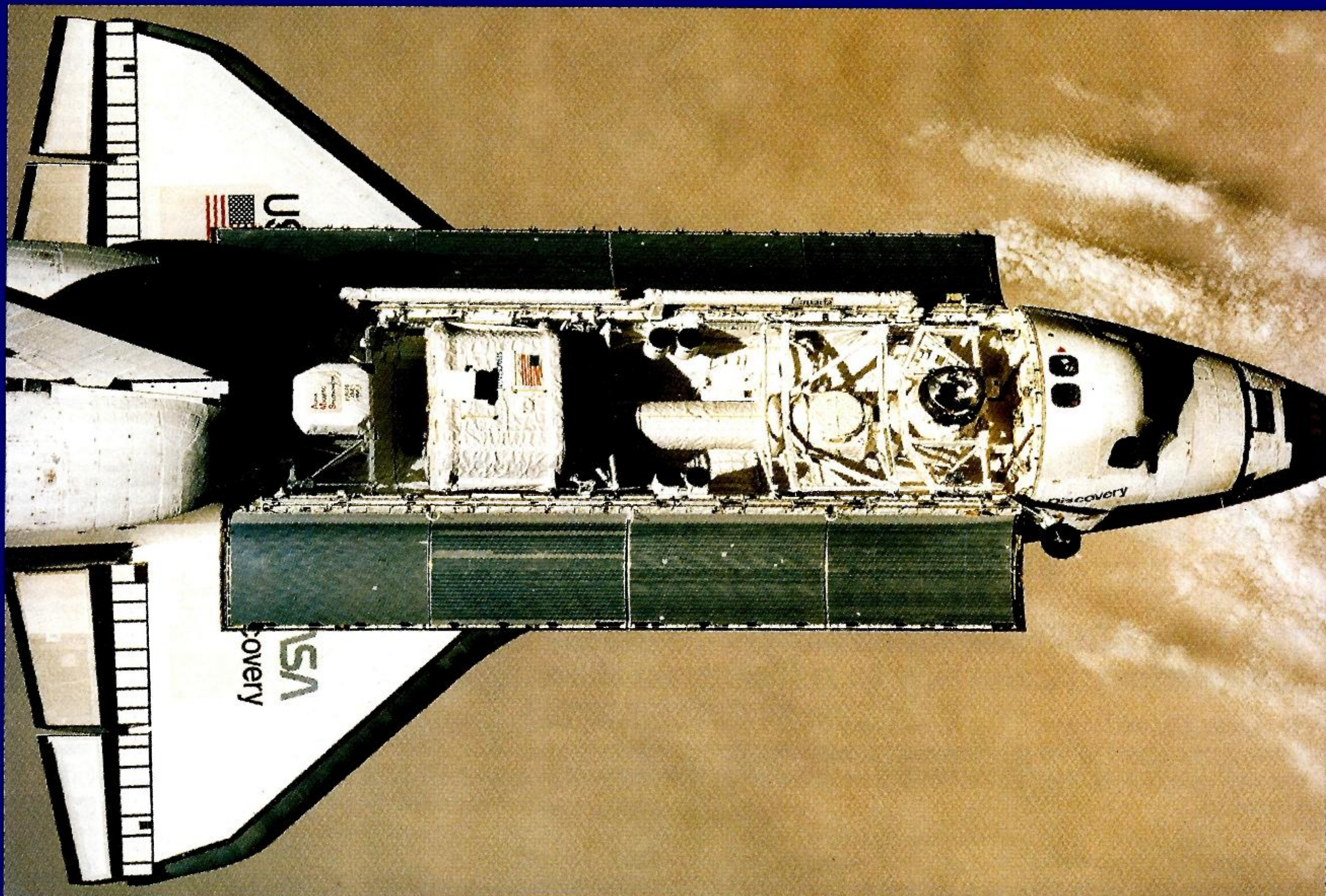
INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 38 NUMBER 7 OCTOBER 1998



Particle physics detector in space

QED IN BULGARIA
Researchers are still pushing at the frontiers of QED, as a workshop in Bulgaria revealed

STARING AT THE SUN
How will Gran Sasso's Borexino experiment work and what will it tell us about the nature of neutrinos?

HADRON THERAPY
The Proton-Ion Medical Machine Study is exploring how particle physics can benefit medical treatment

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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E-mail mark.wormald@ioppublishing.co.uk
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USA/Canada: Janice Voss, Creative Mailing Services, P.O. Box 1147, St Charles, Illinois 60174. Tel. 630-377-1589. Fax 630-377-1569

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

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

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

ISSN 0304-288X

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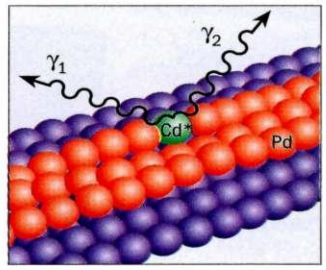
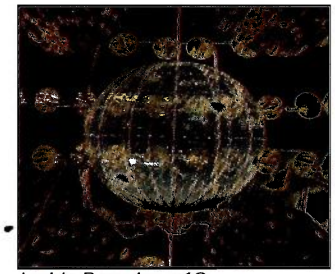
LHC underway **p5**



Nuclei as secret agents **p17**



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Chris Llewellyn Smith explains why particle physics deserves support.

