin Muon Collaboration (SMC) at CERN (blue points). Additional data from HERMES (already in hand) will increase the precision of the distributions significantly.

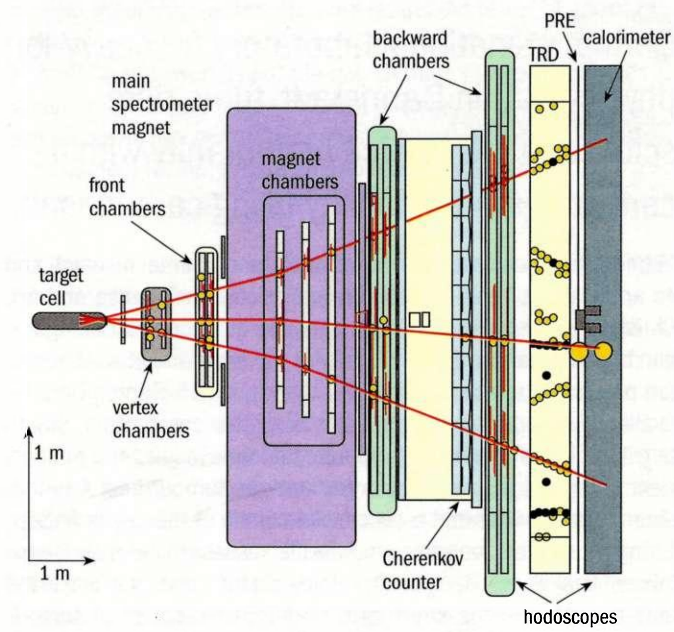
Analyses now focus on including the 1997 proton data, approximately 2.5 times larger than the sample used for the preliminary results. This will give the polarized quark distributions of the proton with unprecedented precision. HERMES is now turning to the study of the neutron with a polarized deuterium target operation for 1998 and 1999, expected to be comparable in size to the hydrogen data set.

For the detector, fresh possibilities will be opened up by the new dual radiator Ring-Imaging CHerenkov (RICH) detector (November, page 10) installed during the winter 1997/98 shutdown to replace the original threshold Cherenkov detector. The new RICH identifies protons, pions and kaons over nearly its entire kinematic range, obviating model dependence.

Flavour tagging of kaons will give HERMES direct access to the strange quarks inside the nucleon sea – where no experiment has been before. Since no heavier quarks (charm) are found in the nucleon sea at such low energies, these quarks must somehow involve the gluons inside the nucleon, for instance through photon–gluon fusion.

The new RICH and a recently implemented muon wall will allow investigation of such events and thus open the way to another missing part of the spin puzzle, the contribution of the gluons.

But HERMES physics will not end there. Other goals include study of further spin structure, quark–gluon correlations inside the nucleon, nuclear effects and investigating the transverse spin of the partons instead of the longitudinal part. But that will be a different story...



A deep inelastic scattering event as seen by the HERMES detector. The scattered positron is identified through the signals of the Cherenkov counter, the transition radiation detector (TRD), the preshower detector (PRE) and the calorimeter. The other tracks are charged hadrons.

GSI treats cancer tumo

The GSI carbon-ion therapy facility's first patient is ready for treatment. PET cameras are positioned above and below the head and the beam enters through the window behind. The lever in the patient's left hand can be used to signal any discomfort.

Germany's national laboratory for heavy-ion physics, GSI in Darmstadt, turns pure science to the service of humanity with a cancer treatment facility using carbon ions.

"A bridge has been established between fundamental research and its applications," said Hessen State Minister for Science and Art, Christine Hohmann-Dennhardt, speaking at the official inauguration of a new cancer therapy facility at the German national heavy-ion physics laboratory, GSI in Darmstadt, on 15 September. The facility uses carbon ions from GSI's heavy-ion synchrotron, SIS, to target traditionally difficult-to-operate tumours. The first two patients were treated at GSI last December and are tumour-free. A further nine patients underwent a successful course of therapy in August.

Cancer is second only to cardiovascular disease in the grisly league table of fatal illness. Gene therapy holds out the hope for a cure in the long-term, but in the short-term traditional methods of surgery, chemotherapy and radiotherapy must be used. GSI's new carbon-ion facility adds a new string to the radiotherapist's bow, allowing tumours in sensitive areas to be targeted safely and effectively.

The idea of using particle beams for cancer therapy is not new. In 1946, Bob Wilson first realized the potential of the technique when he observed that, unlike photons or electrons, proton beams deposit most of their energy at the end of their paths in the so-called Bragg peak. This opened up the possibility of targeting deep-seated tumours, or tumours close to sensitive organs, with much reduced risk to surrounding healthy tissue, by making the dose conform more closely to the volume of the tumour.

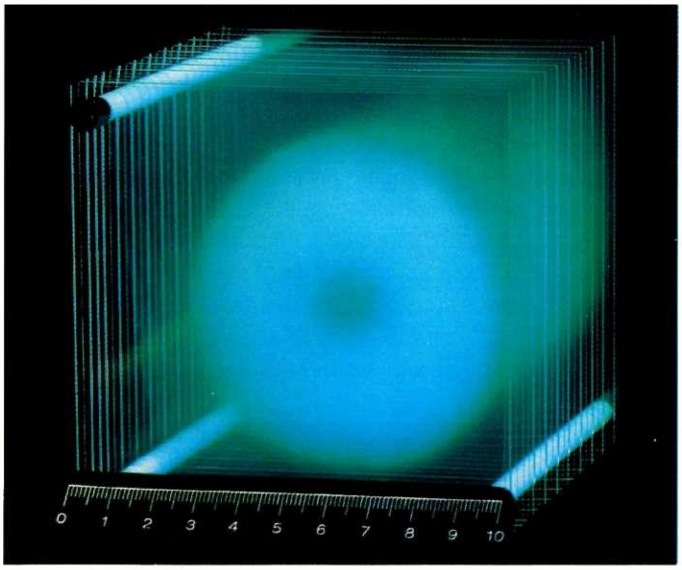
The first treatments were performed in 1954 when John Lawrence, Ernest Lawrence's brother, treated patients with proton beams at Berkeley's 184-inch synchrocyclotron. Three years later the same laboratory scored another first by turning helium ions to therapeutic use. And Berkeley's pioneering role wasn't confined to the United States. In 1956 Lawrence's friend and colleague Cornelius Tobias was a guest scientist in Sweden. Working with Lars Leksel and Borje Larsson at Uppsala, he helped initiate a programme of surgery and therapy using protons from the University's cyclotron.

Pioneering

Harvard's cyclotron laboratory has the longest continuous history of using proton beams to treat patients. The first patients arrived in 1961 and the facility will remain in use until all treatments are transferred to the Northeast Proton Therapy Center, scheduled to receive its first patients in February 1999. Then, having treated over 7000 patients, the Harvard cyclotron will take a well-earned retirement.

The main limitation of these pioneering efforts has been the lack of techniques for shaping the beam. Even today particle therapy units use mainly passive beam-shaping systems, such as absorbers or col-

urs with carbon ions



The GSI beam-scanning technique allows any shape to be irradiated. Here, plastic sheets immersed in water have been irradiated in a doughnut shape. The biological effect along the path of the incoming ions is small, the ions depositing the bulk of their energy in the target volume.

GSI in profile

The Darmstadt GSI heavy-ion laboratory is most famous for its discoveries of transuranic elements numbers 107 to 112. These were filtered out from the fusion products resulting from collisions between a heavy-ion beam from the universal linear accelerator, UNILAC, and a target of lead or bismuth. Element 107, named bohrium after Danish physicist Niels Bohr, was discovered in 1981. Hassium, named after the state of Hessen, followed in 1983, and meitnerium, named after Austrian physicist Lise Meitner, came in 1984. Elements 110 to 112 were discovered between 1994 and 1996 and have yet to be named. Elements 113 and 114, a predicted hidden "valley of stability" are next on the laboratory's hit-list.

GSI's main research theme is the investigation of hot, dense nuclear matter in the collisions of heavy ions with stationary targets. This began in 1975 at the UNILAC which has today been joined by the SIS and the experimental storage ring, ESR. Heavy-ion research has implications for basic nuclear physics as well as for astrophysics and the properties of neutron stars.

In another strand of research using the ESR, scientists can strip off the electron shells from even very heavy atoms. This allows them to study quantum electrodynamics – the most precise theory in physics – to unprecedented levels of accuracy.

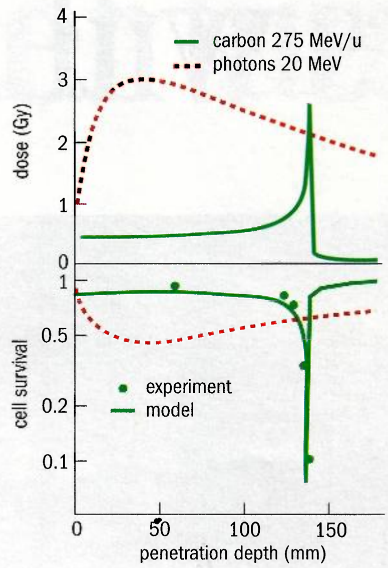
Although GSI is primarily a pure science laboratory, the tumour-therapy work is not the only domain of applied physics under study there. Plasma physics, particularly with the goal of producing energy generation through heavy-ion-driven inertial confinement fusion, is also an important part of the laboratory's work.

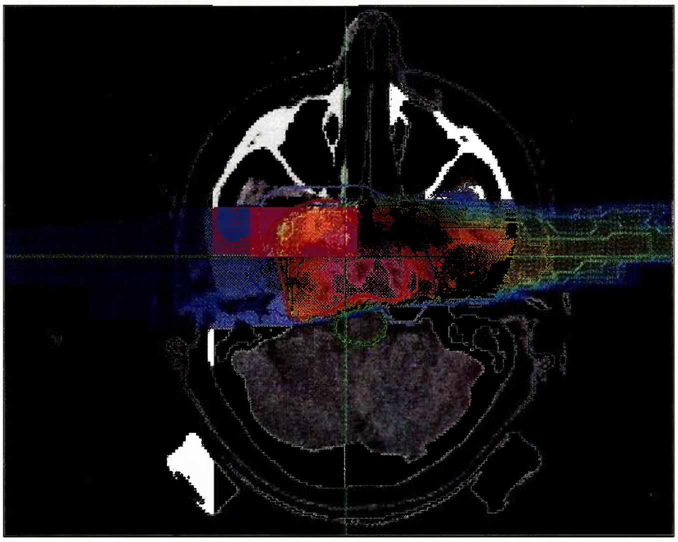
limators, adapted from photon therapy. These shape the irradiated volume to match a target volume identified by tomographic imaging techniques. Passive methods, however, only permit the same limited conformation of dose to tumour that can be reached with conforming photon therapy. The GSI facility is the first to provide extremely precise tumour conformity using magnetic beam scanning in two dimensions and by actively varying the energy of the accelerator to give the third dimension. Beam delivery is based on a novel, fully three-dimensional, treatment planning system that takes into account the differences in biological efficiency of the beam in different tissues as well as so-called early and late effects. Early effects – essentially tumour cell killing – are maximized, while late effects – complications in healthy tissue – are minimized (see box "Why carbon?").

