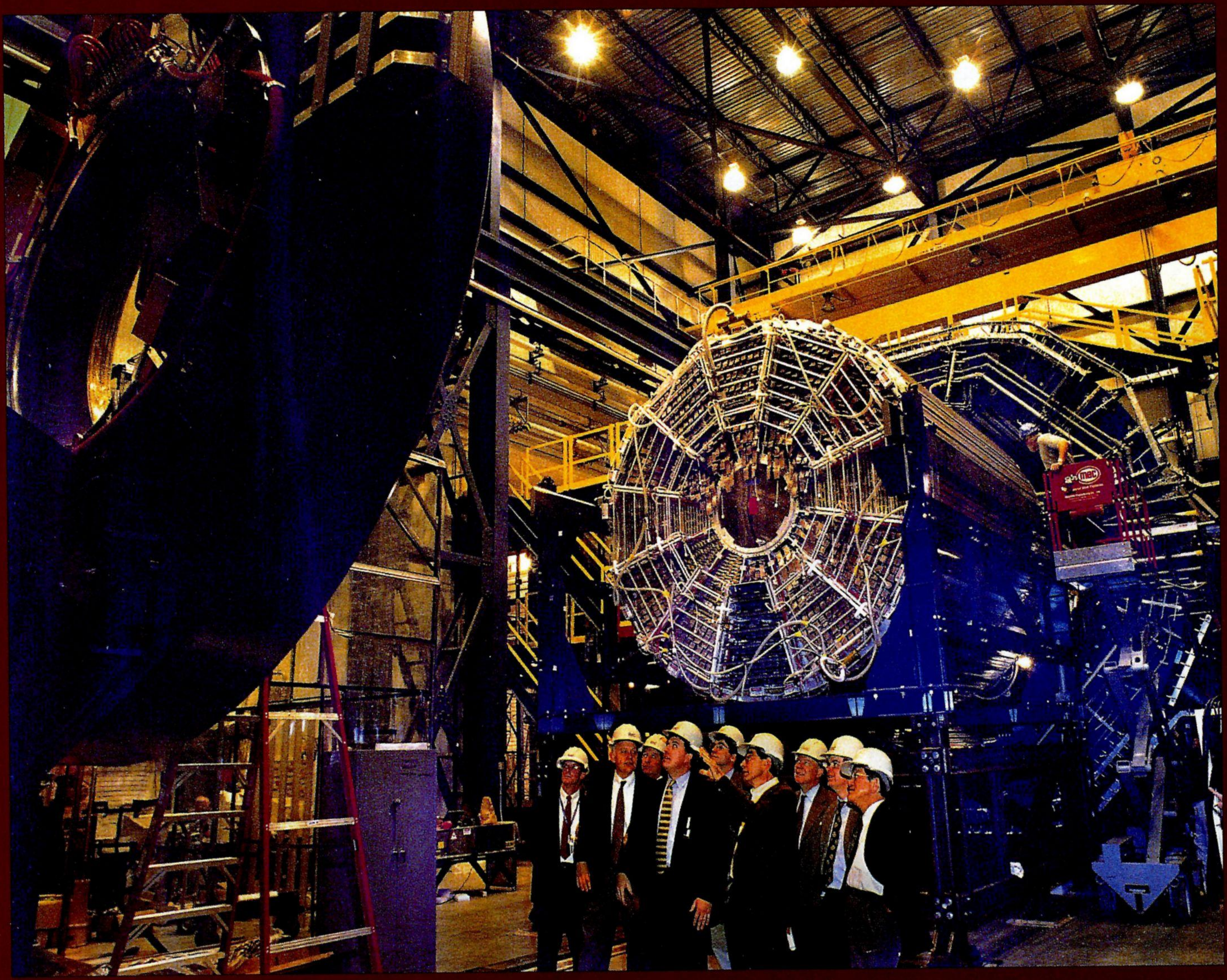
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 39 NUMBER 1 FEBRUARY 1999



A STAR in the making

LHC COLD START
Procurement and construction work for CERN's LHC project begin in earnest

EPIC DEVELOPMENTS
Physics helps and is helped by a new generation of microprocessors being tested at CERN

MYSTERIES OF COSMIC RAYS
Unexplained phenomena in the ultra-high-energy area point to gaps in our understanding

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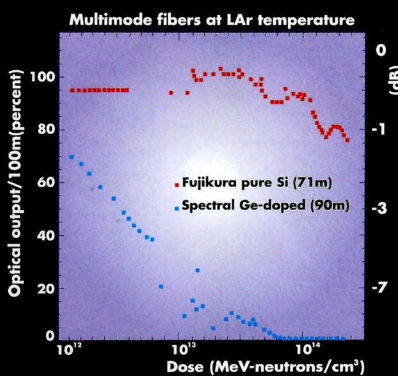
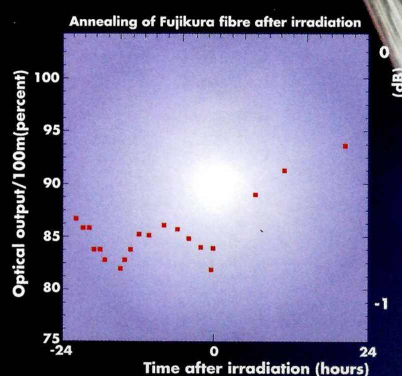
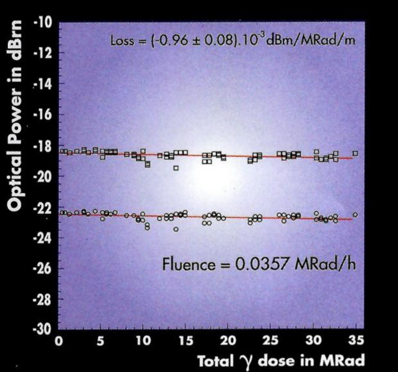


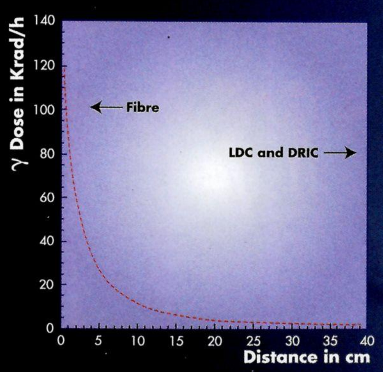
Transmitted light in multimode fibres during neutron irradiation in LAr.



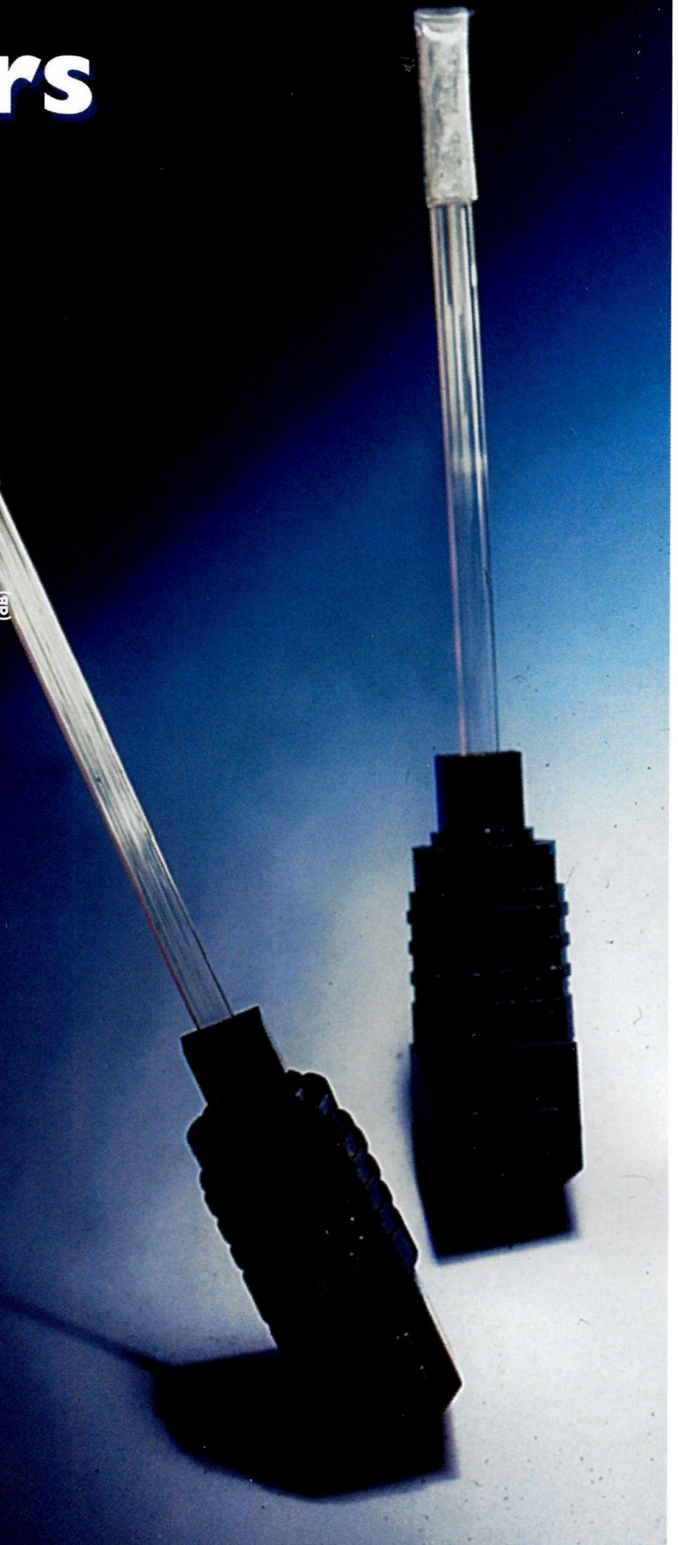
Annealing of Fujikura MM Fibre after end of neutron irradiation



Behavior of LDC and DORIC chips (up to 3 MRaD) (PS file)



Spectrum of the gamma source station



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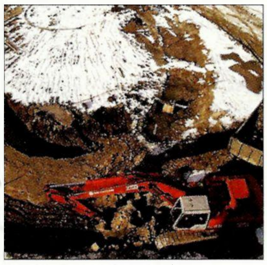
Cosmic rays p26



LHC construction p11

End of line for AmPS p18

Cover: Brookhaven officials look on as the 53 m^3, 140 000-channel Time Projection Chamber for the STAR detector is slid into its magnet at the RHIC Relativistic Heavy Ion Collider. Built at Lawrence Berkeley National Laboratory, the TPC was flown to Brookhaven a year ago and has undergone tests with cosmic rays while the magnet was completed and its field mapped. STAR is one of four RHIC detectors preparing for the first physics run with colliding beams of gold ions during the year. Circulating beams are expected at RHIC this spring, with commissioning runs, and first collisions, in June and July. See also RHIC mock data challenge, page 7.

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

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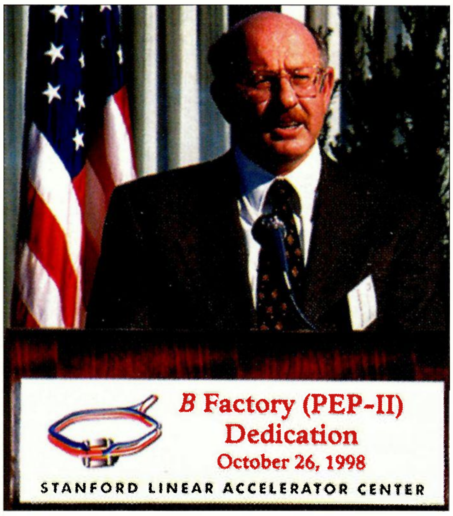
New Director for SLAC

Stanford Linear Accelerator Centre Director Burt Richter will step down on 31 August. His successor will be Jonathan Dorfan, associate director of SLAC and head of its recently dedicated B-Factory project (December 1998, page 5).

When he steps down, Richter will have been Director for 15 years. His career is intimately linked with that of electron colliders at Stanford - the Stanford-Princeton electron collider, the SPEAR and PEP electron-positron rings and the SLC linear collider. Richter came to Stanford as a post-doctoral student in 1956 after his PhD at MIT. In 1963 he joined SLAC, becoming Director in 1984 on the retirement of founding director Wolfgang "Pief" Panofsky. Richter shared the 1976 Nobel Prize in Physics with Sam Ting of MIT for their independent discoveries of the J/psi particle. He will remain at Stanford and will also become President of the International Union of Pure and Applied Physics (IUPAP).

Dorfan, a native of South Africa, is a naturalized US citizen. He earned his doctorate at California-Irvine in 1976 and came to SLAC as a post-doctoral fellow, moving up to research physicist in 1981, associate professor in 1984, full professor in 1989 and associate director in 1994. He led the effort to establish the B-Factory at SLAC, including being in charge of the team that produced the machine conceptual design. He is currently technical co-ordinator for the construction of the BaBar detector at the B-Factory.



Jonathan Dorfan will be the next Director of the Stanford Linear Accelerator Centre.

Particle and nuclear astrophysics and cosmology committee

A new committee, PaNAGIC (Particle And Nuclear Astrophysics and Gravitational International Committee), was created last October by IUPAP (International Union of Pure and Applied Physics) to support the international exchange of ideas and to nurture the emerging field of particle and nuclear astrophysics and cosmology.

Against the need for larger experiments with increasing costs, the Committee will promote worldwide collaboration and ensure the organization of future experiments.

The Committee will cover the following fields: basic constituents of matter and their interactions by non-accelerator means; sources, acceleration mechanisms and the propagation of high-energy particles in the universe; nuclear and particle properties and processes of astrophysical interest in the universe; gravity, including sources of gravitational waves.

The President is Alessandro Bettini, Director of Gran Sasso Laboratories, Underground Physics. Contact "Alessandro.Bettini@lngn.infn.it" or see "http://www.lngs.infn.it".

SLAC B-Factory comes up to speed

Shortly after the dedication of the PEP-II B-Factory at the Stanford Linear Accelerator Centre (SLAC) on 26 October (December 1998, page 5), a team led by John Seeman resumed the task of commissioning the new electron-positron collider.

The 9.0 GeV electron ring and the 3.1 GeV positron ring both turned on quickly, successfully storing beams before the end of the month. Collisions between the two beams, first achieved on 23 July (September 1998, page 17) occurred again on 10 November with 11 bunches in each ring. This time significant luminosity was observed, at about 3×10^{30} per cm^2 per second – but still a factor of 1000 below the design goal.

Further commissioning included attempts to store much higher currents in each beam and focus them better at the interaction point, while improving their lifetimes. With the extensive progress already achieved on the electron ring, attention shifted to the positron beam, which had a lifetime of about 30 minutes in early November and slowly improved during the run. Radiation scrubbing of the vacuum in this ring permitted the stored current to reach 415 milliamps in a total of 291 bunches by run's end. The current per bunch now exceeds the design goal of 2.1 amperes in 1658 bunches.

By run's end a luminosity of 3×10^{31} per cm^2 per second was measured with 261 bunches circulating in each beam. But calculations based on the beam sizes and currents indicate that the true value could be 2 to 4 times higher. Interaction region group leaders Stan Ecklund and Michael Sullivan are studying the reasons for the apparent discrepancy. Several ring parameters (e.g. tunes and emittances) were varied to maximize the luminosity, giving beam-beam tune-shift limits of about 0.01 to 0.02.

Physicists led by Tom Mattison of SLAC and Witold Kozanecki of Saclay monitored the backgrounds in both rings during this run. These backgrounds - believed to be largely due to beam-gas interactions - are 5 to 10 times higher than anticipated in the PEP-II conceptual design report. Although the BaBar detector will be able to handle such backgrounds, they are still a cause for concern. Work continues to understand these backgrounds and reduce them. Additional beam collimators are being installed before the next commissioning run.

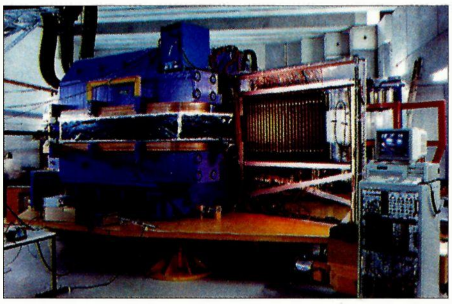
The current schedule calls for a final commissioning run from mid-January to mid-February followed by installation of the BaBar detector at the interaction point. If all goes well, physicists in this collaboration can expect to begin taking data on 1 May. "We are very pleased with this progress," said Seeman, "but we must keep a firm eye on our goals."

The case of the missing neutron stars

Certain heavy stars at the end of their lives collapse in the most violent explosions known in the universe – supernovae. What is left after they have blasted most of their bulk into space is a dense ball of neutrons, a neutron star, or occasionally a Black Hole.

Simulations in the 1980s by Gerry Brown at Stony Brook, New York, suggested that neutron stars of up to two solar masses should be found in supernova remnants, but the heaviest seem to be just 1.5 solar masses. According to Brown's calculations, there should be a two-solar-mass neutron star in the remnants of SN1987A, but so far none has been found. Working with Hans Bethe, Brown has come up with a possible reason why.

Bethe and Brown suggest that in dense nuclear matter, negative kaons could play a similar role to electrons. What would allow them to do this is a curious phenomena whereby the mass of kaons decreases as the density of the surrounding medium increases. But there is a crucial difference between electrons and kaons: electrons are fermions, kaons are bosons. That means that kaons are not limited by Pauli's exclusion principle and many more of them can pack into a dense star than can electrons.



GSI Darmstadt's kaon spectrometer, KAOS, looks at the kaons emerging from heavy-ion collisions. (Photo Achim Zschau/GSI.)

The negative charge of large numbers of kaons allows many more protons to exist in the star. Bethe and Brown calculate that, unlike the case of pure neutron matter, a large proton-to-neutron ratio can precipitate the collapse of the star into a Black Hole. If they are right, then what is left after SN1987A's collapse is probably a Black Hole.

Bethe and Brown's model lends itself well to experimental testing since kaons are easily produced in accelerator laboratories, and the density of neutron stars can be simulated in heavy-ion collisions. And that is exactly what Peter Senger and his colleagues at GSI Darmstadt have done. They studied kaon production in the collisions of high-energy nickel ions with a nickel target. In such collisions nuclear matter is compressed to about three times its normal density.

The GSI team found that the number of positive kaons emerging from collisions was as expected, but the number of negative kaons was far higher. One possible explanation, put forward by Gerry Brown among others, is that the effective mass of negative kaons is strongly reduced in the dense nuclear medium compared to that of positive kaons – just the effect needed by Bethe and Brown's proposal. That means that negative kaons become easier to produce, and more of them emerge from the collision.

According to Bethe and Brown's calculations, an effective negative kaon mass at three times normal nuclear density, which would account for the GSI result, could also provoke the gravitational collapse of neutron stars of 1.5 to two solar masses. GSI's result helps turn Bethe and Brown's idea into a firm prediction. All that remains now is to identify the Black Hole in the middle of SN1987A.