Cover: Summer in space - the Space Shuttle Discovery, with payload doors open, viewed from the Russian Mir station prior to the final Shuttle–Mir docking in June. As well as the large SPACEHAB module with equipment for transfer to Mir, Discovery also carried the Alpha Magnetic Spectrometer (AMS – September, page 28), the first major particle physics detector to go into space. The 4000-pound SPACEHAB module is clearly visible, with the smaller AMS unit immediately aft. (Photo NASA)

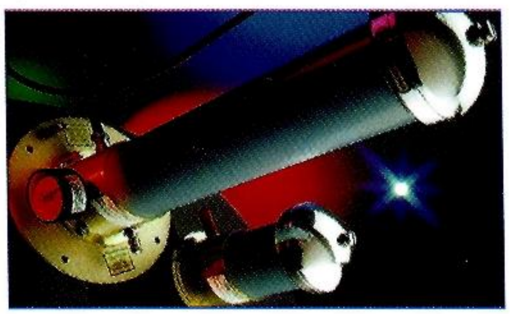
HV SOURCE

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

Glassman launches MORE new products to celebrate 21 years at top

High Performance Dividers

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



High Power, Low Profile

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

SLIMLINE

The NEW Series FC from GLASSMAN

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

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

AC Supplies from DC Specialists

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

GLASSMAN europe

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

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

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French green light for LHC civil engineering

Progress on CERN's next major particle accelerator, the Large Hadron Collider (LHC), took another step forward recently when French Prime Minister Lionel Jospin signed the decree allowing LHC civil engineering work to commence on French territory. This important landmark comes after a long and painstaking study of the environmental impact of the project and follows approval of civil engineering on Swiss territory earlier this year (January, page 1) where work is already underway.

The LHC collider, scheduled to begin operations in 2005, will be constructed in the 27 kilometre tunnel under the Franco-Swiss frontier, which currently houses CERN's LEP electron–positron collider.

LHC civil engineering contracts are being awarded in three separate packages. Excluded from these packages is one of the tunnels which will supply the LHC with protons from CERN's Super Proton Synchrotron accelerator. This tunnel is being built by Switzerland as part of its special host-state contribution to the LHC.

While awaiting the French green light, a collaboration between CERN and the regional directorate for cultural affairs has allowed archaeologists to undertake preliminary excavations at a Roman site adjacent to one of the LHC's experimental areas. Their findings have pieced together a fascinating picture of life in the area some 1700 years ago. A report will feature in a forthcoming issue.

Civil engineering work on CERN's LHC collider is already underway on Swiss territory.

Experiments wanted for CERN neutrino beam to Gran Sasso

The Scientific Committees of the SPS at CERN and of the Gran Sasso laboratories will meet at CERN on 3–4 November for a thorough discussion of the opportunities offered by a neutrino beam pointing from CERN to Gran Sasso. There is a call for ideas for experiments that could exploit this beam to elucidate neutrino masses and mixings. Documents of up to 10 pages describing these experiments. along with a cost estimate, should be submitted to both Committees before 10 October.

To make the meeting more effective, the documents describing appearance and/or disappearance experiments with or without a near station should contain, in the usual Δm^2 versus $\sin^2 2\theta$ plot:

i) the exclusion curve if no signal is observed;
ii) the limit curve within which a discovery of neutrino oscillations can be made at the 4 sigma level. These curves should be based on the reference beams with a shared mode of operation (3×10^{19} proton/year on target) and for three years of running.

Documents on the high-energy and low-energy beams, prepared by the CERN/INFN Working Group should soon be available.

KODEL establishes Korea as major physics player

Marking the emergence of Korea as a major player on the world physics scene, the Korea Detector Laboratory (KODEL) was established this year under director Sung Keun Park of Korea University, Seoul. Its aim is to carry out research and development for high-energy physics detectors and international high-energy physics programmes, and to provide the infrastructure for the ever-increasing scope of major international high-energy physics projects.

About 11 Korean universities have links with KODEL and participate in the research at Brookhaven, CERN, DESY (Hamburg), Fermilab, GSI (Darmstadt), and KEK (Japan).

A guest of honour at the KODEL opening ceremony was 1992 Physics Nobel prize-winner Georges Charpak of CERN. His lecture was televised throughout the country.