After Berkeley and Japan's Heavy Ion Medical Accelerator, HIMAC, in Chiba, GSI becomes the world's third ion therapy centre. The laboratory is a relative latecomer to the field, but development of the innovative beam delivery system and treatment planning based on a more profound understanding of radiobiological particle action took more than a decade of intense experimental work. When GSI switched on its first accelerator in 1975, radiation biology experiments were among the first to be performed. Their initial goal was to investigate the biological effects of cosmic radiation during space flight, but the results have been fed into the modern therapy programme. They showed, in what has come to be known as the "Darmstadt hook", that the microscopic structure of the energy deposition process is far more important in determining biological effects than distinctions between biological systems.

GSI's fully active beam-scanning system works on much the same principle as a television set, where the picture is built up of lines consisting of individual pixels. Instead of a flat, regular screen, the GSI beam plays on a three-dimensional, irregular tumour. The scanning process, however, is very similar. The tumour is mapped and divided into 3-D pixels, the number of necessary particles is calculated for each pixel, and the beam targeted at that pixel until the calculated number has been delivered. The deepest layers are targeted first and the energy of the beam is then reduced by the accelerator to position the Bragg peak on successively shallower layers. This procedure requires extremely reliable accelerator operation guaranteeing spatial beam stability of better than one millimetre at the target. Energy and intensity are changed from pulse to pulse, which for the SIS means within a second. To guarantee the required accuracy, an independent control system monitors the beam's position every 100 microseconds and its intensity every 10 microseconds. If

This window (left) in Wixhausen's baroque church, close to GSI, was commissioned from artist Thomas Duttenhoefer in 1997. It illustrates in its top right pane the deposition of energy with distance for photons (the smooth curve) and for carbon ions which deposit their energy at the end of their path. The pane below shows the corresponding survival rate for cells along the path of the ions. The curves in the window are not to scale and are based on the graphs (right) where the superior biological effectiveness of carbon ions is clear from the cell survival graph.





A section through the head of the GSI's first patient. It is overlaid with the physical dose distribution for a beam incident from the right. Critical structures like the brain stem, shown by a green line, are largely untouched by the beam. On the same day a similar treatment was performed with the beam incident from the left, and the whole treatment stretched over 20 consecutive days.

Standing behind the patient couch are (left to right): former Federal Minister for Education, Science, Research and Technology, Jürgen Rüttgers; GSI Scientific Director Hans-J Specht; Hessen State Minister for Science and Art, Christine Hohmann-Dennhardt; and the Chairman of the Aufsichtsrat (supervisory board) of GSI, Hans C Eschelbacher, who is also President of the CERN Council. (Photo: Achim Zschau, GSI.)

either deviates by more than 2% from what is expected, the beam is shut off within half a millisecond. Such strict operating conditions are far beyond what is required from the SIS in its regular research role, but routine patient treatment has shown that the accelerator is up to the task. Just a handful of interruptions per day have been provoked by the control system during treatments involving the targeting of tens of thousands of pixels.

The GSI facility will be used for a pilot project to treat several hundred patients over a five-year period. A typical course of treatment involves around 20 half-hour sessions on 20 consecutive days. For the irradiation the patient is immobilized on a treatment couch. Treatment currently focuses on head and neck tumours where adequate immobilization can be achieved. The patient's head is held steady to within one millimetre using a mask, and the complete set up is checked by X-ray before each treatment session.

Patient comfort and safety have been given high priority. Whilst on the treatment couch, the patient can signal any discomfort to the radiotherapist. Even in the case of complete power failure to the magnets steering the beam, the patient will not be harmed since the undeviated beam trajectory passes high over the patient's head.

With its new concept in particle therapy the GSI facility joins a growing number of proton and ion therapy centres around the world. There are treatment centres in Canada, France, Germany, Japan, Russia, South Africa, Sweden, Switzerland, the United Kingdom, and the United States. So far, some 25 000 patients have benefited from proton or ion treatment and proton therapy machines are available "off the shelf". The proton-ion medical machine study, PIMMS, at

Why carbon?

Carbon was chosen by GSI following a study of the biological efficiency of all ions from protons to uranium. The radiation damage it causes is repairable to a large extent in the entrance channel of the beam, and becomes irreparable only at the end of the beam's range – in the tumour itself.

The crucial difference arises from the damage caused to cell DNA. Cancer cells and healthy cells alike die when their DNA sustains irreparable damage. In general, this means both DNA strands being broken since single strand breaks can frequently be repaired by the cell. GSI's studies showed that lighter particles such as protons, whilst depositing their energy in the Bragg peak, cause far fewer double-strand breaks than heavier ones like carbon. Moreover, the boundary between single and double-strand damage is particularly sharp with carbon which, coupled with GSI's beam delivery system, allows extremely precise targeting of the tumour – a factor which has been incorporated into GSI's treatment planning system.

Another advantage is that carbon ions do not scatter as much as lighter particles. This allows higher degrees of conformity to be achieved. Heavier ions, such as neon, were discounted because they tend to fragment. Carbon does fragment to some extent, but the fragmentation products include positron-emitting carbon 10 and 11. Positron Emission Tomography, PET, then allows the radiotherapist to observe "live" the position of the beam in the patient with a resolution of 2.5 millimetres. The GSI facility is the first to use PET to give on-line control of a carbon beam during irradiation. This is essential for irradiation of tumours close to critical structures like the brain stem or spinal chord. The Rossendorf Research Centre in Dresden provided GSI's PET cameras.

Carbon ions open up the possibility of treating a range of hitherto difficult tumours, and complement established proton therapy techniques. Protons, however, will remain important at many treatment centres for many kinds of cancer as well as for treatment of benign tumours.

CERN has optimized a design for a dedicated proton and ion therapy synchrotron. From a therapy point of view the PIMMS design improves on existing machines by providing much more stable beam extraction (October, page 20). The PIMMS study has been supported by the Italian TERA foundation and Austria's MED-Austron as well as GSI and CERN. Particle physicist Ugo Amaldi is behind the study and is a leading figure in efforts to coordinate research in the field on a European scale.

The GSI inauguration was attended by then Federal Minister for Education, Science, Research and Technology, Jürgen Rüttgers, and was opened by GSI Scientific Director Hans-J Specht. GSI's Gerhard Kraft presented the technical aspect of the project whilst Jürgen Debus of Heidelberg University's Radiological Clinic and the German Cancer Research Institute, DKFZ, described the medical aspects. In parallel with the inauguration, a detailed proposal for a clinical facility to be installed at Heidelberg University was presented. It is based on knowledge and experience gained during the pilot phase, and also details gantries which will allow treatment planning to be optimized. Funding is expected to come partly from the German government, partly in the form of subsidies from industry which stands to gain a march in this emerging technology, and partly in the form of bank loans. The proposed cost of DM 40 000 for a course of treatment, to be agreed with German health insurers, includes an element to cover loan repayments.

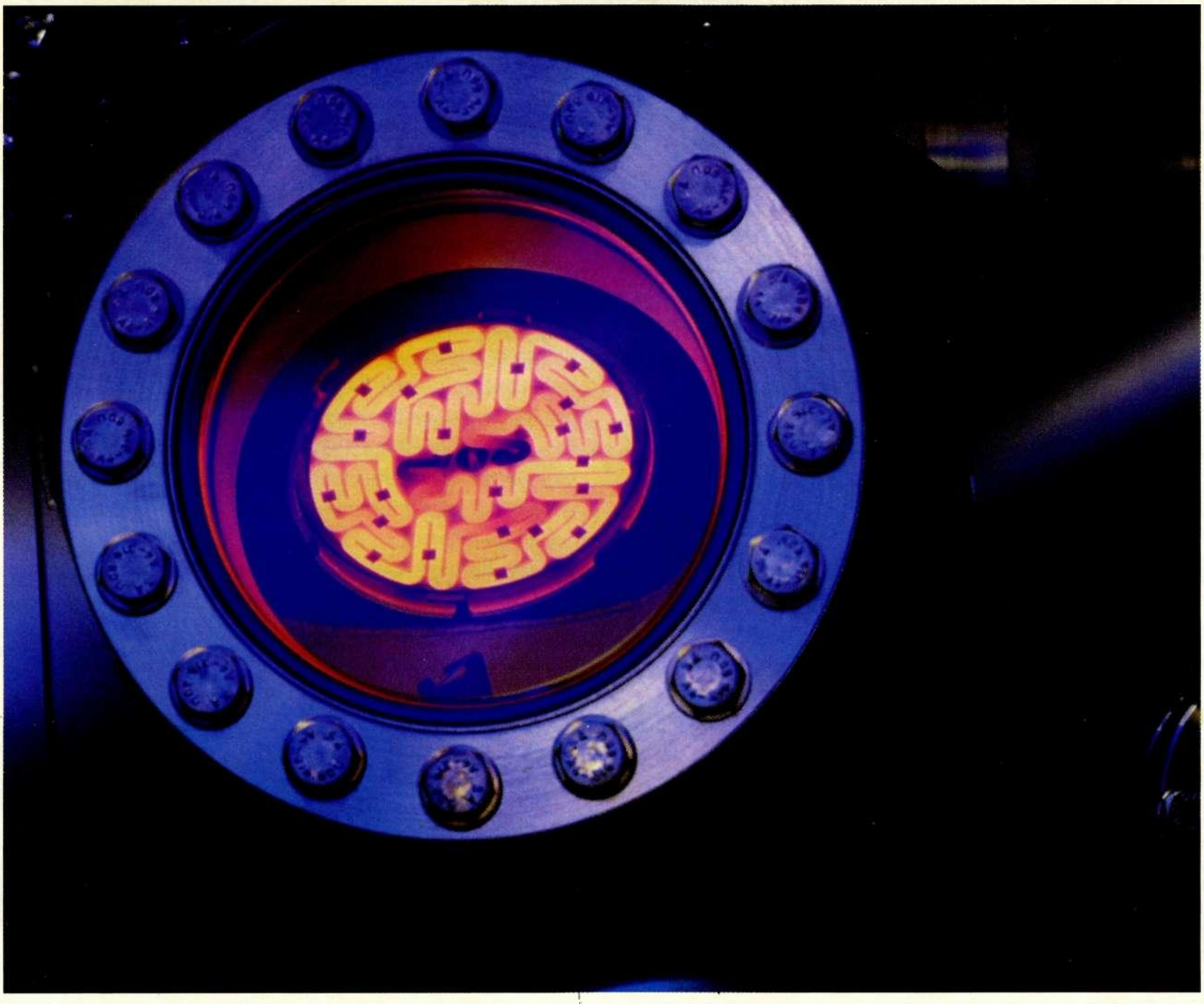
Today, over 40% of patients developing cancer can be cured, but nevertheless in 20% of cases neither surgery nor conventional radiotherapy can be used successfully, even in cases where patients are initially diagnosed with one solid tumour only. With this new project GSI joins a growing world community of proton and ion-therapy centres offering new hope for these patients.