● Further reading:

H Bethe 1990 Supernova Mechanisms *Rev. Mod. Phys.* **62** 801.

R Barth *et al.* 1997 *Phys. Rev. Lett.* **78** 4007.

Physicists enjoy the CERN School of Computing

The annual CERN School of Computing displays the continual close symbiosis between computing and physics. For the 1998 (21st) CERN School of Computing in Madeira, the programme was organized around four themes: agent and distributed computing technology; intelligent monitoring and control; petabyte storage (databases); and software evolution.

The School was organized by CERN in collaboration with LIP, Lisbon and the University of Madeira. 67 students (from 45 institutes, 22 countries and of 22 nationalities) attended, of which 14 were funded by the European Commission and by UNESCO.

After general lectures in the first week, the second week was oriented towards computing problems for particle physics and the LHC programme.

Practical exercises are an important part of the programme and require a complex computing infrastructure. Computing and peripheral equipment was provided by and via CERN. Equipment lent by various manufacturers was delivered to CERN where it was set up, tested, dismantled and shipped to Funchal, Madeira. Portuguese colleagues ensured the provision of the necessary network connection from Funchal via the University of Madeira, Lisbon and CERN and, together with students from Madeira, helped in the installation. Setting up this complex computing facility, even if only needed for a short time, needed close collaboration and was widely appreciated.

The 22nd CERN School of Computing will take place in Stare Jablonki, Poland, from 12–25 September, organized in collaboration with Warsaw University (IFD) and the Department "Internet For Schools" of the Foundation in Support of Local Democracy (IdS). The themes for 1999 are: advanced topics; LHC experiments data communication and data processing systems; software building; and Internet software technologies.

The School is open to postgraduate students and research workers with a few years' experience in elementary particle physics, computing or related fields. The number of participants will be about 80, mostly from the CERN Member States or from laboratories closely associated with CERN, but a few may come from elsewhere.

● Apply to: Miss Jacqueline Turner, School of Computing, CERN, 1211 Geneva 23, Switzerland. Tel. +41 22 767 5049. Fax +41 22 767 7155. E-mail "Computing.School@cern.ch". Web "http://www.cern.ch/CSC/". The deadline for application is 17 May.

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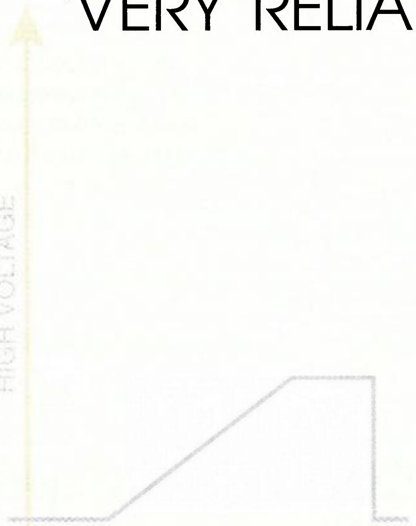

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Are neutrinos seasonal?

The Sun could be surrounded by a flat disc of neutrinos more than a billion times denser than the neutrino cloud permeating the rest of the universe. This is the suggestion from precision measurements of the beta decay of tritium by the Institute of Nuclear Research, Troitsk, Russia, which also give a new upper limit on the electron neutrino mass.

After 1998's harvest of neutrino evidence underlined the possibility that neutrinos may have mass, neutrino mass is back in the spotlight. Neutrinos are conventionally described as massless particles moving with the speed of light, but a tiny mass introduces interesting possibilities, for both physics and cosmology.

Neutrinos cannot be observed directly. Their job in Nature is to carry off energy in beta decay, and the best way of "observing" them is to keep detailed accounts of particle energy. Any mismatch indicates that an unseen neutrino "thief" has been at work.

Mass measurement is particularly difficult and sensitive for the electron neutrino, the lightest. Zero mass is difficult to prove, and refined experiments successively push down the mass limit. To help with the detailed energy book-keeping, physicists look at the beta decay spectrum of tritium as close as possible to the highest possible energy of the emerging electrons. Although this is only a tiny fraction of the total decays, these conditions provide a long lever arm on the neutrino mass.

The experiment at Troitsk provides a new upper limit of 2.5 eV. If the particle indeed has mass, it is probably only a minute fraction of this value, but in unravelling the data the experiment came across an unexpected effect which at first appeared as a small peak very near to maximum electron energy, which moves up and down by some 10 eV every six months!

It is as though the Sun were surrounded by a dense disc of neutrinos at an angle to the Earth's orbit. The Earth thus sees a neutrino density which varies over a six-month cycle. A neutrino reacts with a tritium nucleus, producing a helium-3 nucleus and a monochromatic electron seen as a peak in the tritium beta decay spectrum.

The neutrino cloud needs a concentration of 10^{15} per cubic centimetre, compared to the generally accepted few hundred for background cosmic neutrinos. There is no explanation for such a compact neutrino cloud. Neutrino effects in tritium beta decay have come and gone before, and this one too needs to be checked out.

At the moment only one other operational experiment (Mainz) could reach comparable sensitivity to check the Troitsk observation. A more decisive check could be obtained via a more elaborate setup now being discussed.

RHIC Mock Data Challenge successfully completed at Brookhaven

With Brookhaven's RHIC relativistic heavy-ion collider scheduled to be commissioned this year, preparations for its experimental programme gather momentum. The RHIC Mock Data Challenge 1 (MDC-1) began on 8 September and finished successfully on 19 October.

With installed capacities amounting to approximately 25% of that which will be available at the start of the first RHIC physics run, this six-week exercise involved the RHIC Computing Facility, the US Department of Energy's (DOE's) High Energy and the Nuclear Physics Computational Grand Challenge Initiative, and the four RHIC experimental collaborations, BRAHMS, PHENIX, PHOBOS, and STAR.

The main goals of the exercise were to show the performance of: event data recording; event reconstruction; and data mining (selecting rich subsets from large volumes of data); each for multiple experiments simultaneously.

During the exercise, aggregate event data recording rates into the High Performance Storage System (HPSS) for the four experiments as high as 18 Mbyte/sec for an 8-hour period were measured. (HPSS is hierarchical storage management system software developed under a Cooperative Research And Development Agreement including several DOE Labs, now commercialized by IBM.)

Event reconstruction by the four experiments on a computing farm consisting of up to 104 Pentium II processors, representing some 1400 SPECint95 benchmarks of CPU capacity, were achieved with CPU utilization efficiencies for a 16-hour period averaging 80% across the experiments.

During simultaneous event data mining by the four experiments, a variety of data access measurements were made. These included evaluation of the performance of a Sun server compared with network-connected Pentium farm machines, the use of Grand Challenge Project software to coordinate queries, and the use of an Oak Ridge-developed system to batch files for access from HPSS tapes.

The Grand Challenge Project and STAR were also able to build and exercise a data summary tape level objectivity event data store. Secondary objectives, including running multiple simultaneous functions for a subset of the experiments and running for extended periods for individual experiments, seven days for PHENIX and STAR, were also achieved.

From the perspective of the RHIC Computing Facility, the exercise was valuable in terms of verifying and detailing expected behaviour and limitations of the current facility and by revealing some unexpected problems.

As anticipated, the Managed Data Server (MDS) and in particular the HPSS were found to be the single most complex and critical components. The HPSS showed itself capable of high performance and adequate to the goals of the exercise. However, it was also clear that the time between its initial installation at the RHIC Computing Facility and its large-scale use in the exercise were not adequate to achieve the desired levels of reliability. The limited storage resources, in particular tape drives, available for this exercise also contributed to the stress on HPSS. Except for an initial delivery delay, the performance of the Intel-based Linux processor farms during the exercise were gratifyingly close to what was anticipated. An unexpected issue was the performance of the RHIC Wide Area Network. While the need to tune RHIC Computing Facility network parameters and collaborating remote machines was anticipated, end-to-end problems including the national ESnet and/or commercial links were more serious and less tractable than anticipated.

From the perspective of the RHIC Computing Facility, the ability of all six parties to participate effectively in a unified exercise was the most important outcome. If this synergy continues and convergent iteration can be achieved, effective computing for the RHIC experimental programme will be assured.

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Edited by Emma Sanders

Supernova testbed

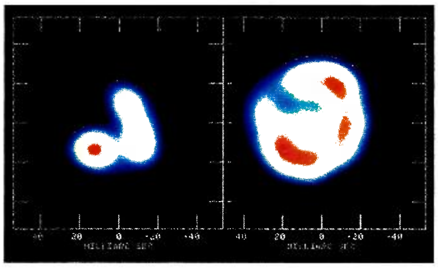
A nearby active galaxy reveals a unique population of exploding stars. Astronomers at the UK's Jodrell Bank radio astronomy laboratory have observed over 50 supernova remnants in the galaxy M82. These shells of gas are blasted into space during the giant explosion at the end of a massive star's lifetime.

For the first time, the astronomers can resolve the individual shells and measure their expansion in a galaxy 10 million light years from our own. They can also measure their luminosity. The 50 supernova remnants are ideal candidates for this kind of population study as they are all at essentially the same distance, unlike the supernovae observed in our own galaxy.

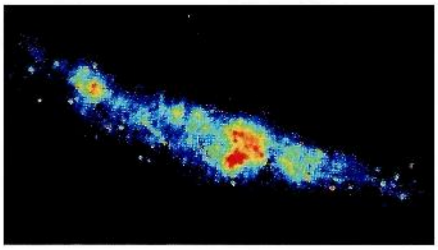
M82 is a "starburst" galaxy with a central region of intense starformation. Mapping the absorption of hydrogen gas in front of the supernovae gives clues to how this activity in the centre is fueled.

The study of supernovae has important consequences for cosmology as certain supernovae are used as standard candles to measure distances in space (October 1998, p10). Spectral studies of supernova remnants reveal how heavy elements are distributed.

Jodrell Bank is the control centre of the MERLIN radio interferometer, comprising seven radio telescopes stretching from Manchester to Cambridge.

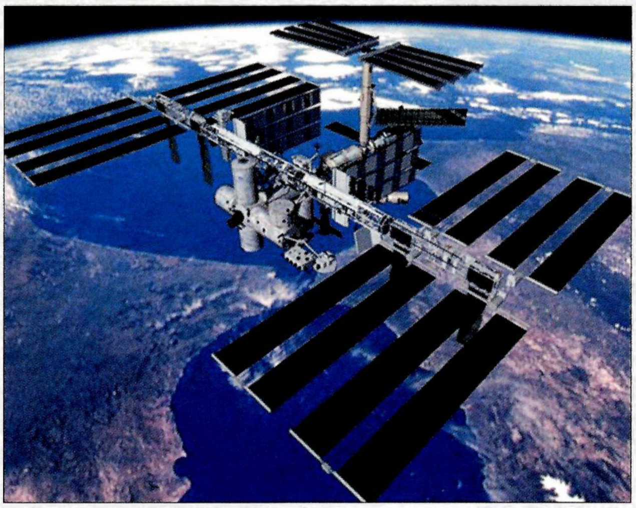


One of the supernova remnants in the active galaxy M82: a hot shell of gas expanding at 10 000 kilometres per second as it looked in 1986 (left) and now. (Pic: Jodrell Bank.)



A radio image of active galaxy M82 showing over 50 supernovae.

Picture of the month



What's as long as a football pitch, weighs 460 tons, has 4000 m^2 of solar panels and will be flying overhead in 2004? The answer is the International Space Station. Construction began at the end of 1998 with the successful launch of the first two modules: the Zarya control module, a 20 ton, 13 metre long module that provides propulsion, command and control systems; and the Unity connecting module with six attachment ports. The complete assembly is shown in this artist's impression. (Pic: NASA/ESA.)

The furthest quasar

Astronomers at the Sloan Digital Survey have broken the record for the most distant quasar ever observed.

Quasars – quasi-stellar objects – are no larger than our solar system, yet can outshine galaxies of hundreds of billions of stars. The new record-breaker has a redshift of 5.0. Because of the expansion of the universe, the greater a galaxy's light is shifted to the red, the further away it is, and the younger the universe when the light was emitted. A redshift of 5.0 means the light was emitted when the universe was less than a billion years old.

The most distant galaxy has been observed with the Hubble Space Telescope at a redshift of 5.60.

The Sloan survey uses the 2.5 m telescope at the Apache Point Observatory in New Mexico. Over the next five years, astronomers will measure the distance of over a million galaxies which will combine to make the largest 3-D map of the universe ever. This will impose important constraints on models of cosmic evolution.

The collaboration consists of eight research organizations from the US and Japan. Fermilab constructed the data acquisition system and the software and hardware to process the 10–20 terabytes of data.

New infrared array

Europe and the United States plan to join forces on the next generation of ground-based infrared telescopes. The European project, the Large Southern Array, consists of antennae covering an area of 10 000 m^2 in the Chilean Andes. In parallel, staff at the US National Radio Astronomy Observatory have designed their own Millimetre Array.

The proposal now up for discussion is whether or not to pool resources and build just one telescope. The council of the European Southern Observatories (ESO) has given the green light for negotiations to start.

A new millimetre-wavelength telescope is a high priority for astronomers as it will complement observations made by the Hubble Space Telescope and ESO's Very Large Telescope. All three would have similar scientific objectives and comparable high angular resolution and sensitivity.

A cold start for LHC

Spearheading the construction effort for CERN's LHC collider is the groundwork for the 1232 superconducting dipole magnets, to be cooled by superfluid helium at 1.9K. Material procurement and tooling is advancing hand in hand with the final research and development work for the production design.

One of the first major LHC procurement contracts was for the superconducting materials – niobium-titanium bars and niobium sheet worth $45 million – with Wah-Chang in the US and using US money. This was followed by contracts for the actual cable manufacture. A total of 13 680 kilometres of cable will be needed, longer than the diameter of the Earth. As well as being for the dipoles, this material will also be used for the 520 focusing quadrupoles and several other magnets.

Involved in this manufacture are Alsthom (France), Vacuumschmelze (Germany), Europa Metalli (Italy), Furukawa (Japan) and IGC (USA), reflecting the worldwide involvement in the LHC.

Testing and quality assurance of the superconducting strands, and subsequently the full cable, is absolutely vital. A new test facility at CERN, equipped with its own helium refrigerator, will come into operation soon. This facility will be used for quality control of the strands during production, whereas most of the final cable will be tested in a similar facility at Brookhaven as part of the CERN–US collaboration.

For the magnets themselves, tests on 1 metre dipole models underlined the wisdom of reverting to the original 6-block coil design (September 1998, page 17) after a flirtation with a 5-block configuration.

During 1998 two more 10 metre collared coils were delivered by industry and assembled at CERN into complete magnets, and the first 15 metre prototype dipole, built by industry under an agreement between CERN and the Italian INFN, was put through its paces. While the nominal field for LHC magnets to handle 7 TeV beams is 8.34 T, 9 T is seen as the ultimate goal. While the former figure is usually a cinch, the latter is not, underlining the need for careful quality control at all stages in the manufacture and assembly, and the importance of the collaring procedure to anchor all components securely under immense magnetic forces and when cooled to 2 K.

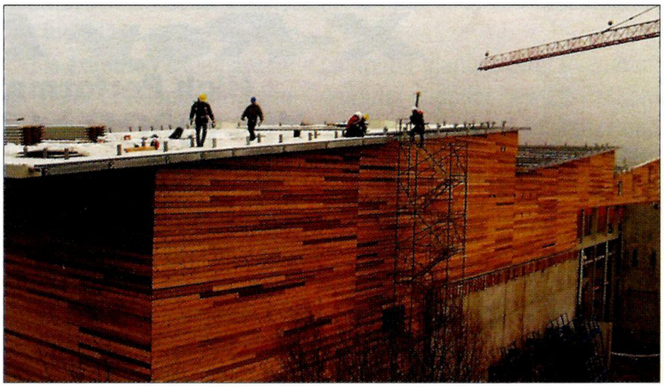
Orders for six prototype collared coils with the series manufacture design have been issued, and the first has even arrived. These will be assembled into cryomagnets at CERN, as industry is not yet equipped with the necessary 15 metre hydraulic presses for the welding of the cold mass.

Prototype high-temperature superconducting current leads have been ordered and tested. Other cryogenic-related equipment reflects further the world involvement in the LHC. Power supplies for quench heaters are being developed by a collaboration working through the Indian Centre of Advanced Technology, Indore, while equipment to handle the extraction of the stored superconducting energy in the event of a quench is being designed and constructed by Russian industry and by IHEP, Serpukhov.

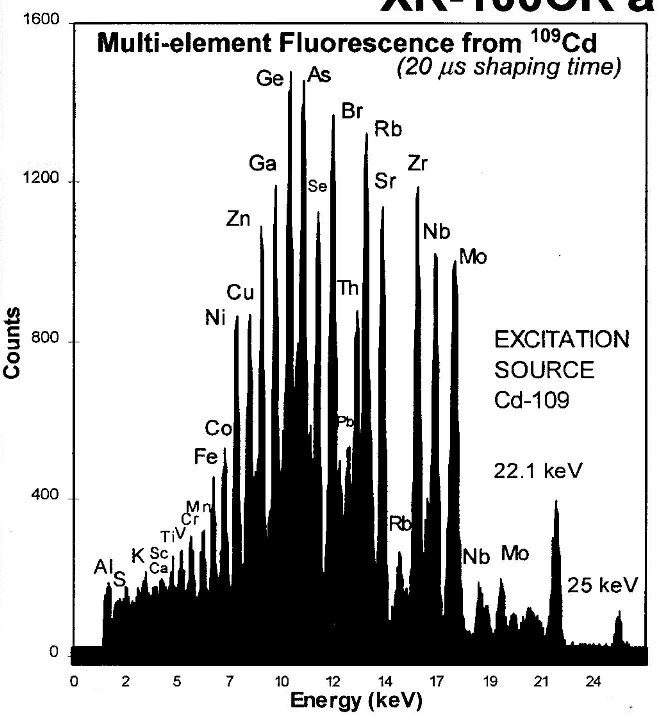
Also being supplied from Russia, in this case the Budker Institute, Novosibirsk, are 360 warm dipoles and 180 quadrupoles for the two 2.5 km transfer lines feeding protons from the SPS to the LHC. The first magnets have arrived.

With the technical specification of the dipole cold masses complete, almost the last act of 1998 at CERN was to issue a call for tenders for the first phase of LHC dipole procurement.

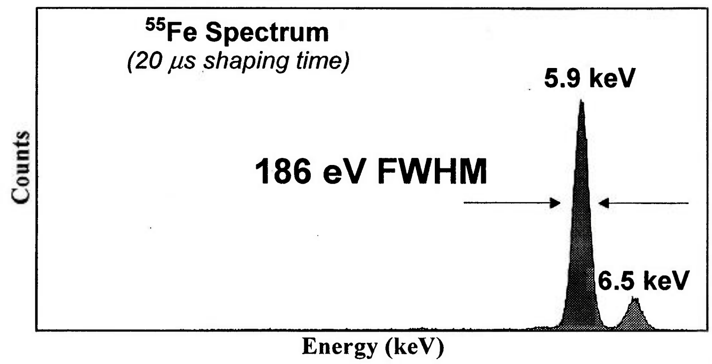
Excavation work begins at the far end of CERN's Meyrin site for the access shaft for one of the two transfer tunnels which will take protons from the SPS to the LHC. During LHC construction the big LHC magnets will be lowered down this shaft.



