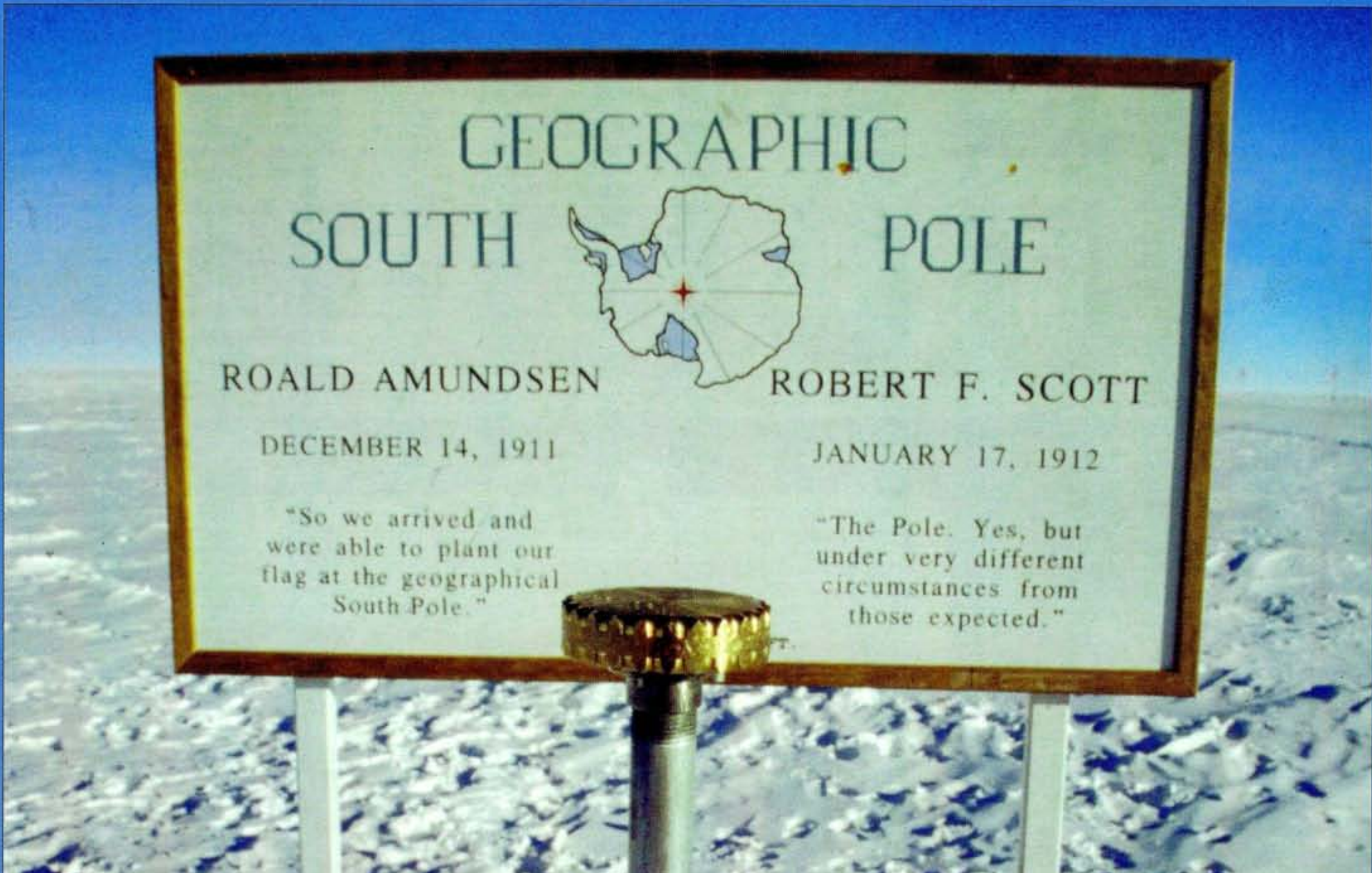
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 41 NUMBER 5 JUNE 2001



The ultimate particle polarization

Instrumentation for Measurement & Control

▸ Magnetic Field

THM-7025

Application	Product	Specifications: Range	Resolution	Bandwidth
Linear sensing. Non-contact measurement of position, angle, vibration. Small size, low power.	CYH-22 1-axis Hall element	± 20mT	± 4μT	DC to 10kHz
	2D-VD-11 2-axis Hall element	User option	± 30μT	DC to 10kHz
	3D-H-30 3-axis Hall element	User option	± 100μT	DC to 10kHz
High sensitivity and accuracy for low fields. Site surveys and monitoring. Active field cancellation.	MAG-01 1-axis Fluxgate Teslameter	± 2mT	± 0.1nT	DC to 10Hz
	MAG-03 3-axis Fluxgate Transducer	± ImT	± 0.1nT	DC to 3kHz
Linear measurement. Feedback control. Mapping, quality control.	YR100-3-2 Hall Transducer, 1-axis	± 2T	± 12μT	DC to 10kHz
	3R100-2-2 Hall Transducer, 3-axis	± 2T	± 12μT	DC to 10kHz
Hand-held, low-cost, 3-axis for magnet and fringe fields.	THM 7025 Hall Teslameter, 3-axis	± 2T	± 10μT	DC
Precision measurement and control. Laboratory and process systems.	DTM-133 Hall Teslameter, 1-axis	± 3T	± 5μT	DC to 10Hz
	DTM-151 Hall Teslameter, 1-axis	± 3T	± 0.1μT	DC to 3Hz
Calibration of magnetic standards. Very high resolution and stability (total field).	2025 NMR Teslameter (total field)	± 13.7T	± 0.1μT	DC
	FW101 NMR Teslameter (total field)	± 2.1T	± 0.5nT	DC
Precision flux change measurement.	PDI 5025 Digital Voltage Integrator	40 V.s	±2E-8V.s	1ms to 2^{23}ms

Field units: 0.1nT = 1μG, 100nT = 1mG, 100μT = 1G, 1mT = 10G, 1T = 10,000G

▸ Electric Current (isolated measurement)

IPCT

Application	Product	Specifications: Range	Resolution	Bandwidth
High sensitivity for low currents, currents at high voltage, differential currents.	IPCT Current Transducer	± 2A	± 10μA	DC to 4kHz
	MPCT Current Tranducer	± 5A	± 10μA	DC to 4kHz
Linear sensor for low-noise, precision current regulated amplifiers and power supplies.	864I-2000 Current Transducer	± 2000A	<4ppm	DC to 300kHz
	866-600 Current Transducer	± 600A	<4ppm	DC to 100kHz
Instruments for calibration, development, quality control.	860R-600 Current Transducer	± 600A	<5ppm	DC to 300kHz
	860R-2000 Current Transducer	± 2000A	<8ppm	DC to 150kHz
	862 Current Transducer	± 16kA	<5ppm	DC to 30kHz
Passive sensor for rf and pulse current.	FCT Fast Current Transformer	1:5 to 1:500	limited by following amplifier	150Hz to 2GHz
Passive sensor for pulse charge.	ICT Integrating Current Transformer	± 400nC	± 0.5pC	1μs to<1ps

▸ Distributed I/O

CNA

FTR

Application	Product	Specifications: Range	Resolution	Bandwidth
High resolution Input/Output modules that can be placed locally at the transducer or controlled unit. High Voltage and/or high noise environments. PC, PCI, VME, CAMAC host computer options.	DNA for DeviceNet	± 100mV to ± 10V	16 bit	DC to 150Hz
	CNA with fiber optic communication	± 100mV to ± 10V	16 bit	DC to 150Hz
	FTR fiber optic to RS-232-C			50 to 200kB

GMW *955 Industrial Road, San Carlos, CA 94070*
Tel: 650-802-8292 Fax: 650-802-8298

www.gmw.com

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

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

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

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

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

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

ISSN 0304-288X

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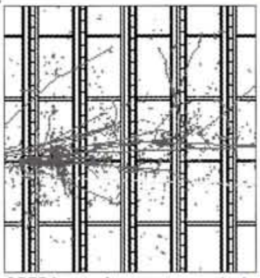


OPERA experiment approved p4

Polar physics with AMANDA p13

Nature's chaos and harmony p38

Cover: The South Pole – an unusual setting for physics (Torsten Schmidt, p13).

CERN

Neutrinos get their grand OPERA

The 2000 tonne OPERA (Oscillation Project with Emulsion Tracking Apparatus) experiment has been approved for construction and operation in the CERN Neutrino Beam to Gran Sasso project. The experiment involves 33 research institutes in 12 countries, including CERN, China and Japan.

The CERN Neutrino Beam to Gran Sasso project, now under construction (December 2000 p7), will send a beam of high-energy neutrinos from CERN to the Italian underground Gran Sasso laboratory, a distance of 730 km, where the OPERA detector will be assembled. The first neutrinos are expected to be sent in 2005.

Classically, neutrinos come in three varieties – electron, muon and tau, depending on their partner particles. These neutrino varieties are supposed to be immutable, so that a neutrino born alongside a muon should remain a muon neutrino for ever.

However, major experiments monitoring the arrival of neutrinos produced in the atmosphere by cosmic rays provide strong indications that neutrinos are not immutable (October 2000 p31). To explain this observed behaviour, some neutrinos that start off muon-like could transform en route into tau-like neutrinos.

To maximize the chances of seeing such neutrino "oscillations", the experiment needs a long "baseline", in this case the 730 km between CERN and the Gran Sasso laboratory. Because of these oscillations, a neutrino beam starting off muon-like as it left CERN would contain tau-neutrinos on arrival at Gran Sasso. When they interact, these tau-neutrinos can produce highly unstable tau leptons, which decay within 1 mm of the neutrino interaction point. Recognizing these tiny decay kinks is the main goal of the OPERA experiment.

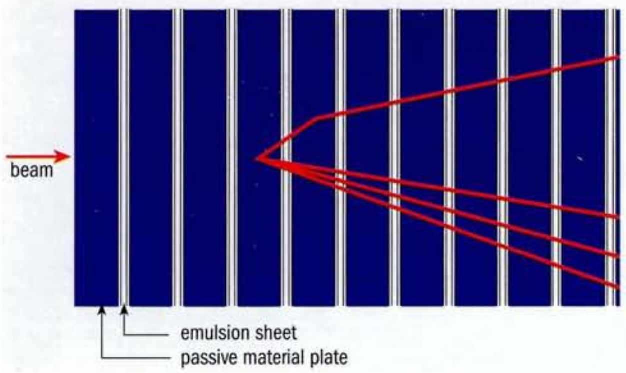
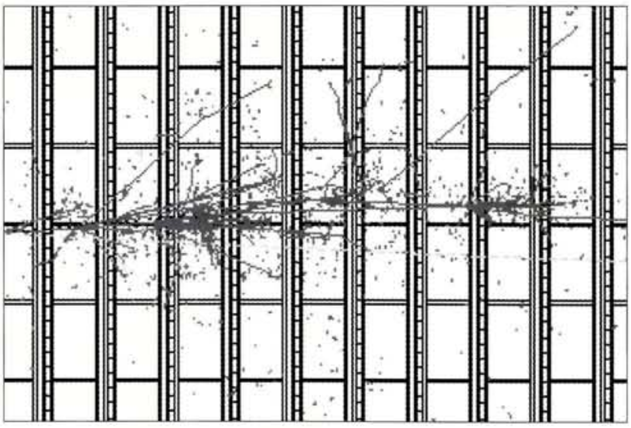
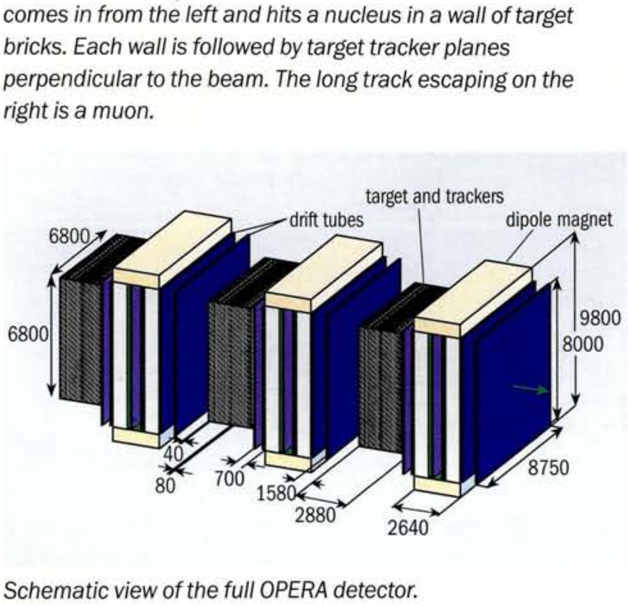


Fig. 1. OPERA uses cells of 1 mm thick passive lead plates interspersed by thin films, made of a pair of about 50 μm emulsion layers on either side of a 200 μm plastic base. This shows how neutrino tracks would begin.



Simulation of a tau neutrino interaction in OPERA. The beam comes in from the left and hits a nucleus in a wall of target bricks. Each wall is followed by target tracker planes perpendicular to the beam. The long track escaping on the right is a muon.



Schematic view of the full OPERA detector.

To do so it must use a detector with excellent spatial resolution over its whole 2000 tonne mass. The technique chosen is that of the Emulsion Cloud Chamber (ECC), with sheets of passive absorber (lead) material interspersed with emulsion layers to reveal the tracks left by neutrino interactions. The basic OPERA unit is a cell made of a 1 mm thick lead plate followed by a thin film, made of a pair of 50 μm emulsion layers on either side of a 200 μm plastic base (figure 1). Cells will be arranged in turn in removable "bricks", and the bricks used to build "walls", modules and supermodules. Downstream of the ECC lattice will be a muon spectrometer.

Each removable brick, weighing 8.3 kg, will have dimensions of 10.2×12.7 cm transverse to the beam and 7.5 cm along the beam, and will be made up of 56 individual cells. A wall will be built of 3264 bricks and, with two planes of electronic trackers (plastic scintillator read out by wavelength-shifting fibres), will make up a module. Each target supermodule will consist of 24 modules, and the whole detector, with a cross-section of about 6×7 m perpendicular to the beam, will contain three supermodules, representing a total of 235 000 bricks.

The effectiveness of the ECC technique was shown last year through its use in the first observation of explicit tau-neutrino signals by the DONUT (Direct Observation of the NU Tau) experiment at Fermilab (September 2000 p6). DONUT monitored the neutrino outcome after slamming a high-energy proton beam into a compact "beam dump", thus generating a small number of tau-like neutrinos directly, rather than through oscillations.

Because of its natural divergence, by the time the neutrino beam reaches Gran Sasso it will have spread out across an area of about 800 m. This means that OPERA, mighty as it is, will only see a small slice of the arriving beam.

To build the detector, an assembly line at Gran Sasso will stack lead plates and emulsion films into bricks at the rate of about two per minute. Computer-controlled robots will arrange the bricks in their allocated positions. It will take about a year to fill the detector with bricks.

Emulsion films have a long history in particle physics experiments, one milestone having been the discovery of the pion in 1947 cosmic-ray studies. Automatic emulsion scanning by computerized microscopes was pioneered by the Nagoya group, starting in the late 1970s. Japanese emulsions were used for the CHORUS neutrino experiment at CERN and for DONUT at Fermilab. However, OPERA will need a much greater amount of emulsion than any of its predecessors, and new industrial techniques are being perfected in a collaboration between Nagoya and Fuji Film.

While the experiment is running, the complete detector will be continuously monitored by its own electronic detectors. These electronic trackers, located downstream of each wall, will also be used to identify the brick where a neutrino interaction occurs. These bricks (about 30 per day) will be removed outside the underground hall for calibration. They will then be taken apart and the emulsion plates developed.

Faster scanning procedures than those used for the CHORUS and DONUT experiments will be needed to locate the neutrino interactions. These are now being developed. Further scanning will search for a tell-tale millimetre track followed by a kink, the characteristic fingerprint of a tau decay and therefore of a tau-neutrino interaction.