James Gillies, *CERN.*

Further reading

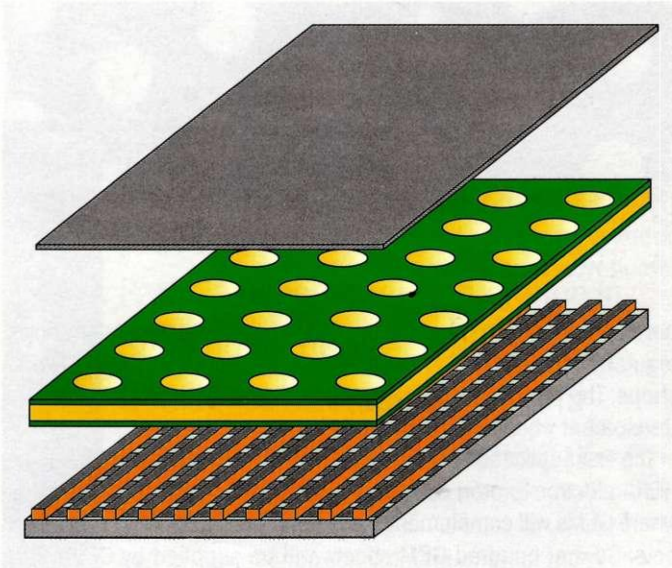
PTCOG: The Harvard Cyclotron Laboratory and Massachusetts General Hospital host the Web site of the international Proton Therapy Co-operative Group, PTCOG, which holds biannual meetings and issues a twice-yearly newsletter called *Particles* dealing with proton and ion therapy. An archive of the newsletter and links to other proton and ion therapy resources are maintained on the Web site which can be found at "http://neurosurgery.mgh.harvard.edu/hcl".

GSI: "http://www.gsi.de/".



A GEM of a detector

A particle detection technique developed at CERN promises increased performance for major new physics experiments – or anywhere where the detection of charged particles is needed, such as radiography and medical diagnosis.



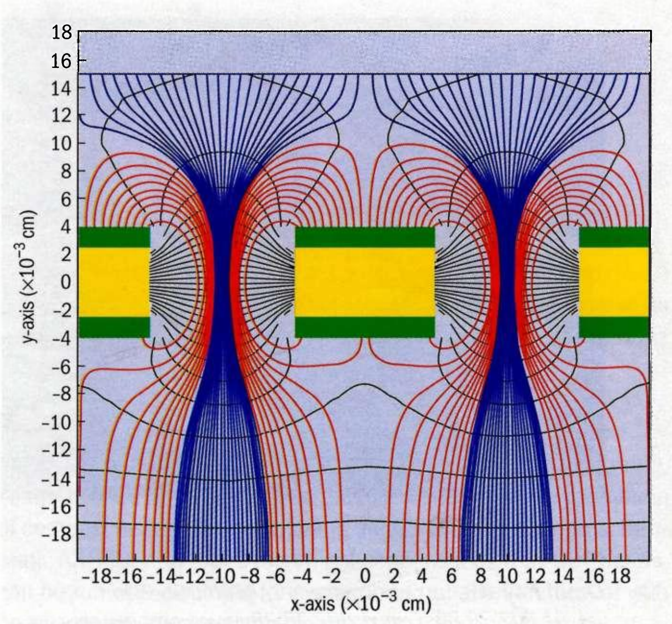
GEM – the gas electron multiplier – is a robust and accurate new particle detector technique. It uses a thin sheet of plastic coated with metal on both sides and chemically pierced by a regular array of holes a fraction of a millimetre across and apart. Applying a voltage across the GEM, the resulting high electric field in the holes makes an avalanche of ions and electrons pour through each. The electrons are collected by a suitable device, here a pickup electrode with x- and y-readout.

As physics experiments get more ambitious, the detectors they use have to keep pace – in 1913 Geiger counters, in 1968 Georges Charpak's multiwire chambers, and more recently, Anton Oed's microstrip gas chambers. However, the name of the game is always the same – to collect and to amplify the electrons knocked out of a gas by charged particles as they pass through. A new idea, the gas electron multiplier – GEM – from Fabio Sauli at CERN, continues this tradition. Developed as a way of boosting the performance of microstrip gas chambers, GEMs could soon come into their own.

The objective is to match the harsh running conditions in future experiments, such as those at CERN's LHC collider, where detectors will have to cope with high data rates and will be exposed to intense bombardment by high-energy particles.

Microstrip gas chambers achieve high precision and high rate by emulating the field structure of multiwire chambers using a sequence of alternating anode and cathode strips on an insulating support. Using photolithography instead of physical wires, the distance between sensitive elements can be reduced to a fraction of a millimetre. A separate electrode gives a drift field to move the electrons towards the amplifying plate.

Increasing the amplification in a microstrip gas chamber to achieve a bigger signal means increasing the operating voltage, but this cannot be continued indefinitely. The energy lost as ionization by charged particles decreases with energy, high energy "minimum ionizing" particles producing relatively small numbers of electrons. High gains are needed to pick up these signals. At these levels, collision by-products such as heavy, slower particles can release substantial additional ionization, resulting in a discharge which could ruin delicate instrumentation.

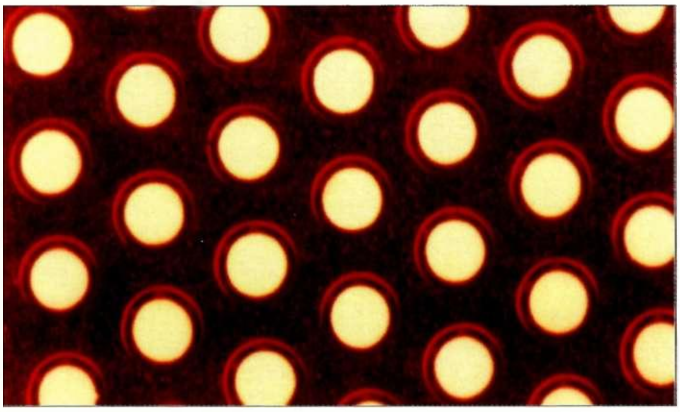


The electric field in a GEM microhole.

Chemical piercing

A new solution is GEM – a thin sheet of plastic coated with metal on both sides and chemically pierced by a regular array of holes a fraction of a millimetre across and apart. Applying a voltage (about 500 V on 50 microns) across the GEM conducting layers, the resulting high electric field in the holes makes an avalanche of ions and electrons pour through each. The electrons are collected by a suitable device, such as a microstrip gas chamber.

The idea, proposed two years ago, has now been consolidated by



The technology to produce the precision GEM arrays of submillimetre holes has been developed at CERN's Printed Circuit Workshop under Angelo Gandi.

development work to produce the GEM sheets with their micro-holes regularly spaced. This know-how was perfected in CERN's workshops. The resulting GEM layers look like metallic plastic, but are transparent when held up to the light.

The first application of GEM will be in the HERA-B experiment at the HERA electron-proton collider at the DESY laboratory in Hamburg, where GEMs will complement the experiment's microstrip gas chambers. Several hundred GEM sheets will be supplied by CERN. This approach is also the baseline design for the LHCb experiment at CERN.

Even with a moderate GEM gain, around 30 for HERA-B, the microstrip gas chamber can be operated at a much lower gain, requiring less voltage and therefore being less susceptible to breakdown. However, the overall gain of the tandem device is still optimal.

Sturdier devices have been developed based on a single high gain GEM with printed circuit board readout (where a discharge does less damage), and double GEM configurations with printed circuit board readout where the discharge probability is almost zero. This has been adopted for the small angle tracker of the forthcoming COMPASS experiment at CERN (May 1997, page 4).

Several other groups are currently investigating GEM solutions, looking at different configurations, geometries, operating conditions, gas filling etc.

With high gains obtained in purified gases, another possible application is large area photomultipliers capable of picking up single photons. Development in this direction is in collaboration with Israel's Weizmann Institute and the Budker Institute, Novosibirsk.

GEM-based detectors, like other micro-pattern devices, offer localization to around 40 microns. However, their unique feature is that two co-ordinates can be recorded on the pickup electrode, manufactured using GEM technology. Both x- and y-strips are at ground potential, essential when using high-density readout. Such two-dimensional localization, useful in particle tracking, is necessary for medical imaging.

Small storage ring and getters win EPS prizes

The European Physical Society's Interdivisional Group on Accelerators prizes, awarded at the European Particle Accelerator Conference in Stockholm this year, reflect the traditional resourcefulness and ingenuity that keeps this field of physics so dynamic.

Left to right: Sergio Tazzari, Chairman of the European Physical Society's Interdivisional Group on Accelerators (EPS-IGA); Søren Pape Møller of Aarhus, awarded the EPS-IGA prize for a young physicist or engineer; Cris Benvenuti of CERN, awarded the EPS-IGA prize for outstanding work in the accelerator field; Werner Joho, Chairman of the Prize Selection Committee.

Electrifying particle rings

This year's EPS-IGA prize for a young physicist or engineer was awarded to Søren Pape Møller of Aarhus, for the design, construction, and commissioning of ELISA, an electrostatic storage ring for atomic physics.

ELISA – ELectrostatic Ion Storage ring, Aarhus – is a novel front-line physics machine holding charged particle beams using only electrostatic fields. Just a few metres long, ELISA opens a door to table-top accelerator facilities.

Beams of charged particles in storage rings are normally held in captive orbit by magnetic fields, electrostatic intervention being confined to refinements, such as suppressing unwanted collision points with counter-rotating beams of electrons and positrons.

Charged particles at rest can be supported on electric and magnetic cushions in traps, such as the Penning variety. The trap developed by Wolfgang Paul relies solely on electric fields to preserve its stationary particles. Paul shared the 1989 Nobel Prize with Hans Dehmelt for their work on ion trapping.

Role model

On the storage ring front, CERN's LEAR low-energy antiproton ring, commissioned in 1983, became the role model for a new generation of compact storage rings, including the ASTRID ring at Aarhus, Denmark. ASTRID, with four 8 m straight sections joined by 90° bends, can be run with electrons for synchrotron radiation studies, or with heavy ions for physics experiments.

Several years ago, Søren Pape Møller at Aarhus had an idea for an

The 7 m circumference ELISA – ELectrostatic Ion Storage ring, Aarhus – which was commissioned this year, uses a purely electrostatic ring to store beams of charged particles – the first time this has been done since the mid-1950s.

electrostatic storage ring, using deflectors to steer the beam and quadrupoles to focus it. Electrostatic bending can be done much more compactly, so that the ring is small, making vacuum treatment much easier.

The absence of magnetic fields would considerably facilitate atomic physics measurements, while technically there would be no need for a cooling system to remove heat from electromagnetic coils. With no lag between applied field and resulting effect (hysteresis), electrostatic signals are also much more direct than magnetic ones.

Their different electrodynamics means that while magnetic rings store particles with identical momenta, electrostatic rings store particles with identical kinetic energies – ions of any mass but with the same kinetic energy can be stored using the same electric fields. (Such a ring was built at Brookhaven in the mid-1950s en route to the AGS Alternating Gradient Synchrotron, commissioned in 1960 as the world's then highest energy machine, attaining 30 GeV. The 14 m diameter AGS Electron Analogue, a particle accelerator in its own right, was built to investigate particle orbits for the AGS and went on to demonstrate effects very difficult to calculate in those days.)