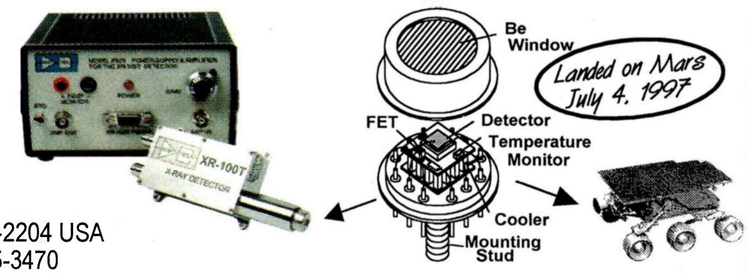
Across the road from CERN's main entrance, work advances on the large building which will shelter the shafts down to the large underground experimental area for the ATLAS detector. (Photos: CERN/ST-CE.)



Multi-element Fluorescence from ^{109}Cd
(20 µs shaping time)
Counts
Energy (keV)
EXCITATION SOURCE Cd-109
22.1 keV
25 keV
Al S K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Rb Sr Zr Nb Mo Th Pb Rb Nb Mo
0 400 800 1200 1600
0 2 5 7 10 12 14 17 19 21 24



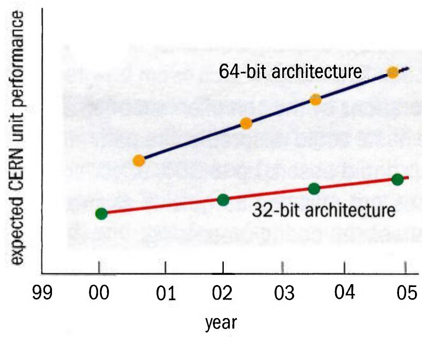
^{55}Fe Spectrum
(20 µs shaping time)
5.9 keV
186 eV FWHM
6.5 keV
Counts
Energy (keV)



Be Window
FET
Detector
Temperature Monitor
Cooler
Mounting Stud
XR-100T
Landed on Mars July 4, 1997

EPIC developments in processing power

CERN's demanding data processing requirements provide the testbed for a new range of semiconductor chips and associated software developed jointly by industrial giants Hewlett-Packard and Intel and which are aimed at new generations of computers.



64-bit processors will set computing performance on a new path. The chart compares their projected evolution with that of 32-bit architecture over the construction period for CERN's LHC.

In the long run, technology always benefits from new scientific insights. Modern semiconductor technology, for example, is one of the ultimate applications of quantum mechanics.

But there are other ways in which science can drive technology. For science to advance, researchers look at the world around us in new ways and under special conditions. The further science advances, the more unusual these conditions become. Irrespective of the ultimate scientific breakthrough, these increasingly stringent demands frequently catalyse new technological developments. Cryogenics, high vacuum and data acquisition and processing are examples of areas where the special requirements of particle physics have fostered industrial progress.

At CERN's LHC collider now under construction, the very high event-rates call for a major push in data acquisition and processing power for the experiments. Each LHC experiment will generate a torrent of information, about 100 Mbyte per second, equivalent to a small library. With raw events happening every 25 nanoseconds, the data volumes will grow at an alarming rate, and a major upgrade in data handling capability is called for in order that precious physics information is not to be lost.

In addition, to minimize the requirement for expensive computer power downstream, as much processing as possible has to be done by hardware strategically distributed upstream.

Moore's Law

At the same time, the highly competitive computer industry is continually at work developing its next generation of products. The industry accepts a law first put forward by Intel founder Gordon Moore, which states that the number of transistors that can be harnessed for a particular task doubles every 18 months. With processing speed thus also increasing at an annual rate of 60%, new approaches are continually sought to take maximum advantage of this incredible rate of advance.

It is extremely expensive for a computer manufacturer to embark on major development alone. Computer supplier Hewlett-Packard and semiconductor giant Intel announced a joint research and development project in 1994 with the objective of catering for systems to appear on the market at the end of the 90s. At the time, it was already clear that 32-bit technology would soon have yielded all it could, and future developments would have to turn to a more flexible approach.

The outcome – the new Explicitly Parallel Instruction Computing (EPIC) technology – is a milestone in processor development. EPIC is the foundation for a new generation of 64-bit instruction set architecture driving the flow of operations through the microprocessor.

The main advance is the chip's capacity for parallel processing, handling different operations at the same time rather than the traditional sequential approach. A good example of sequential processing is a traditional airline check-in, where although there are normally many parallel counters, each customer can only use one. At each counter a single clerk handles a long sequence of operations – ticket, seat allocation, baggage, boarding pass etc.

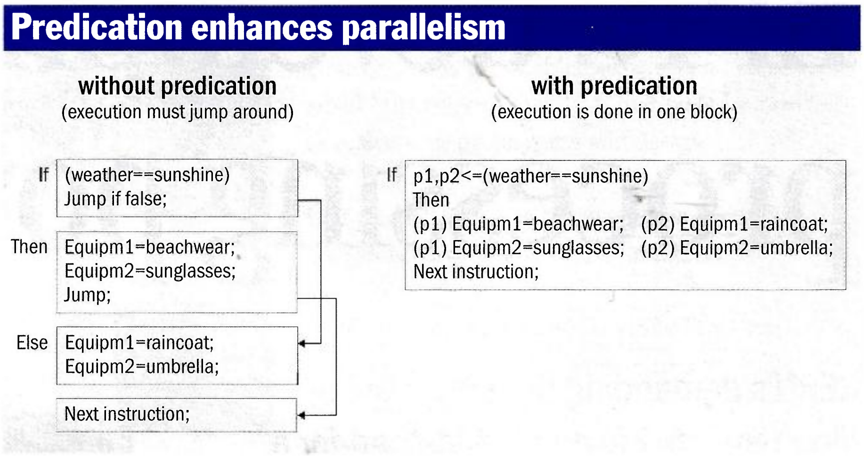
Throughput could be increased with more clerks behind each counter, each clerk being responsible for a specific operation, but this is not true parallelism. Even in the traditional check-in approach, sequential operations eventually become parallel – baggage is accepted item by item before being assembled into parallel loads for different aircraft.

However, in a fully parallel processing environment, all check-in tasks would be handled at separate counters coordinated by a central processor. Customers would be tagged as they entered the airport building and the whole check-in operation would become scheduled to occur in parallel.

The new EPIC design advances on current X86 Intel architecture by allowing the software to tell the processor when parallel operations are needed. This reduces the number of branches and optimizes the links between processing and memory. Under the codename Merced, the first 64-bit processor is scheduled for production next year.

Software

With Intel taking responsibility for the hardware, Hewlett-Packard focuses on the associated compilers and other software. HP, with its long tradition of scientific computing, has special requirements in this area.



The sequencing of operations by the compiler had been a bottleneck. The compiler in its haste could mispredict the path an operation should take, and this could absorb up to 30% of performance. Memory technology does not advance as quickly as processing power, and memory lags were hindering processing.

The vital interface between the client's application environment and the processor is the compiler, the software which translates the customer's high level program into cryptic instructions which the semiconductor logic can follow. A data processing client wants to benefit from increased performance, but without disrupting his way of working.

Existing compilers had acknowledged the advent of parallelism and extracted whatever aspects they could see. However, the new approach goes for explicit parallelism from the start, introducing an element of prediction, trying to get as many things as possible ready in advance.

In the first part of this joint Hewlett-Packard project several key applications at CERN will be prepared for the IA64 architecture by testing them with Hewlett-Packard's existing compilers. In one recent milestone, the brand new GEANT4 object-oriented simulation kit has functioned correctly in this environment. Similarly, several CERN benchmark programs have been run and other applications will be ported to the new environment over the coming months. CERN project manager is Sverre Jarp, and Elzbieta Richter-Was from Krakow and a member of the ATLAS experiment at CERN's LHC is project associate.

This effort should allow CERN and high-energy physics to become "early adopters" of the new processor – the applications will be ready to run as soon as the new computers appear on the market. The project will also ensure that the programs reap the full benefit of the parallel architecture. This will enable the global computing needs of the four major LHC experiments to be achieved inside a realistic financial envelope.

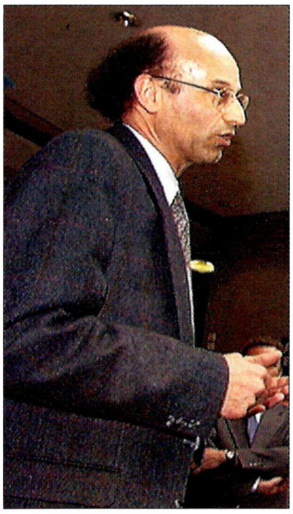
Library

In the second part of the project, CERN and Hewlett-Packard are implementing a highly accurate and optimized mathematical library. Many of CERN's programs, such as physics event generators, rely heavily on mathematical functions such as exponentials, logarithms, and power functions.

Floating-point calculations for high-energy physics are increasingly being done to 64-bit precision. If an experiment needs a resolution of one micron over 10 metres, 32-bit precision becomes insufficient. 64-bit precision is so good, however, that even with a detector as big as Jupiter we could still compute to an accuracy of about a hundredth of a micron!

Important additions, such as high-speed random number generators, will be added to the library. Detector simulation programs are notorious consumers of random numbers and the new EPIC technology will be able to churn out these numbers faster than ever before.

ATLAS of the world



1800 physicists from 33 countries are participating in the ATLAS experiment, the largest detector being built for CERN's LHC collider. *CERN Courier* asked ATLAS Spokesperson *Peter Jenni* how the collaboration works.

The LHC will collide protons at higher energies (7 TeV per beam) than ever achieved before under laboratory conditions to penetrate still further into the structure of matter and recreate the conditions of the universe just 10^{-12} seconds after the Big Bang when the temperature was 10^{16} degrees. Designing and building a particle physics detector like ATLAS – 7000 tonnes of high technology equipment – involves more than just following a sheet of instructions. In a modern-day parallel of a potential Tower of Babel scenario, scientists have to work together as a team while remaining thousands of miles apart.

What is the balance between individual creativity and being part of such a large collaboration?

The successful design and construction of a large and complex state-of-the-art detector requires the creative participation of many people. It is not the collaboration that is creative, but the sum of its individual members. There are many subsystems, so that people mostly work in small groups, contributing creatively. Ensuring that all systems fit and work together, and are affordable, constrains the creative process, but good ideas will make their way!

How are important decisions made? How are individuals heard?

Many important decisions involve just one or two subsystems. They are discussed initially in the subsystem plenary meetings, where everybody can participate and make their voices heard. Recommendations are then discussed in the ATLAS Executive Board, and presented in plenary meetings which play a primary role in forming a consensus when decisions are required. The leadership can only "lead" the collaboration to decisions which are understandable to all, or at least to a large majority. Practical constraints – costs, schedule, the availability of manpower etc – also come into the equation. There is a clear sequence of steps from subsystem to systems, with the vote by the Collaboration Board being the ultimate step for major decisions.

How is such a large and far-flung collaboration managed?

Each subsystem has its own management team. At the same time, the Executive Board and Spokesperson maintain general oversight.

The Technical Coordination team is responsible for making sure that all subsystems fit together. In parallel, there are national representatives who monitor the use of resources from their respective countries and make sure they are well used.

The Collaboration Board sets out policy issues, and is not involved with execution, which is a management responsibility. However, frequent contacts, between for example the Spokesperson and the Collaboration Board Chair, ensure that policy issues are properly handled, and that fair solutions are found for difficult problems. Finally, direct contacts between individuals and teams with the collaboration management also play an important role.

How do 1800 people communicate among themselves? How do you bridge large distances and overcome time differences?

Electronic communication (e-mail, Web, telephone, video conferencing) is obviously very important. However, regular direct human contacts are crucial. Meetings play a significant role.

How are tasks apportioned?

By trying to match the interests and resources of the participating teams to the tasks. This can succeed only if everyone is also willing to share the less interesting but necessary tasks such as building support structures, contributing to buying cables, writing utility software etc. This works because the physicists are motivated by the prospect of exciting results, which depend on having a complete, working detector system. Of course it is not always easy to arrive at an optimal task-sharing to everyone's satisfaction, with all tasks assigned.

How are the costs apportioned?

There is no absolute formula. Large teams from wealthy countries are expected to carry a larger share of the costs than small teams from countries with developing economies. Matching the possible contributions of teams and countries to the overall effort is a central part of forming the collaboration.

Where does the money come from?

Mostly from the funding agencies of the various participating countries. There are also significant contributions from CERN, and some resources from individual universities.

How do people join?

Teams interested in ATLAS may contact the Spokesperson, and their interest is then brought to the attention of the Collaboration Board (CB). After examining their resources, their potential share of the work, their relationships with other teams already working on ATLAS etc, the CB votes on their admission.

How do you ensure that all the detector pieces fit together?

The Technical Coordinator, supported by the Technical Coordination Team, works with all the subsystem groups to ensure that the sepa-

Assembling a tile calorimeter for the ATLAS experiment at CERN.

rate pieces will fit together without interfering with each other, and that the full detector can be assembled.

How will data analysis be shared among 1800 people?

The data will provide experimental input for many separate research topics. ATLAS scientists will pursue these research areas mostly in small groups working at their home institutions. All collaborators will be invited to analyse the data by being part of analysis teams.

In some respects data analysis by individual ATLAS physicists can be compared to data analysis by astronomers using the Hubble Space Telescope. In both cases, scientists choose the research areas and data that interest them most.

How does a collaborator get credit for his/her contributions?

This is of course a major question. Internal publications within the collaboration, usually with one or a few authors, will document individual contributions. These can be made known to the whole scientific community. Also, leading contributions are often recognized by asking the person to speak at conferences. However, the large collaborations still have to learn how to handle this question. Major results are obtained collectively, because people are willing to share the tasks. It is not only the final analysis which counts, but all the work which makes it possible to collect the data, and calibrate and prepare it for final analysis.

What is the impact of the global spread of the collaboration? How does one contribute from 6000 miles away?

The global spread implies that factors such as transport of components need to be taken into account during the construction, and that communication logistics play a major role. Full information, eventually including data analysis, must be available simultaneously all over the world. Nevertheless, it also implies that scientists from outside Europe have to travel long distances to participate in discussions and meetings, in the detector assembly and testing, and eventually in the operation of the experiment. They may have to spend extended periods away from their homes and home institutions. However, all ATLAS scientists are after the same goal of doing frontline LHC physics, and are therefore willing to endure these inconveniences to achieve that goal. But being away from home is not necessarily always a disadvantage. In particular young people are stimulated by such experience.

Electron-positron pioneer

In 1960 Bruno Touschek gave a talk on electron-positron collisions that would change the face of physics. Last November, 30 years after his death, physicists gathered to celebrate Touschek's work.

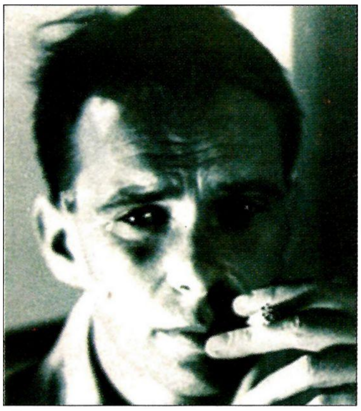
On 16 November 1998 the INFN Laboratori Nazionali di Frascati celebrated the memory of Bruno Touschek, the spiritual father of electron-positron physics, on the 30th anniversary of his premature death. On the occasion, Frascati announced the institution of the Bruno Touschek grant for high-school students who excel in science.

After escaping from a concentration camp during the Second World War, the Austrian-born Touschek began work in Göttingen and Glasgow, and eventually reached Rome in 1952. On 7 March 1960 he gave a historic seminar at Frascati that would change the face of physics. Pointing out the importance of carrying out a systematic study of electron-positron collisions, he suggested that this could be achieved by constructing a single magnetic ring in which electrons and positrons circulate at the same energy but in opposite directions. Soon afterwards, the first electron-positron accumulation ring, AdA, was built under his leadership in Frascati.

The memorial meeting, held in the main auditorium of the laboratory, named after Touschek, was the occasion for distinguished physicists to review the past, present and future of this still dynamic field of research. After Touschek's close friends and collaborators, Giorgio Salvini and Carlo Bernardini, recalled his brilliant personality and the "glorious days" of AdA, Jacques Haissinski described the second step of this pioneering work – the move of AdA to Orsay, and the subsequent construction of the ACO ring in that laboratory.

Revolutionary results then flowed from electron-positron rings all over the world. In particular, in the early 1970s electron-positron collisions helped change our view of hadrons (particles that, like the proton and the pion, and unlike the electron, carry the "strong" force) from elementary to composite particles. This was covered by Massimo Testa, who underlined the major role of Adone, Frascati's second-generation electron-positron machine, in these developments.

Carlo Bernardini, a colleague of Bruno Touschek, addresses the memorial meeting.



Bruno Touschek in 1964.

Emilio Picasso's comprehensive review of electron-positron machines, from AdA to the world's largest ring, LEP at CERN, introduced the present role of electron-positron physics. Guido Altarelli stressed the prominent role of LEP and its US counterpart, Stanford's SLC, in the detailed confirmation of the Standard Model, our best description of elementary particle interactions so far.

LEP is in the forefront of the search for physics beyond the Standard Model. One hint of such new physics might be the recent results from the SuperKamiokande Collaboration in Japan, looking at neutrinos produced by cosmic rays in the Earth's atmosphere and which suggest neutrino oscillations. CERN Director-General Luciano Maiani showed why this is so exciting and underlined the importance of conducting accelerator experiments under controlled conditions to explore neutrino masses and mixings. Projects for such experiments are already under way, both in Japan and the USA, but there is still room for Europe to participate in such a venture. The question "Is a meaningful international scientific programme possible?" begs an answer.

For the immediate future, Frascati will again be in the forefront of electron-positron physics with the new DAFNE phi-factory, which obtained its first collisions last March. Miro Preger explained how the machine has already exceeded a luminosity of 10^{30} per sq.cm per s operating with only one bunch of electrons and one of positrons. In the near future the machine is expected to run with more than 100 bunches per beam to reach the design record luminosity of 5×10^{32}.

The reason behind such a high luminosity was explained by Paolo Franzini: it will allow about 5000 phis per second to be produced and will detect their subsequent decays into charged or neutral kaon pairs. Their study should shed light on the long-standing puzzle of the violation of CP symmetry. A new big detector, KLOE, built for this purpose, is a common effort by more than 120 physicists from Italy, Germany, the USA, Russia, China and Israel, and initial results are eagerly awaited.

For the longer term future, the electron-positron community is focusing on projects for a new very-high-energy linear collider, as presented by the final speaker, Marcello Piccolo. Three independent study groups have already addressed this issue in Europe, Japan and the USA. A costed design is expected for 2001; after a selection and approval procedure, construction could start in 2003.