At the neutrino oscillation rate suggested by experiments to date, OPERA should see about 15 tau-neutrino interactions in five years of running with the nominal performance of the neutrino beam from CERN to Gran Sasso. If so, it will have proved that the disappearance of muon-like neutrinos observed in atmospheric neutrino experiments is indeed due to oscillations into tau-like neutrinos.

US

Three new experiments set to arrive at SLAC's End Station A

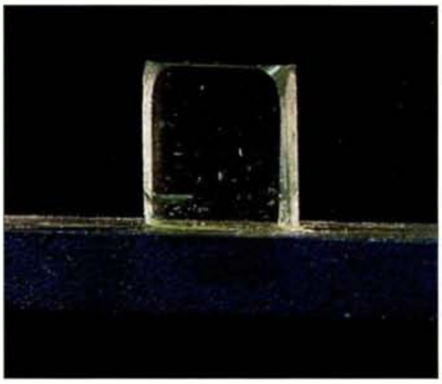
End Station A, the venerable fixed-target facility at the end of the two mile electron linear accelerator beam at SLAC, Stanford, where quarks were discovered in 1967, will soon see a high-energy beam of polarized (spin-oriented) photons as three newly approved experiments move onto the floor.

An international collaboration led by Peter Bosted and Stephen Rock (Massachusetts), Donald Crabb (Virginia) and Keith Griffioen (William and Mary) will use paper-thin diamond wafers to generate coherent photon beams with energies of up to 48 GeV.

Louis Osborne and Roy Schwitters pioneered this technique at SLAC in 1970, when the maximum electron energy was 20 GeV. Specific crystal planes of the diamond are precisely aligned with the electron beam to create a diffraction grating for the bremsstrahlung photons produced by electrons interacting in the crystal. This process yields distinct spikes in the photon energy spectrum. Small-angle collimation then enhances the ratio of coherent to incoherent radiation. SLAC's highly polarized electron beam, with energies now as high as 50 GeV, will be used to generate more than a billion circularly polarized photons per second.

The three new experiments are known as E159, E160 and E161. E161 will study the contribution of gluons to the spin of nucleons. Since the 1980s, Lepton-nucleon scattering experiments at CERN, SLAC and DESY have established that the constituent quarks are responsible for only 25 per cent of the nucleon's spin. The rest must come from the orbital motion of quarks and gluons and from the intrinsic spin of the gluons.

E161 will study gluon contributions to nucleon spin via a photon-gluon fusion process, in which a circularly polarized photon merges with a polarized gluon to form an unbound charm-anticharm quark pair. The production of charm quarks is established via their decay to muons, which will be identified using a long dipole magnet filled with alumina. Polarized LiD will be used as the target, cooled to 300 mK with a dilution refrigerator inherited from CERN.



A set of new experiments at End Station A at SLAC, Stanford, will use thin diamond wafers to generate coherent photon beams with energies of up to 48 GeV from the SLAC electron beams. The 8 × 8 mm diamond target is 1 mm thick.

E160 will measure the dependence of J/psi production on nuclear composition by firing unpolarized photons at several different unpolarized nuclear targets. This experiment will aid searches for the quark-gluon plasma at CERN's SPS (Super Proton Synchrotron) and Brookhaven's RHIC (Relativistic Heavy Ion Collider), in which one expected signature is the suppression of J/psi production. A better understanding of the simpler photo-production process should help to interpret those results.

E159 will test the Gerasimov-Drell-Hearn sum rule using polarized photons and polarized ammonia and ND_3 targets. In this sum rule, the difference between the total cross-sections with the photon spin-polarized parallel versus antiparallel to the nucleon spin is related to the anomalous magnetic moment of the nucleon. If this prediction is not verified, it could suggest possible excitations of the nucleon not previously identified – or even new particles or interactions not encompassed by the Standard Model.

At the heart of all three experiments lie diamonds and charm. Once beautifully set to show their best facets to the electron beam, these diamonds will indeed become a physicist's best friend.

Peter Bosted, University of Massachusetts.

CONFERENCE

High-energy accelerators look to R&D

The rhythm of the International High Energy Accelerator Conference (HEACC), held once every three years, is well matched to the gradual evolution of the accelerator scene. The latest venue, in Tsukuba, Japan, in March, reflected the continued emergence of colliders as the preferred experimental tool, both at high energy and for special physics areas, and the change in emphasis on high-energy fixed target experiments. A small, select meeting, HEACC provides a sharp overview of the current scene, contrasting with the blurred, subjective picture that can emerge from large meetings with many parallel sessions.

In his introductory HEACC talk, Hirotaka Sugawara, director of the host KEK laboratory, stressed that the real physics objectives are for a 100 TeV proton collider and a 10 TeV electron-positron collider, for which current projects are only precursors. His call for more accelerator R&D effort was echoed throughout the meeting.

For high-energy electron-positron colliders, the machines at SLAC, Stanford, and LEP, CERN, have ceased operation since the previous HEACC at Dubna in 1998, and the emphasis has turned instead to lower-energy colliders – PEP-II at SLAC and KEKB, Japan, using unequal electron and positron energies to probe the physics of B particles, containing the fifth ("b") quark. These colliders have quickly broken all records for luminosity (collision rate), exceeding $10^{33}/cm^2/s$.

Having made major contributions to B physics for many years, the CESR electron-positron collider at Cornell is now looking to reduce its operating energy to investigate other quark sectors. Another special research focus is the tau-charm sector, where the Budker Institute at Novosibirsk, long-time an electron-positron collider stronghold, continues to develop plans.

In its build-up, LEP was frequently referred to as the last of the big electron-positron rings. However, with talk of a possible Very Large Hadron Collider (VLHC), the ring of which would dwarf CERN's 27 km LHC project, the ultimate circular electron-positron machine could be built in such a tunnel, attaining collision energies of around 370 GeV.

However, the preferred route to high-energy electron-positron colliders is now via linear machines, and, at many major laboratories, vigorous research and development work is looking at the problems to be solved en route to higher energies.

The damping ring at the Accelerator Test Facility (ATF) at the Japanese KEK laboratory has attained promising beam emittances (size × divergence) for new electron-positron linear colliders.

At the Accelerator Test Facility (ATF) at KEK, Japan, the emittance (size × divergence) of a beam has reached 10^{-11} rad m – a promising figure for linear colliders. Less constructive at first glance is the breakdown effects encountered at 60 MV/m in non-superconducting accelerating cavities at ATF, at the counterpart facility at SLAC (for the "Next Linear Collider") and elsewhere.

However, not all delegates were that pessimistic: Greg Loew of SLAC dismissed this obstacle as "a bump in the road", while Ron Ruth of SLAC proposed new cavity configurations exploiting standing waves.

On both sides of the Pacific, R&D pushes ahead towards an X-band (11.4 GHz) scheme using high-power klystrons based on periodic permanent magnet focusing, yielding 70 MW and a few microseconds in pulse length.

CERN has its own plan for a linear electron-positron collider – the CLIC scheme – using a drive beam instead of conventional klystrons. The CTF2 CLIC test facility at CERN uses transfer structures yielding 100 MW of 30 GHz power to study how the main linac could withstand accelerating fields of more than 60 MV/m. A major design report is expected in 2005. In his summary talk, Alexander Skrinsky of Novosibirsk thought that a normal conducting S-band (3 GHz) route was the way to go for a "frontier" machine, despite the 60 MV/m threats.

Fresh from the recent launch of the superconducting TESLA idea at DESY (May p6), laboratory director Albrecht Wagner described how 500 GeV collision energy was already on the cards with the achieved 23.4 MV/m accelerating fields, but that 800 GeV was attainable if performance could be guaranteed at 35 MV/m, and even beyond with careful electropolishing.

LHC project director Lyn Evans of CERN pointed out the sterling work already achieved by the PS synchrotron at CERN, which will be the LHC pre-injector. This beam-preparation baton now passes to the next link in the LHC injector chain, the SPS. The LHC commissioning schedule foresees a sector test in 2004, the complete ring cooled to 2 K in 2005 and commissioning in 2006.

New ring on the block is Brookhaven's RHIC heavy-ion collider, which was commissioned last year (October 2000 p5) and has already produced initial physics. Derek Lowenstein pointed out that ion-collision energy will soon be boosted to the 200 GeV per nucleon design figure. Polarized protons will be accelerated using a Siberian Snake magnet structure. Another new RHIC plan is a 52 MeV electron linac for cooling the heavy-ion beam to increase collision (luminosity) performance (52 MeV is the electron mass scale for RHIC's 100 GeV per nucleon beams).

Fermilab's Tevatron proton-antiproton collider has just begun its new run, and luminosities should eventually attain $5 \times 10^{32}/cm^2/s$. Electron cooling should soon be introduced for the antiproton collector ring (May p7).

For the long-term future, there was talk of LHC II at CERN, with new magnets operating at almost double the current field, while Fermilab is looking at various VLHC options to attain collision energies of some 40 TeV, compared with the LHC's 16 TeV. VLHC circumferences range from 100 to 500 km, depending on the strength of the bending magnets used.

Although not strictly a hadron collider, DESY's HERA electron-proton machine has a field of physics all to itself and is seeking to boost collision rates by squeezing the colliding beams more tightly together (May p5).

The relatively new idea of using muon rings as intense neutrino sources has already resulted in several proposals (April 2000 p17), which were summarized by Alessandra Lombardi of CERN. The energies of the envisaged proton driver machines range from 2.2 GeV at CERN to 15 GeV at Fermilab, 24 GeV at Brookhaven and 50 GeV in Japan, using different approaches. The CERN scheme foresees a superconducting proton linac, which could also be used as a new injector for the synchrotron chain. Work in Japan is helped by the recently approved KEK/JAERI proton scheme (March p8). However, worldwide enthusiasm for the new neutrino factory idea is being hampered at the moment by inadequate resources.

R&D for new accelerator methods appears to have reached something of a plateau, where conventional ideas have run out of steam and where there are few new contenders to take their place. Continually increasing laser power is one pointer, however, and Konstantin Lotov of Novosibirsk underlined that the high accelerating fields available over plasma dimensions need to be extended over longer distances.

In his concluding talk, CERN accelerator director Kurt Hübner proudly pointed to the accelerator physicists' track record of "delivering rather than promising". He stressed that all hardware should be "tested, tested, tested" to avoid disappointment and to exploit success, and recommended that new projects should request adequate resources from the start, and not feel apologetic about it. With notable accomplishments already having been achieved by international collaborations, it is important to continue this tradition, said Hübner.

The Tsukuba HEACC was organized by Koji Takata of the KEK laboratory. Many HEACC delegates will reassemble in Chicago in June for the US Particle Accelerator Conference. Conscious that the accelerator conference agenda is possibly overloaded, there was discussion of how this could be reduced, and a committee headed by Ferdinand Willeke of DESY ("we cannot do enough work to fill the available speaking time") will make recommendations. However, HEACC in some form or another will surely continue to appear on the high-energy accelerator agenda.

Information from Karlheinz Schindl, CERN.

Edited by Archana Sharma

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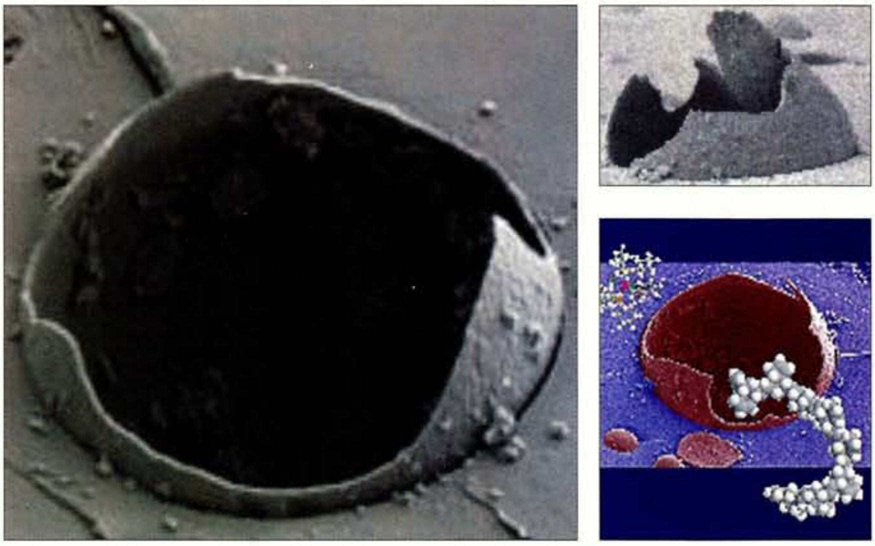
Self-healing polymers could put an end to stress and fatigue



Above left, top right: scanning electron micrographs of a ruptured capsule on its way to mending the surrounding polymer. Bottom right: self-healing polymers in action, as seen by a scanning electron microscope. The ruptured capsule is red; the fracture plane is light blue. The chemical structure appearing to emerge from the capsule is the polymerized healing agent. The other chemical structure in several colours is that of the catalyst.

Inspired by biological systems in which damage triggers an autonomic healing response, researchers at the University of Illinois have developed a synthetic material that can heal itself when cracked or broken.

These self-healing polymers are on their way to extending the reliability and operational life of electronic and allied components, mitigating the costly and inconvenient weakening effects of material "fatigue". Destined for commercial use within three to five years, the new plastic will heal tiny fissures known as microcracks, which over time can develop into the kind of catastrophic structural fatigue that breaks up aircraft or causes electronic failure in vital microelectronics and mechanical systems. Often these cracks occur deep within the structure, where detection is difficult and repair is virtually impossible. In the new material, however, the repair process begins as soon as a crack forms.

The new material incorporates microcapsules that contain a liquid healing agent. Structural composites are typically made up of high-strength fibres embedded within a polymer matrix. Although lighter than metals, these high-tech materials can fall victim to fatigue – the gradual loss of strength and eventual failure of a material caused by stress-driven cracking.

The fatigue damage is controlled by embedding microcapsules of dicyclopentadiene (DCPD), a polymer precursor, into a composite's matrix material. When a growing crack ruptures one of the 100 μm capsules, the DCPD flows into the fissure and comes into contact with a catalyst in the matrix. Within minutes at room temperature, the DCPD forms a new polymer that bonds the surfaces of the crack together.

When the material cracks, the microcapsules rupture and release the healing agent into the damaged region by means of capillary action. As the healing agent comes into contact with the embedded catalyst, polymerization is initiated, which then bonds the crack face closed.

Laboratory experiments showed that samples of the self-healed composite material can take up to 75 per cent of the maximum tension that the intact composite can take. If microcracks are healed before they can connect or grow into larger fissures, structures made of composites can have longer functional lifetimes, with less maintenance required.

On the microscopic scale, the small capsules of DCPD provide weak spots towards which cracks grow. However, this can be an advantage if cracks locate and burst these bubbles of healing fluid.

Despite the microcapsules' slight weakening effect on the material immediately around them, the rounded shape of the burst capsule reduces the stress at the formerly sharp tip of a crack. This slows the growth of the crack and extends the life of the component.

One of the biggest challenges to this research was developing microcapsules that were weak enough to be ruptured by a growing crack but strong enough to withstand the curing step of the composite's manufacturing process. Capsules with 1 μm walls made of a hardened polymerized blend of urea and formaldehyde were used.

In the long term, self-healing composites show potential for addressing the problem of large cracks appearing in load-bearing structural components. Manufacturers could build this self-healing capability into many types of composite. It would be particularly useful for applications for which repair is either impossible or impractical, such as electronic circuit boards or other components of deep-space probes or implanted medical devices. *Nature*

New optical fibres make it all crystal clear

New methods of manufacturing optical fibres could revolutionize these vital communications materials.

A normal optical fibre is made up of a glass core that has a high refractive index and bends light strongly, and an outer cladding that has a lower refractive index and bends light less. Light signals thus bounce their way along the core as though they were inside a pipe with a mirrored coating.