Compact ring

The ELISA ring is considerably more compact than ASTRID. With a total circumference of 7 m, it consists of two sharp 160° spherical electrostic deflectors with 10° deflectors and four pairs of quadrupoles in the two "straight" sections, one of which is fitted with a radiofrequency system for beam gymnastics. With no acceleration envisaged, these will be confined to bunched beam operations.

After commissioning with 14 keV singly-charged ions of deuterium and nitrogen, many ions of different masses have been stored, with lifetimes around 5 seconds. After an improvement of the vacuum, lifetimes of several tens of seconds are expected. The heaviest ions used so far are "buckyballs" consisting of 60 carbon atoms, with a total mass of 720 proton masses.

Molecular sticky tape

The 1998 EPS-IGA prize for outstanding work in the accelerator field went to CERN's Cris Benvenuti for "major breakthroughs in achieving ultra-high vacua in storage rings using the NEG system, and for the development of niobium coatings of superconducting radio-frequency cavities in LEP".

Getters are materials with a strong affinity for gases which molecules stick to like fluff to sticky tape. At CERN's Large Electron-Positron collider, LEP, getters provide ultra-high vacuum. Now a new thin-film alloy developed at CERN promises even better vacuum, and could also spell good news for avid television watchers.

Since the advent of particle storage rings, high-energy physics and vacuum technology have advanced hand-in-hand. Storage rings demand high vacuum so particle beams are not lost through collisions with stray gas molecules, and getter pumps are commonly used. The most widely used getters in accelerators work by heating a titanium filament causing sublimation, the direct conversion of titanium metal to gas. This gas is then deposited on the surrounding vacuum vessel where it traps stray gas molecules in the vacuum chamber.

These so-called sublimation pumps provide a localized pumping action, whereas particle accelerators require distributed pumping. In the 1970s Cris Benvenuti addressed this problem by developing a new way of using getters for CERN's LEP. The accelerator's main pumping system is provided by linear strips of non-evaporable getters, NEGs, which cover 23 kilometres of the accelerator's 27 kilometre ring. They are made of a zirconium-aluminium alloy which is activated by heating to 750 °C. Instead of sublimating the gettering material, heating gives the oxygen enough energy to diffuse into the bulk material, leaving a clean surface to trap any residual gas inside LEP's beam pipe.

In LEP, vacuum is established by sealing the accelerator's vacuum chamber, heating to around 150 °C to remove any residual water vapour – the so-called "bake-out", and pumping with conventional suction pumps. These take the vacuum to 10^{-7} torr, a pressure below which the major source of stray atoms in the accelerator is gas escaping, or "out-gassing", from the walls of the vacuum chamber itself. LEP's NEGs are heated by an electrical current of 90 amps, and they mop up gas molecules which have out-gassed from the vacuum chamber walls and improve the vacuum to an impressive 10^{-12} torr.

Nevertheless, the high activation temperature of the zirconium–aluminium alloy is a handicap. Ideally, accelerators would be lined with a gettering material which became active at bake-out temperature. Baking out at 750 °C is not possible because it would damage the vacuum chamber. A gettering material which could be activated at a lower temperature would obviate the need for electrical heating, and thus the need for electrical insulation from the beam pipe.

In the 1970s, the world's foremost manufacturer of getters, SAES Getters in Milan, developed a gettering material which is activated at 400 °C. This is now widely used in steel vacuum systems which can withstand a high bake-out temperature. In particle accelerators, however, lighter materials are often required. LEP's vacuum chamber, for example, is made of aluminium and 200 °C is the bake-out limit.

Another technology brought to fruition by Benvenuti's team has provided a way forward. The cavities which pump energy into LEP's beams rely on superconducting niobium. Early cavities are made of solid niobium, but since only a thin layer is needed, Benvenuti's team set to work on techniques to coat copper cavities with niobium to the high degree of uniformity required. Their work has resulted in over 90% of the accelerator's superconducting cavities being made from niobium-coated copper, whilst only 20 are made from solid niobium.

With Benvenuti's long association with vacuum, it was not long before his team turned its thin-film experience to the gettering question. Three years of development have resulted in two patents and a zirconium–vanadium–titanium alloy, discovered earlier this year, which is fully activated after 24 hours at 200 °C, low enough for any vacuum chamber's bake-out. Moreover, this new alloy can be used as a thin-film coating of the vacuum chamber walls which gives the added bonus of effectively eliminating or strongly suppressing out-gassing from the underlying vacuum chamber. CERN's next major accelerator project, the Large Hadron Collider, is currently evaluating the new alloy with a view to using it in certain sections of the accelerator.

So what of that good news for television fans? Flat-screen displays are a much-touted new technology, but they have yet to make a significant impact on the market. Liquid-crystal displays are currently the most common, but they are expensive. An alternative technology is field-emission displays, FEDs. These work by using a single field-emission diode to illuminate each pixel of the screen, and they require ultra-high vacuum to work. Benvenuti's zirconium–vanadium–titanium alloy could be just the ticket.

Further reading

C Benvenuti, P Chiggiato, F Cicoira and Y L'Aminot 1998 Non-evaporable getter films for ultrahigh vacuum applications *J. Vac. Sci. Technol.* A 16(1), 148.

C Benvenuti 1998 Nonevaporable getters: from pumping strips to thin film coatings *Proc. of EPAC 1998* Stockholm, June.

C Benvenuti *et al.* 1998 A novel route to extreme vacua: the nonevaporable getter thin film coatings, Invited talk given at IVC 4, Birmingham, September.

The AUSTRON: Austria's

International partners are being sought for the AUSTRON, a proposal for a pulsed high-flux neutron spallation source which could provide an international research centre in central Europe. Austria has offered to put up a third of the costs.

In 1996 the Austrian Government declared its intention to aim for a large-scale international research facility, and the AUSTRON proposal was submitted by the Ministry of Science and Research to the European Science Foundation (ESF) for assessment.

In November 1997 the ESF panel recommended the AUSTRON project as a potential candidate for a medium- to large-scale international research facility based on a pulsed high-flux neutron spallation source. It was suggested that some aspects of the regional impact and specific issues regarding the instrumentation should be added. The Ministry requested a project group to gather the extra information and to prepare a project proposal for international presentation.

Based on a decision of the Austrian Government dated 20 August 1998, Austria is offering to contribute one-third of the total cost of the AUSTRON, and international partners are now invited to participate. Although the AUSTRON offers obviously attractive and unique possibilities for research with neutrons, extensive political negotiations with potential transnational partners will be needed to conclude such co-financing agreements. The partners may contribute to the project both in cash or in kind. Political as well as financial decisions need to be taken within the next few months.

Around 1000 users of neutron facilities have been identified within the Central European Region (the catchment area of AUSTRON) according to a report by the European Neutron Scattering Association. And the number is growing, particularly in the eastern countries.

In contrast, the number of neutron sources in Europe (today more than 20) will have dropped to less than six by 2015. The proposed AUSTRON project for a pulsed neutron spallation source is a great opportunity for the neutron scattering community in Europe to counteract this developing "neutron gap".

The birth of AUSTRON

As European horizons widened in the late 1980s, new projects and wider collaboration beckoned. At a meeting of the Central European Initiative ("Hexagonale") working group on science and technology at CERN in 1991, a panel of experts representing more than 50 research institutions unanimously supported the construction of a neutron spallation source in the Central European Region.

Prior to this, a commission under the patronage of the Austrian Academy of Sciences (Chairman Peter Skalicky, Technical University of Vienna; Secretary General Meinhard Regler, Institute of High Energy Physics of the Austrian Academy of Sciences) had been studying a project for an accelerator (provisionally called AUSTRON) which could fill this role.

By the end of December 1992, Dr E Busek, then Minister for Science and Research, had officially declared the support of the Austrian Government for the AUSTRON (for one-third of the estimated cost). The International Scientific Advisory Board was founded in 1993 and is chaired by Albert Furrer, PSI and ETH Zürich. A detailed study of the centre was published in November 1994 with the additional help of CERN, research centre Seibersdorf, the Technical University of Graz and several international experts and industrial firms.

In the following years the design work continued at a lower level, culminating in the recent proposition by Meinhard Regler, following an instrumentation meeting during May of this year chaired by Helmut Rauch, for a second ring that acts as a bunch accumulator for a 10 Hz target.

Accelerator

The AUSTRON is based on an accelerator design using state-of-the-art technologies to allow for a relatively short construction period and a favourable ratio of cost to scientific and technological potential. The proposal is for a 0.5 MW neutron source which can be operated with 10 Hz repetition rate. To generate a proton beam with 1.6 GeV energy per particle and an average beam current of 0.311 mA, the accelerator chain comprises an H^--ion source, a radiofrequency quadrupole and a drift tube linac, providing a final ion energy of 130 MeV, from which the ions enter a rapid-cycling synchrotron via a stripper foil which removes their electrons to enable the acceleration of a high-intensity proton beam to a final energy of 1.6 GeV. Using a dual-frequency magnetic cycle, losses should be kept to about 0.5%, occurring at lowest energies during trapping only.

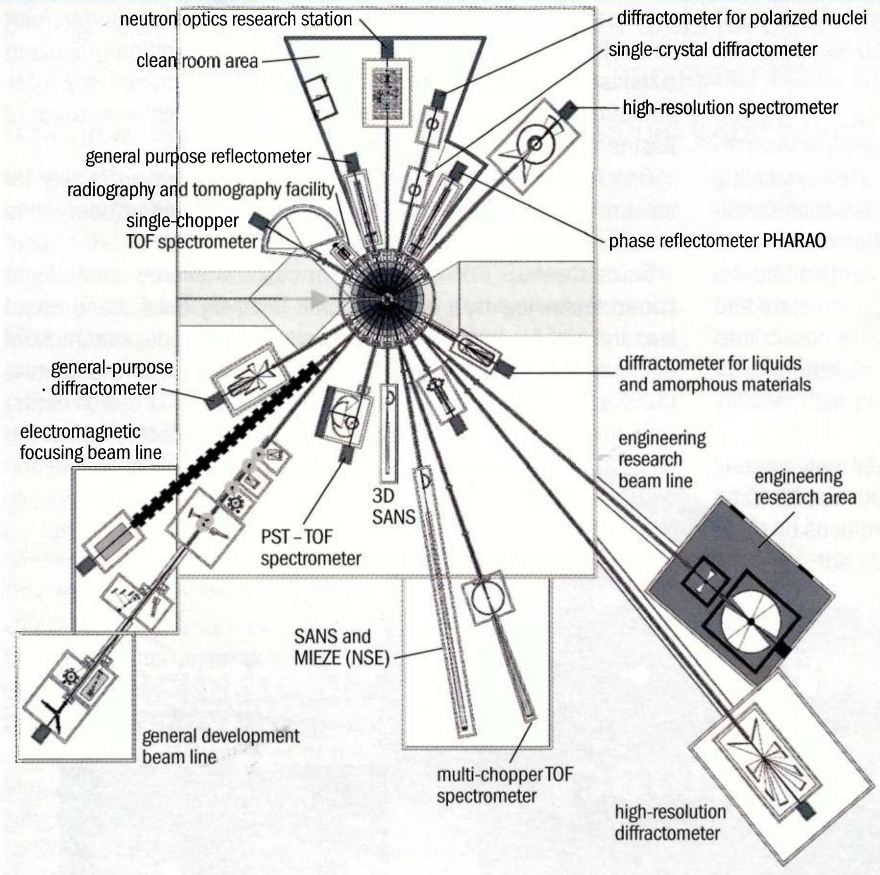
The operation frequency of the acceleration process has been determined to be 50 Hz. In principle, all neutron scattering instruments could be operated at this repetition rate. Since, however, there is strong emphasis on cold neutron instrumentation, a preference for a lower operation frequency was expressed for these instruments.