In the new century, Touschek's ideas will continue to guide our exploration of the fundamental interactions.

In retrospect: electron s

The recent closure of the Amsterdam Pulse Stretcher marks the end of 30 years of electron accelerators in the Netherlands.

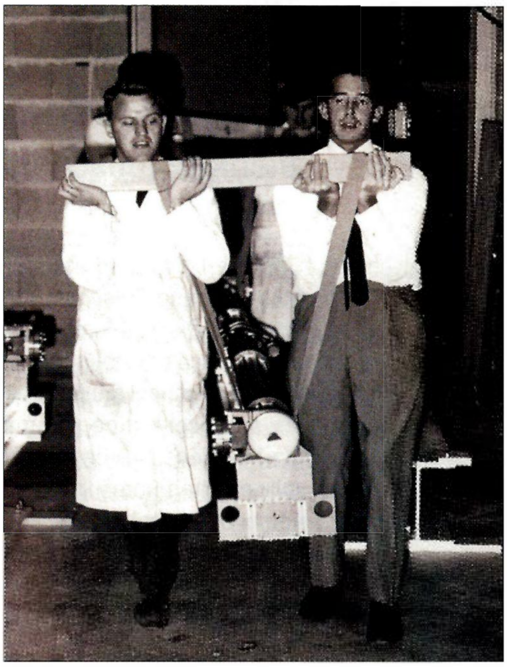
The turn of the year was significant for the Dutch NIKHEF laboratory: 1998 was the last year in which data were taken at the institute's Amsterdam Pulse Stretcher (AmPS). Even before the AmPS was built, funding organizations had decided that it would only be exploited from 1992 to 1998 because it was a heavy load on the Dutch science budget.

The first steps towards electron scattering experiments in Amsterdam were taken at the beginning of the 60s when institute director Prof. Gugelot sent his former PhD student Conrad de Vries to Stanford. There, at the cradle of electron scattering, de Vries worked in Robert Hofstadter's group. The 3 km linear electron accelerator was being designed next door at SLAC. On his return to Amsterdam, de Vries convinced the institute (then called IKO, the Instituut voor Kernfysisch Onderzoek) that electron scattering provided the best possibilities for future nuclear physics experiments.

While de Vries formed a research group and designed experiments, a linear accelerator was constructed in a joint effort by IKO and the Philips company. In 1946 Philips had built the synchrocyclotron at IKO – the first in Europe. Now it wanted to gain experience in constructing linear accelerators, thereby using superconductivity. It was an ambitious goal, and when the detectors were ready there were still problems with the accelerator. Long delays were foreseen and de Vries turned to his former colleagues in Stanford. In 1966 the US Atomic Energy Commission approved a plan to send two spare SLAC sections to Amsterdam – officially "on permanent loan". The two 3 metre sections formed a 90 MeV linear accelerator (with the Dutch acronym EVA), which became operational in 1968.

Since the Netherlands could not go for large accelerators or huge projects, de Vries decided to aim for precision measurements. Very precise data on the charge radius of carbon-12 are still standard today. The spatial magnetic distribution was measured for a variety of nuclei, ranging from lithium-6 to indium-115. At these low energies it is difficult to separate the small magnetic contribution from the much larger charge contribution, with one exception: at a scattering angle of 180° only the magnetic component contributes. In a specially built 180° arrangement – comparable to the one built by Barber and Peterson at SLAC – magnets were used to separate back-scattered electrons from the incoming electron beam. The resulting data were complementary to higher energy results at the 600 MeV electron accelerator (ALS) at Saclay.

From the start it was clear that a larger accelerator than EVA was needed, and the first plans for a medium-energy accelerator (MEA) were submitted at the end of the 60s. The cost of this 500 MeV machine – about 40 million guilders for construction – was very high by Dutch standards, and the project required much prior organization. Construction started only in 1975 and the first measurements with MEA electrons were made in 1981. In 1983 MEA could deliver up to 40 microamps at a duty factor of 1%. This was lower than the 10% originally aimed for, but much higher than the 0.02% of EVA.

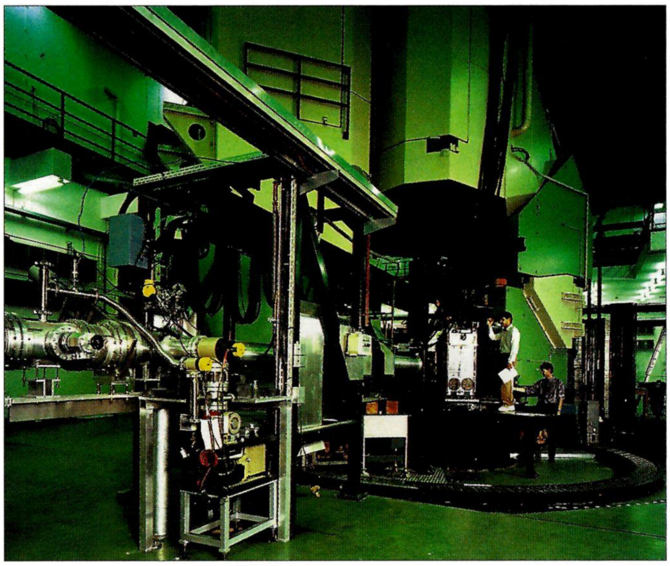


In 1966 two spare sections of the then new SLAC linac arrived in Amsterdam to form the 90 MeV EVA linear accelerator. Here Conrad de Vries (right) and accelerator engineer Pieter-Hans Bruinsma are carrying one of the sections.

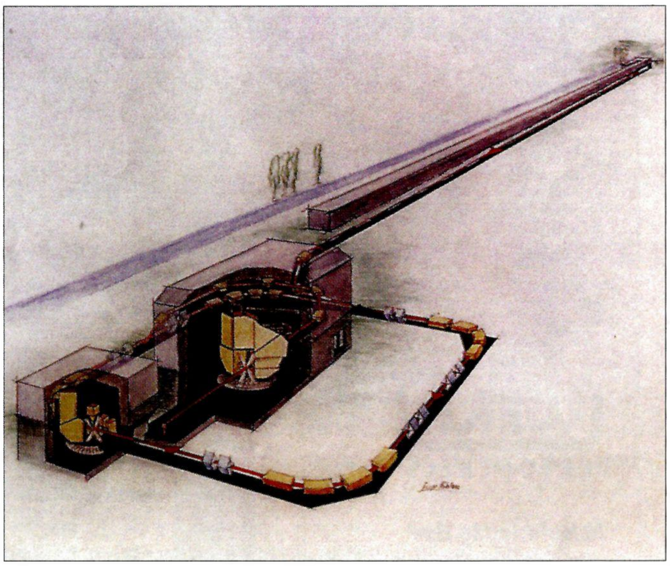
Precision measurements

Again the emphasis was on precision measurements, including experiments in which a proton was knocked out of the nucleus by the electron. By carefully measuring the momenta of the emerging proton and of the incoming and scattered electron, the initial momentum of the proton in the nucleus can be reconstructed. For this, two spectrometers were built with precisely known magnetic fields and a momentum resolution of 10^{-4}. Each covered a limited angular range but they could be moved with respect to the target and precisely positioned over a wide range of angles. The obtained resolution on the missing mass – the energy of the proton in the nucleus – was 100 keV. An intriguing result of measurements on a variety of nuclei was that about 35% of the protons in the nuclei were missing! An explanation was that the "missing protons" were moving much faster in the nucleus than expected, and faster than could be detected in the MEA measurements. Such high proton momenta could be due to strong repulsive forces between nucleons

scattering in Amsterdam



The QDD- (left) and QDQ-spectrometers, with their precisely known magnetic fields and high momentum resolution, carried out precision studies of nuclear proton knockout by electrons.



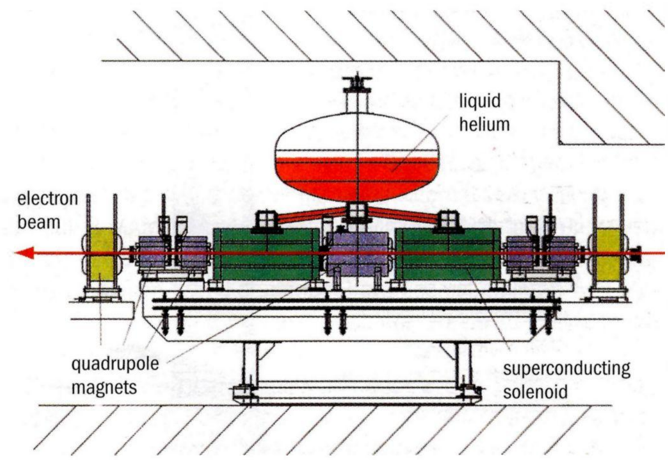
The Amsterdam Pulse Stretcher – fed by the 200 m MEA linac.

that were close together.

To solve the puzzle of the high-momenta protons, a new generation of more precise experiments was needed. This was one reason to extend the accelerator with a pulse stretcher and storage ring (AmPS), which was duly completed in 1992. Electrons revolve around this 212-metre-circumference ring in 0.7 microseconds. MEA pulses of between 0.7 and 2.1 microseconds are therefore stretched to a continuous electron stream which, in stretcher mode, is then slowly extracted. The continuous low-intensity electron beam allows detectors to work more efficiently than when intense pulses lead to saturation. It also allows for a much better background suppression.

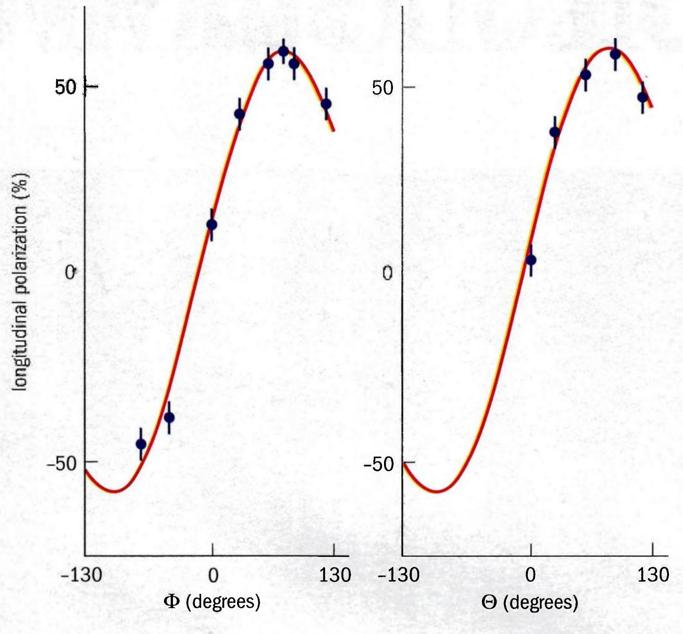
In 1997 first results were obtained on measurements of simultaneous two-proton knockout in helium-3 and oxygen-16 (December 1997 p16). The protons were detected in two "HADRON" detectors, built by NIKHEF and the Free University in Amsterdam. The scattered electron was detected, as before, in one of the spectrometers. The measured proton and electron momenta allowed reconstruction of the momentum of the proton pair and of the excitation energy of the resulting nucleus. This led to a better insight into nucleon correlations, especially at short distances, and an improved description of the dynamics of nucleons inside the nucleus. With the NIKHEF experimental programme terminated, further measurements on helium-3 and oxygen-16 will be performed at the MAMI electron accelerator in Mainz.

With AmPS used in storage mode, polarized electron bunches from MEA – a current of 4 milliamps and a length of 0.7 microseconds – are

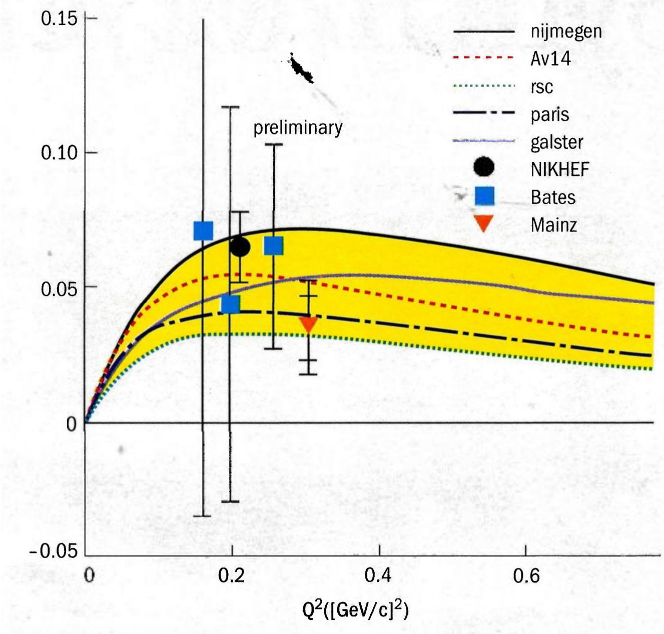


Longitudinally polarized electrons were produced using a "Siberian Snake" superconducting solenoid, supplied by Novosibirsk.

injected and stacked in the ring (January 1997 p5). Stable operation with 150 milliamps of circulating current and a lifetime up to 45 minutes is possible while the energy can be ramped up to 900 MeV. The spin-polarized electrons are produced via photoemission from a gallium arsenide source built at the Budker Institute in Novosibirsk, which has been closely co-operating with NIKHEF since 1986. When injected into AmPS, the electron spins – which are longitudinally polarized – precess around the vertical fields of the ring's dipole magnets. To achieve the strictly longitudinal polarization at the target, as required by the experiments, a so-called "Siberian Snake" was used.



Variation in longitudinal polarization for 442 MeV electrons with spin angle. The data were obtained from Compton back-scattering with a laser and reveal a maximum longitudinal polarization at the target of 61±3%, only slightly less than the longitudinal polarization at the electron source (69.8±1.3%) measured with Mott scattering. This was the first time (1996) that polarized electrons were injected and their longitudinal polarization was preserved in a storage ring for substantial periods of time.



The neutron charge-form factor measured at AmPS compared with other measurements.

This superconducting solenoid was also built in Novosibirsk.

From 1997 the AmPS physics programme focused on the scattering of polarized electrons from polarized nuclei. The ultra-thin targets resemble that of the HERMES experiment at DESY. They consist of a T-shaped storage cell, placed inside the beam pipe, through which a rarefied gas – hydrogen, deuterium or helium-3 – is pumped. The atoms were polarized beforehand and the average polarization in the gas was up to 90%. Such thin targets offer several advantages, notably no background from scattering in the target walls. Polarization is also relatively high and can be reversed rapidly, which is essential for reducing systematic uncertainties. Finally, low-energy recoiling particles can escape and be detected.

One of the goals was to study the charge-form factor of the neutron. Its anomalous magnetic moment implies that the neutron has a charge distribution. In 1947 Enrico Fermi and Isidor Rabi obtained further evidence for this charge distribution from an experiment in which atomic electrons were bombarded with thermal neutrons from a nuclear reactor. The neutron appeared to have a slightly positive core surrounded by a region of negative charge. Since stable targets of free neutrons do not exist, subsequent experiments resorted to unpolarized deuterium. However, the electron scattering is then largely dominated by scattering from the proton charge and moreover is sensitive to uncertainties in the nuclear structure. State-of-the-art experiments with deuterium at SLAC and Saclay therefore resulted in data with systematic uncertainties of about 5%.

A new series of measurements of the charge-form factor of the neutron scatter polarized electrons from neutrons in polarized deuterium or helium-3 nuclei. Due to interference effects the small charge-form factor is amplified by the dominant magnetic-form factor. When measuring the effect for opposite spin directions, an asymmetry is found from which the form factor can be deduced. There is a worldwide effort to measure the charge-form factor from this asymmetry, with experiments using external beams being carried out at MAMI in Mainz, at the Jefferson Laboratory (previously CEBAF) in Newport News, and at MIT–Bates. At NIKHEF, measurements on helium-3 and deuterium have been completed, and preliminary data for deuterium reveal the precision that can be achieved using internal targets.

Other scattering experiments use polarized hydrogen and deuterium. In the latter the electric monopole- and quadrupole-form factors of the deuteron were separated. The spin structure of the deuteron was studied via polarized electron-induced proton knockout from polarized deuterium. These and other data together form a rich harvest of electromagnetic spin observables for the nucleon and few-body systems. Spin-dependent electronuclear internal target physics will now continue in the US with the recently approved BLAST-programme at MIT–Bates.

The curtain has now fallen for AmPS, on which 40 Dutch physicists and 60 physicists from 25 foreign institutes collaborated. It is not all over, however, because the MEA–AmPS installation will be shipped to the Joint Institute for Nuclear Research in Dubna for a new life as a synchrotron.

Margriet van der Heijden *and* **Jo van den Brand**, *NIKHEF, Amsterdam.*

Synchrocyclotron survivor

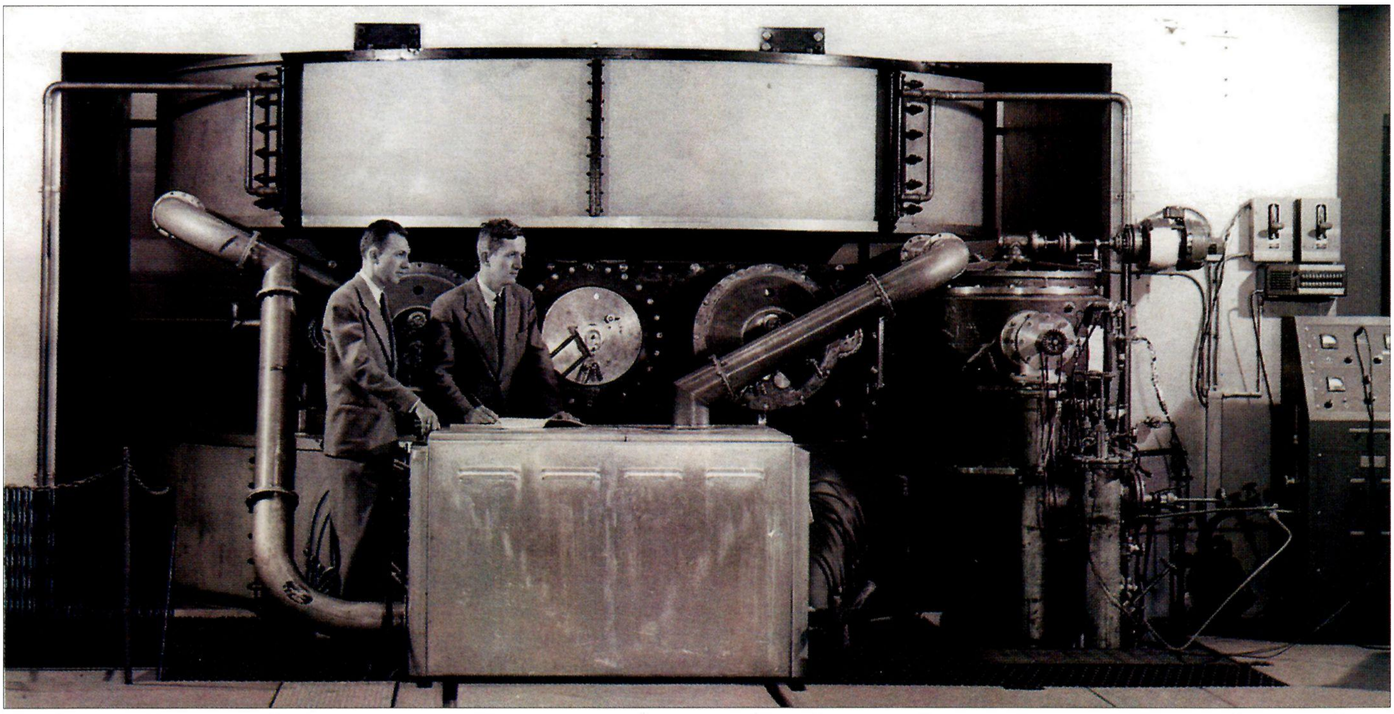


Fig. 1: Harvard Cyclotron Laboratory Deputy Director Lee Davenport (left) and Norman Ramsey, Chairman/Director of the Physics Department's Cyclotron Committee, with the machine just before its dedication on 15 June 1949.