Bundles of microscopic pipes are laid along the length of the new type of fibre, creating "holes" that run through the glass and alter the refractive index. A cross-section of the fibre would show that these holes are arranged neatly in an array, like the atoms in a crystal – hence the name "crystal fibre".

These crystal fibres can work in one of two ways. In "index-guided" fibres, one or more holes are missing at the centre of the array. Without the holes, the glass at the centre has a higher density, and thus a higher refractive index, than its more porous surroundings. Light entering the core is confined, much as it would be in a conventional fibre, but the advantage is that this effect is achieved without the need to use two different kinds of glass. An added benefit is that the light can be squeezed into a much narrower core than in conventional fibres.

In the second mode of operation, the crystal fibre uses a regular array of holes to influence light – in much the same way that the arrangement of atoms in a crystal can determine whether electrons are able to travel easily through it, and hence whether or not the crystal has electrically conducting properties. For example, graphite and diamond are both made of carbon, but the difference in the crystalline arrangements of their atoms means that graphite conducts electricity while diamond is a good insulator. The pattern of holes in a crystal fibre can affect the behaviour of light within it, just as coating a graphite core with diamond might affect how it conducted electricity.

A crystal fibre.

In both types of crystal fibre, the pattern of holes is generated by stacking 1 mm hollow glass tubes together to form a rod several centimetres thick. The rod is heated until the glass flows easily, and is then drawn into hair-thin fibres. In the filaments, the same cross-sectional pattern of holes is preserved, but on a microscopic scale.

Danish company Crystal Fibre (a spin-off from the Technical University of Denmark) has developed an advanced software tool for predicting the optical properties of new fibres. The software makes it possible to identify quickly which types of hole array, out of the literally infinite range of possibilities, have industrially interesting properties.

One new development is a crystal fibre that squeezes light into such a narrow core that the intensity of the light modifies the optical properties of the glass. The "nonlinear" properties of the resulting fibre force light that was transmitted at one wavelength to shift into a range of other wavelengths. This provides a means of switching a signal between two wavelengths – a good trick for using bandwidth more effectively.

A different hole design results in the opposite effect, with light being spread much more evenly across the width of the fibre, thereby reducing nonlinear effects. This could be important in the future for high-speed links, because when data transfer rates approach 100 gigabits per second, nonlinear effects spoil the signals.

Using yet another pattern of holes, it is possible to generate so-called "endlessly singlemode fibres", which transfer light at widely different wavelengths with exactly the same bell-shaped intensity profile. Until now, this has been possible only at infrared wavelengths and, even then, only within a narrow range of wavelengths. However, crystal fibres push the range of singlemode wavelengths right into the visible part of the spectrum, opening up a huge new territory of wavelength for use in telecommunications. *The Economist*

Virtual materials are tailored atom by atom

In a modern-day hunt for hidden treasures, scientists are swapping the painstaking and messy processes of work at the laboratory bench for the neater, cleaner world of the virtual. Instead of experimenting with chemicals in their search for better materials, MIT scientists are utilizing the laws of physics to synthesize new ones.

Their method employs the Schrödinger equation rules to compute the properties of a theoretical atomic structure. Adding an atom here and removing one there eventually creates a material with the desired properties. However, the technique is not as simple as it sounds. In quantum mechanics, every electron affects every other. This means that the calculations are so complicated that even a powerful computer cannot handle an arrangement involving more than a few atoms.

To the rescue comes density functional theory, a 30-year-old concept that allows the electrons in many-atom systems to be treated independently. Only recently, however, has it been viable to put theory into practice, thanks to the availability of vastly more powerful computers. It is now possible to compute the quantum-mechanical properties of atomic systems that are, in effect, infinite.

Unfortunately, no-one is really sure what causes materials to absorb microwaves over too wide a frequency. It could be caused by defects due to missing atoms, thermal vibrations of the crystal lattice or even the boundaries between the small, imperfectly formed crystals that make up the material.

Nevertheless, this is good news for materials scientists and engineers, and it signals the arrival of a new high-tech industry.

Edited by Emma Sanders

Supernova supports negative energy theory

Images of a supernova 10 billion light-years from Earth give new weight to Einstein's theory of negative gravitational energy (the cosmological constant). The observations of the exploding star, made using the Hubble Space Telescope, appear brighter than they should if the universe had been expanding at a constant rate.

The bright supernova, the most distant ever detected, supports a picture of the universe where gravity dominated in the early years, slowing down expansion and holding galaxies relatively close together so that they appeared brighter. Later, a repulsive force – a kind of "negative energy" – started to counteract the attraction of gravity and the rate of expansion of the universe began to accelerate, stretching the expanse between galaxies and making objects within them appear to be dimmer.

This view is supported by microwave observations, and calculations of dark matter using gravitational lensing techniques (June 2000 p11; October 2000 p15). At such a great distance, the observation of this new supernova is an important step forward. It is 50% farther away than the next farthest supernova observed by other survey groups.

Gamma-ray bursts are linked to star-forming regions

At the Gamma Ray 2001 conference in Baltimore, Luigi Piro of the Istituto Astrofisica Spaziale in Rome presented new evidence linking gamma-ray bursts to dense regions of star formation.

Gamma-ray bursts (GRBs) are by far the most powerful events known to occur in the universe since the Big Bang. Their brightness can be enormous – it has been known to reach 1 billion times that of the combined emission from all of the stars in the host galaxy. The mechanisms fuelling GRBs are, however, still unknown.

Piro and collaborators observed the afterglow emission that follows GRBs and found evidence that the blast wave was braking against very dense gas, such as would be found in regions where new stars were forming. The results support the hypernova model of GRBs, in which the explosion of an extremely massive star produces an enormous blast of material. This fireball expands at relativistic speeds. The observations were made using NASA's Chandra X-ray observatory and the Italian-Dutch BeppoSax observatory.

Meanwhile, astronomers using the Parkes radiotelescope in Australia have found 30 young pulsars, counterparts of otherwise unidentified galactic gamma-ray sources. Previously, seven gamma-ray sources had been identified with pulsars. Pulsars are neutron stars formed by the collapse of massive stars during supernova explosions. Their intense magnetic fields are expected to make them prolific sources of high-energy radiation.

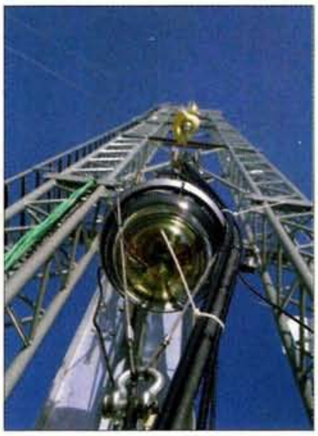
Picture of the month

This Hubble Space Telescope image shows the Whirlpool galaxy's spiral arms and dust clouds. The gravitational influence of a companion galaxy is triggering intense star formation, shown by the numerous clusters of bright young stars highlighted in red. (NASA/ESA.)

The observatory at the end of the Earth

Physics student Torsten Schmidt of DESY Zeuthen regularly undergoes the ultimate terrestrial physics experience – living and working at the South Pole with the AMANDA neutrino experiment. In this interview, he describes polar life.

In September 1997, PhD student Torsten Schmidt began working at DESY Zeuthen, near Berlin. Three months later he was visiting the realm of perpetual ice at the South Pole. The 30-year-old has now been to Antarctica four times to help to build the neutrino telescope AMANDA-II, most recently in December 2000. *CERN Courier* asked him about his experiences.



Left: an optical module of the AMANDA neutrino detector being lowering into the Antarctic ice. Right: physics under Antarctic conditions – deploying a photomultiplier at AMANDA.

Is it difficult to endure three to four weeks at the Pole?
It varies from person to person. I really like it there. Four weeks is a good time limit. As far as life at the station goes, you could hold out for longer, but since you go down there to work, you keep working more or less continuously for the whole four weeks.

So there's no time left to have a look around?
There isn't much to see there, actually. It's flat, cold and there are at most two "sights" worth seeing: a crashed aeroplane at the end of a runway, which is a trip of two to three hours; and a ski cabin about 10 km away – but trips there will be prohibited next season.

Why is that?
The pole is run by a company, and the company – for whatever reason – has stopped allowing people to go there.

So a company runs the South Pole?
To be more exact, the company was hired by the US National Science Foundation to take care of transportation, logistics and operations. NSF is the real host of the Amundson-Scott station and determines the various science programmes at the Pole.

Another example of a prohibited location is the old station, which was abandoned in the early 1970s. It's located in the so-called dead sector, which in reality means that anyone who goes there will be on the next plane north and won't be allowed back to the Pole ever again. It's simply too dangerous there. The station has been standing there deserted for over 30 years. It's covered with snow and ice and could collapse at any time.

AMANDA in the ice

The Antarctic Muon and Neutrino Detector Array (AMANDA) consists of 667 photomultipliers buried in the 3 km deep glacier ice cover at the South Pole.

Neutrinos interact only weakly with other particles, so they can penetrate enormous amounts of matter and therefore have the potential to convey astrophysical information directly from deep inside the most cataclysmic high-energy regions. In a recent article in *Nature* (March 22; see also *CERN Courier* May p14), the AMANDA collaboration reported the detection of more than 200 highly energetic neutrinos that had been generated in the Earth's atmosphere.

Searches for neutrinos from celestial accelerators such as active galactic nuclei, gamma-ray bursters, magnetic monopoles, supernova collapses and cold dark matter signals from the centre of the Earth are in progress, and, with only 138 days of data taken in 1997, yield limits are comparable to or better than those from much smaller underground detectors that have been in operation for many years.

The results obtained establish that this technology could be used to create the ultimate large-scale neutrino observatory.

Isn't it much too cold, in the winter at least, to do any work outside?
Well, it does get very cold, but in the first few weeks after the last plane left there were days when it was only -40 °C. Deepest winter temperatures are around -80 °C.

Is the new station right at the Pole?
Yes, but so was the old one at one time. The ice actually moves about 10 m each year. So every year on New Year's Eve, the "new" South Pole is measured, and on New Year's Day a post is driven into the ice at that point. That's always a big party for the whole station.

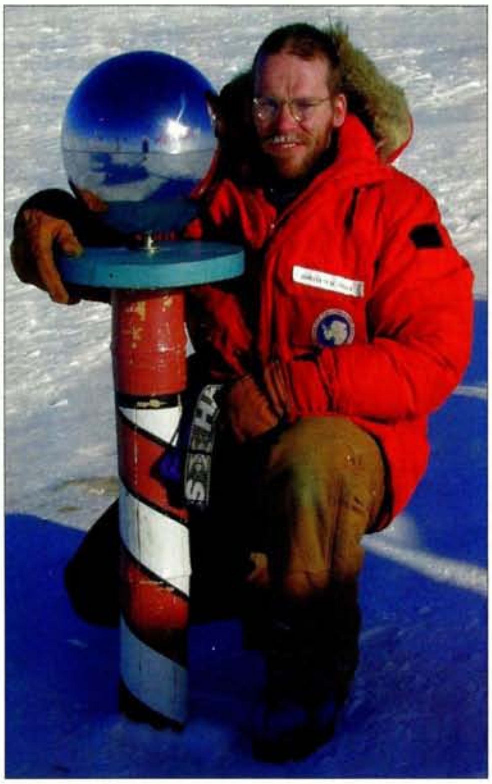
There are, in general, many social events. One might think that it's boring and lonely at the Pole, but that's not true. There's something going on every day. That's because only 50 of the 250 people who live there are scientists. The rest are "support" people: electricians, roofers or crane operators, both men and women. They work their 8 to 10 hours a day and then they're done – unlike us researchers. And, of course, they want to enjoy their leisure.

So there are weeks and weekends. What about days and nights?
There is, so to speak, a day and a night for the support people because of their shifts, but there are no routine hours for us researchers. Of course, when work is done in the group, a time has to be agreed upon, but otherwise you're completely free in that regard. You can't sleep much anyway because the sun is always shining, but there are hot meals every six hours.

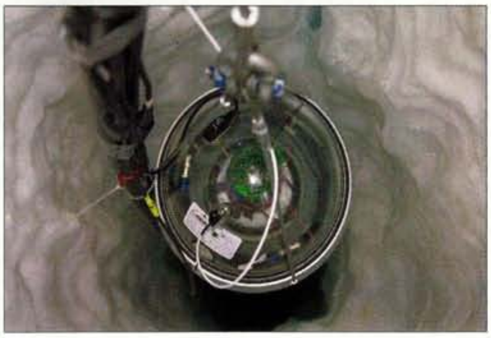
I can live any way that I want, which is something I like very much. If I don't have to work with other people, then I work for as long as I can, and then go to sleep and lose all sense of time in a flash.

How many hours do you work and sleep in that kind of system?
On average, it's 12–15 hours of work a day, but if necessary we can work for as long as 30 hours non-stop. After that come five hours of rather fitful sleep. It's hard to rest any longer. We sleep in huge military tents with about 20 people in each. And since it's always daytime, there's no regular lights-out time either.

The result is that people are constantly trudging through the tent in heavy boots and slamming the door. Outside, aeroplanes are landing around the clock. You really have to be dead tired to be able to sleep at all.



Dedicated research – Torsten Schmidt at the "ceremonial" South Pole.



The AMANDA detector slides into the ice.

The tents must make the place look like a campsite.
Actually, the Amundsen-Scott station is a high-tech place, with a huge metallic dome and several elevated houses. The summer population, however, lives in those 20–30 tents. In the middle is the bathhouse, which includes a very well frequented toilet – the reason being that the dry air means you need to drink as much and as often as possible. But it's unpleasant when you've just lain down to sleep and then have to go outside again – in your whole outfit including trousers, boots and anorak. How often have I cursed that toilet! Some people avoid the trip and put a bottle next to their beds.

What other problems does the Pole novice have to reckon with?
Along with the small amount of sleep, there's also the physical strain because of the high altitude. After all, the station is nearly 3000 m above sea level. The air is thin, cold and dry, and you become dehydrated very quickly.

Things are particularly bad in the first few days: every step is a strain; you collapse into bed wearily but still can't sleep. Even the small climb of 5 m at the exit of the winter camp makes newcomers break into a sweat.

After the weariness has faded, you live very well at the Pole for a few weeks, but then you start to feel the lack of sleep and the exhaustion from the work. At that point it's time to begin the trip home.

Are there moments that allow you to forget all of the exertions of polar life?
One particularly nice social event is Christmas, of course. Christmas at the Pole is really good fun. On Christmas Eve the Americans organize a party. On Christmas morning there's the "race around the world" – three laps around the South Pole. After that comes the Christmas meal, which is actually served three times because the team is so large.

New Year's Eve is naturally a big celebration too. Last time some of the hard-core types even celebrated the New Year in a different time zone every hour – that's possible at the Pole.

Other highlights last season were bocci-ball and golf. We also go to the sauna at least once a year and then run around the South Pole almost naked.

Alright then, enjoy your next trip to the Pole!

LHC lattice magnets enter production

With the start-up of CERN's Large Hadron Collider just five years away, the laboratory's new flagship accelerator is moving firmly from prototyping to production. R&D is coming to an end and contracts for magnet production are being placed.

The prototyping of the main dipole magnets for the LHC reached a conclusion last year with successful tests of the final prototypes, manufactured in a collaboration between CERN and industry. All dipoles delivered to CERN from now on will be installed in the new accelerator. Dipole prototyping began in 1990 when the machine's design called for 10 m magnets with a 50 mm aperture and a field of 8.6 T. The initial plan was for all of the prototyping to be carried out in industry, and work was soon under way in five companies.

A short straight section, containing a prototype LHC main quadrupole, on its testbench at CERN.

By 1995, however, it had become apparent that a closer working partnership between CERN and industry was needed for the R&D phase. From then on, collared coils were produced in industry, while assembly and cryostating were carried out at CERN. A hydraulic press was installed at the laboratory to precompress and curve the complete assembly during the welding of the magnets. By this time, two of the initial companies had withdrawn, leaving France's Alstom-Jeumont consortium, Germany's Noell, and Italy's Ansaldo still in the running.