This can be achieved by adding an additional storage ring which works as a bunch accumulator for the proton bunches leaving the rapid-cycling synchrotron (RCS). With such an installation, stacking of up to four proton bunches is feasible. Extracting these bunches together with the bunch which has just reached its final energy in the RCS gives a 10 Hz source with 1.6 GeV protons (some 2×10^{14} protons in total), which deposit 50 kJ per pulse on the spallation target.

The average thermal neutron flux is expected to be 7×10^{12} neutrons $cm^{-2}\,s^{-1}$ with a peak flux of some 3.5×10^{16}. This configuration will make AUSTRON truly unique among present neutron sources.

invitation to Europe

The proposed instrumentation



The effective flux for certain classes of neutron instruments will be increased by a factor of 15–20 compared to present standards.

With more than an order of magnitude higher performance, the exploration of completely new fields of research can be envisaged. Furthermore, the 10 Hz option takes the increasing demand for cold neutron scattering into account and no flux penalty will be experienced by those instruments usually operated at higher frequencies.

Concerning AUSTRON's relation to the proposed European Spallation Source (ESS – March 1994, page 15), these facilities will belong to two different generations of neutron sources which will be separated by a decade in time and an order of magnitude in beam power.

For the target design, a flat target geometry is proposed. The target material under consideration is solid tungsten/5%-rhenium with its excellent thermal and mechanical properties. The target block will be 10 cm high, 30 cm wide and 60 cm long. Due to the edge-cooling concept, cooling channels are only installed within 2 cm of the top and bottom surfaces.

Calculations of the temperature distribution in the target, based on a 0.5 MW version of AUSTRON running at 50 Hz, yield a maximum of 1200–1300 °C. Edge-cooling is possible under these conditions and an improved cooling system has been designed. Material properties such as ductility, thermal conductivity or self-healing after irradiation damage look favourable for this temperature range. From the present point of view, a 50 Hz, 0.5 MW solid W–5%Re target is feasible. Operation with 10 Hz/0.5 MW leads to a marginal temperature increase of less than 10 °C.

The suggestion has also been made to operate the target at even higher temperatures, above 2000 °C, and to cool by radiation cooling only, which would help to avoid thermally induced stress inside the target block. The final decision on the target design will take place in the design phase immediately after approval of the project.

Instrumentation

The key part of the AUSTRON facility is the neutron instrumentation. After intensive discussion this year a set of 21 instruments has been proposed from which the initial instrument suite will be chosen. For these instruments, four moderators will be needed, one at ambient or intermediate temperature and three cold moderators.

The proposed instruments for the ambient/intermediate moderator are a high-resolution powder diffractometer (covering a very large detector solid angle), a diffractometer for liquids and amorphous materials (emphasis on low- and small-angle scattering), a direct chopper time-of-flight spectrometer (magnetic excitations and vibrational spectroscopy), a crystal analyser spectrometer for molecular excitations, a radiography and tomography facility (providing the option of time-gated energy selection), and an engineering research beamline.

The instruments proposed for the high-resolution cold moderator are a general-purpose powder diffractometer (following the recommendations in the Autrans report for new developments in this field), two single-crystal diffractometers (one enabling protein crystallography, the other dedicated to the investigaton of samples with polarized nuclei), a phase reflectometer (allowing a model-independent and unique reconstruction of the investigated surface profiles), a high-resolution crystal analyser spectrometer (with several diffraction options), a neutron resonance spin echo project optimized for a pulsed neutron source, and two development beamlines for general and for neutron optics developments, respectively.

The proposed instruments for coupled cold moderators are: a general-purpose reflectometer, an instrument for combined small- and wide-angle scattering, a high-resolution small-angle neutron scattering (SANS) instrument with neutron spin echo option, a SANS project based on spin echo technique, a multi-chopper time-of-flight spectrometer with variable energy resolution, a TOF spectrometer based on phase space transformation for high-resolution spectroscopy studies, and a neutron optics research station.

This scenario offers a good balance between instrumental and scientific possibilities with an acceptable ratio of established and novel instrument arrangements and techniques. Most instruments are particularly suited to installation at a pulsed neutron source and a majority of them will profit considerably from 10 Hz operation.

Clean room

Detailed consideration was given to an optimized sample environment. The proposed installation of a clean-room area (including temperature stabilization) combined with vibration isolation conditions (important, for example, for ultra-low temperature experiments too) is novel for neutron sources. It will eventually contain about a quarter of the AUSTRON instruments, such as reflectometers and single-crystal diffractometers, which will gain from these possibilities for the investigation and development of advanced materials for high technology. The clean-room area will also offer high stability conditions for sensitive neutron optics experiments.

Another special environment is the proposed engineering research area which allows heavy or large industrial samples to be delivered and investigated under full operating conditions on dedicated instrumentation.

The AUSTRON could be a regional centre of excellence along the lines of a vision of the Central European Initiative (CEI). This is also in line with the spirit of the Fifth Framework Programme which seeks to promote advanced research activities involving potential members of the European Union.

In this context, a transnational facility in Austria would help the anticipated enlargement of the European Community on forefront scientific grounds supporting the envisaged integration of Eastern scientists in research centres of excellence. In addition, the location of the facility in Austria will help offset the traditional export of Austrian human research capital and know-how.

Complementary to the AUSTRON will be a medical facility for research and treatment of cancer using protons and heavy ions simultaneously.

Since the AUSTRON is based on custom-tailored solutions in known technologies, it could be built relatively quickly and would lead the world in peak neutron intensity for a decade or more. After approval and a design period, it could be built for an expenditure (1998 prices) of 4700 million Austrian schillings (337 million euros) with an addition of 1100 million schillings (70 million euros) for the Medical Ring, distributed over seven years. The earliest completion date would be 2006.

Helmut Weber, *AUSTRON project management.*

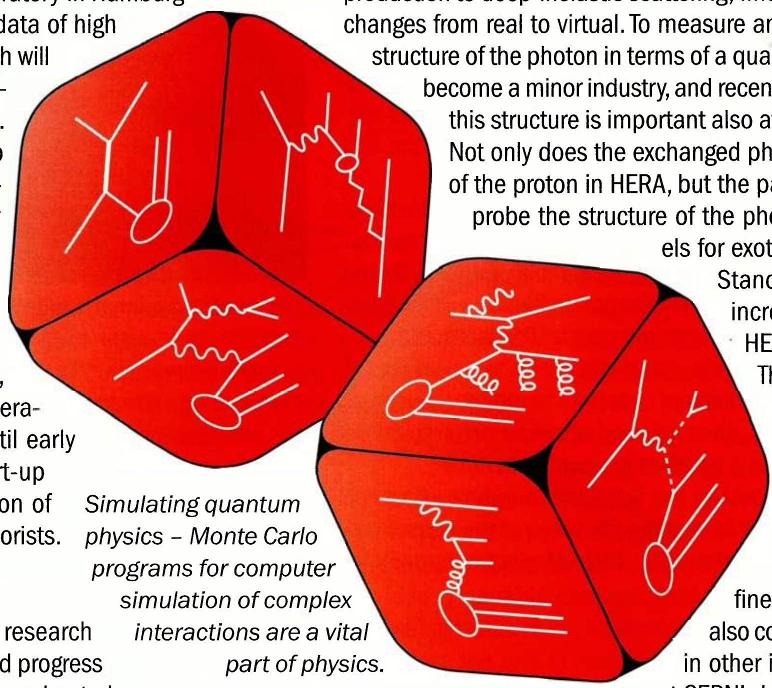
The full Monte-Carlo

Monte-Carlo methods are vital simulation tools for studying high-energy particle collisions. To push the development of the Monte-Carlo generators, their underlying models and technical solutions, DESY is running a "Monte Carlo Generators for HERA Physics" workshop.

Monte-Carlo programs for computer simulation of complex interactions in high-energy particle collisions are indispensable tools for today's experiments. Their usefulness includes the extraction of physics and testing theories and models, as well as planning future experiments and analyses. Although the development of such Monte-Carlo simulations are based on theoretical models, it is to a large extent pushed by experimental results.

The H1 and ZEUS experiments at the unique electron-proton collider HERA at the German DESY laboratory in Hamburg are now in full swing. They produce data of high quality and increasing precision, which will be further boosted after the forthcoming luminosity upgrade of HERA. This subjects the Monte-Carlos to stringent tests and can reveal important gaps in our understanding, for example when data demonstrate that the Monte-Carlos are deficient.

To push the development of the Monte-Carlo generators, their underlying models and technical solutions, DESY is running a "Monte Carlo Generators for HERA Physics" workshop until early 1999. It was launched with a start-up meeting in April with the participation of about 100 experimentalists and theorists.



Simulating quantum physics – Monte Carlo programs for computer simulation of complex interactions are a vital part of physics.

Welcome

They were welcomed by the DESY research director Albrecht Wagner, who outlined progress on the HERA upgrade in 2000/2001 and noted that there would be yet more data to understand. He encouraged theorists and experimentalists to get together in a coordinated effort to improve their models and develop new ones. To set the scene for the following discussions, H1 and ZEUS experimentalists presented their latest results with the spotlight on problem areas for Monte-Carlos.

Much time was then devoted to various aspects of quantum chromodynamics (QCD), the quantum field theory for the strong interactions of quarks and gluons. The focus was on the connection between the latest theoretical developments and their Monte-Carlo implementation, since it is not easy to transform the theoretical formalism into computer simulation code.

Many different processes are of interest here, such as how to simulate properly the emission of many gluons in a so-called QCD cascade and the resulting final state of observable hadrons. Also of great interest are the attempts to understand the dynamics giving rise to the kinematically biassed "rapidity gap" events discovered at HERA a few years ago.

Virtual photon

Another challenge is to understand the transition from photoproduction to deep-inelastic scattering, when the exchanged photon changes from real to virtual. To measure and explain the "resolved" structure of the photon in terms of a quark and gluon content has become a minor industry, and recent HERA data indicate that this structure is important also at higher photon virtuality. Not only does the exchanged photon probe the structure of the proton in HERA, but the partons in the proton also probe the structure of the photon! Monte-Carlo models for exotic processes beyond the Standard Model will become increasingly important as HERA luminosity increases. The search for new physics requires improved precision in the Standard Model calculations of, for example, radiative corrections.