After 15 years in physics, Harvard University's 160 MeV machine was converted into a cancer therapy centre. Having treated over 7500 patients in the ensuing 34 years, it is being phased out after two distinguished careers.

3 June 1999 will mark 50 years since the first beam was accelerated at the Harvard Cyclotron Laboratory (HCL). Originally built for physics research, the lab switched direction and went on to play a dominant role in the development and application of charged-particle radiation therapy.

The first Harvard cyclotron, built in 1937, was taken to Los Alamos for the Manhattan Project in 1943 and never returned. Planning for the present lab began in 1946 with the involvement of Kenneth Bainbridge, Robert R Wilson, J Curry Street and Edward M Purcell as well as R W Hickman, then Director of the Physics Laboratory. The US Office of Naval Research (ONR) funded the machine while Harvard paid for the building. Figure 1 shows HCL Deputy Director Lee Davenport and Norman Ramsey, Chairman/Director of the Physics Department's Cyclotron Committee, with the machine just before its dedication on 15 June 1949. Harry Truman was starting his second term as US President, television and FM radio were gaining in popularity and commercial transistors were still a few years away.

In the synchrocyclotron boom of the 1940s and 50s, the Harvard machine was for a time the third largest in the USA. The 14 foot diameter magnet coils were shipped edgeways from General Electric in western Massachusetts using one of the two deepest flat-well railroad cars in the country. The lowest bridge on this route dictated the size of the cyclotron!

Initially the proton energy was 95 MeV, with only weak (scattered) external proton and neutron beams. Many experiments used the internal beam. The physics programme was a mix of proton–nucleus and nucleon–nucleon experiments at what we now call medium energy: much greater than nuclear binding, but below particle production. Counter, emulsion and activation techniques were used. Experimenters included Norman Ramsey, Ralph Waniek, Walter Selove, Jim Meadows and Karl Strauch.

Throughout the physics period there was a host of graduate students, many later achieving recognition in high energy and other fields of physics. Eventually HCL produced some 30 PhD theses and countless articles. William M Preston was named Director in 1953. In the same year Andreas M Koehler arrived, and eventually became *de facto* Technical Director and chief troubleshooter.

to bow out after 50 years

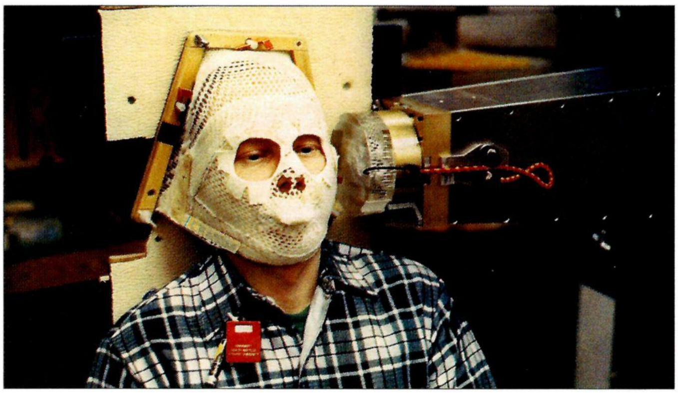


Fig. 2: *An early "Room 2" patient showing the rudimentary immobilization (which worked very well), the brass beam aperture and lucite range compensator.*

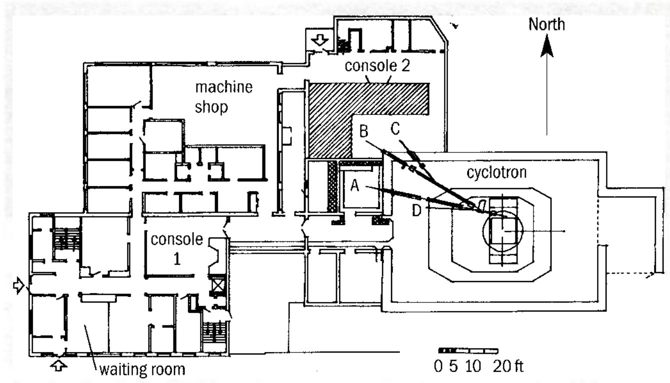


Fig. 3: *Harvard Cyclotron Laboratory floor plan showing three treatment beamlines (A, B, C), a test (physics) beam (D), and two treatment rooms.*

A young British physicist, Richard Wilson, arrived in 1955 to apply the new "regenerative extraction". HCL emerged from that one-year upgrade – the only substantial shutdown in 50 years – with 160 MeV protons and external polarized and unpolarized proton beams of respectable intensity.

The physics programme grew steadily, peaking around 1958 with 38 personnel. The annual report for that year describes a new ion source (Koehler), quasi-elastic proton–proton collisions and inelastic proton cross-sections (Strauch *et al.*), various polarized proton scattering experiments (Cormack, Palmieri, Ramsey and Wilson *et al.*), proton triple scattering (Wilson *et al.*) and proton–deuteron scattering (Wilson *et al.*). Eventually a quasi-monoenergetic neutron beam was built (Measday). The last major physics upgrade was a stochastic extraction system to improve the beam duty factor, leading to the first observation of proton–proton bremsstrahlung in 1965 (Gottschalk *et al.*).

Biological uses

In 1960 under a new heading "Biological uses of proton beams", the Annual Report said: "During the past year we have attempted to develop the proton beam as a tool for producing accurately localized lesions in brain tissue..." (Preston, Koehler, Sweet and Kjellberg). William H Sweet was Chief of Neurosurgery at the Massachusetts General Hospital (MGH) where Raymond Kjellberg was a young neurosurgeon. As early as 1946 Robert R Wilson had described how proton beams could be used to advantage in medicine. A medical programme was proposed for HCL, building on the work of Tobias and Lawrence at Berkeley and Larsson and Leksel at Uppsala. The first step was a series of animal experiments to determine the tolerance of normal brain tissue and the geometric accuracy of the isocentric technique, which used a water-filled compensator. Around this time the experimental area occasionally smelled like a zoo!

The first HCL patient was treated by Kjellberg for a malignant brain tumour in 1961, and a patient with a pituitary gland disorder followed soon after. The first arterio-venous malformation (AVM) was irradiated in 1965. These intracranial targets only needed relatively small beams, obtained by single scattering. A high target dose and a low entrance dose were obtained by combining the 3.5-fold Bragg peak enhancement with a large number of entrance portals (up to 12). Aided by a Biomedical Annex funded by the National Aeronautics and Space Administration (NASA), the medical programme expanded until 275 patients had been treated by 1967.

That year ONR ceased its support of cyclotron operations. Instead of physically removing the cyclotron according to its contract with Harvard, ONR compensated the university for expected removal costs. Harvard decided, after reviewing the physics programme, to close the lab unless alternative funding could be found. An *Excess Property Bulletin* issued by the General Services Administration in 1968 describes a synchrocyclotron with ancillary equipment available for the cost of removal. That year HCL personnel hit bottom. Koehler was the sole employee, half time.

At this critical moment it was agreed that HCL could continue on a limited schedule and concentrate on biomedical applications on a fee-for-service basis. From 1967–75 the machine ran less than 1000 hours per year. Kjellberg continued to treat patients, and by his death in 1993 he had treated nearly 3000. Some space-related research was done, and NASA and the National Science Foundation supported development of extended beams (laterally and in depth) to treat larger lesions. HCL parted company with the Physics Department and became a separate entity within the Faculty of Arts and Sciences. It is guided by a Cyclotron Operations Committee chaired by S J Adelstein of the Harvard Medical School. Richard Wilson, still an enthusiastic supporter, is a member.

By 1974 the staff had grown to six and a second clinical programme began, to treat larger tumours with fractionated therapy. The original collaborators from the Department of Radiation Oncology at MGH were Herman D Suit and Michael Goitein, one of many radiation

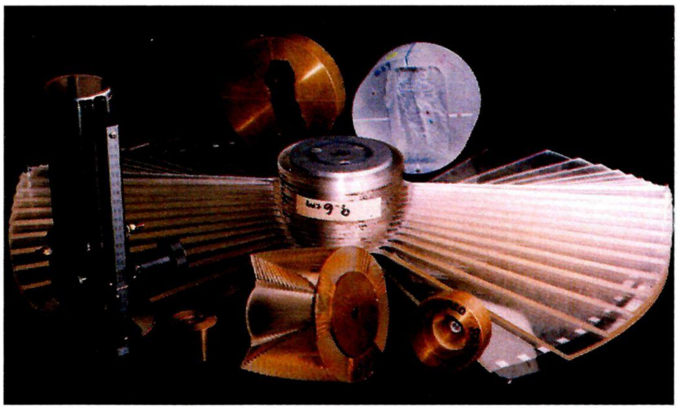


Fig. 4: Some of the technology developed at the Harvard Cyclotron Laboratory: a propeller-type range modulator surrounded (clockwise from top) by an automilled aperture with matching automilled range compensator; an energy-compensated contoured second scatterer; a scattering-compensated compact "upstream" modulator; an eye-treatment aperture; and a water telescope for intracranial radiosurgery.

physicists with high-energy training. They continue their activity to this day, with scores of colleagues over the years. Tumours treated in this programme are usually larger than in the "radiosurgery" program, but above all they receive multiple fractions depending on the diagnosis.

The parallel development of computer tomography (for which an HCL alumnus, the late Alan Cormack, received a Nobel prize), and later magnetic resonance imaging, provided accurate data on tumour volume and adjacent critical structures to complement the excellent dose localization possible with protons. Increased computer power made 3-D planning practical. Good patient immobilization techniques had to be developed, and remain a difficult problem today. Figure 2 shows a treatment setup for primitive but effective immobilization. Today's is somewhat more elegant.

In the early 70s Koehler and Ian Constable had developed techniques for treating eye tumours. The original objective was to treat retinoblastoma, a rare but serious problem in very young infants. This is now treated at HCL – sparing normal tissue is more important, especially for younger patients – but at the time it was considered too difficult and risky to treat babies. Instead, the new technique was used for choroidal melanomas and other eye tumours.

Under Evangelos Gragoudas of the Massachusetts Eye and Ear Infirmary (MEEI) this soon became the most common and unequivocally successful single procedure at HCL and has been emulated around the world. HCL currently treats about five eye patients a day, each patient receiving five fractions on successive days. Recently HCL has also begun to treat certain forms of macular degeneration in a trial programme.

In 1977 the high-voltage equipment room was converted to HCL's second treatment room. No longer did the heavy, carefully aligned collimating systems for the two separate programmes have to be swapped, and the way was open to treat relatively large numbers of patients. In the 1980s vacuum tubes in the control system were finally replaced by modern circuitry. A digitally controlled patient positioner was built for Room 2. In 1987 an additional beamline exclusively for eye treatments was completed, as well as fast beamline switching. Figure 3 shows the present floorplan with its two treatment rooms and three medical beamlines.

HCL's most recent collaboration with the Department of Neurosurgery at MGH replaces Kjellberg's program. A device dubbed STAR (StereoTaxic Alignment for Radiosurgery) allows the patient to be rotated about horizontal and vertical axes so that any target in the head can be irradiated through many portals. The chief physicians are Paul Chapman and Jay Loeffler of MGH.

In 1972 Bill Preston stepped down and was replaced by Andy Koehler as Acting Director, a title he held for 21 years until he turned over administrative duties to Miles Wagner, the current Director.

Today HCL still serves as a radiation therapy clinic in close collaboration with teams from MGH and MEEI, delivering about 25 treatments (fractions) per day, five days a week. 460 patients were treated in 1997. Three beamlines serve three patient streams. The patient tally to 30 September 1998 was: radiosurgery 2929 (Kjellberg) plus 418 (STAR), eye 2568 and large-field fractionated therapy 1896, for a grand total of 7811.

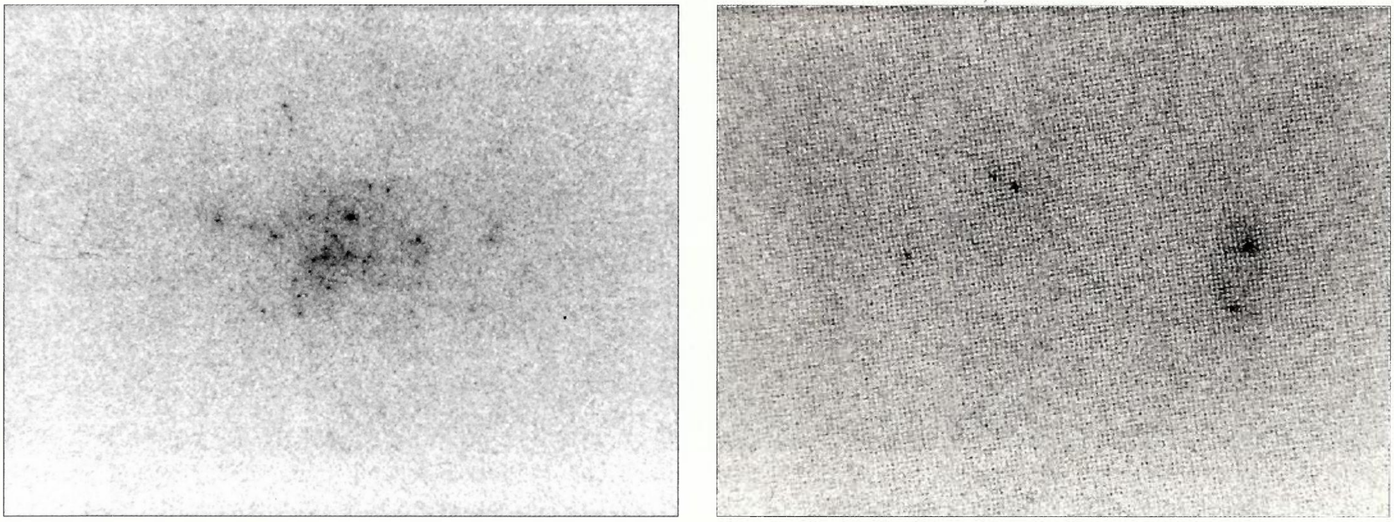
Diverse work

In addition to the clinical program, some 10% of HCL effort goes into diverse experiments including space-probe calibrations and radiation damage and single-event upset studies of semiconductor devices. An in-house research programme run by Janet Sisterson, with many collaborators from other labs, makes measurements to interpret extraterrestrial data from the space programme. All this applied physics work takes place in the evenings and at weekends. The single most important factor in the success of the clinical program has been the constant availability of the machine, with less than 2% downtime.

Though the HCL/MGH collaboration was not the first to use proton therapy, it has by far the largest and longest experience, including long-term followup in the medical literature for several treatment sites. Many techniques now widely used were pioneered at HCL, including lucite range modulators and compact "upstream" modulators to spread the beam in depth; various double scattering techniques to spread it laterally; automilled patient-specific lucite range compensators and brass apertures; an efficient dedicated proton nozzle for eye treatments; various dosimetry techniques; a comprehensive study of proton multiple scattering; and finally the "corkscrew" gantry, a space-saving way of directing a proton beam at any angle to the patient. Figure 4 shows some of these devices.

This technology influenced the design of the hospital-based Northeast Proton Therapy Center (NPTC) newly constructed on the MGH campus by Bechtel Industries and Ion Beam Applications SA of Belgium. NPTC features a 235 MeV isochronous cyclotron with energy degrader and reanalyser, two rooms with gantries and one room with several fixed horizontal beams. The gantries will speed up treatment delivery and improve patient immobilization while the increased energy will allow new body sites to be treated. By 2000 HCL will have passed the baton to this new facility, ending a lengthy career as a contributor to medium-energy physics and as a leader in the application of particle beams to medicine.

B Gottschalk, A M Koehler, J M Sisterson, M S Wagner, *Harvard.*



One of the mysterious "Centauro" events seen by the Brazil–Japan collaboration operating X-ray emulsion chambers at an altitude of 5200 m on Mt Chacaltaya in the Bolivian Andes. Given the number of hadrons seen in the lower chamber (left) physicists are intrigued by the relative lack of corresponding electromagnetic effects in the upper chamber (right).

The mysteries of cosmic rays

Until the advent of high-energy accelerators in the 1950s, high-energy cosmic rays were the main source of information on subnuclear particles. Now they are back in the research spotlight and unexplained cosmic-ray phenomena could point to gaps in our understanding, as discussed at an international symposium.

Cosmic rays, the extraterrestrial particles which rain down on the Earth, extend to energies greater than those available via the biggest laboratory machines. This ultra-high-energy frontier is the traditional focus of the International Symposium on Very High Energy Cosmic Ray Interactions, and the most recent event at the Italian Gran Sasso laboratory highlighted the continual enigma of the universe's highest particle energies.

High-altitude emulsion chamber experiments record the tracks left by these particles. The Pamir experiment, at an altitude of 4400 metres in Central Asia, confirmed earlier observations (April 1997, page 15) of coplanar sheets of hadrons from primary particles with energies above 8000 TeV.

This phenomenon is seen in multiple "halo" events with total visible electromagnetic energy above 700 TeV recorded in X-ray emulsion chambers. (Haloes are large black spots on the film, up to several square centimetres.) The events have several separate haloes whose centres lie in a straight line even after having passed through the atmosphere. A number of phenomenological models, some invoking unusual heavy penetrating hadrons, attempt to explain this, but the process remains a mystery.

The long-standing Brazil–Japan collaboration operating X-ray emulsion chambers at 5200 m on Mt Chacaltaya in the Bolivian Andes, described in detail a recent clean example of a "Centauro" event.

Centauros were first reported in 1980 by the Brazil–Japan team and confirmed in 1984 by the Pamir collaboration. These events contain relatively few particles, but which are almost entirely hadrons, with very few photons. They show that at these energies, hadrons can be generated without neutral pions or eta mesons (which decay into photons).