Lattice redesign

A redesign of the LHC lattice soon emerged: the dipole length was increased to 15 m to allow a greater operational margin with a field of 8.3 T and an aperture of 56 mm. Two full-scale prototype collared coils were ordered from each company, and these were assembled into magnets at CERN during the course of 1999 and 2000. All worked satisfactorily, achieving the required field with little training. The second magnet from Alstom-Jeumont performed particularly well, reaching 9 T with just a single quench. It also displayed good enough field quality to be used in the accelerator.

Lessons learned from these final prototypes were quickly fed back to the three manufacturers, all of which are now producing a preseries batch of 30 magnets each. The first of these, produced in a collaboration between Alstom-Jeumont and CERN, confirmed the excellent behaviour of the prototype. A close relationship between CERN and industry is being maintained for the start of this phase of production, with industry personnel being based at CERN to assemble the collared coils into magnets. The ultimate goal, however, is for the full production process to be transferred to industry. To this end, CERN has installed a press at each of the three companies. These differ from the one at CERN in that the welding procedure will be automated, whereas at CERN a manual procedure was implemented to give maximum flexibility.

By 1995 it had become apparent that a closer working partnership between CERN and industry was needed

Preseries dipole production will be complete by mid-2003. The call for tender to allocate the remaining production of 1158 magnets was launched in May, with contract adjudication expected for September. When full-scale production gets under way, a second coil-winding and curing line is scheduled to ▷

Above: members of the CERN and Alstom–Jeumont teams with the first LHC preseries dipole magnet in October 2000. Right: the LHC's first two preseries sextupole corrector magnets.

be installed at each company, bringing the total production capacity to 10 magnets a week. The last dipole is scheduled to arrive at CERN in July 2005.

Dipoles, however, are not the first LHC magnets to receive the production green light. That honour belongs to the 2464 sextupoles that will correct for slight field imperfections at the extremities of the dipoles. These have been developed by CERN in collaboration with India's CAT laboratory, resulting in an efficient, low-cost design and two patent applications for ingenious construction methods.

One – a so-called diaphragm centring system – could be used for holding wheels on axles, for example. The other is for an automatic coil-winding machine. Production is to be shared between the Kirloskar Electric Company of Bangalore in India and Spain's ANTEC, with the Indian consignment forming part of India's in-kind contribution to the LHC project. A first preseries production of 10 magnets each from India and Spain was tested at CERN in 2000, with a second batch expected soon. Most have performed entirely within specification. These preseries sextupoles have paved the way for full-scale production to start in the middle of this year and the green light has already been given to one of the two firms.

Octupole and decapole magnets will also be used to correct for field imperfections. Fewer are needed because only one in two of the LHC's main dipoles will be equipped with them. Their production is also shared between an Indian and a European firm – Crompton Greeves and Tesla Engineering respectively. Ten pre-series magnets from each company are expected to undergo acceptance tests at CERN before the middle of the year, and the go-ahead for series production should follow a few months later. Like the dipoles, the LHC's main quadrupoles are also equipped with corrector magnets. Here the aim is to steer and control the beams precisely. These correctors – dipoles, quadrupoles, sextupoles and octupoles – have now all been ordered from industry. By the end of this year, CERN engineers expect to have a full bouquet of corrector magnets under test.

Sextupoles have been developed by CERN in collaboration with India's CAT laboratory, resulting in an efficient, low-cost design and two patent applications for ingenious construction methods.

A total of 392 short straight sections will house the LHC's main focusing quadrupoles, along with other beam-correcting magnets. The main quadrupoles have been designed and prototyped by France's CEA laboratory at Saclay, which will also be responsible for the technical follow-up in industry. Their integration into fully equipped short straight sections has been taken care of by the neighbouring CNRS-IN2P3 laboratory at Orsay. The contribution of both laboratories is part of France's host-state contribution to the LHC project.

Short and straight

From 1989 to 1994, CEA-Saclay designed, constructed and successfully tested two prototype quadrupoles to an early design. A further three built to the present LHC design were made and tested between March 2000 and January 2001. All showed highly satisfactory behaviour, with at most one quench on their way to a nominal operating current of 11 870 A, corresponding to a field gradient of 223 T/m. After thermal cycling, all "remember" their training. Moreover, their measured field quality meets expectations, indicating that the design fulfils all requirements for LHC operation.

The German firm Accel has won the contract for producing the quadrupoles, and engineers from Saclay are currently transferring their tooling from France to the Accel plant near Cologne. The first series production quadrupole is expected at CERN by the end of the year. Other magnets and components for the short straight sections will come from all over Europe, leading to a complex logistical puzzle for CERN. The company Balcke-Dürr in Germany has been awarded the contract for constructing the cryostats and assembling the short straight sections.

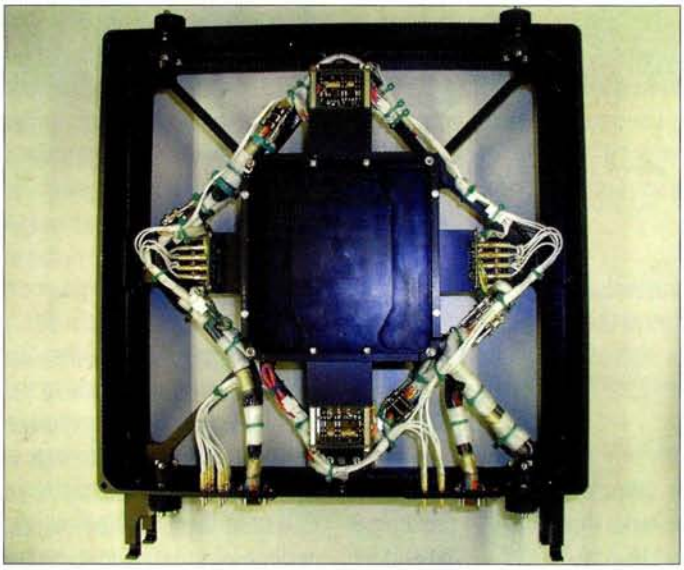
In addition to the LHC's main lattice magnets, a large number of specialized magnets, known as insertions, will be employed at the LHC. These will perform specific tasks, such as injecting and ejecting beams, and providing the final focus before the collision points. The LHC's insertions will be the subject of an article in a future issue of *CERN Courier*. □

Can gas detectors still compete with silicon?

The big topic of debate at the 9th Vienna Conference on Instrumentation held in February was whether gaseous detectors can still compete with semiconductor technology. This conference series offered the perfect forum to discuss the latest developments.

Whether to bank on techniques with gaseous detectors or to go for alternative modern semiconductor technology is a continual dilemma in experiment design. To enable delegates to draw their own conclusions, a new approach was adopted for the invited talks at the recent Vienna Conference on Instrumentation.

In the past, the invited talks have concentrated mainly on classes of detectors (e.g. calorimeters), but this time they also included overviews of detector systems dictated by the type of accelerator to be used; e.g. B-factories (D R Marlow, Princeton) and triggering at LHC experiments (W H Smith, Wisconsin).



The telescope cassette of the Prototype Synchrotron Radiation Detector for the Alpha Magnetic Spectrometer space experiment. Its two plastic scintillators are each read out by two photomultipliers. The scintillators and lucite light guides are in closed aluminium cases with venting channels. The photomultipliers and the triple layer of circuit boards are embedded in the structure and secured by aluminium hoods. Note the typically neat cable layout of space applications.

Gaseous detectors still strong

The first Vienna conference, held in 1978, concentrated exclusively on gaseous detectors. However, as gaseous detectors began to be used as parts of complex subdetectors, such as calorimeters or ring imaging Cherenkovs, or for functions such as rate of energy loss, the remit of the conference was extended to include wire chambers and alternative techniques.

With the advent of silicon detectors, the conference began to focus more and more on general instrumentation. Contributions to the first conference had been almost exclusively on high-energy physics (with a few exceptions on medical applications). Now, however, the scope of the conference has grown to incorporate nuclear physics, synchrotron radiation and neutron experiments, astrophysics, biology, medicine and associated electronics. This change was reflected in the renaming of the conference, to the Vienna Conference on Instrumentation.

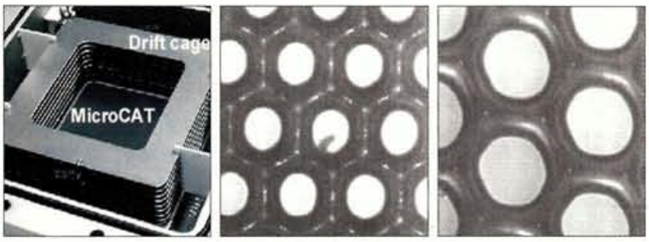
However, gaseous detectors are still very actively discussed at the conference, with the majority of new developments presented this year dealing with micropattern detectors. The first session on micropattern gas detectors opened with an invited talk by R Bellazini (Pisa) who gave a comprehensive overview of the various structures. The ingenuity of this community is amazing, with an overall trend towards the de-coupling of amplification and readout, e.g. the gas electron multiplier (GEM) plus the microstrip gas chamber, or the GEM plus the micro-groove. The most exciting prospect for future developments could be pixel readout structures for these kind of devices.

Several of the conference talks and posters showed results from multi-stage detectors, with two or more amplification layers being suggested as a possible way to achieve a high gas gain with a low discharge probability (low spark rate). J Va'vra (SLAC) clearly held the record at this year's conference, with results on single electron detection with a quadruple GEM detector.

The Micromegas detector was the subject of the invited talk by G Charpak. This attractively simple detector is already used for several applications, for example in the COMPASS experiment ▷

A thin silicon sensor (67 μm thick) used as a beam counter for antiprotons at the ATHENA experiment at CERN (P Riedler, Zürich). The counter is installed in vacuum at 10 K and a magnetic field of 3 T.

A truly intercontinental coffee break: the regional spread of attendance at the Vienna conference has greatly increased.



View of the pressure chamber of a MicroCAT detector developed for X-ray imaging in material science, biology and medicine (A Orthen, Siegen). In such a detector, the insulator of a normal CAT (compteur à trous) is removed, leaving a micromesh.

at CERN. The Micromegas detector developed for this experiment (A Magnon, Saclay) has an active area of $0.4 \times 0.4\ m^2$ and achieved a position resolution of 75 μm in a high-intensity beam with negligible spark rate.

Silicon detectors have their day

A full day was devoted to silicon detectors, beginning with an overview by H Dijkstra (CERN). The talks that followed presented prototype work for strip detectors for LHCb (P Collins, CERN) and for drift detectors for ALICE (E Crescio, Torino). The news from L Casagranda (CERN) that silicon detectors cooled to cryogenic temperatures can withstand fluxes of more than 5×10^{14} ions/cm^2 and still deliver sufficiently high signals was particularly exciting. And Y Gornushkin (Strasbourg) presented a brand new development on monolithic active pixel sensors.

Naturally, the two large multipurpose CERN LHC experiments, ATLAS and CMS, which are beginning production of their very large silicon trackers, were well represented. P Riedler (Zürich) described the application of very thin silicon detectors, just 5–70 μm thick, used in the ATHENA low-energy antiproton experiment as a beam counter.

On 24 February, a satellite workshop concentrated mainly on applications in radiology and monitor systems for teletherapy in radio-oncology with protons and heavier nuclei, which is of increasing interest in view of the Med-AUSTRON project (December 1998 p24).

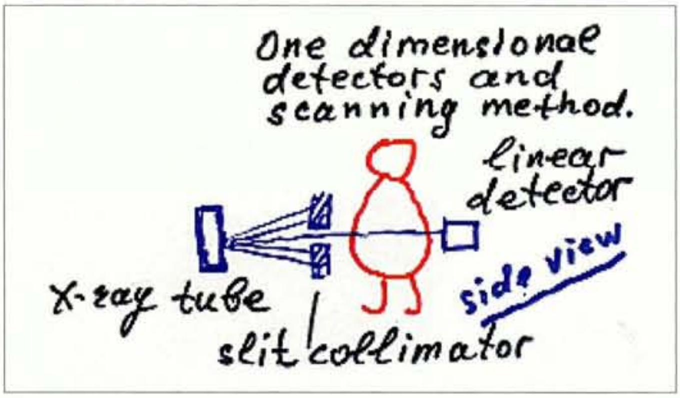
Judging by the latest developments as presented at Vienna, the answer to the question of whether gas detectors can compete with silicon is probably that both gas and silicon detectors are required to build an up-to-date high-energy physics experiment. However, it is clear that there are two areas in large experiments where each technology is superior to the other. Firstly, semiconductor detectors perform better very close to the interaction region, where a precision of a few micrometers is required and the radiation is extremely high. But at large radius where large areas have to be covered, e.g. the muon chambers, it is unrealistic to use anything other than gas detectors.

It is in the intermediate region between about 20 cm and 2 m radius where the two technologies meet as rivals. From the presentations given in Vienna it became clear that silicon and micropattern gas detectors fulfil all the necessary requirements concerning precision, rate capability and radiation hardness. And, from the many comments made, it seemed that participants were split into two factions: the cautious, who don't accept a single spark over the detector's lifetime – an attitude which drives them towards spending their money on silicon; and the bold, trying to convince the audience that a very small spark rate in a gas detector is fully acceptable for a large system.

For the LHC experiments now under construction, this debate is over, but it will be interesting to see how further developments will influence the detector layout of future experiments.

A brief history of the Vienna series

The Vienna Wire Chamber Conference series was first mooted in 1977 when it was realized that there was a real need for such a conference. (There was only one detector conference in 1977, in Novosibirsk, Russia, but none in Europe.) A total of 170 people took up our first invitation to Vienna, and nobody thought that 23 years



A sketch explaining the scanning method for digital radiography, shown by S E Baru (Novosibirsk) during the satellite workshop on applications in Vienna.

later we would be fixing the date for the 10th Vienna Conference for February 2004.

The number of participants rose to a maximum of 300 at subsequent meetings, although in February 2001 this dipped to 250. The main reasons for this were that support from the European Union has become more restrictive, and several participants cancelled when their contributions were not accepted. In addition, there are now several competitive conferences each year, and US researchers have travel budget restrictions. Despite this, the regional spread of attendance was wider this year, in terms of region as well as nation of origin. Russia, for example, had a strong delegation from St Petersburg.

The selection process

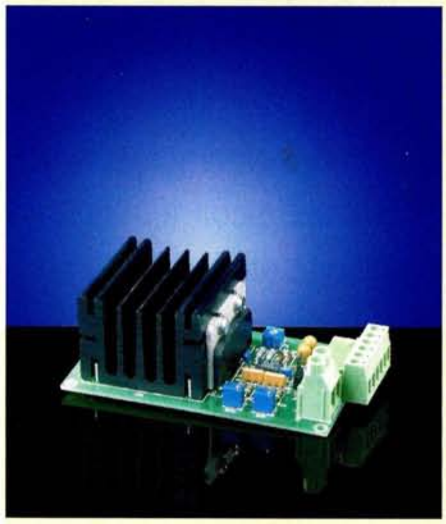
It is a strict rule at the Vienna Conference that all contributions (talks and posters) have to be accepted by the International Scientific Advisory Board. All material was sent to the members of this committee three months before this year's conference; six weeks later, a meeting was held at CERN to make the selection. Members who cannot attend this part of the process can give their judgment by mail, and all efforts are made to discuss by telephone before the final decision is made.