The workshop is not confined to HERA physics, but also considers related problems in other interactions, for example at CERN's LEP electron-positron collider or Fermilab's Tevatron. The meeting addressed these topics in 16 plenary and 28 parallel talks. Among them were talks by T Abe, S Baranov, C Berger, R Engel, D Graudenz, G Ingelman, H Jung, Y Kurihara, L Lönnblad, B Pötter, J Rathsman, G Salam, M Seymour, T Sjöstrand, A Solano, H Spiesberger, and L West – authors of many of the Monte-Carlo programs used at HERA and elsewhere.

Several working groups were formed to study these issues in depth. These groups meet regularly and the whole workshop had a mid-term meeting in October. The final results will be reported in a meeting at DESY from 1–5 February 1999.

Anybody interested is welcome to join. More information is available at the workshop homepage "http://www.desy.de/~heramc/".

Neutrinos stop go

Research using neutrino beams began at CERN in 1963 using particles from the PS proton synchrotron. The highlight of the PS neutrino act was the discovery of the weak neutral current in 1973, and in 1977 the new SPS synchrotron took over the neutrino role.

Twenty-one years later, with the completion of the CHORUS and NOMAD experiments in September, an era of neutrino physics – at least in its traditional setting of the West Area of the SPS – has now drawn to a close.

Plans for this facility were laid in 1971 during plans for CERN's "300 GeV Project" – which became the 450 GeV SPS. The BEBC bubble chamber, then under construction, was a fixed point through which the beams had to pass, but two possibilities were considered for the primary proton target, where the pion and kaon parents of the neutrinos would be produced. The alternatives were a surface beam, or a beam beginning at the SPS, 40 m below ground and pointing upwards at an inclination of 4.25°. The "underground" solution was chosen because it allowed operation at any energy possible from the SPS.

In addition to BEBC, an electronic detector, that of the WA1 collaboration, was approved and both were available when the first SPS neutrino beams appeared early in 1977.

Over the years four types of beam have been available: the basic diet of wide-band horn-focused beams; the added spice of narrow-band beams using momentum-selected parent particles; "beam dump" beams obtained by dumping the proton beam into a massive target; and low-energy beams from the smaller PS accelerator.

This versatility allowed a wide variety of physics to be covered. A key factor also was the provision of detectors to monitor the flux of the accompanying muons, which allowed absolute determinations of the neutrino flux, always a problem in neutrino beams.

In 1977 BEBC was joined by the Gargamelle bubble chamber, moved from the South West Area at the PS, scene of the neutral current discovery. A year later the 100 t CHARM electronic detector became operational.

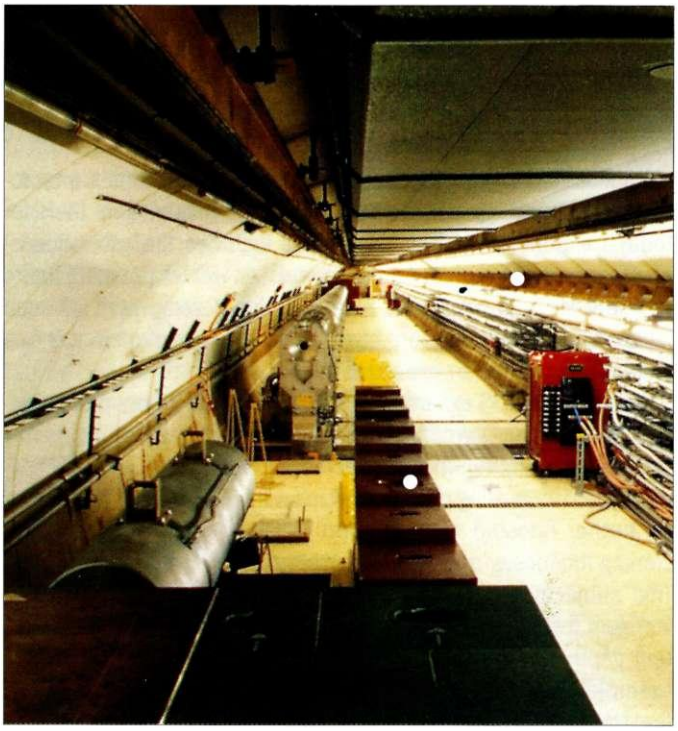
First studies

Initial physics centred on studies of neutral currents, on the quark structure of matter, and on quantum chromodynamics (QCD), the field theory of quarks and gluons. The results obtained were, and still are, still important input for tests of the Standard Model.

The targets for the neutrinos were "heavy" nuclei (iron in WA1 and marble in CHARM, freon or propane in Gargamelle, or neon in BEBC) or "free" nucleons in hydrogen and deuterium in BEBC. The latter enabled the distributions of up and down quarks in the nucleon to be measured. As well as BEBC, there was also a 1.5 t liquid-hydrogen target upstream of the WA1 detector.

In December 1997 a novel type of experiment was carried out - the "beam dump". The primary SPS proton beam was pointed toward the detectors and dumped into an intervening massive copper target. In such a target the pions and kaons, the usual parents of neutrinos, do not have time to decay before being absorbed, so that the neutrino supply from these sources is reduced by a factor of more than a thousand. However, any neutrinos produced in the decays of very short-lived parents will be unaffected. In fact such "prompt" neutrinos were observed and are now known to be due to the decays of charmed particles, although at the time measurements had claimed that charm production by protons was much too small. These initial results were confirmed by further dump experiments in 1979 and 1981, which also set limits on the production of tau neutrinos.

Gargamelle took part in the first beam dump experiment and in wide-band and narrow-band running in 1978. However, in October of that year leaks detected in the chamber were found to be due to deep cracks in the steel vessel, which unfortunately it was not possible to repair. However, in its short career at the SPS, Gargamelle nevertheless succeeded in observing for the first time a touchstone weak interaction – the purely leptonic process in which a muon neutrino hits an electron, producing an electron neutrino and a muon.

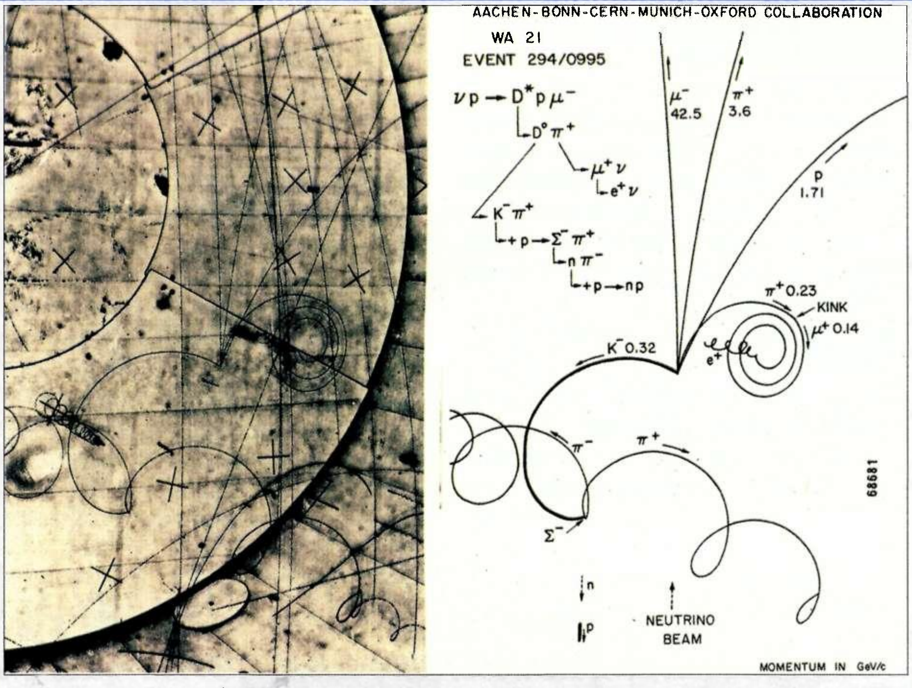


The neutrino cavern of CERN's West Area beam. Protons from the SPS strike a beryllium target (hidden by blocks in the foreground). Immediately after the target is a beam collimator and then can be seen the first of the "magnetic horns" that focus the parent particles before they decay to produce neutrinos.

ing West

Neutrinos have been a mainstay of CERN's research – until September, when a generation of studies at the SPS synchrotron came to an end.

Analysing a bubble chamber image



A "textbook" picture from the BEBC bubble chamber. A neutrino interacts with a proton in the liquid hydrogen to produce a negative muon, a proton and an excited charmed meson (D*). The D* decays to a charmed D^0 meson plus a positive pion and the D^0 itself decays to a negative kaon and another positive pion. After stopping in the liquid the kaon interacts with another proton to produce a hyperon.

After a few years gathering rust in the West Area, Gargamelle is now proudly displayed in CERN's Microcosm Park.

During its lifetime BEBC recorded many thousands of neutrino interactions. This was much less than in the electronic detectors, but the enormous amount of detail available in bubble chamber pictures allowed the study of particular final state particles, notably charmed particles, and the measurement of production cross-sections, masses and decay modes.

During 1984, WA1 and CHARM made very accurate determinations of basic electroweak parameters in high statistics studies of neutral-current interactions using the narrow-band beams. These measurements still serve as an "anchor point" to which the precision high-energy measurements made at CERN's LEP electron–positron collider can be related, giving an insight into electroweak radiative corrections, and hence to the mass of the Higgs boson.

Throughout the lifetime of the West Area facility, the possibility of neutrino oscillations – electron, muon and tau neutrino types transforming among themselves – has been the object of continual conjecture and study. The well-understood neutrino beams and the variety of detectors available allowed very stringent limits to be placed on such oscillations, within the kinematic limits imposed by the beam energies and the locations of the detectors.

Narrow band, wide band and beam-dump beams have all been exploited to search for neutrino oscillations. The existence of oscillations runs counter to neutrino orthodoxy, requiring that neutrinos have mass.

In order to explore very small neutrino masses, a special neutrino beam was derived from the CERN PS with a new "near station" 130 m from the target. WA1, CHARM and BEBC took part in this search in 1983–84. However, no oscillation evidence was found.

Muon neutrinos

Of particular interest is the possibility of muon neutrino/tau neutrino oscillations. With the West Area well served with muon neutrinos, specialized detectors (NOMAD using kinematic techniques, and CHORUS using nuclear emulsion to observe the final state tau leptons) began operation in 1993.

From 1983–91 the WA79 (CHARM II) experiment detected several thousand events in which a muon (anti)neutrino scatters off an electron, remaining a a muon (anti)neutrino. (One event of this type, observed in Gargamelle in 1972, was the precursor of the discovery of neutral currents.) These purely leptonic interactions provided a valuable measurement of electroweak mixing, free of uncertainties due to the hadronic structure of nuclear matter.

However, the end of neutrino beams in the West Area does not mean the end of neutrino physics at CERN. The evidence for neutrino oscillations in neutrinos from the Sun, from cosmic rays in the atmosphere and from accelerators, indicates that much longer "base lines" are required.

One possibility, not pursued at CERN, was to take advantage of the upward inclination of the West Area beam and install a detector in the Jura mountains 17 kilometres from the target. Instead, interest has turned to the Neutrino Beam for Gran Sasso project (November, page 13) in which a beam generated at CERN could be pointed south-east towards the Italian Gran Sasso Laboratory, 730 kilometres away.