Man and horse

In Greek mythology, a Centaur was highly asymmetric, with the top half of a man and the legs of a horse. The latest physics Centauro is totally free of photons and with a similar appearance to the original Centauro I. Centauro events have always been a puzzle and remain the subject of speculation.

Other mysterious phenomena seen by these experiments include anomalous cascades penetrating very large thicknesses of densely absorbing material.

It is certainly difficult to explain the exotic phenomena seen by such high-altitude emulsion chamber experiments using conventional physics. This was underlined at the meeting by simulations described by M Tamada of Kinki, Osaka.

The KASCADE experiment in Karlsruhe, comprising 252 detector stations for the measurement of electrons/photons and muons, a fine segmented hadron calorimeter (centre) and a shielded tunnel equipped with streamer tubes for the tracking of muons (hidden).

Presenting the status of today's Standard Model, Guido Altarelli of CERN laid special emphasis on the riddles posed by the observation of ultra-high-energy cosmic rays, above 10^{20} eV (November 1998, page 5).

Increased understanding strengthens the links between cosmic ray and accelerator experiments. An important part of the conference was devoted to this topic, with status reports from major laboratories.

Of particular interest to cosmic-ray physics is the search for the quark-gluon plasma, the precursor of nuclear matter, in heavy ion collisions. The subject was reviewed by Jürgen Schukraft of CERN with special emphasis on the recent data from lead ion experiments at CERN (March 1998, page 13).

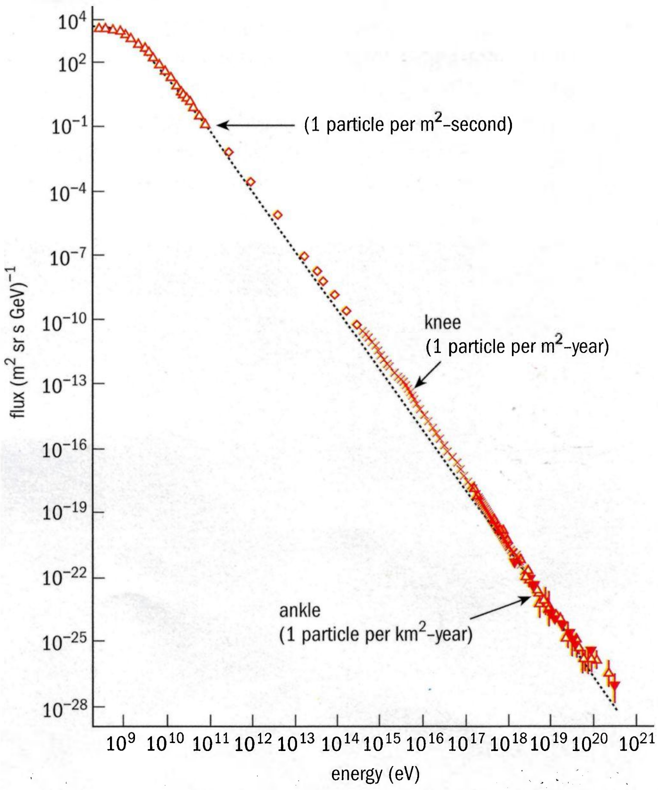
Another major focus of the conference was the extreme cosmic-ray energy spectrum. The energies of primary particles extend from around 10^9 eV (1 GeV) to above 10^{20} eV, the latter being more than 100 000 times the energies at which it has been possible to observe the primaries directly with balloon- or satellite-borne experiments. Information on this very-high-energy region comes instead from indirect methods via the investigation of extensive atmospheric air showers (EAS) using detectors on the ground.

Spectrum features

The spectrum has two main features: a steepening of the slope near 10^{15} and 10^{16} eV - the "knee", and a flattening near 10^{18} and 10^{19} eV - the "ankle". The interpretation of EAS results relies on the comparison of the measured effects with simulations of shower development in the atmosphere. The most crucial ingredient is the modelling of hadronic interactions, requiring bold extrapolations to regions where no accelerator data exist and theoretical guidelines are only vague.

In recent years these EAS simulations have nevertheless reached a high level of sophistication and employ many of the standard hadronic interaction models from accelerator particle physics. The status of EAS simulation was reviewed by J Knapp of Leeds who underlined the need for a common reference program as a standard tool.

Several explanations could account for the slope changes in the energy spectrum. The knee could be associated with features of propagation of galactic cosmic rays, and the ankle to a transition from galactic to extra-galactic cosmic rays. A reliable determination of the contribution of different nuclear species to the energy spectrum is needed to understand the implications of these features, and to discriminate between the various models.



The energy spectrum of cosmic rays has two main features: a steepening of the slope near 10^{15} and 10^{16} eV – the "knee", and a flattening between 10^{18} and 10^{19} eV – the "ankle".

Results presented at the conference, such as those from the KASCADE experiment in Karlsruhe, confirmed the existence and position of the knee, with evidence for a light composition below it and for a clear trend towards heavier composition above. Such behaviour ties in with models which interpret the knee as the onset of the leakage of cosmic rays outside the magnetic field of the galaxy – for cosmic ray particles of the same energy, the lighter, less charged ones are less rigidly bound and would be the first to leave.

One of the most challenging issues in astroparticle physics is to understand the origin of cosmic rays with energies above 10^{20} eV when there are no obvious nearby sources.

A different intriguing phenomenon in the study of EAS was reported by G B Zhdanov (Lebedev) who presented results from an 18 m^2 neutron monitor at 3330 m used in conjunction with an EAS array. Considerable doses of neutrons (and of electrons) have been recorded in the wake of EAS of about 10^{16} eV, the delay relative to the EAS front being about 500 microseconds. This could be due to very massive primary particles.

The status of ultra-high-energy cosmic rays was reviewed by A M Hillas (Leeds) and V Berezinski (Gran Sasso). The energy spectrum of cosmic rays suggests a transition to an extra-galactic source at energies above the ankle and the composition at the highest energies is consistent with protons.

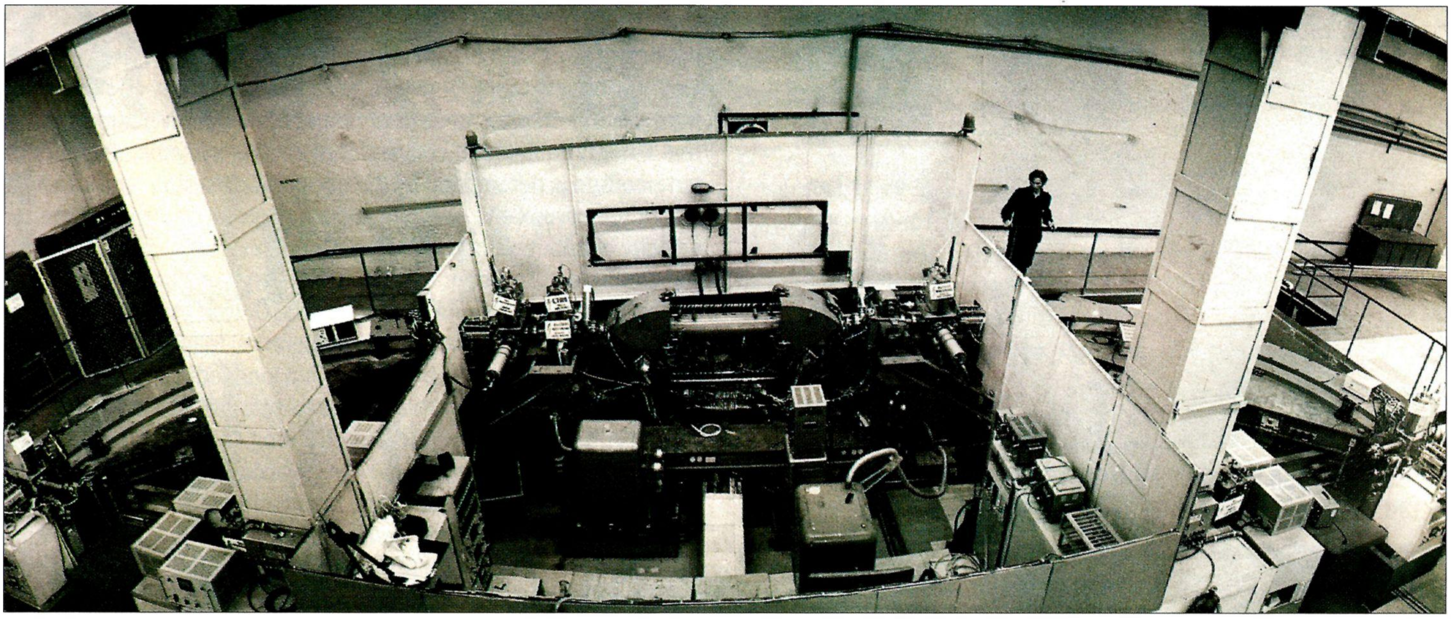
It is very difficult to understand how particles or nuclei can be accelerated to such multi-Joule energies. One scenario associates the highest energy cosmic rays with gamma-ray bursts (also awaiting a generally-accepted explanation). The two could be generated simultaneously, but the transit times of charged particles would be smeared over many years by intergalactic magnetic fields.

Another scenario avoids the problem of acceleration by attributing the origin of the highest energy cosmic rays to decays of particles with masses at the grand unification scale (10^{15}–10^{16} GeV) created by topological defects (monopoles, cosmic strings and domain walls).

One of the most challenging issues in astroparticle physics is to understand the origin of cosmic rays with energies above 10^{20} eV when there are no obvious nearby sources. In 1966 Greisen, Zatsepin and Kuzmin pointed out that the universe is not transparent to protons above about 4×10^{19} eV as they would interact with the 2.7 K microwave background radiation. This led to the argument that if the sources of cosmic-ray particles of such energies are extra-galactic, they must be relatively near (within 300 million light-years) otherwise no such particles will be observed.

With such a long list of intriguing phenomena and challenging problems, this area of astroparticle physics will remain an active, exciting field for many years.

Aris Angelis, *Athens.*



Cooling in Siberia. The NAP-M ring at Novosibirsk in the early 1970s, showing (centre, in one of the ring's straight sections) the world's first electron cooling device. The wedge-shaped lenses bend the electrons in and out of the beam.

Exploring new trends in electron cooling

The invention and development of electron cooling by Gersh Budker's team in Novosibirsk in the late 1960s and early 1970s set physics on a new route to discovery. Electron cooling has become crucial for controlling disorganized particle beams, and new electron cooling techniques could extend its range of applicability.

A Medium Energy Electron Cooling workshop (MEEC98) organized recently by the Joint Institute for Nuclear Research (JINR), Dubna, brought together specialists from all over the world, including many of the Novosibirsk cooling pioneers. From Gersh Budker's initial idea, electron cooling has undergone more than 30 years development. 10 cooler rings are in operation and electron cooling has become a routine tool.

Simon van der Meer's stochastic cooling scheme has been the technique of choice for controlling proton and antiproton beams of energy higher than about 0.5 GeV (even though its cooling time increases with the intensity). Higher intensities have meant that electron cooling (less dependent on the particle intensity) has had to rise to a new challenge.

In the standard scheme, an electrostatically accelerated (maximum energy 300 keV), magnetically confined electron beam at low temperature is merged with an ion beam in a straight section of the storage ring. The progress concerns mainly an increase of the magnetic field quality and the generation of an intense electron beam at extremely low temperature – beam expansion by a factor of up to 8 (at SIS, GSI Darmstadt), 20 (ASTRID, Aarhus), 25 (TSR, Heidelberg), 100 (Cryring, Stockholm and TARN II, Tokyo).

The first proposal to use electron cooling with MeV-range electrons came from Novosibirsk (Kuksanov, Meshkov, Salimov *et al.*, 1986) where a prototype at 1 MeV electron energy was constructed. A 1 amp DC electron beam was obtained in an energy recuperation scheme.

MEEC's first

The first MEEC project, based on a proposal by T Ellison at Bloomington, Indiana, aimed to increase the luminosity in the ill-fated US Superconducting Supercollider by electron cooling 12 GeV protons in the Medium Energy Booster for that project. Presently the electron cooling of GeV ions is an integral part of a number of modern projects.

Electron cooling pioneers at Novosibirsk in 1974 – left to right: V Parkhomchuk, A Skrinsky, I Meshkov, N Dikansky.

Older and wiser – the same pioneers in 1998: Dikansky, Skrinsky, Parkhomchuk, Meshkov.

At Fermilab, the Tevatron luminosity upgrade programme includes the electron cooling of 9 GeV antiprotons in the Recycler ring to compensate for beam heating during stacking. Electron cooling of 10–20 GeV protons in the PETRA storage ring at DESY aims to halve the emittance and boost luminosity in the downstream HERA collider. Electron cooling is also planned to boost luminosity in electron-ion and ion-ion collisions at ion energies up to 1.5 GeV/nucleon for light ions and 3.5 GeV for protons in the MUSES project of the Japanese RIKEN radioactive ion beam factory (construction of the first stage of which began in 1998).

Electron–nucleon collider

Operation of an electron-nucleon collider, now in the conceptual design stage by GSI Darmstadt and Novosibirsk, would be impossible without intensive beam cooling at ion energies of 10–30 GeV/nucleon. Electron cooling of protons at energy of 2.5 GeV can be used for luminosity support of the COSY ring in experiments with an internal target.

Compared with previous Medium Energy Electron Cooling workshops (Fermilab in 1995 and 1996 and Novosbirsk in 1997) the emphasis this time was more speculative. In his talk "Colliders for Medium Energy with Electron Cooling", pioneer A Skrinsky pointed out that the goal in such machines is not a deep cooling of ions, but to compensate for various heating effects and to stabilize the ion beam parameters.

Cooling is carried out under new conditions: intensive, bunched GeV ion beams, cooling over a few tens of metres, cooling times from several minutes to several hours. The electron beam parameters differ from those of conventional cooling systems: the electron temperature is determined by the acceleration system and can lie in the range several eV; one can expect destruction of the flattened velocity distribution of the electrons; nonmagnetized and probably bunched electron beam can be used; very high beam power etc.

New conditions require new concepts. Only in the electron beam energy range below 5 MeV is DC acceleration feasible in an electrostatic device with the electron beam in a longitudinal magnetic field. Such a device is conceivable without major research and development (V Parkhomchuk – Electron Cooling of Hadrons in the GeV Energy Range). But even in this case new cooling system designs are needed to reduce the cost of the installation (J MacLachlan – Fermilab Conceptual Design for an Electron Cooler for 8 GeV Antiprotons, S Nagaitsev – Electron Beam Transport Scheme for the Fermilab Electron Cooling System).

Electron transmission line

The high power of the electron beam requires development of the electron transmission line (A Shemyakin – Performance of Pelletron Based DC Recirculation System). To reduce the average electron beam power, the electron beam can circulate in an additional ring. The circulation period is limited by different factors, which induce heating of the electron beam (I Meshkov – Principles of MEEC with circulating Electron Beam). In combination with a longitudinal magnetic field and betatron acceleration of the electrons, such a scheme has potentially minimal cost. However, for its practical realization particle dynamics problems have to be solved (A Smirnov – The Stability of the Circulating Electron Beam in the Electron Cooling System Based on Modified Betatron).

To cool the bunched ion beam at 10 GeV and higher, bunched electron beams look very attractive. In this case electron acceleration can be performed with a relatively-low-frequency linac which can provide electron bunches of about one metre and small momentum spread (V Parkhomchuk). Electron beam quality is determined not only by the generation scheme, but by the ion beam parameters. At an optimum electron temperature, the cooling rate is higher than for cold electrons (J MacLachlan – Optimizing Parameters for MEEC). Fast cooling can also make the intense ion beam unstable. The cold central part of the ion beam has coherent oscillations and heats the particles with large betatron oscillations (V Parkhomchuk – Limitation of ion beam intensity in electron cooling system). The MEEC results obtained at Fermilab (the maximum recirculated electron beam current is 0.6 A for 1.5 MeV electrons – A Warner, S Nagaitsev, A Shemyakin). New projects to test the scheme with circulating (A Sidorin) and bunched electron beam (T Winkler) were discussed as well as new results from traditional cooling systems (M Steck, J Stein) and the development of technology and electron beam operation (P Lebedev, E Syresin).

To cool the bunched ion beam at 10 GeV and higher, bunched electron beams look very attractive.

Quarks in hadrons and nuclei

The idea of quarks as the ultimate constituents of strongly interacting particles has long been conventional dogma. Less well known, but no less important, is the role of quarks in nuclei. A recent meeting in Austria looked at this frontier between particle and nuclear physics.

35 years ago, in the autumn of 1963, the idea of quarks as the elementary constituents of all nuclear and hadronic matter was conceived, both at Caltech in Pasadena by Murray Gell-Mann and at CERN by George Zweig. However, it took about another 10 years before it was realized that with the help of the quarks a relativistic field theory of all strong interaction phenomena could be formulated: quantum chromodynamics (QCD).

Today QCD is the basic and comprehensive theory of strong interactions, covering both nuclear and particle physics. However, solving QCD at low and at high energies requires different approaches, and attempting to describe strong interaction phenomena via QCD in both nuclear and in high-energy physics remains a great challenge.

This problem was highlighted recently when about 60 particle and nuclear physicists working in hadron physics met for a symposium on "Quarks in Hadrons and Nuclei" in the unusual setting of the Hall of Armed Knights of the thousand-year-old Rothenfels castle above the small town of Oberwölz in Styria, Austria.

Topics

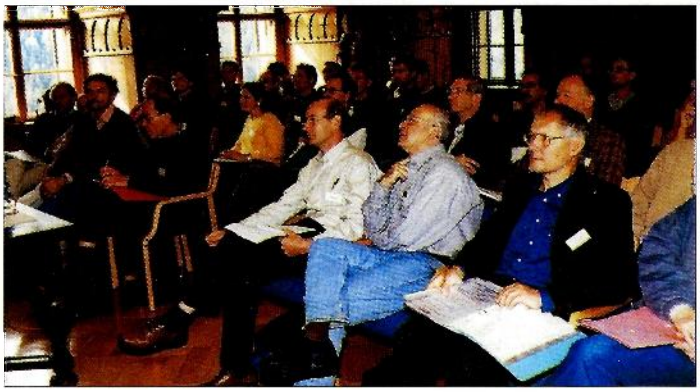
Physics topics included constituent quark models, structure functions of hadrons, spin structure of the nucleon, meson-baryon physics, chiral perturbation theory, diffractive processes, lattice gauge theory, quark masses etc.

The meeting began with a general historical account by Harald Fritzsch (Munich) of the development of strong interaction theory. This history dates back to a 1932 paper on the need for a new strong force inside the atomic nuclei by Werner Heisenberg, and culminates in the formulation of the fundamentals of QCD in 1972–73. The property of "confinement" shows that quarks exist as quasi-free particles when close together, but feel increasingly strong binding forces when they try to move apart.

Among the many facets of QCD that have emerged over the past 25 years is the problem of quark–gluon dynamics at low energies, responsible for the properties of hadrons and nuclei as building blocks of matter. Effective models of QCD (such as the constituent quark model) work remarkably well at low energies though a fundamental derivation from fundamental QCD is still lacking.