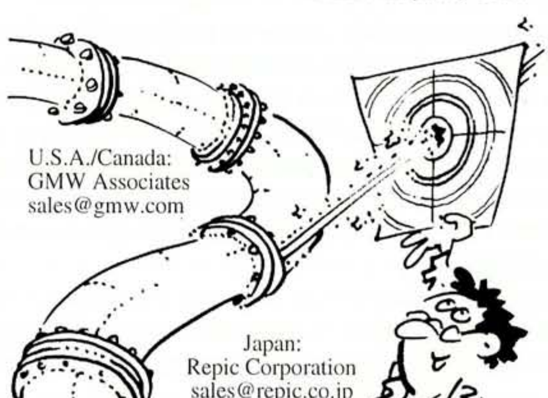
Applications for financial support (e.g. from the Exchange Programme of the Austrian Academy of Sciences, the European Physical Society, or the Austrian Ministry of Education, Science and Culture, with support from the organizers) are totally independent of acceptance for publication.

Transparencies of the talks were scanned and made available immediately at "http://wcc.oeaw.ac.at/". The draft papers of all talks and posters will also be put on the Web until the final proceedings – a consecutively numbered volume of *Nuclear Instrumentation and Methods*, as usual – become available in the late autumn.

The memorable concert by a string quartet in the Great Hall of the Austrian Academy of Sciences was dedicated to the history of music in the hall, and a CD of the concert, mastered overnight, was given as a souvenir to all participants. The organizers (M Jeitler, M Krammer, G Neuhofer, M Regler) are very much looking forward to the 10th Vienna Conference in February 2004.

M Krammer *and* **M Regler**, *Vienna.*





TESLA project goes public

The DESY laboratory in Hamburg recently published plans for a superconducting linear electron-positron collider: TESLA. This article amplifies these ambitious plans and outlines the objectives of the project.

At a major event held at the DESY laboratory in March (May p6), the international TESLA collaboration, together with the members of various study groups, released the TESLA Technical Design Report. This five-volume opus presented the final facts and figures concerning a grand plan for the future: the "TeV-Energy Superconducting Linear Accelerator", a 33 km electron-positron linear collider with an integrated X-ray laser laboratory.

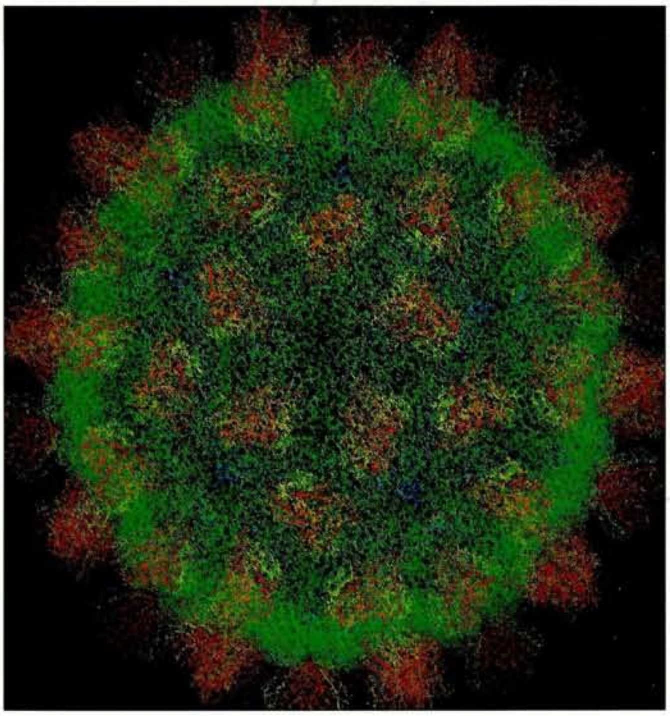
To be built near the DESY laboratory in Hamburg, the facility would not only provide particle collision energies of 500 GeV - which could be increased to 800 GeV - but also include powerful X-ray lasers that would open up new research opportunities in a variety of fields, ranging from condensed matter physics through chemistry and material science to structural biology.

It is widely acknowledged among particle physicists that a linear accelerator colliding electrons and positrons is the ideal machine to complement CERN's Large Hadron Collider, which is due to start operation in 2006. As well as the TESLA collaboration, plans for similar next-generation linear electron-positron colliders are being worked on by other teams.

SLAC in the US and KEK in Japan are jointly developing two similar designs - known respectively as the Next Linear Collider and the Japan Linear Collider - which could be ready for construction at around the same time as TESLA. CERN is also working on a next-generation collider, CLIC. However, the TESLA proposal is the first to be fully costed and made public. It is also the only project to include an X-ray laser laboratory and thus to address a large interdisciplinary research community.

Resources needed

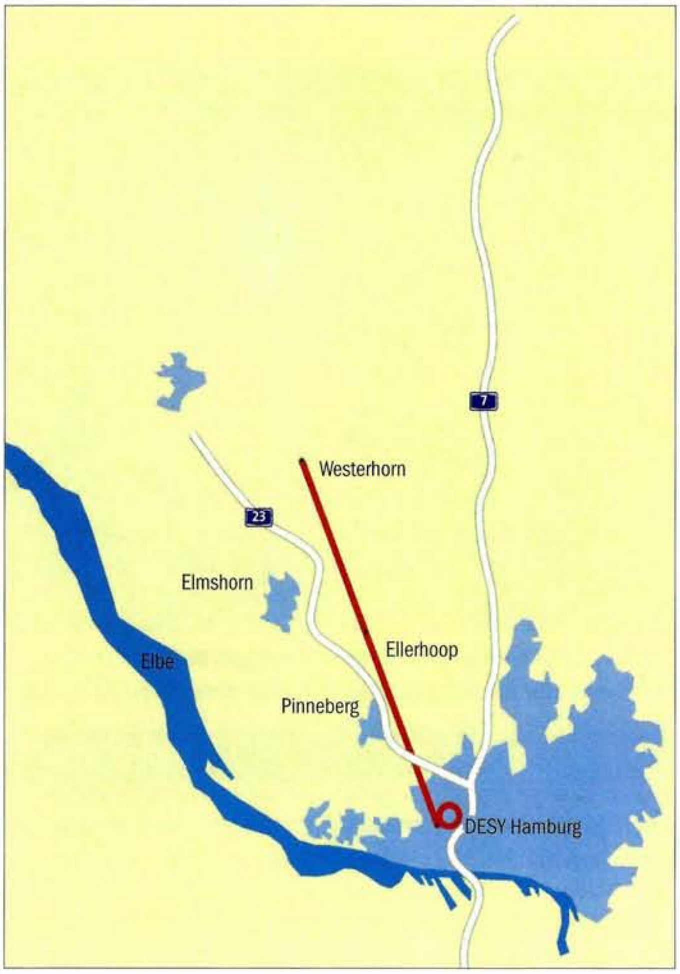
More than 1100 scientists from 36 countries have contributed to the 1424-page report, which describes the scientific and technical details of TESLA, including cost estimates and time schedule. Based on the experience gained in building the TESLA test facility at DESY and on industrial studies, the cost of the TESLA project in its baseline design of 500 GeV has been estimated at a total of €3877 million spread over a period of 10 years: €3136 million is earmarked for the 500 GeV electron-positron collider, €241 million for the accelerator components for the X-ray free electron laser, €290 million to equip the X-ray free electron laser laboratory and €210 million for one detector for particle physics. The costs are based on prices for the year 2000. The person-years required to build the accelerators amount to 7000, and the total costs for the operation of the accelerators have been estimated at €120 million per year, assuming current prices and an annual operation time of 5000 h. Staff costs are not included in this evaluation.



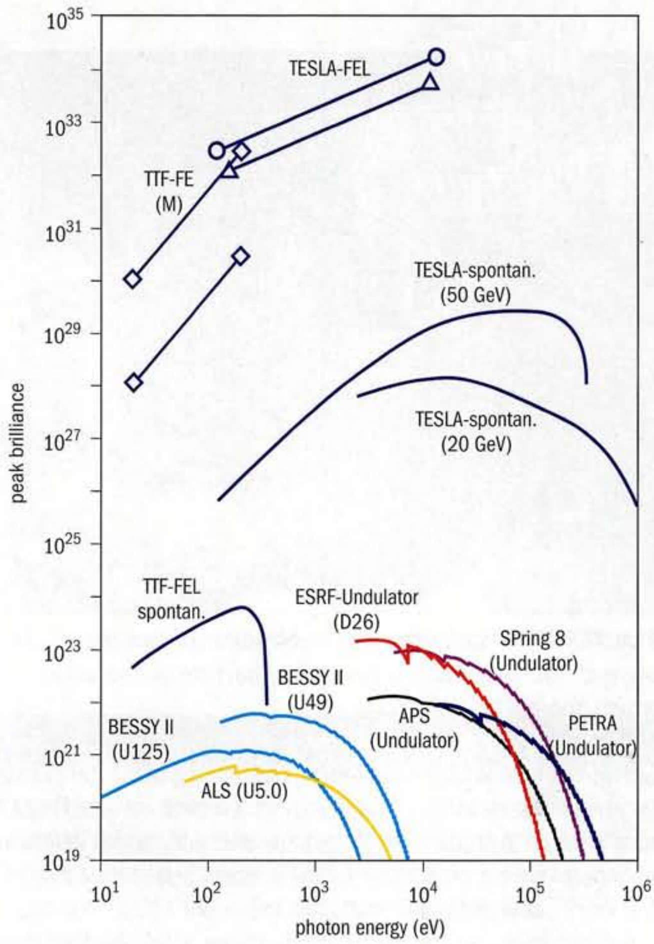
Numerous computer programs and procedures had to be used to translate the recorded synchrotron radiation diffraction patterns of the Tomato-Bushy-Stunt-Virus (TBSV) into this three-dimensional electron density map, which then yields clues as to the exact structure of the molecule. With their large numbers of photons per pulse, their very short pulsewidth and the possibility of focusing the laser beams onto extremely small focal spots, the X-rays from the TESLA free electron lasers will open the way for diffraction from single virus particles, in which case crystallization is not needed.

The size and complexity of the TESLA endeavour means that it requires international input. From its onset in 1992, therefore, TESLA was planned and developed by members of a sizeable collaboration that now comprises 44 institutes from 10 countries. The intention is to build and operate TESLA as an international project for a limited duration, initially of 25 years.

As a possible model for the realization of TESLA as an international co-operation, the collaboration has proposed using a "Global Accelerator Network" of many existing accelerator and research centres, which would allow the facility to be maintained and run, to a large extent remotely, from the participating laboratories (June 2000 p19). This approach would allow participating



The tunnel for the TESLA particle collider runs at a depth of between 10 and 30 m below the ground and has an inner diameter of about 5 m. It reaches from the DESY site in Hamburg Bahrenfeld (0 km) to Westerhorn (32.8 km) in the German federal state of Schleswig-Holstein.



This comparison of current third-generation synchrotron radiation sources worldwide shows the dramatic leap in peak brilliance offered by the TESLA project. Already the free electron laser included in the TESLA Test Facility (TTF-FEL) will exceed peak and average brilliance of current radiation sources in the energy region up to 200 meV by orders of magnitude. The free electron lasers integrated into TESLA would produce X-rays of the highest brilliance in the 0.1 nm wavelength range. (ALS, APS, SLAC/LCLS: US; BESSY-II, PETRA: Germany; ESRF: France; SPring 8: Japan.)

institutes to share the responsibility for the facility as a whole. It would effectively allow the project to draw on worldwide skills, ideas, manpower and financial resources, with site selection becoming a less critical issue. In this approach the host country would carry roughly half of the investment cost.

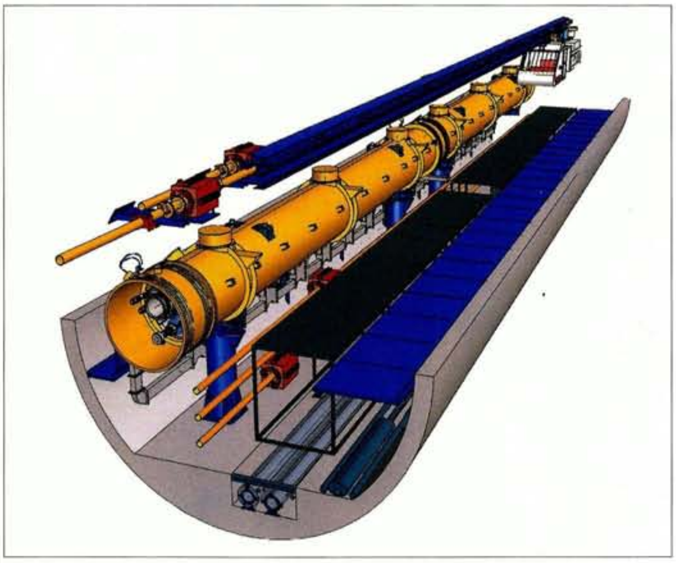
Particle physics

In its baseline design, the TESLA electron–positron linear collider will reach a centre-of-mass (collision) energy of 500 GeV, five times as high as that of the first linear collider, SLC at Stanford, and 2.5 times as high as that of LEP at CERN. At the same time the luminosity of TESLA – a measure for the event rate a collider can deliver – is about 1000 times as high as that of LEP at 200 GeV ($3.4 \times 10^{34}\,cm^{-2}\,s^{-1}$). In a second phase, the energy range of TESLA could be extended to about 800 GeV without increasing the length of the machine.

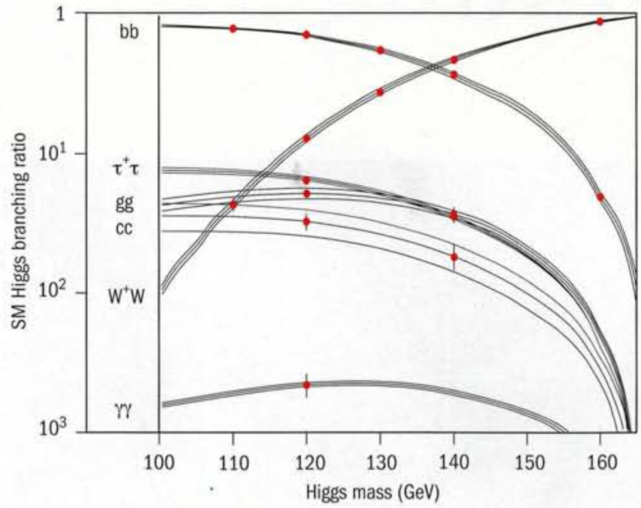
Together with the "clean" and well defined experimental conditions provided by the collisions of point-like electrons and positrons, the energy range and luminosity of TESLA will make it an ideal machine to measure the properties of new particles unambiguously and with high precision. These precision measurements will be essential to complement the experiments being carried out at the world's next flagship machine, CERN's LHC proton collider. A telling example from the past is the Z boson, which was discovered at a proton–antiproton collider, while its properties could be determined with high precision only at electron–positron colliders. These measurements were crucial for establishing the Standard Model. In particular, they allowed an indirect determination of the mass of the top quark prior to its discovery, and are responsible for the present constraints on the Higgs mass.

Higgs exploration

The Higgs boson will play a central role at TESLA. The Higgs mechanism is a compelling way to give the particles a mass: *a priori*, massless particles acquire "effective masses" by interaction with a background medium, the Higgs field. Recently, events observed at the highest energy of LEP have given a tantalizing hint that the Higgs particle might have a mass of around 115 GeV (March p25). The Higgs particle is likely to be discovered at the Tevatron or the LHC. The precise measurements of its properties, however, which ▷



How TESLA will look – the yellow cryostats conceal the superconducting niobium cavities for particle acceleration, which operate at –271 °C.



The predicted branching ratios of the Higgs particle (i.e. the probability for the Higgs particle to decay into different particles) in the Standard Model (SM), as a function of the mass of the Higgs particle. The points with error bars show the expected experimental accuracy that can be obtained after two years of data taking, while the lines show the theoretical values and uncertainties of the SM predictions.

are indispensable for a complete understanding of the mechanism by which masses are generated, require a lepton collider. TESLA is ideally suited to produce the Higgs particle directly and to determine its mass, lifetime, production cross-sections, branching ratios and the way it couples to itself and to the top quark.