Gerald Myatt, *Oxford.*

Statistics for physicists

Statistical Data Analysis, by Glen Cowan, Oxford University Press, ISBN 0 19 8501560, hardback £35,1998.

Statistics ought to be the same for everyone, but physicists are a special breed of scientists and they want a book written by one of their own. There are some perfectly valid reasons for this; for example, a physicist expects statistical methods, like physical laws, to be invariant under general co-ordinate transformations, whereas neither the mathematician nor the biologist sees the need for any such requirement. However, when a physicist writes a book on statistics, he is by definition an amateur in the field, so there is the danger that he will get something wrong.

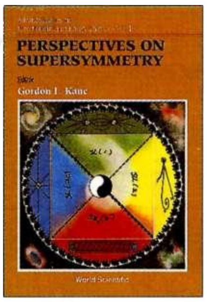
Glen Cowan is a particle physicist who seems to have got everything right. Results are stated clearly, without mathematical proof but with enough explanation to satisfy the physicist's need to understand not only how, but also why.

The research physicist will not find explicit solutions to all his problems here, but given the limitation imposed by the modest size of the volume (197 pages), the depth and breadth of coverage is quite impressive. As the title indicates, the book is intended for data analysis so there is, for example, no chapter on decision theory which would be needed for a complete presentation of Bayesian methods. There is, on the other hand, a very relevant chapter on unfolding, which rarely appears in statistics books because mathematicians classify it as "integral equations".

Those teaching an advanced undergraduate or graduate course in statistics for physicists will find this a good textbook as well. Do not be fooled by the fact that it does not have the "textbook look" – the exercises have been made available separately on a Web site.

Fred James, CERN.

New titles from World Scientific



- *Perspectives on Supersymmetry*, edited by Gordon L Kane, 9810235534, £58, August 1998.

Gordon Kane has assembled 20 contributions which provide a useful guide to this topical subject. The experimental discovery of supersymmetry might be just round the corner, and this book could help.

- *Massive meutrinos in physics and astrophysics*, by Rabindra N Mohapatra and Palash B Pal, 9810233736, £33, June 1998.

Another subject currently in the spotlight is the possibility of neutrino oscillations. This is the second edition of a book which first appeared in 1990, and has therefore been suitably updated.

- *String theory in curved spacetimes*, edited by N Sanchez, 9810234392, £66, July 1998.

This book represents the main effort of a collaboration "String Gravity and Physics at the Planck Energy Scale", supported by the European Commission and which also led to a String Gravity meeting at the Observatoire de Paris in 1996. The book resembles the proceedings of this meeting.

Books on quantum mechanics

- *Relativistic Quantum Mechanics*, by Paul Strange, Cambridge, 0 521 56271 6 (hbk £80/ $110), 0 521 56583 9 (pbk £30/$49.95).

This attractive text emphasizes applications in condensed matter and atomic physics.

- *Quantum Mechanics – A Modern Development*, by Leslie M Ballentine, World Scientific 9810227078, £41.

The first edition of this book, published by Prentice-Hall in 1990, took into account more recent developments in the foundations of quantum mechanics, so that the treatment of practical aspects and interpretation became more coherent. The new edition includes material on path integrals, phase space, Bell's theorem etc.

RECRUITMENT

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DESY

DESY announces a

Post-Doc Position

The DESY laboratory invites applications for a postdoctoral position for work in the area of data acquisition and higher level triggering for the HERA-B experiment.

HERA-B will measure CP-Violation parameters in the B meson system. The experiment is presently being installed in the HERA storage ring at DESY, Hamburg. HERA-B uses collisions of 920 GeV protons with a wire positioned close to the proton ring to produce B mesons. The decay products are analyzed in a forward spectrometer.

The high interaction rates (40 Mhz) and large particle densities force HERA-B to push the state of the art in several areas of detector technology, triggering and data acquisition.

The higher level triggering and data acquisition system is the first large switch-based system, which relies on high-speed data paths connecting the primary event data to a farm of commodity PCs. Similar architectures are being planned for the LHC experiments. Data taking has begun but many challenges remain. The successful candidate will play a major role in evolving the architectural design, programming, commissioning and operating the system.

Familiarity with the C programming language is required. Experience with the Linux operating system and client-server computing would be an asset.

Interested candidates, who have recently completed their Ph.D. and are under 32 year of age, should submit an application consisting of a curriculum vitae, copies of university degrees and a publication list; and should arrange to have three letters of recommendation send directly to: **DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg. Code-number: 90/98**

Handicapped applicants will be given preference to others with the same qualifications. Women are especially encouraged to apply.

GSI Darmstadt

the National Laboratory for Heavy-Ion Research, a member institute of the Helmholtz-Society of German Research Centers, invites applications for the position of

Head of the Information Technology Department (reference 81100-98.43)

Major tasks of this department are data processing and operation of computer networks throughout the laboratory. It consists of over 50 scientists and technicians who support the research division in the data acquisition and -analysis and by the development of specialized electronics. In addition to routine services, the development of new activities in the area of information technology are of particular importance.

The successful candidate should demonstrate the ability to develop new computing strategies jointly with the research and accelerator divisions as well as to introduce new hardware and software concepts for the experiments.

Applicants should have a PhD in physics and several years of experience in running or coordinating a large group of scientists and technicians.

The salary is according to the Bundesangestelltentarifvertrag. GSI is committed to employment equity. Women are especially encouraged to apply. Handicapped applicants will be given preference to other applicants with the same qualification.

Applications should be submitted not later than January 8, 1999 to

GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG MBH
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64291 DARMSTADT

RESEARCH ASSOCIATE POSITION EXPERIMENTAL HIGH ENERGY PHYSICS INDIANA UNIVERSITY

The Department of Physics at Indiana University invites applicants for a research associate position to work with the high energy physics group on the OPAL experiment at CERN.The position will be available beginning in February 1999.

In OPAL the Indiana University Group has been playing a leading role in the development of the silicon microvertex detectors and their radiation monitoring. In physics analysis our interests are in searches for new particles at LEP2 and in heavy flavor physics. We also have developed and maintain the offline analysis facility, SHIFT.

Applicants should have experience in physics analysis and an interest in silicon microvertex detectors. Candidates must have a Ph.D degree. Applications, including vitae, list of publications, and three reference letters, should be sent to:

High Energy Physics Secretary
Department of Physics
Indiana University
Bloomington, IN 47405

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Colorado State University

Postdoctoral Research Associate in High Energy Physics

Applications are invited for a postdoctoral research position in the **experimental High Energy Physics Group at Colorado State University.** The successful applicant will join an active program in the BaBar experiment and possibly the BES experiment. The CSU group has a large involvement with the BaBar drift chamber, DIRC detector and Physics Analysis.

Candidates with a strong interest in detector simulation and data analysis in CP violation and the weak decays of B mesons are particularly encouraged to apply. The candidate would be based at CSU and expected to travel to the laboratory sites for research.

Please send a resume and have three letters sent to **Professor Walter Toki,** Department of Physics, Colorado State University, Fort Collins, CO 80523, by January 1st, 1999. The position will open January 15th 1999.

Visit http://omega.physics.colostate.edu/~toki/post-doc/job-desc-v2.html for further information and our **HEP group Webpage** at http://omega.physics.colostate.edu/~hep/.

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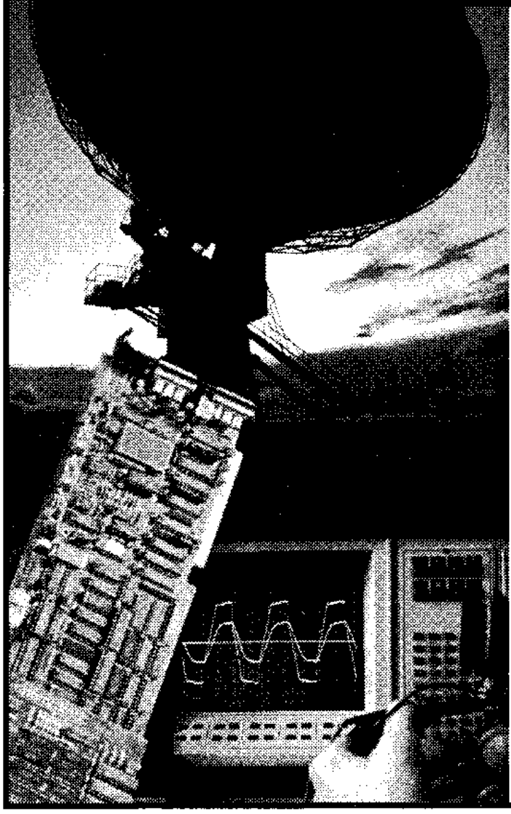

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Application forms can be obtained from: Recruitment Office, Personnel Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) quoting reference VN1713/98. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 27 November 1998.

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OPAL, ATLAS, MINOS, CDF, ZEUS, Linear Collider.

Research Fellow(s) in Experimental Particle Physics

The HEP group at University College London is analysing data from OPAL at LEP, CERN, and from ZEUS at DESY. We are members of ATLAS at the CERN Large Hadron Collider and of the MINOS long-baseline neutrino experiment at Fermilab. Very recently we have been admitted to CDF at the Fermilab Tevatron. Members of the group are leading European and World-wide studies of physics and detectors for an e+e- Linear Collider.

There will be a vacancy for at least one PPARC supported three-year postdoctoral Research Associate starting early in 1999. Applications are invited from candidates with an interest in any part of our programme. The immediate need is for someone to spend approximately 60% of their time for two years completing the OPAL studies of the photon structure function, a field pioneered at LEP by UCL, with a prospect of achieving definitive results by the time LEP2 closes in Autumn 2000. The balance of their time would be spent on simulation and second level trigger studies for ATLAS. In the third year the ATLAS work would become the major activity. Bids are being made for further positions to work on MINOS and CDF.

The post(s) will be on the 1A scale, with salary between £15,735 and £23,651 per annum, according to experience, plus £2,134 London allowance. Please send a letter of application with a full cv, publications list and the names and addresses of two referees to **Professor David J. Miller, Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK. (Informal enquiries by email to DJM@HEP.UCL.AC.UK).**

Working towards equal opportunity

Mississippi State UNIVERSITY

POST-DOCTORAL ASSISTANT EXPERIMENTAL NUCLEAR PHYSICS

The Department of Physics and Astronomy at Mississippi State University has an opening for a Post-Doctoral Assistant in Experimental Nuclear Physics starting January 1, 1999. The experimental group at MSU consists of five faculty members, one post doc. and five graduate students. The group is active in several research areas including the study of nuclear and nucleon structure, and meson production. This position is available through a partnership between MSU and Thomas Jefferson National Accelerator Facility (Jefferson Lab), and the candidate's research will be focused on Jefferson Lab's nuclear physics program. In particular, the candidate will be encouraged to be actively involved in two upcoming Hall C experiments: the measurement of the nuclear dependence and momentum transfer dependence of quasielastic (e,e'p) scattering, and the measurement of the σ_L/σ_T ratio in the nucleon resonance region. Additional responsibilities will include working on an MSU proposal for J/ψ meson production. Initially, the candidate will be required to reside near Jefferson Lab.