At low energies the nucleon appears to be a composite structure of three valence (constituent) quarks, while at high energy it can appear as a complicated mixture of current quarks and antiquarks as well as gluons. These dual pictures of the nucleon and the link between them are still not fully understood.

Progress and new attempts in the description of hadrons in terms of constituent quarks were reported by M Beyer (Rostock) and W Lucha (Vienna). The delicate problem of the composition of the spin of the nucleon from low to high energies was addressed from the experimental and the theoretical sides. While the constituent (valence) quark model suggests that (most of) the spin of a nucleon should arise from the quark degrees of freedom, experiments – described by K Rith (Erlangen) – indicate that the quark contribution to the nucleon spin is only about 30%. Theoretical attempts to solve this problem were reviewed by M Karliner (Tel Aviv). A Vogt (Leiden) reported insights from deep-inelastic structure functions. Whatever the final solution to the nucleon spin problem will be, it is clear that gluonic degrees of freedom plays a role and that gluons are either directly or indirectly contributing to the nucleon spin. (This is currently being addressed by the HERMES experiment at DESY's HERA electron ring – November, page 10.)



Reconciling the quark/gluon picture of high-energy particle physics with the properties of nuclear matter is not straightforward. The narrow bridge was crossed in September when particle and nuclear physicists met in the unusual setting of the Hall of Armed Knights of the thousand-year-old Rothenfels castle above the small town of Oberwölz in Styria, Austria.

Since the early days of QCD physicists have predicted the existence of hadronic objects – "glueballs" – formed primarily of gluons rather than quarks, or "hybrids" with both quarks and gluons as constituents. These aspects of QCD and their connections with elastic-like diffractive processes were covered by F Close (CERN), P Landshoff (Cambridge), and P Minkowski (Bern). While the existence of glueballs and hybrids is now generally accepted on theoretical grounds, it is only recently that coherent evidence has begun to emerge supporting predictions that the simplest gluonic mesons exist between 1.4 and 1.8 GeV.

Some basic properties of hadrons and nuclei, such as their masses, are directly related to the structure of the hadronic vacuum, which influences the otherwise difficult-to-calculate (nonperturbative) aspects of QCD. The influence of the hadronic vacuum can be described via QCD sum rules. M Shifman (Minneapolis) gave an account of recent developments and also reviewed 20 years of the sum-rule technique. R Rückl (Würzburg) described specific applications for exclusive decays of heavy mesons. The question of quark masses was covered by M Jamin (Heidelberg).

Lattice QCD

Gauge theory using an underlying lattice rather than a continuum, pioneered by Kenneth Wilson to describe the otherwise difficult-to-handle aspects of QCD, has undergone a tremendous development. A number of variants have been developed and it became clear from the talks of F Jegerlehner (DESY, Zeuthen) and A Schäfer (Regensburg) that lattice QCD will continue to be a powerful tool for QCD problems at low energies.

Another salient feature of low-energy QCD is the role played by topological properties of gluonic field configurations like colour-magnetic monopoles and instantons. They might be responsible for quark confinement and also play a decisive role in the formation and dynamics of the lightest mesons, as was discussed by F Lenz (Erlangen) and H Reinhardt (T¸bingen).

In the same context, with respect to meson–baryon physics and more generally any hadron properties, consideration of chiral (left-handed and right-handed) symmetry and chiral-symmetry breaking turns out to be important. G Ecker (Vienna) gave an instructive summary of chiral perturbation theory, and P Kroll (Wuppertal) addressed exclusive charmonium decays.

While QCD relies on quarks and gluons, quark and gluonic degrees of freedom are relatively inconspicuous for the dynamics of nuclei. However, as emphasized by A Thomas (Adelaide), nuclear matter cannot be described solely by nucleons moving in a nuclear potential; quark and gluonic aspects also need to be taken into account.

The symposium was co-organized by the Institutes for Theoretical Physics of the Ludwig-Maximilians-Universität Munich and the Karl-Franzens-Universität Graz, with H Fritzsch and W Plessas chairing the organizing committee. It was funded by the Province of Styria, the Austrian Federal Ministry for Science and Transportation, and the German W.E. Heraeus Foundation. It was also supported by sponsors from commerce and industry as well as the town of Oberwölz.

H Fritzsch, *Munich and* **W Plessas**, *Graz.*

Letters

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

Culture

The problems discussed by Pascolini (Point of view, November) are important and his article is interesting. It is a pity that in the comparison of science with neutrinos the importance of neutrinos for our life is not mentioned (without neutrinos the Sun would not shine, they are behind all our sources of energy). My second remark is about the sentence: "Since Galileo, the language of physics has been mathematics..." Everybody who read Galileo's books knows that they have no mathematics, only images, and beautiful prose.

When publishing articles on spreading physics culture, you should demonstrate that culture yourself.

Lev Okun, ITEP, Moscow

Alessandro Pascolini replies:

I appreciate this suggested improvement for the analogy between science and neutrinos and will use it in future. My reference to Galileo was to his clear statement in *Il Saggiatore:* "La filosofia e' scritta in questo grandissimo libro... (io dico l'universo), ma non si puo' intendere se prima non s'impara a intender la lingua... ne' quali e' scritto. Egli e' scritto in lingua matematica..." Mathematics is not only formulae but "a language plus logic... a tool for reasoning", in the words of Richard Feynman. Galileo was a master in the use of this powerful tool.

Cannette tell the difference?

I was delighted to see attention given to the talented Les Horribles Cernettes (November) in James Gillies' "Physics Spice!" article, but am perplexed by any comparison between the Cernettes and the Canettes. While the Cernettes can sing and put on a show, none of them play the washboard and I am certain that none would consider covering Big Bill Broonzy. The Canettes, a name admittedly also starting with a "C" and ending with an "S", are a classic blues band.

An anonymous Canettes fan

James Gillies replies:

No comparison between the musical styles of the Cernettes and the Canettes was intended. My remark was simply an observation of the similarity between the names of two of the greatest bands to emerge from the cradle of the CERN Music Club. If any readers are interested in learning more about the Canettes, they too can be found on the Web along with many other CERN bands at "http://www.cern.ch/CERN/Clubs/Music/rock.html". [Following our November "Physics Spice!" story, we were pleased to see the *New York Times* run a story on Les Horribles Cernettes and Lynda Williams. They did not mention the Canettes – Ed.]

Bookshelf

● *Elementary Particles and their Interactions* by Quang Ho-Kim and Pham Xuam Yem, Springer 3 540 63667 6. An introduction for serious students of particle physics, this is basically a textbook of the Standard Model. All chapters have extensive suggestions for further reading and problems, some with solutions. It is up-to-date, including the MSW effect for neutrinos, neutral B mixing etc.

● *Basic Ideas and Concepts in Nuclear Physics – An Introductory Approach* (2nd edition) by K Heyde, Institute of Physics Publishing 0 7503 0534 7 (hbk £105/US$156), 0 7503 0535 5 (pbk £35/US$57). The second edition of this established textbook on nuclear physics for senior undergraduates and postgrads includes an extensive set of problems. A new chapter covers nuclei at the extremes of stability. This balanced account of theoretical and experimental nuclear physics emphasizes depth of treatment.

● *An Introduction to the Standard Model of Particle Physics* by W Noel Cottingham and Derek A Greenwood, Cambridge University Press 0521 58832 4 (pbk £17.95/US$29.95) 0521 58191 5 (hbk £47.50/US$74.95). With the Standard Model such an integral part of our understanding of fundamental physics, it is good to have a textbook aimed at senior undergraduates and beginning graduate students which uses the Standard Model as a launchpad. Written by theoreticians, it is oriented towards formalism rather than experiments and recent experimental details. It includes some problems and hints on how to solve them.

RECRUITMENT

DESY

DESY announces several

"DESY-Fellowships"

for young scientists in experimental particle physics to participate in the research mainly with the HERA collider experiments H1 and ZEUS, with the fixed target experiments HERA-B and HERMES and in R & D work for TESLA.

New fellows are selected twice a year in April and October.

DESY Fellowships in experimental particle physics are awarded for a duration of two years with the possibility for prolongation by one additional year.

The salary for the fellowship is determined according to tariffs applicable for public service work (II a MTV Ang.).

Interested persons, 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 sent directly to:

DESY, Personalabteilung, Notkestr. 85, D-22607 Hamburg
by 31 March 1999 Code-Number 91/98

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

As DESY has laboratories at two sites, in Hamburg and Zeuthen near Berlin, applicants may indicate at which location they would prefer to work. The salary in Zeuthen is determined according to II a, BAT-O.

Beam Physics Department Head

Beams Division

Fermilab

The **Fermilab Beams Division** is seeking a physicist to head the Beam Physics Department. Depending on individual qualifications, this position would be tenured or tenure-track. The Department provides theoretical and calculational support for existing and future accelerators. The Department Head plays a leading role in identifying research topics and guiding the progress of about 15 accelerator physicists, as well as supervising the maintenance and development of the department's accelerator physics software tools and computer system. Another major responsibility is to foster communication within the group and with other departments in the Beams Division.

A Ph.D. in physics or its equivalent and several years of experience in the field of accelerator physics is required. A significant record of scientific publications or other, comparable evidence of scientific excellence is also required.

Our highly talented professionals are rewarded for their contributions through competitive salaries and exceptional benefits, including medical/dental/life, tuition reimbursement, and access to our 6,800 acre nature preserve. Please send a copy of your curriculum vitae, and three letters of recommendation to: **Attn: Dr. Stephen D. Holmes, Fermilab National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois, 60510-0500. E-mail: holmes@fnal.gov** We are an EEO/AA Employer M/F/D/V

Fermilab

Minds Over Matter

www.fnal.gov

MICHIGAN STATE UNIVERSITY

Research Associate Position at Michigan State University

The MSU High Energy Physics group has openings for the position of Research Associate to participate in our ongoing work with the D0 experiment at Fermilab and the ATLAS experiment at CERN's Large Hadron Collider. At D0, the MSU group is active in analyses of the top quark. W mass, QCD studies and SUSY searches. We are also responsible for upgrades to the Level 1 and Level 2 trigger systems. In ATLAS we are developing elements of the Level 2 trigger system as well as participating in triggering simulation studies. Applicants should have a PhD in high energy physics. Working experience with fast electronics and modern computer languages is highly desirable. Michigan State University is an equal opportunity institution. Applications from women and minorities are encouraged. For further information contact: **Professor Maris Abolins, Department of Physics and Astronomy, Michigan State University, East Lansing MI 48824. Telephone: (517) 353-1677. Email: Abolins@dirac.msu.edu.**

Faculty Position in Experimental Particle Physics University of Alabama

Applications are being sought for a tenure-track faculty position in experimental particle physics at the University of Alabama. The appointment will begin August 1999. It is anticipated that the appointment will be made at the assistant professor level, but appointment to higher rank may be considered for a candidate with exceptional qualifications. The present experimental particle physics faculty are involved in collider experiments (L3 and CMS at CERN) and non--accelerator neutrino experiments (Palo Verde and KamLAND). The successful applicant for the position will have a Ph.D. in experimental particle physics or a related field, demonstrated potential to pursue a productive research program at the forefront of particle physics, and the ability to teach effectively at the undergraduate and graduate levels.

Applicants should send a resume, which includes a list of publications research and teaching interests, and the names of three references, to

Prof. Jerry Busenitz, Search Committee Chair,
Department of Physics and Astronomy, Box 870324,
University of Alabama, Tuscaloosa, AL 35487-0324
(busenitz@bama.ua.edu)

Applications should be received by February 15, 1999 to ensure consideration.

EO/AAE W/M

The Faculty of Science at the University of Nijmegen, the Netherlands, carries out research and teaching in Physics, Chemistry, Biology, Environmental Science, Mathematics and Informatics.
The Deparment of Experimental High Energy Physics at the University of Nijmegen has an opening for lecturer.

Katholieke Universiteit Nijmegen
Faculty of Science

Lecturer (UD) f/m

Experimental High Energy Physics

Together with the Department of Theoretical High Energy Physics the department forms the High Energy Physics Institute Nijmegen (HEFIN). The department is also a partner in the national institute for sub-atomic physics NIKHEF and the Dutch research school for sub-atomic physics.
For its research the department makes use of the facilities of the European Laboratory of Particle Physics (CERN) in Geneva and the Fermi National Accelerator Laboratory (FNAL) in Chicago, USA.
At the moment the department is extensively involved in the L3 experiment at LEP. At the same time it prepares for a new period of data collection with the DO-experiment at the Tevatron, and realisation of the new to build ATLAS experiment at LHC.

Position
The position is aimed on participation in DO and ATLAS. The teaching associated to this position is inside the subfaculty of physics and comprises both general physics and specialistic topics. The candidate must be willing to fulfil the usual share of administrative tasks.

Profile
- PhD in physics and several years of post-doc experience
- broad knowledge of High Energy Physics, in analysis and interpretation of experimental data
- deep knowledge of and extensive experience in the field of instrumentation for High Energy Physics experiments
- didactical qualities and interest in teaching.

For foreign candidates it will be required to master the Dutch language within two years.

Terms of employment
On satisfactory performance, after 1 year a tenure appointment will be offered. The salary depends on experience and is maximally NLG 8387 gross per month.

Information and application
More information can be obtained from prof.dr. S.J. de Jong, tel. +31 24 365 21 68, e-mail: sijbrand@hef.kun.nl
Application letters, including curriculum vitae, a list of publications and 3 reference letters can be sent before March 1 1999 to: University of Nijmegen, Personnel Department, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands, mentioning reference number 98.76 on letter and envelope.

UNIVERSITY OF VICTORIA

POSTDOCTORAL RESEARCH POSITION
EXPERIMENTAL HIGH ENERGY PHYSICS

The High Energy Physics Group at the University of Victoria has an opening for a Research Associate to work on the BaBar experiment at the SLAC B Factory. Our group is part of the team which has ongoing responsibilities for the BaBar Drift Chamber. The successful applicant will write BaBar reconstruction software in C++, participate in data taking and play a leading role in physics analysis. A recent Ph.D. in experimental particle physics is required with demonstrated software and data analysis experience. This position is a two-year appointment, with the possibility of renewal. Candidates should supply a CV, with list of publications, description of research interests and three letters of reference to:

Professor J. M. Roney
Department of Physics and Astronomy
University of Victoria
Box 3055 Stn CSC
Victoria, B.C.
CANADA
V8W 3P6

This position will be filled as soon as a suitable candidate is identified.

Enquiries may be sent by e-mail to: mroney@uvic.ca

The University of Victoria strongly encourages applications from women, persons with disabilities, visible minorities, and aboriginal persons. In accordance with Canadian immigration requirements, this advertisement in the first instance is directed to Canadian citizens or permanent residents. However, all suitably qualified physicists are encouraged to apply.

DESY

DESY is a physics research laboratory with 1.400 employees and more than 3.000 guest scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of an

Experimental Physicist

The candidate is expected to take a leading role in the research program of the ZEUS experiment at the HERA electron-proton collider, to participate in and to coordinate physics analysis, and to participate in the development and maintenance of detector components. The candidate should also be highly qualified in the area of modern information technologies and should take responsibility in the offline programming and data management of the ZEUS experiment.

Applicants should have a Ph.D. in physics, several years of experience in experimental particle physics and should be active in research in this field. They should have an established record in the analysis of particle physics data and be able to coordinate and work in close collaboration with physicists and technicans of the ZEUS experiment.

The appointment will be indefinite with a salary according to federal tariffs (BAT Ib, IIa depending on experience and qualification).

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

DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg, Germany

by March 1st, 1999 **Code number 3/99**

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

DEUTSCHES ELEKTRONEN SYNCHROTRON DESY

DESY is one of the leading laboratories in particle physics and synchrotron radiation research. For its location in Zeuthen near Berlin DESY is offering a

POSTDOCTORAL RESEARCH POSITION

to young scientists to participate in the preparation of the e^+e^- linear collider TESLA. This includes studies for the physics motivation of the project as well simulations for the optimization of the detector.

Applicants should have a PhD in experimental high energy physics.

The position is limited to a duration of 2 years. The salary will be according to the German civil services BAT-0 IIa.

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

Interested young scientists should send their letter of application and three names of references and their addresses by February 28th, 1999 to:

DESY Zeuthen, Personalabteilung
Platanenallee 6, 15738 Zeuthen, Tel.: 0049/33762/77210

PHYSICIST/ ENGINEER

The National Synchrotron Light Source Department at Brookhaven National Laboratory (NSLS) is seeking an Accelerator Physicist/Engineer to work on the operation and improvement of the existing NSLS storage rings. Important areas of work include lattice modeling, orbit control, injection optimization and study of beam intensity limiting effects. Experience in the development of the related hardware and diagnostic equipment is desired, as well as skill in developing software application programs. Demonstrated independence in work and the ability to coordinate activities also required.

For consideration, please forward your resume indicating Position #DD4512, to: Donna Dowling, Brookhaven National Laboratory, HR Division, Bldg. 185, PO Box 5000, Upton, NY 11973-5000, Fax: (516) 344-7170, Email: dowling@bnl.gov. For the hearing disabled: TDD 516-344-6018. BNL is an equal opportunity employer committed to workforce diversity.

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
www.bnl.gov

UPPSALA UNIVERSITY
The Svedberg Laboratory
Postdoctoral fellowship in accelerator physics

The Svedberg Laboratory (TSL) in Uppsala, Sweden invites outstanding applicants for a postdoctoral position in accelerator physics. The appointment is for one year, with the possibility of an extension to a second year. Candidates must have passed their PhD examination not more than three years ago.

The laboratory operates the Gustaf Werner cyclotron and the CELSIUS cooler ring. The cyclotron is a synchrocyclotron/isochronous cyclotron hybrid. It delivers beams of heavy-ions as well as protons, which are used for a multitude of applications. In the CELSIUS ring, protons and other ions are stored, accelerated to different energies, electron cooled, and used for physics research. Information about the laboratory can be found at http://www.tsl.uu.se/.

In the framework of the R&D phase of the European Spallation Source (ESS) project, the laboratory will develop a monitor, which will be used to map the longitudinal phase space of an intense 2.5 MeV H- beam from an RFQ.

Further information about the laboratory and the position can be obtained from Dag Reistad (phone +46-18-471 3177, e-mail Dag.Reistad@tsl.uu.se) and from Volker Ziemann (phone +46-18-471 3867, e-mail Volker.Ziemann@tsl.uu.se).

Applications must reach the Director, The Svedberg Laboratory, Box 533, S-751 21, UPPSALA, Sweden (fax no. +46-18-471 38 33) not later than 12 April 1999.