A comparison with the predictions of the Standard Model will establish whether or not the Higgs mechanism is responsible for electroweak symmetry breaking and test the self-consistency of the picture. TESLA will achieve a precision of 50 (70) MeV on the mass of a 120 (200) GeV Higgs, and will measure many of the branching ratios to an accuracy of a few percent. The Higgs coupling to the top quark will be measured to 5%. The accuracy of all of these measurements is vital to a full understanding of the origin of mass.

Supersymmetry

Today, particle physics is in an excellent, yet curious, state: although practically all experimental observations are perfectly accounted for by the Standard Model, it is still based on too many assumptions and leaves too many facts unexplained. Supersymmetry is the favoured candidate for an extension of the model. It provides a framework for the unification of the electromagnetic, weak and strong forces at large energies, and it is deeply related to gravity, the fourth of the fundamental forces. Supersymmetry predicts that each matter and force particle has a supersymmetric partner.

TESLA's precision measurements are required to determine the parameters of this supersymmetric theory accurately. By sweeping the well defined centre-of-mass energy of TESLA across the thresholds for new particle production, it will be possible to identify the particles one by one and to measure their masses with very high precision. At LHC, part of the supersymmetric particle spectrum can be resolved. Many final states are, however, overlapping, which will complicate the reconstruction of some of the supersymmetric particles. Therefore, only the combination of the results from TESLA and LHC will provide a complete picture.

The highest possible level of precision is needed to extrapolate the supersymmetric parameters measured at the energy attainable with TESLA to even higher energy scales, where the mechanism of supersymmetry breaking and the structure of a grand unified supersymmetric theory may be revealed. This may be the best way to link particle physics with gravity through an experiment.

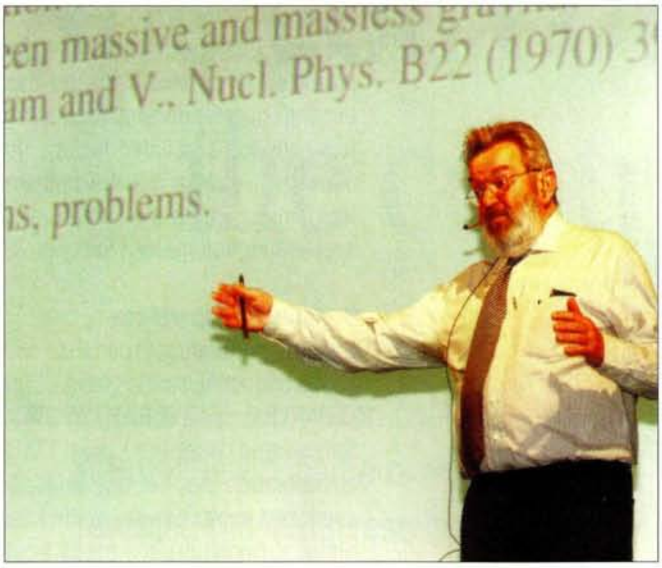
New theories suggest that, at very high energies – such as existed shortly after the Big Bang – all four forces merge to become one single force. The discovery of supersymmetry and the measurements of the properties of supersymmetric particles could provide a glimpse of the underlying fundamental theory.

Also, astronomical evidence suggests that more than 90% of the mass in the universe is invisible and of a type that is totally different from ordinary matter. The nature of this "dark matter" is completely unknown, but supersymmetric particles might provide an explanation. If supersymmetry is indeed realized in nature, these particles will surely be found and investigated in detail at TESLA.

While most of the particle physics programme will be using TESLA as an electron-positron collider, the facility can also be operated to generate photon-photon, photon-electron and electron-electron collisions. The electron beam of TESLA could also be used for other studies in particle and nuclear physics, such as the analysis of the inner structure of the nucleon and the properties of the strong force.

X-ray free electron laser

The X-ray free electron laser laboratory proposed as part of the TESLA project is conceived as a multi-user facility following the experience of existing large synchrotron radiation facilities like HASYLAB at DESY and ESRF in Grenoble. The X-ray laser hall will comprise 20 experimental stations, which could be increased to 30. It is



Left: Martinus Veltman gave a talk on the implications of TESLA for particle physics. Right: the TESLA colloquium on 23–24 March 2001 at DESY in Hamburg attracted around 1000 participants.

Major event

Around 1000 participants – 40 per cent of them from abroad – attended the TESLA colloquium on 23–24 March 2001 at DESY in Hamburg, where the international TESLA collaboration presented the scientific perspectives and technical realization of its planned 33 km electron–positron linear collider with an integrated X-ray laser laboratory.

Netherlands physicist and Nobel prizewinner Martinus Veltman opened the presentations with a profound and entertaining talk on the prospects of TESLA for particle physics. He was followed by the director of the Max Planck Institute for Metals Research, Helmut Dosch, who gave an impressive presentation on the various application possibilities of the TESLA X-ray laser in the fields of physics, chemistry, materials science, molecular biology and medicine. TESLA scientists Reinhard Brinkmann and Jörg Roßbach then dealt with the technical aspects of TESLA. Finally, Albrecht Wagner, chairman of DESY's board of directors, discussed how TESLA would operate as an international project within the framework of a Global Accelerator Network, and he concluded by disclosing the long-awaited details of the planned costs and schedule for the project.

On Saturday 24 March, seven talks were given that covered the whole spectrum of research possibilities with TESLA, from time-resolved studies of chemical reactions, through investigation of surfaces and opportunities in plasma physics and structural biology, to the Higgs boson and Grand Unification.

located near the collider interaction point on the TESLA research campus in the middle of the facility. The TESLA X-ray lasers will make use of the electron beam accelerated in the first part of the linear collider, which will then generate intense beams of X-ray laser radiation via the self-amplified spontaneous emission (SASE) process inside a series of long undulators (July 2000 p26).

X-rays play a crucial role when the structural and electronic properties of matter are to be studied on an atomic scale - particularly when looking at atoms in molecules, in large biomolecular complexes and in condensed matter. They are one of the most important tools in basic science and medical diagnostics, as well as in industrial R&D. The TESLA free electron lasers (FEL) will open up a whole range of new possibilities for X-ray research: they will provide lateral, fully coherent polarized X-rays of wavelengths between 1 and 0.1 nm, and with peak brilliances more than a 100 million times as high as are available today from the best synchrotron radiation sources.

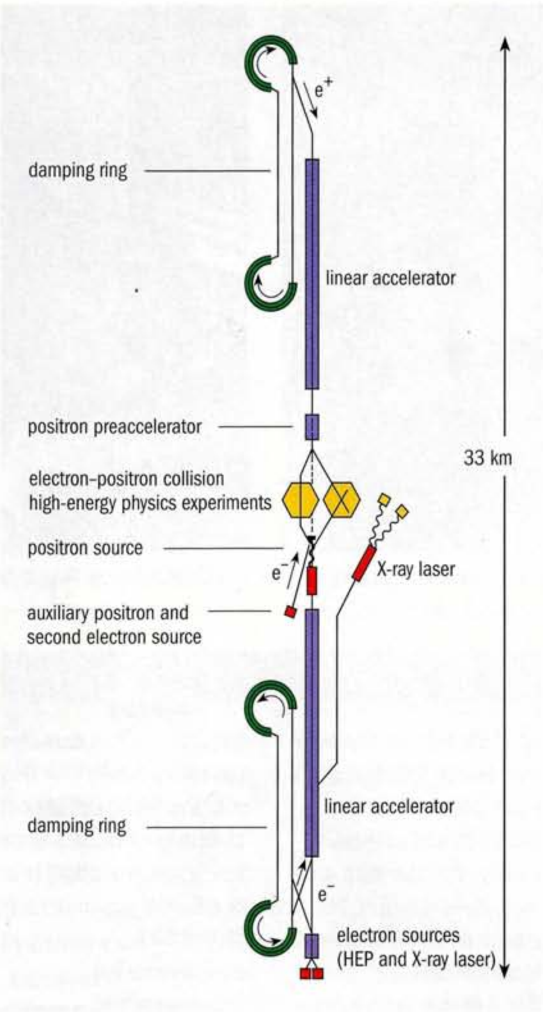
In addition, the X-rays will be delivered in flashes with a duration of 100 fs or less, allowing the observation of fast chemical processes with atomic-scale spatial resolution. Scientists will be able to address challenging questions such as: Can we take pictures of single macromolecules? Can we see the dynamical behaviour of the electrons as they form chemical bonds? Can we make a movie of a chemical reaction or of fast switching in magnetic storage devices? Can we make real-time studies of the formation of condensed matter? Can we follow, for instance, a viral infection in a cell at high resolution?

Nanostructures

Perhaps one of the most challenging, far-reaching applications suggested for X-ray free electron lasers is the imaging of nanometre-scale biomolecular assemblies and the determination of their structure with atomic resolution. The X-ray laser is expected to play an important role in the structural and functional analysis of large molecular complexes, which are crucial to the functioning of cells, but extremely difficult to crystallize and to study using present-day techniques.

In condensed matter physics, traditional techniques such ▷

as neutron scattering or spectroscopy taking place at today's synchrotron light sources, face their limits of applicability for many questions related to the study of novel materials, especially when trying to understand ultrafast processes on a nanometre scale. The X-rays from the TESLA FEL probe the dynamic state of matter and can thus be used to study non-equilibrium states and very fast transitions between the different states of matter. These non-equilibrium states are of eminent importance for the tailoring of material properties in nanoscale devices.



Sketch of the overall layout of TESLA (the second interaction region with crossing angle is optional and not part of the baseline design).

Superconducting technology

The TESLA collider is composed of two linear accelerators pointing towards one another, one for electrons – which will be used in parallel to drive the X-ray FEL – and one for positrons. The TESLA approach differs from other linear collider concepts in its choice of superconducting accelerating cavities as its basic technology. Both the Next Linear Collider and the Japan Linear Collider are based on normal-conducting copper cavities, whereas TESLA uses a total of 21 024 niobium cavities operating at –271 °C, which are fed with pulsed radiofrequency (RF) electromagnetic fields of 1.3 GHz to accelerate the particles.

Superconducting technology provides important advantages for a linear collider. As the power dissipation in the cavity walls is extremely small, the power transfer efficiency from the RF source to the particles is very high, thus keeping the electrical power consumption within acceptable limits (around 100 MW), even for a high average beam power. The high beam power is the first essential requirement for obtaining a high rate of electron–positron collisions, the second being extremely small electron and positron beams at the interaction point.

The low RF frequency of the TESLA linear accelerators is ideally suited to conserving the ultrasmall size of the beams during acceleration, since the interfering wakefields generated by the particle beams are much weaker in the larger cavities of accelerators working at low RF frequencies than in smaller cavities operating at higher frequencies. For the same reasons the superconducting linear accelerator of TESLA is also extremely well suited to driving the X-ray FEL, which also requires an electron beam with large average power, high bunch charge, small energy spread and small beam size.

The benefits of superconducting cavities have been known since the beginning of linear collider research and development. However, the accelerating fields achieved in the early 1990s were too low and the projected costs based on the then existing superconducting installations too high for a collider facility. The main challenge for TESLA was therefore a reduction in the cost per unit accelerating voltage by a factor of 20.

Building on experience

Building on existing experience with superconducting cavities from CERN, CEBAF (Jefferson), Cornell, DESY, KEK, Saclay and Wuppertal, the TESLA collaboration met the challenge: by continued improvements of the base material (niobium), the cavity treatment, and the welding/ assembly procedures, accelerating gradients exceeding 25 MV/m have been reliably achieved. Recently, further progress in cavity performance has been obtained by applying a new surface treatment – electropolishing – to the niobium surface. One-cell test cavities have reached gradients of as high as 42 MV/m, thus paving the way for the operation of TESLA at 800 GeV, which requires gradients of 35 MV/m.

Through numerous design optimizations the costs per unit length of the superconducting structures and the cryostats were reduced by a factor of four for a large-scale production. These achievements – including the successful operation of the TESLA test facility with its test accelerator and FEL for more than 8600 h – now provide the basis for a realistic superconducting linear collider, with all of its advantages.

In preparation for the German position concerning the approval of TESLA, the German Research Ministry has asked the German Science Council (Wissenschaftsrat), which advises the German government in matters of science, to review TESLA together with other large-scale projects.

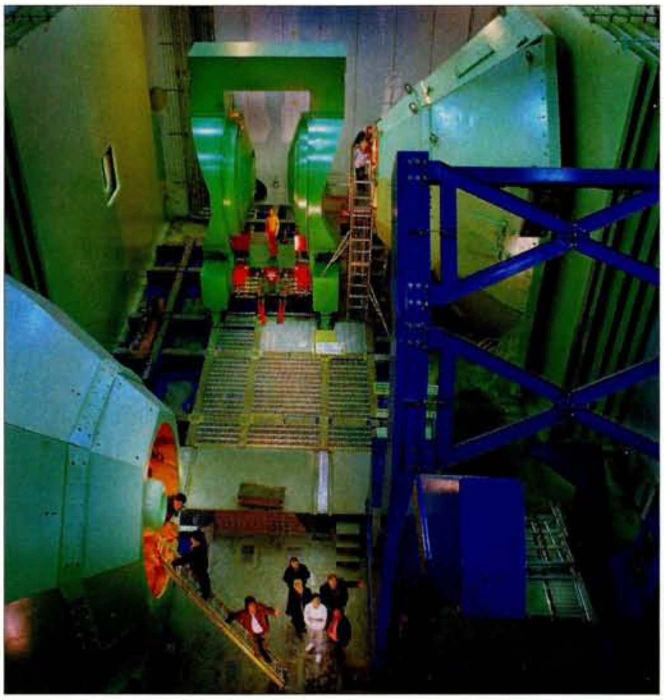
In parallel, a number of international reviews are taking place on a European and worldwide scale, addressing the long-term road map of particle physics, and the scientific potential and the technologies of electron–positron colliders and X-ray lasers. The German Federal Government, the Senate of the City of Hamburg and the Federal State Government of Schleswig-Holstein will then have to come to a decision on the project. Construction is expected to take around eight years, so the TESLA facility could be in operation by 2011.

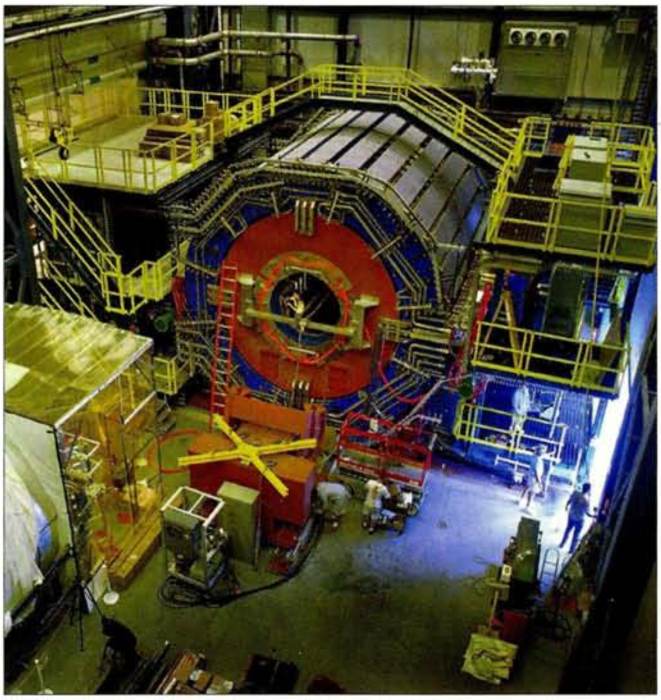
• The full TESLA Technical Design Report is available via "http://tesla.desy.de/new_pages/TDR_CD/start.html".

Ilka Flegel, *DESY.*

Nucleon collisions reach the central plateau

The world's first heavy-ion colliding beam machine, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven, came on line late last year. At a recent conference, RHIC experiments revealed the initial results of exploring nuclear behaviour in this new energy regime.





Left: PHENIX – one of the big detectors at Brookhaven's new RHIC. Right: STAR – another major RHIC player.