This position offers an exciting opportunity to be part of a growing program. A Ph.D. in experimental nuclear or particle physics is required, and experience with electromagnetic probes is preferred. The initial appointment is for one year with the expectation of renewal for an additional year upon mutual agreement and satisfactory performance. Please send curriculum vitae, list of publications, and three letters of recommendation to:

Professor James A. Dunne, Mississippi State University, P.O.Box 5167, Mississippi State MS 39762-5167, e-mail:dunne@ra.msstate.edu

Department information http://www.msstate.edu/Dept/Physics. MSU is an affirmative action/equal opportunity employer

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Studentships funded by **EPSRC**, **PPARC** and industry exist for research training leading to MPhil/PhD and for taught/research courses leading to MSc or MRes.

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Our opportunities are organised within the following areas:

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- Condensed Matter Physics
- Experimental Gravitational Physics
- Nanoscale Physics
- Nuclear Physics
- Particle Physics
- Solar and Stellar Physics
- Theoretical Physics

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Teaching Assistantships of up to four years duration involving paid undergraduate teaching are available in some of the research areas.

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- Medical and Radiation Physics
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Or write, specifying your area(s) of interest, to: **Professor J M F Gunn, Director of Graduate Studies, School of Physics and Astronomy, The University of Birmingham, Edgbaston, Birmingham B15 2TT**
or email Mrs Norma Simpson, Graduate Admissions
email: n.a.simpson@bham.ac.uk
Tel: +44 (0) 121-414-4568 **Fax:** +44 (0) 121-414-4577

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Faculty Position in Atmospheric Physics

New Mexico Institute of Mining and Technology

The Department of Physics and the Geophysical Research Center invite applications for a tenure-track position in atmospheric physics. The appointment is likely to be at the level of Assistant Professor, but appointments at a higher level may be considered for exceptional candidates.

Applicants must have a strong background in physics and a Ph.D. in physics or a closely related field.

We seek a candidate who can demonstrate the ability to be an excellent physics teacher at the university level, has an outstanding record of research accomplishments, and shows excellent promise for leading a significant and independent research program in experimental, observational and/or theoretical atmospheric physics.

Current atmospheric research interests at New Mexico Tech include cloud and precipitation physics, thunderstorm electrification, lightning studies, radar meteorology, instrumentation, geophysical fluid dynamics, clouds and climate, physics of the middle and upper atmosphere, and environmental radioactivity and aerosols. Major facilities include the Langmuir Laboratory for Atmospheric Research.

Informal enquiries may be made to the Chair of the Physics Department, Alan Blyth (blyth@kestrel.nmt.edu). Information about the department is also available at **http://www.physics.nmt.edu**

Interested individuals should send a resume, significant reprints, a letter describing both proposed research directions and teaching interests, and the names, e-mail addresses, and phone numbers of three references to:

Physics Search,
Human Resources,
New Mexico Institute of Mining and Technology,
Wells Hall Box C-121
Socorro,
NM 87801.

The preferred starting date is the fall semester 1999.

Applications received before January 29, 1999 will be given full consideration; however, applications will continue to be accepted until the position is filled.

NMT is an Equal Opportunity/Affirmative Action Employer.

President of the Czech Academy of Sciences Rudolf Zahradnik (left) presents the Academy's prestigious Ernst Mach Medal to CERN staff physicist **Ivan Lehraus** for his contributions to particle physics and detector technology.

At the opening of the "**Britain at CERN**" trade show, British ambassador to Switzerland Christopher Hulse (centre) and CERN Director General Chris Llewellyn Smith (left) admire the work of Lancashire Fittings, represented by Chairman Dick Wakelin.

At a meeting "**Around VIRGO**" at Pisa which looked at worldwide progress on gravitational wave detectors, left to right: Jean-Eudes Augustin of Lyon; Gerard Fontaine, head of astroparticle physics at the French CNRS; and Emilio Picasso of Pisa. Construction work has begun at Cascina, near Pisa, for VIRGO, a laser interferometer with two orthogonal 3 km arms. Multiple reflections in the arms will extend the optical length to 120 km. In its search for one of the most elusive effects in physics, gravitational wave detectors have to achieve new precision goals – the VIRGO mirrors will have to attain a reflectivity of 99.999% with surfaces true to a hundredth of a micron. VIRGO is funded by the Italian INFN and the French CNRS.

Charles Planner 1938–1998

Charles Planner, who joined the Rutherford Laboratory in 1961, died on 14 August after a two-year fight against cancer.

Charles started his career in accelerators on the 15 MeV Linac Injector for the 7 GeV Proton Synchrotron Nimrod, where he developed his expertise in radiofrequency (rf) system design and beam theory. During his career he contributed to the design of many accelerators, including HERA at DESY, the ESRF at Grenoble, the TRIUMF Kaon Factory design and the European Spallation Source study.

At Rutherford he was responsible for the rf system of the 70 MeV proton linac as a new injector for Nimrod. It is a tribute to its robust design that the repetition rate of this linac could be increased from 1 Hz to 50 Hz, with little change, when it was used as the ISIS injector. On ISIS he was responsible for the injection system, the elegant rf shields in the ring magnets, the optics of the extracted proton beam and the development of extraction kicker magnets. His novel approach to the manufacture of the large but very thin (0.25 micron) foils needed for beam injection into ISIS has been a major success and typifies his work.

For the last few years he was group leader of the ISIS Linac and Radiofrequency Quadrupole linac (RFQ) Group concentrating on increasing the performance of the ISIS linac. His innovative and determined approach has led to developments in RFQ design codes and to the development of a beam-matching system between the ISIS ion source and the RFQ.

Workshops and conferences

- An International Workshop on "Electron–Positron Collisions from Phi to J/Psi" will be held at the Budker Institute of Nuclear Physics, Novosibirsk, Russia from 1–5 March 1999. It will bring together theorists and experimentalists interested in low-energy hadron physics.

More information from: e-mail "vepp99@inp.nsk.su"; fax 7-383-234-2163; tel. 7-3832-359833 (T Purlatz) or 7-3832-359734 (A Bondar); home page " http://www.inp.nsk.su/phipsi/".

- DIS99, the 7th International Workshop on Deep Inelastic Scattering and QCD will be organized by DESY Zeuthen from 19–23 April 1999, at the institute.

For more information see "http://www.ifh.de/~dis99/". E-mail "dis99@ifh.de". DESY-Zeuthen – DIS99, D-15738 Zeuthen, Germany. Fax +49 33762 77-413.

- The next "Workshop on small x Physics" will be held at Tel Aviv University from 15–19 June. This workshop follows those held in Saclay (1994), Cambridge (1995), Durham (1996), Madrid (1997) and Berlin (1998).

Further information at "http://www.tau.ac.il/~smallx".

- The Chicago International Conference on Kaon Physics (KAON '99) will be held on the campus of the University of Chicago, 21–26 June 1999. It follows a series of conferences of similar emphasis, formerly held at KEK, at Frascati, and most recently at the Orsay Workshop on K Physics, in June 1996. The symposium is being hosted by the Department of Physics and the Enrico Fermi Institute of the University of Chicago; Jon Rosner and Bruce Winstein are co-chairpersons. Attendance is by invitation only.

E-mail "KAON99@hep.uchicago.edu".

- FEL99, the 21st International Free Electron Laser Conference and 6th FEL Applications Workshop will be held on 23–28 August 1999 in Hamburg, Germany. The conference will cover scientific and technological aspects of Free Electron Lasers.

Conference secretary: Ingrid Nikodem, FEL99, DESY, Notkestr. 85, D-22607 Hamburg, Germany. Tel. +49 40 8998 2800 Fax: +49 40 8998 4200. E-mail "fel99@desy.de". Web "http://www.desy.de/fel99".

Prof. Horia Ene, Romanian Minister of Research and Technology (second from left) visited CERN on 30 September. With him are (left to right): Atlas experiment spokesman Peter Jenni; CERN co-ordinator for Russia and other Eastern countries Nicholas Koulberg; Acting Director of Romania's International Agreements and Programs Division Iulia Mihail; Romanian physicist Petre Dita; Director General of Bucharest's Institute for Atomic Physics Voicu Lupei; and physicists Michaela Niculescu and Mihai Caprini. Bucharest's Institute for Atomic Physics is involved in the Atlas experiment.

US ambassador to Switzerland **Madeleine Kunin** and Political Officer David Jaberg inspect a model of the CMS experiment for CERN's LHC collider with CMS spokesman Michel Della Negra. The US is providing substantial in-kind contributions for LHC experiments.

Hadron therapy is increasingly attracting attention as a highly effective means of combatting cancer. CERN's "**Hadrons for Health**" exhibition recently visited Helsinki. At the opening were (right to left): Vice Rector of Helsinki University of Technology Paavo Uronen; CERN Director General designate Luciano Maiani; Toivo Katila, responsible for the exhibition at Helsinki; Cecilia Jarlskog, responsible for Member State relations at CERN; Finnish delegate to CERN Council Risto Nieminen; Mona Grönstrand of Instrumentarium Oy; Helsinki Institute of Physics Director Eero Byckling. (Photo: Exhibition organizer Werner Kienzle.)

American Academy of Arts and Sciences

New members of the American Academy of Arts and Sciences include: William Bardeen of Fermilab; Darleane Hoffmann, Director of the Glenn T Seaborg Institute for Transactinium Science at Lawrence Berkeley National Laboratory; John Mather at NASA's Goddard Space Flight Center; Helen Quinn at SLAC; Pierre Ramond at Florida; and Miguel Virasoro, Director of the Abdus Salam Centre for Theoretical Physics, Trieste.

Bulgarian visit

The Bulgarian Minister of Education and Science Vesselin Metodiev visited CERN on 29 September.

Field theory, Fields Medal

The 1998 award of the prestigious Fields Medal for Mathematics reflects a continuing trend of mathematicians obtaining inspiration from theoretical physics.

The Fields Medal, officially called the "International Medal for Outstanding Discoveries in Mathematics", is awarded every four years at the International Congress of Mathematicians, and is widely considered the highest scientific award for mathematics.

The 1998 award went to Richard Borcherds of Cambridge, Maxim Kontsevich of the French Institut des Hautes Etudes, Timothy Gowers of Cambridge and Curtis McMullen, currently visiting Harvard.

Borcherds' award recognizes in particular his proof of the "Moonshine conjecture" which links "monster groups" – which have more elements than there are elementary particles in the universe – and elliptical functions. He employed many of the ideas of physics string theory.

Also an expert in string theory is Maxim Kontsevich, who has been motivated by the work of Richard Feynman and Edward Witten. He has proved a conjecture of Witten and shown the mathematical equivalence of different models of quantum gravity.

Witten, of Princeton's Institute for Advanced Study, has long spearheaded the challenge to achieve the ultimate objective of physics – a unified theory which encompasses quantum gravity, a quest which has had to invoke both bold new physics ideas and considerable mathematical sophistication. He won the Fields Medal in 1990 for mathematical advances (proving the so-called positive mass conjecture) using ideas of particle supersymmetry.


WHAT WILL IT CAPTURE NEXT?
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Hamamatsu large diameter photomultiplier tubes (PMTs) are now waiting for chance to "show their stuff" all over the world by a unique ability to capture interesting information from unknown matter and phenomena.
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