THE UNIVERSITY *of* LIVERPOOL

Department of Physics

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Applications are invited from candidates with excellent research records to join our experimental groups in Condensed Matter Physics, Nuclear Physics and Particle Physics. Current research interests are:
Condensed Matter Physics: X-ray and neutron scattering to investigate magnetic materials.
Nuclear Physics: Stable and radioactive beams to study extremely deformed nuclei and nuclei far from stability.
Particle Physics: Colliding beam experiments at CERN, DESY, FNAL and SLAC to probe the Standard Model and beyond.
Successful candidates will participate in the undergraduate and postgraduate teaching programmes.
Informal enquiries to Professor E Gabathuler on 0151 794 3349 or email: erwin@hep.ph.liv.ac.uk, Departmental web site http://www.ph.liv.ac.uk

Quote Ref: B/071/PW **Closing Date: 15 March 1999**

Further particulars and details of the application procedure may be requested from the Director of Personnel, The University of Liverpool, Liverpool L69 3BX on 0151 794 2210 (24 hr answerphone) or via email: jobs@liv.ac.uk
Web site at http://www.liv.ac.uk

COMMITTED TO EQUAL OPPORTUNITIES

Project Manager

Neutrinos at the Main Injector (NuMI)

Fermilab invites applications and nominations for the position of Project Manager of the Neutrinos at the Main Injector (NuMI) project – a DOE funded project with a total budget of $136M. The NuMI project encompasses construction of an intense muon neutrino beam, generated using the new Main Injector at Fermilab, and on-site and remote detectors (designated MINOS) in support of a long baseline neutrino oscillation experiment. The remote detector will be located 730km from Fermilab in the Soudan mine in northern Minnesota. The neutrino beamline and MINOS detectors are scheduled for first operation in late 2002. The Project Manager carries executive responsibility for the design, construction, installation, and commissioning of both the neutrino beam and the MINOS detectors.

Candidates should have demonstrated experience in leadership of physics experiments and large projects, as well as a strong interest in neutrino oscillation physics.

For further information about this position or to submit an application, please contact **Dr. Hugh Montgomery, Chair, NuMI Search Committee, MS 357 Fermilab, Box 500, Batavia, IL 60510, e-mail address: mont@fnal.gov, phone: 630-840-4708.** Applications should include a curriculum vita and a list of at least three references and they should be received by February 28, 1999. We are an EEO/AA Employer M/F/D/V

Fermilab

Minds Over Matter

www.fnal.gov

DESY announces a

Post-Doc Position

The DESY laboratory invites applications for a postdoctoral position to participate in the commissioning of the **First Level Trigger** of 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.

The large background, large number of detector channels, and high event rate makes HERA-B triggering a special challenge. For the first time a HEP experiment is confronted with a situation as expected for the LHC. At a latency of about 10 micro seconds the First Level Trigger finds tracks of leptons and hadrons, calculates their momenta, and reconstructs the invariant mass of all possible track pairs of a given event. The First Level Trigger consists of about one hundred specialized processor boards that simultanously process detector data at a rate of 1 Tbit/sec.

The position is an excellent opportunity for a motivated individual to play a major role in the commissioning of the First Level Trigger. Contributions are especially expected to the development of the software architecture that will allow to operate the processor network, and the software implementation. The successful candidate is expected to participate in the upcoming physics data analysis.

Prospective applicants should have demonstrated software experience. In particular, familiarity with the C programming language is required. Knowledge of a Unix type operating system and data bases would be of advantage.

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 also arrange to have three letters of recommendation sent directly to: **DESY, Personalabteilung, Notkestraße 85, D- 22607 Hamburg by 20 of February 1999 Code-number: 103/98**

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

Faculty Positions Experimental Particle-Astrophysics

The Ohio State University

The Department of Physics invites applications for two faculty positions in experimental particle-astrophysics beginning in Fall 1999. One position is expected to be at the senior (tenured)level. and one position is expected to be at the Assistant Professor (tenure track) level. Candidates for the junior level position should have a Ph.D. in Physics, some postdoctoral experience and demonstrated outstanding research accomplishments. Applicants for the senior position should have an active research program. A commitment to excellence in teaching at both the undergraduate and graduate levels is essential. Successful applicants will form the core of a new experimental particle-astrophysics group. While applications from all areas of experimental particle-astrophysics will be considered, preference will be given to the areas of underground physics, ultra-high energy cosmic rays, and multi-TeV gamma-rays.

The Physics Department has strong research groups in high energy experiment and theory, nuclear experiment and theory, nuclear astrophysics, and theoretical particle-astrophysics. The Department of Astronomy has a strong overlap with these groups. The Physics Department also has excellent support facilities for experimental research including its own electronic and machine shops.

Applicants should submit a CV, including a list of publications and a brief statement of research interests, and arrange to have at least three letters of reference sent separately. To achieve full consideration, all materials should be received by March 15, 1999. Send all correspondence to:

Professor Terry Walker, Chair
Experimental Particle-Astrophysics Search Committee
Department of Physics, The Ohio State University
174 West 18th Ave., Columbus, OH 43210.

The Ohio State University is an equal opportunity/affirmative action employer. Qualified women, minorities, Vietnam era veterans, disabled veterans, and individuals with disabilities are encouraged to apply.

Bergoz Instrumentation has job opportunities at its new facility in Saint-Genis, France, 2 km from CERN

Senior Engineer

Task: design / develop new beam diagnostics
Solid background in analog electronics design
Occasional travel abroad for short periods
Age, sex, indifferent. Any nationality
2-year contract leading to permanent contract
Excellent growth opportunity for candidates with managerial skills

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5 years experience. Analog electronics background an advantage
Occasional travel abroad for short periods
Age, sex, indifferent. Only European nationals may apply.
Permanent contract

Mail application with full job history to:
Julien Bergoz, 01170 Crozet, France

bergoz *Instrumentation*

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MICHIGAN STATE
UNIVERSITY

TENURE TRACK FACULTY POSITION IN NUCLEAR PHYSICS

MICHIGAN STATE UNIVERSITY

The Department of Physics and Astronomy is seeking outstanding candidates to fill a tenure-track position in experimental nuclear physics, nuclear astrophysics, accelerator physics, fundamental interactions or another field related to nuclear physics. Candidates must exhibit unusually high promise for excellence in both teaching and research. The successful candidate will be a member of the Department of Physics and Astronomy with a joint appointment in the National Superconducting Cyclotron Laboratory (NSCL), where he/she is expected to develop a strong research program. The present unique research opportunities offered by a variety of projectiles and by modern equipment will be enhanced when the ongoing Coupled Cyclotron upgrade is completed in 2001.

The intensities of radioactive beams, for example, will be increased by several orders of magnitude. The NSCL offers many opportunities for collaborative research, with assistance from an expert technical staff. There is also a tradition of frequent interaction with the nuclear theorists in the Department. The position is expected to be filled at the assistant professor level, but a higher level will be considered in an exceptional case.

Applicants please send a resume, including a list of publications, and the names and addresses of at least three references to **Prof. Raymond Brock, Chairman, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824-1116.**

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

FACULTY POSITION
THE UNIVERSITY OF TEXAS AT AUSTIN

The Department of Physics at The University of Texas at Austin is seeking candidates for a tenure-track position starting September, 1999. This is a teaching and research position. The successful candidate will assume full teaching responsibilities for undergraduate and graduate courses in the Department of Physics and will also conduct a vigorous research program. Excellent English language communication skills are required. Applicants must have a Ph.D. (or equivalent) and a demonstrated potential for excellence in teaching and research. Preference will be given to candidates with a strong postdoctoral research record. In exceptional cases, appointment with tenure will be considered. Areas of particular interest to the Department include experimental particle physics and the new physics made accessible by ultrafast laser sources. Interested applicants should send a curriculum vitae, a list of publications, a statement of research interests, and at least three letters of reference to **Professor Kenneth W. Gentle, Chairman, Department of Physics, RLM 5.208, The University of Texas at Austin, Austin, TX 78712-1081.**

The University of Texas at Austin is an Equal Opportunity/Affirmative Action Employer.

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DISPLAY AD INDEX

CERN's new Director General **Luciano Maiani** receives the degree of Doctor Honoris Causa of St Petersburg State University, Russia, from Rector Ludmila Verbitskaya in recognition of his distinguished contributions to theoretical physics, including the prediction of the existence of charmed particles and his work on the theory of weak interactions. The award was part of the centenary celebrations of the birth of Vladimir Fock during a special commemorative session on 21 December 1998. Prof. Fock created St Petersburg's Department of Theoretical Physics and was associated with the university for more than half a century, during which time he pioneered important new methods in theoretical physics such as Fock space and the Hartree–Fock method.

Formal farewells to outgoing Director General **Chris Llewellyn Smith** (left) at the meeting of CERN's governing body, Council, in December paid tribute to his leadership in making the LHC happen and in extending the project to world status. In recognition of this role, Department of Energy Associate Director for High Energy and Nuclear Physics Peter Rosen, on behalf of US Secretary of Energy Bill Richardson, presented the outgoing Director General with the DOE's Distinguished Associate Award. Llewellyn Smith is now Provost of London's University College.

Russian Minister of Science and Technology **Mikhail Kirpichnikov** (right) at CERN on 21 November with (right to left) CMS experiment spokesman Michel Della Negra, senior ministry specialist Oleg Patarakin and ITEP Protvino Director Anatoly Logunov.

Prizes and awards

- Jacques Séguinot of the Collège de France and Tom Ypsilantis of CERN and Bologna share a special prize of the Société française de physique for their continual innovative work in the field of particle detectors, in particular for the conception and development of the Ring Imaging Cherenkov (RICH) technique for particle indentification.
- Karl-Ludwig Kratz of Mainz, driving force behind the nuclear astrophysics programme at CERN's ISOLDE on-line isotope separator, wins the 1999 ACS Award in Nuclear and Radiochemistry.
- On 4 November Johann Bienlein of DESY was made professor honoris causa at the Henryk Niewodniczanski Institute of Nuclear Physics, Cracow, Poland. The honour was also bestowed on DESY Director Bjoern Wiik on 9 January.

Johann Bienlein of DESY (left) receives his diploma of professor honoris causa from H Hrynkiewicz, Chairman of the Scientific Council of the Institute of Nuclear Physics, Cracow, Poland (centre). K Rybicki (right) gave the "laudatio".

CERN elections and appointments

At the meeting of CERN's governing body, Council, in December, G Kalmus (Rutherford Appleton Laboratory, UK) was appointed Chairman of CERN's Scientific Policy Committee for one year from 1 January 1999. D Trines (DESY), S Ozaki (Brookhaven), A Golutvin (ITEP, Moscow) and J Feltesse (CEA, France) were elected members of the Scientific Policy Committee for three years from 1 January 1999.

J Van der Boon, previously Head of Personnel at NWO (the Netherlands Organization for Scientific Research) in The Hague, has been appointed as Leader of CERN's Personnel Division for three years from 1 April 1999. From 1 January to 31 March W Blair will run the division *ad interim*.

Nicholas Kemmer 1911–98

Nicholas Kemmer's legacy to physics was his monumental work in the late 1930s on the application of the charge independence of nuclear forces using the new idea of isotopic spin, which led to his prediction of the neutral pion, the first example of the prediction of a particle using a symmetry principle.

Kemmer had an extraordinary international background – born in Tsarist Russia and educated initially in the UK and then in Germany, eventually moving to Göttingen, the cradle of modern quantum mechanics, then Zurich, where he went on to work with Pauli at the ETH, and London. During World War II he worked at Cambridge, and after a spell in Montreal returned after the war to Cambridge, where he nurtured a generation of new theoretical physics research talent at a valuable time. In 1953 he moved to Edinburgh to inherit Max Born's chair.

Meetings

- The XVth Particles and Nuclei International Conference (PANIC) will be held in Uppsala, Sweden, from 10–16 June.
See "http://www.tsl.uu.se/panic99" or e-mail "panic99@tsl.uu.se".
- A Workshop on Polarized Protons at High Energies – Accelerator Challenges and Physics Opportunities – will be held at DESY, Hamburg, Germany from 17–20 May, covering both accelerator physics and spin physics in polarized scattering.
Secretariat: H Haertel/heraspin, DESY; "heraspin@desy.de"; "http://www.desy.de/heraspin".

Late news...

The heaviest element yet discovered, with 114 protons per nucleus, has been synthesized by a team led by Yuri Oganessian at the Flerov Laboratory for Nuclear Problems, Joint Institute for Nuclear Research, Dubna, near Moscow. With 175 neutrons, the nucleus sits comfortably on a long-predicted "island of stability" and has a half-life of 30 seconds. In comparison, nucleus 112, discovered in 1996 at the GSI heavy ion laboratory, Darmstadt, decays in less than a thousandth of a second. Nucleus 113 has yet to be discovered.

Prominent nuclear physicist becomes Japanese Education and Science Minister

A prominent nuclear theorist and the former president of the University of Tokyo, Prof. Akito Arima, Japan's new Minister of Education and Science in Japan, was welcomed by many Ministry employees on his first day at his new job.

Prof. Akito Arima, former president of the University of Tokyo and a prominent nuclear theorist, has been appointed Minister of Education, Culture, Sport and Science in the new Japanese cabinet. He is well known worldwide for his contribution to the shell model of the atomic nucleus.

As the president of the University of Tokyo, he re-established relations between universities and the government and revitalized Japanese universities. After retiring from the University of Tokyo, he served as president of the RIKEN Institute of Physical and Chemical Research and as science advisor to the Education Minister. He also played important roles in many government councils for national education and basic research.

In his new position he receives proposals from councils and makes decisions about not only higher education and basic research, but also nationwide education, culture and even sport. Although his new responsibilities are wide, his previous experience covered most of them. He is also a well known poet.

It is the first time in Japanese history that a nuclear physicist, even a scientist, assumes the nation's top position in education, culture, sport and science. Welcoming this move, many scientists in Japan see it promising well for basic research.

Longtime *CERN Courier* Advertising Manager and Production Assistant Micheline Falciola took a well-earned retirement at the end of 1998. *CERN Courier* advertising is now handled by the Institute of Physics Publishing, Bristol, UK. For contacts see the masthead on page 3.

Admiring a model of the CMS experiment for CERN's LHC collider are (left to right): LI Weiguo, Deputy Director of the Chinese Institute of High Energy Physics; WANG Naiyan, Vice President of the Chinese National Natural Science Foundation; SHAO Liqin, Vice Director General, Department of Basic Research, Ministry of Sciences and Technology; QIAN Sijin of CERN and Wisconsin; Michel Della Negra, CMS Spokesman; ZHANG Kan, Director General, Bureau of International Cooperation, Chinese Academy of Sciences.

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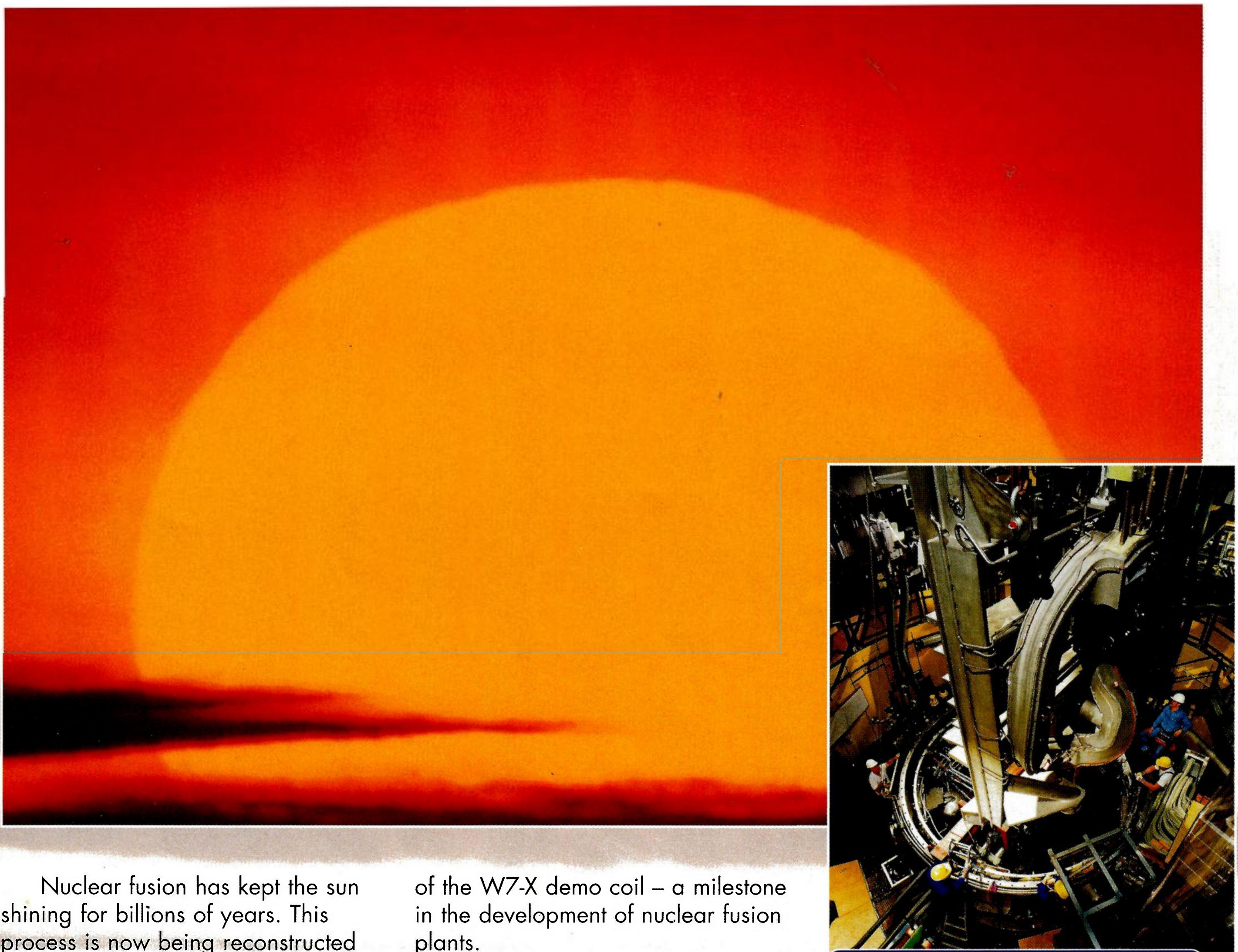

Installation of the W7-X demo coil into the cryostat

Nuclear fusion has kept the sun shining for billions of years. This process is now being reconstructed on earth in a reproducible manner and under controlled conditions with a view to solving pressing energy problems.

After a period of extensive development work on superconducting magnets, major components in nuclear fusion plants, Noell-KRC Energie- und Umwelttechnik GmbH has gathered vast experience in pioneering magnet engineering over many years. This is exemplified by the successful industrial manufacture of the W7-X demo coil – a milestone in the development of nuclear fusion plants.

It is due to this know-how that Noell-KRC, as the lead management company of a consortium, was awarded the largest contract in the world to date for the development and production of 50 non-planar superconducting magnets. They are required for the Wendelstein 7-X plasma experiment, which is currently being set up in Greifswald/ Germany.

In addition to these magnets, Noell-KRC is developing and manufacturing dipole magnets for LHC as well as magnet components for the nuclear fusion experiments JET and ITER. One more reason to talk to us about magnet engineering. Just call us.

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