Following the commissioning last year of Brookhaven's Relativistic Heavy Ion Collider (RHIC; October 2000 p5), the Quark Matter 2001 conference, held on 15–20 January at the State University of New York (SUNY), Stony Brook, and organized jointly by Brookhaven and Stony Brook, provided the first shop window for results under these new physics conditions.

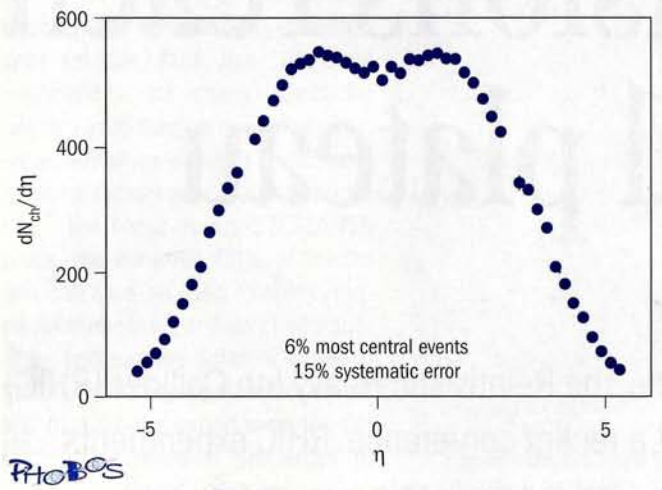
RHIC is the world's first heavy-ion colliding beam machine. In these colliders, the figure of merit is the collision energy per nucleon pair (E/A, where A is the atomic number of the nucleus), and RHIC reaches higher E/A than had previously been possible. The results presented at QM 2001 came from just one month of RHIC running in late 2000 with gold nuclei (A = 197), at E/A = 130 GeV. The machine luminosity, a measure of the collision rate, was $0.2 \times 10^{26}/\mathrm{cm}^2/\mathrm{s}$, which is one-tenth of RHIC's design figure.

Also presented at the meeting were the latest results from heavy-ion experiments at other machines, notably from CERN's fixed target programme at the SPS synchrotron, where E/A ranges from 9 to 17 GeV with nuclei up to lead (A = 208) were recorded, and from Brookhaven's Alternating Gradient Synchrotron, where E/A ranged from 2 to 6 GeV with gold nuclei.

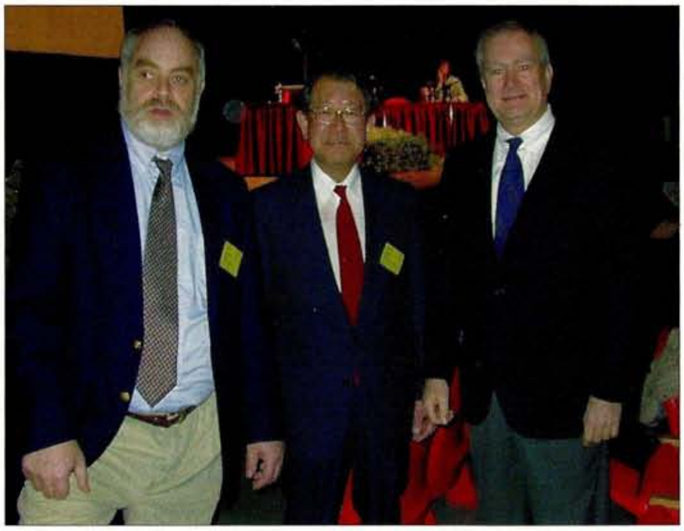
Rising to the central plateau

Nucleus-nucleus and proton-proton collisions should be compared at the same value of E/A. To a first approximation, the overall total particle production (multiplicity) in a nucleus-nucleus collision should resemble A times that of a proton-proton collision. Thus an understanding of nucleus-nucleus collisions in the RHIC requires a similar understanding of comparable behaviour in proton-proton collisions.

In the 1970s, proton-proton collision at collision energies of 20–60 GeV were studied at CERN's Intersecting Storage Rings, ▷



One of the preliminary results to emerge from RHIC gold–gold collisions, as shown at the Quark Matter 2001 conference – charged particle multiplicity versus (pseudo)-rapidity, illustrating the central plateau of ± 2 units. (Courtesy of the PHOBOS collaboration.)



The Quark Matter 2001 conference, run by Brookhaven and Stony Brook. Left to right: conference co-organizer Michael Marx of Stony Brook; Satoshi Ozaki, Brookhaven director's assistant for accelerator projects; and Brookhaven director and former Stony Brook president John Marburger. (Stephen Adler.)

which found a marked change at around 20 GeV.

If the produced particle multiplicity is measured as a function of rapidity, y (a measure of production angle), the multiplicity is symmetric about y = 0 (perpendicular to the colliding beam axis). At 17 GeV, there are about two produced hadrons per unit rapidity at y = 0, where the multiplicity is greatest, and an emerging central plateau, out to y = ±1, with the multiplicity falling to zero by about y = ±2.5. For proton–proton collisions, by 130 GeV there are about three produced hadrons per unit y with a central plateau, this time extending to y = ± 2.

Seeking the central plateau

In nucleus–nucleus collisions under CERN SPS conditions, no such central plateau had yet emerged, the total multiplicity being a single peak around y = 0, falling quickly on either side. At y = 0 there are about 500 produced hadrons per unit y, approximately 50% higher than would be expected from simply A times the proton–proton behaviour.

At RHIC, however, the central plateau becomes evident in nucleus–nucleus collisions. The PHOBOS detector finds that this extends over y = ± 2, in a total distribution going out to y = ± 5. There are some 900 (± 10%) hadrons per unit y at y = 0, again about 50% higher than simply A times the proton–proton behaviour. Theoretical estimates of the produced particle multiplicity at RHIC were generally higher than those found experimentally, although some models (e.g. EKRT and HIJING) were close.

Understanding nucleus–nucleus collisions in RHIC requires a similar understanding of the comparable behaviour in proton–proton collisions

Once the central plateau opens up, the y = 0 behaviour changes dramatically. The fraction of net baryons plummets from 14% at SPS conditions to just 3% at RHIC. The ratio of antiprotons to protons jumps from 0.1 at the SPS to 0.65. This latter figure was found by all four RHIC detectors – BRAHMS, PHENIX, PHOBOS and STAR – and is comparable to the behaviour seen in proton–antiproton collisions.

Can the central plateau be used as a laboratory to measure the behaviour of constituent quarks and gluons? The radius of a nucleus of atomic number A is $A^{1/3}$ that of a proton, so in high-energy nucleus–nucleus collisions one can study proton–proton collisions in a transverse volume up to $A^{2/3}$ larger. As A increases (very large nuclei), so does the transverse volume, and perhaps central nucleus–nucleus collisions reach equilibrium at a certain temperature.

Simulations of quark–gluon field theory (quantum chromodynamics) using a hypothetical lattice (May 2001 p29) show a sudden rise in "pressure" at a critical "temperature" of 175 MeV. The increase above this value is because quark and gluon constituents have many more degrees of freedom than composite particles like pions.

Studying new effects

Are this and other lattice predictions seen in nucleus–nucleus collisions? Even from the thin sliver of RHIC data presented at QM2001, it is clear that there are pronounced differences in the spectrum of produced particles in nucleus–nucleus, compared with proton–proton, collisions.

A change in the spectrum of particle production with transverse momentum is very evident. Above 1.5 GeV, the number of neutral pions found by PHENIX decreases sharply with increasing transverse momentum. STAR and PHENIX find a similar but less dramatic suppression for all charged hadrons. This suppression is always at least 50% of what is expected from A times the proton–proton behaviour.

Explaining this and other gross features is a challenge. At soft momenta, nucleus-nucleus collision behaviour at both RHIC and the SPS differs from the proton-proton case. In this region, particle spectra can be fitted to a thermal distribution with a final temperature related to pion "freezeout" and a relative velocity of the thermal bath. Below about 0.5 GeV transverse momentum, the STAR detector finds that the final temperatures at the SPS and RHIC are about the same – around 100 MeV. The velocity, however, increases sharply.

Elliptic flow, related to asymmetries in peripheral collisions, increases markedly between the SPS and RHIC energies, the corresponding asymmetry parameter increasing from 3.5% to 6%.

Looking for new horizons

Another surprise from January's Quark Matter conference was that system sizes, as measured by particle interferometry, do not change drastically. Classic Hanbury Brown–Twiss interferometry gives an estimate of the size of the system that last emitted two identical particles, such as neutral pions. Radii increase by no more than 10–20% (to about 6 fm) from SPS to RHIC conditions (PHENIX and STAR). However, the "lifetime" of the system is brief and, while some models had predicted that this would increase, at RHIC, big nuclei appear to blast apart just about as fast as they can.

Another criterion of interest is the fluctuation in behaviour on an event-by-event basis. Some signs of this had been seen at the SPS, but at RHIC this appears to increase dramatically.

> Even from the thin sliver of RHIC data presented at QM2001, it is clear that there are pronounced differences in the spectrum of produced particles in nucleus-nucleus, compared with proton-proton, collisions.

At QM 2001, new results also appeared from continuing analysis of the SPS experiments' data, where the anomalous suppression of J/psi particles seen by the NA50 experiment and the change in shape of the dilepton spectrum below the rho peak, seen by the CERES experiment, are notable (April 2000 p13).

For 2001, RHIC is scheduled to run at its full collision energy of 200 GeV per nucleon with gold beams at the machine's design luminosity. Polarized (spin-oriented) proton-proton collisions should also be on the menu. Given the interesting initial results, it is important also that RHIC should increase its energy coverage stepwise, and in the type of beam used, for only in this way can changes in behaviour, such as those already noted, be tracked and explained.

Robert D Pisarski, *Brookhaven*.

PEOPLE

MEETINGS

The **31st International Symposium on Multiparticle Dynamics** will be held in Datong, China, on 1–7 September. The symposium will cover all aspects of multiparticle dynamics, both theoretical and experimental, in various interactions: hadron–hadron; hadron–nucleus; ion–ion; electron–positron; lepton–hadron; and astroparticle physics interactions. For additional information see "http://ismd31.ccnu.edu.cn/".

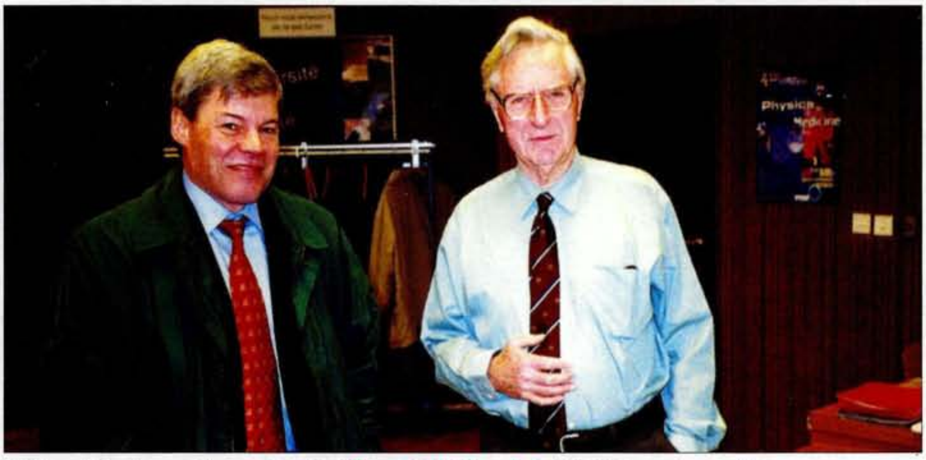
A **Topical Seminar on The Legacy of LEP and SLC** will take place in Pontignano, Siena, Italy, on 8–11 October. Organized by F-L Navarria (Bologna), M Paganoni (Milano), and P G Pelfer (Firenze), it is the seventh in a series devoted to experimental and theoretical results in high-energy particle physics and astrophysics.

The 2001 meeting will focus on what has been learned from electron–positron collisions at the Z energy and at LEP2, in terms of precision measurements and the search for new particles. Progress in physics below the Z energy and the prospects for experimentation at much greater energies will also be discussed.

The seminar will include reviews summarizing different perspectives on the progress that has been made within the major sectors of high-energy particle physics and astrophysics, as well as shorter contributed talks on specific issues. Attendance will be by invitation only and will be limited to approximately 100 physicists. Interested parties should contact F-L Navarria, Dip. di Fisica, V. le Berti-Pichat 6/2, I-40127 Bologna, or e-mail one of the three organizers: "kaos@bo.infn.it", "paganoni@mib.infn.it" or "pelfer@fi.infn.it".

For futher information see "http://www.bo.infn.it/sminiato/pontignano01.html".

Romanian Minister of Foreign Affairs **Mircea Dan Geoana** signs CERN's VIP visitors' book during his visit on 30 March.



Distinguished cosmic-ray physicist **Arnold Wolfendale** (right) has stepped down as president of the European Physical Society after completing the statutory two-year period. His place is taken by **Martial Ducloy** (left), quantum electronics specialist and director of research at CNRS, France.

AWARDS

UK Institute of Physics Awards 2001

Of the UK Institute of Physics Awards for 2001, the Harrie Massey medal goes to **Anthony W Thomas** of Australia's Special Research Centre for Subatomic Structure. Thomas has made outstanding contributions to a variety of problems in nuclear and particle physics, including internationally recognized work on problems ranging from low-energy nuclear scattering to deep inelastic scattering processes.

The Bragg medal and prize goes to distinguished nuclear and particle physicist **George Marx** of Budapest's Roland Eotvos University for a lifetime of achievement in physics education, and the Kelvin medal and prize goes to theoretical physicist and science communicator **Paul Davies** for his outstanding contributions to the popularization of physics.

A working group on Women in Physics organized by the International Union of Pure and Applied Physics met at CERN earlier this year to plan for the first global International Conference on Women in Physics, to be held in Europe in March 2002. Small teams of physicists from about 60 countries are being invited to attend. For further information see "http://www.iupap.org/working.html#women".

Cosmology centre to open at SLAC

A new centre for particle astrophysics and cosmology will soon be established at the Stanford Linear Accelerator Center (SLAC), thanks to the generosity of Dr Pehong Chen, founder and president of the software company BroadVision. In March, Chen donated $15 million to Stanford University to construct a new building for the Pehong and Adele Chen Particle Astrophysics and Cosmology Institute and to create an endowed professorship for its director.

"We anticipate that the institute will serve as a focal point for eminent researchers and visitors," said SLAC director Jonathan Dorfan. "We'll also appoint several fellows to promote the best young talent in the field." The Stanford departments of physics and applied physics will be closely involved in research activities at the institute, a director for which is currently being sought.

- Distinguished Russian physicist Academician Alexander Baldin died just a few months after celebrating his 75th birthday (April p37). A full tribute will appear in the next issue.

Alphonse Capella (centre) of Orsay recently received an honorary doctorate from the University of Santiago de Compostela, Spain "for his contributions to multiparticle production and for his role in keeping very active a long collaboration between Orsay and Santiago in this field". He is flanked by **Carlos Pajares** (Santiago) and University Rector **Dario Villanueva**.

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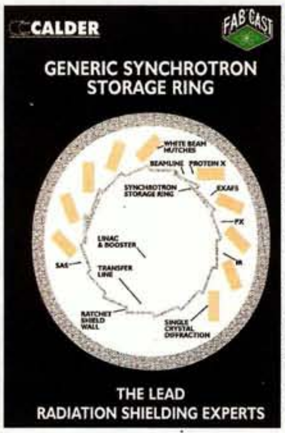

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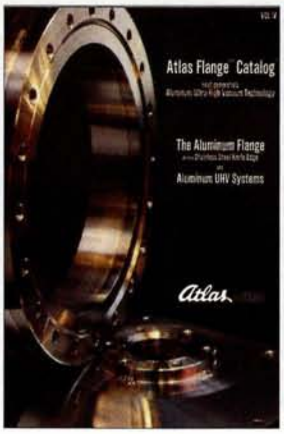

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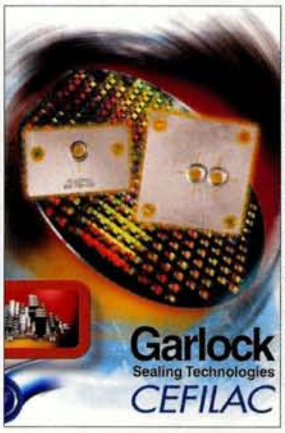

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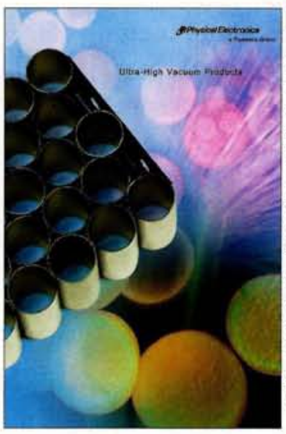

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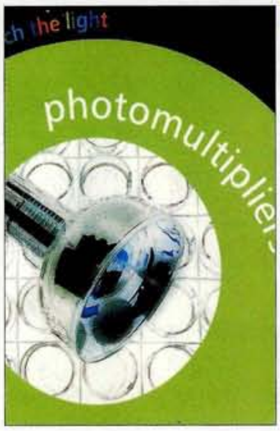

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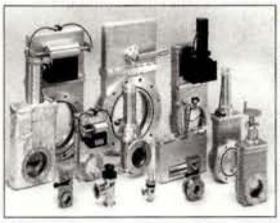

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Applications, including CV, publication list, concise statement of research interests (3 pages or less) and three letters of reference, should be sent by August 31, 2001 to:

Professor Gerard Ben Arous
Chairman of the Search Committee
Department of Mathematics
Ecole polytechnique fédérale de Lausanne (EPFL)
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Prof. Dr. Kay Koenigsmann
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Universitaet Freiburg
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Given equal qualifications, candidates with disabilities will be given preference. Qualified women are strongly encouraged to apply.

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Our group is involved in various aspects of H1 Physics analysis such as structure functions, heavy quark and jet production, heavy vector meson production and search for instantons in QCD. The substantial increase in luminosity will emphasize the physics at high Q^2. We expect the successful candidates to become engaged in one of our upgrade projects and to participate in one of our physics programs.

Our Institute is seeking to increase the number of women in high energy physics. Therefore qualified women are especially encouraged to apply. Applicants with a physical handicap will be given preference, if equally well qualified.

Applications with full CV, statement of research interests, publication list, and names and addresses of three referees, or any inquiries should be made as soon as possible to:

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The Department currently has 49 faculty members and has strong theoretical and experimental programs. Our webpage contains detailed descriptions of the reasearch topics covered.
Applicants should send their curriculum vitae, list of publications, copies of 5 principal publications, statement of research interests, and arrange three letters of reference to be sent to: **Professor Kazuhiko Okuno, Chair of the Search Committee, Department of Physics, Tokyo Metropolitan Unversity, Hachioji, Tokyo 192-0397, Japan**. For full consideration, completed applications should be received by **August 15, 2001**. Inquiry by e-mail may be addressed to **search@phys.metro-u.ac.jp**.

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Qualified and interested candidates should send a resume, with a list of three references, to: M.J. Fultz, Spallation Neutron Source Project, 701 Scarboro Road, MS-6477, Oak Ridge, TN 37830; e-mail: fultzmj@sns.gov. Please reference the job title when applying. Applications will be accepted until the positions are filled.

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Applicants should submit a letter outlining their qualifications and interests and a curriculum vitae, including a list of publications and brief summaries of research interests and accomplishments. Send applications to, and arrange to have at least three letters of reference sent directly to,

Prof. Paul Avery, P.O. Box 118440, Department of Physics, University of Florida, Gainesville, FL 32611-8440, USA,
Questions can be addressed by e-mail to
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Professor Norman Christ, Department of Physics, Columbia University, 538 W. 120th Street, New York, NY 10027

Review of applications will begin on June 15th, 2001 and will continue until the position is filled.

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Professor Laszlo Baksay, Department Head,
Physics and Space Sciences,
Florida Institute of Technology, Melbourne, FL 32901, USA.

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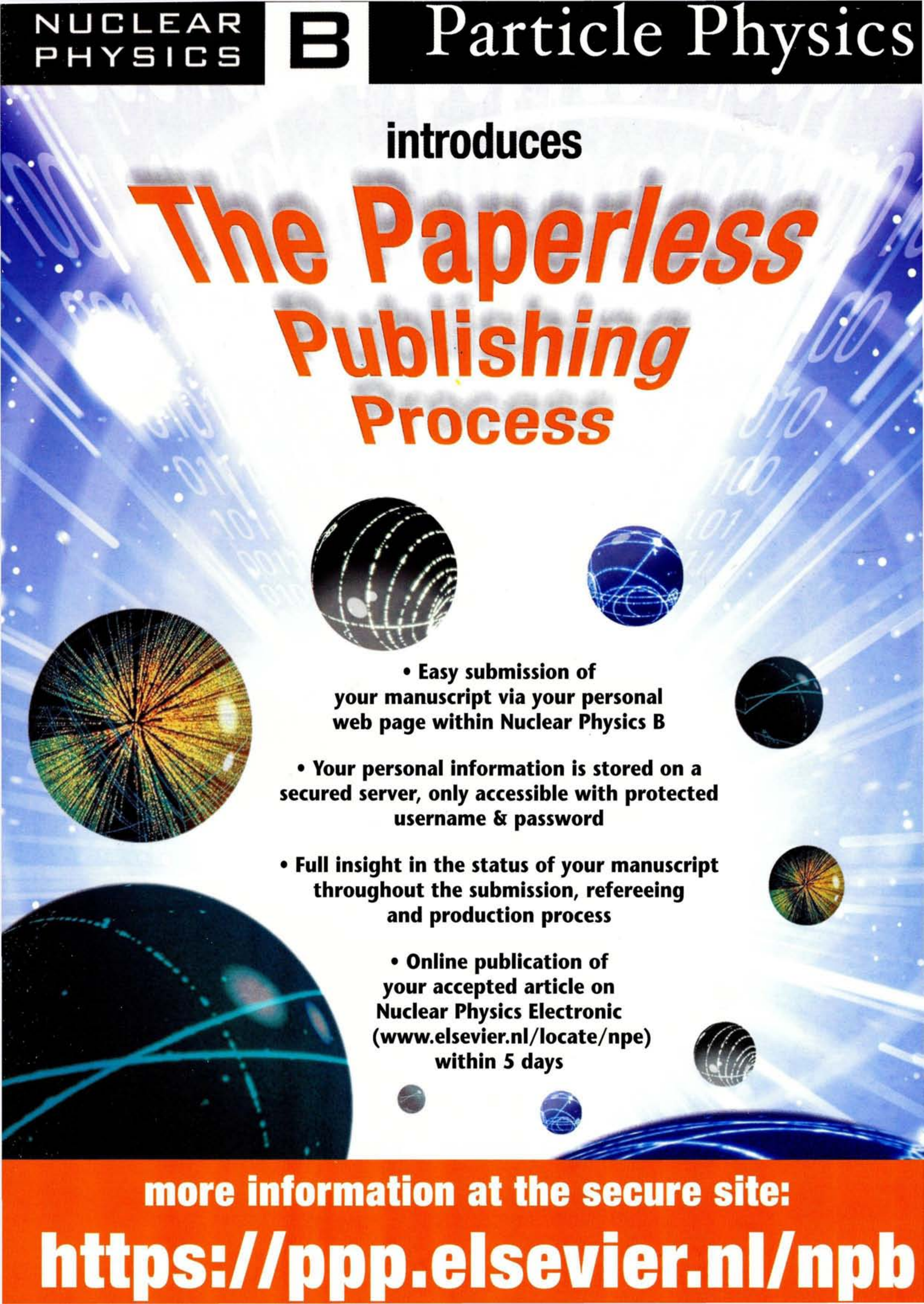
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BOOKSHELF

BOOK OF THE MONTH

Chaos and Harmony, Perspectives on Scientific Revolutions of the 20th Century, by Trinh Xuan Thuan, Oxford University Press, ISBN 0 19 512917 2.

In a refreshing alternative to books that try to promote elegance, as opposed to correctness, as a reason to accept scientific theories, Trinh Xuan Thuan takes his readers on a fascinating romp through the world of modern physics. Starting with a discussion of truth and the elusive concept of beauty as opposed to elegance (a difference that he carefully explains), Thuan zeroes in on inevitability, simplicity and congruence as the key guiding notions in the search for the beautiful theories of nature. Much to his credit, he nevertheless makes it clear that, while truth is ultimately something that is decided by experiment, beauty is a subjective concept.

Although the subject matter of this book is deeply philosophical, it is discussed in wonderfully concrete terms. Rather than making vague statements about staggering cosmic or microcosmic magnitudes, Thuan offers hard facts (e.g. that the Sun turns 400 million tonnes of hydrogen into helium per second). A refreshingly down-to-earth follow-up to the esoteric discussion of truth and beauty is a description of the solar system, and the complex interplay between the strict laws of physics and plain random chance that gives rise to the world we so often take for granted.

In subsequent chapters Thuan describes chaos – with its range of applications from meteorology to medicine – and symmetry, emphasizing the symmetries between electricity and magnetism, and between space and time. A recurring theme in the book is the way in which seemingly opposing principles like these actually work together.

Moving on from classical mechanics and the need for both ordering and disordering principles in order to obtain structure, we meet quantum mechanics. A clear – if perhaps rather standard – introduction, with no mathematics, leads the reader to the

Beauty in nature – Saturn's aurora, as seen by the Hubble Space Telescope.

inevitable conflict between that greatest of classical theories – Einstein's General Theory of Relativity – and quantum mechanics. Here the author allows himself a few pages of deviation from the otherwise strict adherence to established fact that forms a great part of the book's not inconsiderable charm.

A mercifully brief discussion of higher dimensional unification and string theory outlines the basic idea in a balanced way without any Bible-thumping. There's little hope of steering clear of strings and other speculations these days, but the author makes a good job of maintaining a healthy perspective. The book could, in good faith, be recommended to the lay reader without fear that the line between established fact and interesting speculation be too blurred.

The last two chapters are delightful, and unusual in a book of this kind. The penultimate one invites the reader to think about the nature of life and the origins of its highly sophisticated and diverse structures – and to consider to what degree we can begin to understand these as coming from physics. Thuan discusses how one can find the appropriate level of description for the task, and suggests that we should hope not for detailed explanations of single phenomena but rather for an understanding of the global organizing principles that give rise to life and other complex structures.

The final chapter echoes Wigner's famous concerns about what he called the "unreasonable effectiveness of mathematics" and asks why thought itself should be so effective – that is, why it is that we are able to make sense of anything, let alone the panoply of physics presented in the foregoing six chapters. Here the text takes an almost metaphysical turn, but, given the nature of the questions being asked, this is to be expected. While the practising scientist is unlikely to find much here that s/he hasn't already thought about, the discussion is well suited to a layperson and offers quite a range of concepts to consider, from the idea of a Platonic world of mathematical forms, through the limits imposed by Gödel's theorem, to the question of whether a God is needed, and the issue of why there should be such a thing as consciousness at all.

All in all, at a time when it is becoming increasingly difficult to find popular science books that are suitable for the intelligent non-scientist, and that make clear distinctions between known fact and speculation, this book is a winner. The writing is graceful, smooth and rich in historical and cultural background, while at the same time keeping real physics close to the forefront. Perhaps most compelling is the book's remarkable coherence. Topics flow easily and naturally into each other and one would be hard-pressed to guess that it is a translation into English. Most people I know, practising physicists included, could learn something from this book, in addition to enjoying its style. To my high-energy physics colleagues: ask yourself how much you really know about the mechanisms involved in getting matter to clump together and make a planet. After all, there aren't many of them in this solar system, are there? Get the book and have a look at Chapter 2!

John Swain, Northeastern University, Boston.

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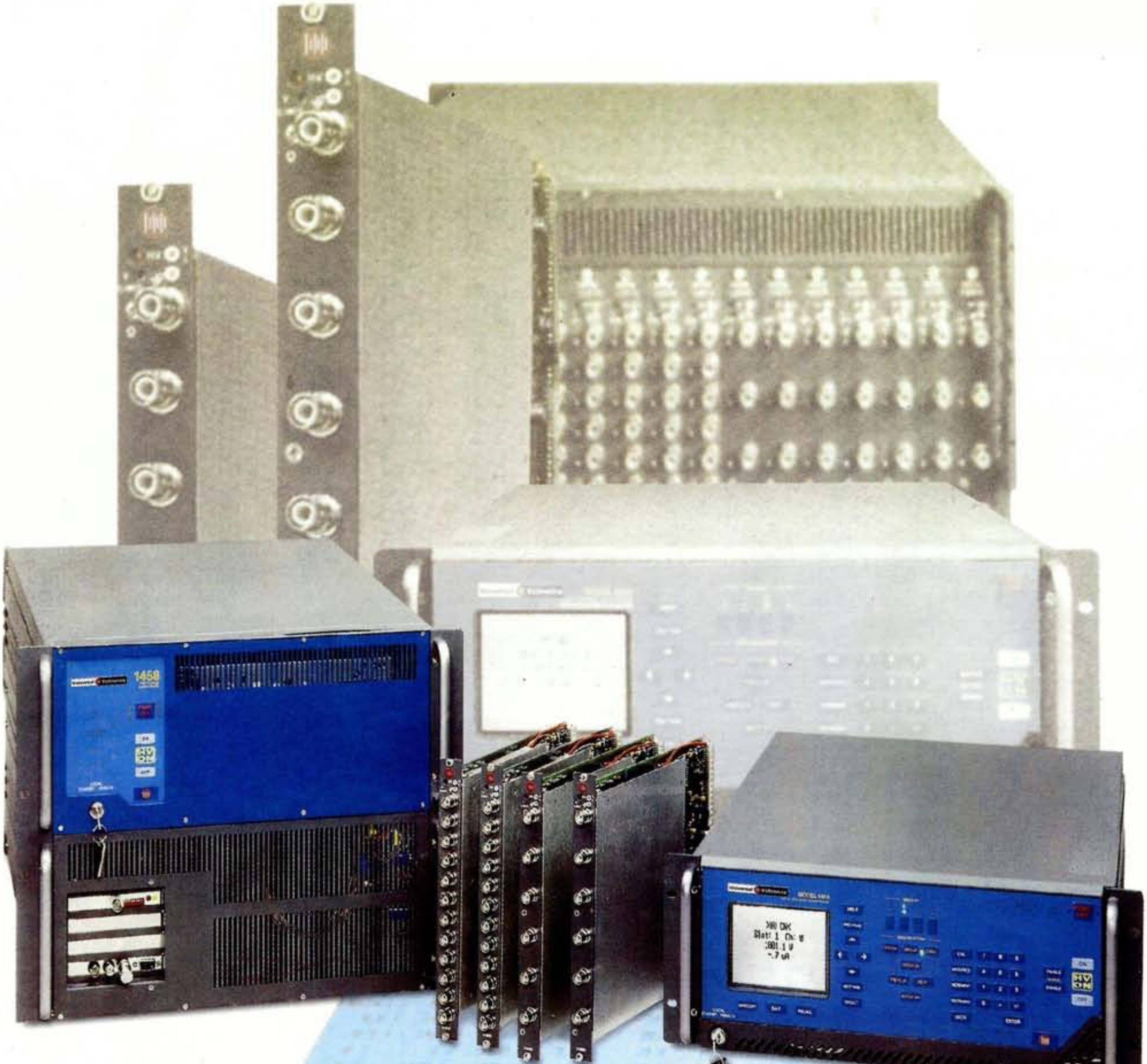

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