Georges Charpak (right) at the new Korea Detector Laboratory (KODEL) with (right to left) KODEL director Sung Keun Park, Kwangsouk Sim and Juntaek Rhee.

While at KODEL, Charpak stressed the importance of research and development for high-energy physics detectors in Korea, and Korea's collaboration with CERN in the LHC Collider project.

At a news conference Charpak affirmed that present economic problems could be alleviated by higher investment in basic research to provide a solid foundation for future technological advancement.

Charpak also met with the Korean Prime Minister, the Minister of Science and Technology and the Minister of Information and Communication, and gave a talk to the Korean Physical Society entitled "Recent advances on gaseous detectors and their applications for medicine and biology", a subject for which his enthusiasm never wavers.

KODEL produces prototypes of forward resistive plate chamber for the CMS detector at the LHC and is obtaining very encouraging results. It will be the main Korean laboratory for mass production of these units.

US 'reneges' on SSC decision

US President Bill Clinton has questioned the momentous decision to cancel the Superconducting Supercollider, in a recent speech to MIT graduates.

The world of particle physics was stunned in October 1993, when the US Senate voted to cancel the Superconducting Supercollider (SSC), an 87 kilometre ring then being built in Texas to collide 20 TeV proton beams. On 28 October 1993, the giant machine's death warrant was officially signed by Clinton. The decision changed the face of world particle physics, with the emerging US involvement more outward looking. A major US commitment now constitutes a significant part of CERN's LHC proton collider project and its physics programme.

However, on 5 June this year, speaking to graduates at the Massachusetts Institute of Technology, President Clinton said: "Scientific research is a basic prerequisite for growth. Just yesterday in Japan, physicists announced a discovery that tiny neutrinos have mass (September, page 1). Now that may not mean much to most Americans [or anyone else – Ed], but it may change our most fundamental theories – from the nature of the smallest subatomic particles to how the universe itself works.

"This discovery was made in Japan, but it had the support of of the US Department of Energy. This discovery calls into question the decision ... to disband the Superconducting Supercollider, and reaffirms the importance of the work now being done at the Fermi National Accelerator Facility."

Fermilab – importance underlined by Clinton.

Physicist dies in air crash

Klaus Kinder-Geiger, 35, a leading theorist in relativistic heavy-ion physics, died tragically on 2 September aboard the Swissair New York to Geneva flight which crashed near Nova Scotia.

His Parton Cascade Model has decisively influenced our view of high-energy nuclear reactions, with important implications for future programmes at Brookhaven's RHIC and CERN's LHC colliders.

After his thesis on glueball decays at Frankfurt in 1989, Klaus spent postdoctoral years at Duke University and Minnesota, where he developed the Parton Cascade Model. While a Fellow in CERN's Theory Division from 1994–96, he worked with John Ellis on hadronization theory. He joined Brookhaven's nuclear theory group in 1996. His recent research also covered the application of the renormalization group to QCD transport theory.

His enthusiasm and vision was an inspiration to his many friends and collaborators, who mourn his untimely death.

Walter Greiner (Frankfurt) and Berndt Mueller (Duke U.).

Meetings take theorists beyond the Standard Model

To strengthen research links between theorists working on physics beyond the Standard Model, high-energy theory groups at Bonn (H P Nilles), Oxford (G Ross), Padua (F Zwirner), Pisa (R Barbieri), Warsaw (S Pokorski), Ecole Polytechnique in Palaiseau (I Antoniadis), CERN (J Ellis), and ICTP (G Senjanovic) and SISSA (A Masiero) in Trieste initiated a new series of annual meetings "From Planck Scale to Electroweak Scale", emphasizing the span of the underlying fundamental processes.

The first meeting was organized in Kazimierz, Poland, an old grain-shipping town on the Vistula, this spring. Its topicality was underlined by the Superkamiokande results for neutrino oscillations (September, page 1) and new limits on the proton decay life time.

A major focus of the meeting was the status of the search for the Higgs boson. The Higgs boson is not only the missing link of the Standard Model, but its discovery would also be a bridge to new physics. The new lower limit on the Higgs boson mass from CERN's LEP2 (above 90 GeV) pushes it for the first time into the region most expected from fits to electroweak precision data and central for the predictions of the Minimal Supersymmetric Standard Model.

With the discovery potential in the last phase of LEP2 extending to the Higgs masses up to almost 110 GeV, the long-awaited particle could make a dramatic appearance. As confirmed by recent theoretical calculations, this region covers most of the range for the Higgs mass predicted by supersymmetry.

The second major theme of the meeting was what is generally now considered as the most plausible framework for the Theory of Everything, what was formerly known as string theory. This approach is now formulated in a non-perturbative manner, termed M-theory.

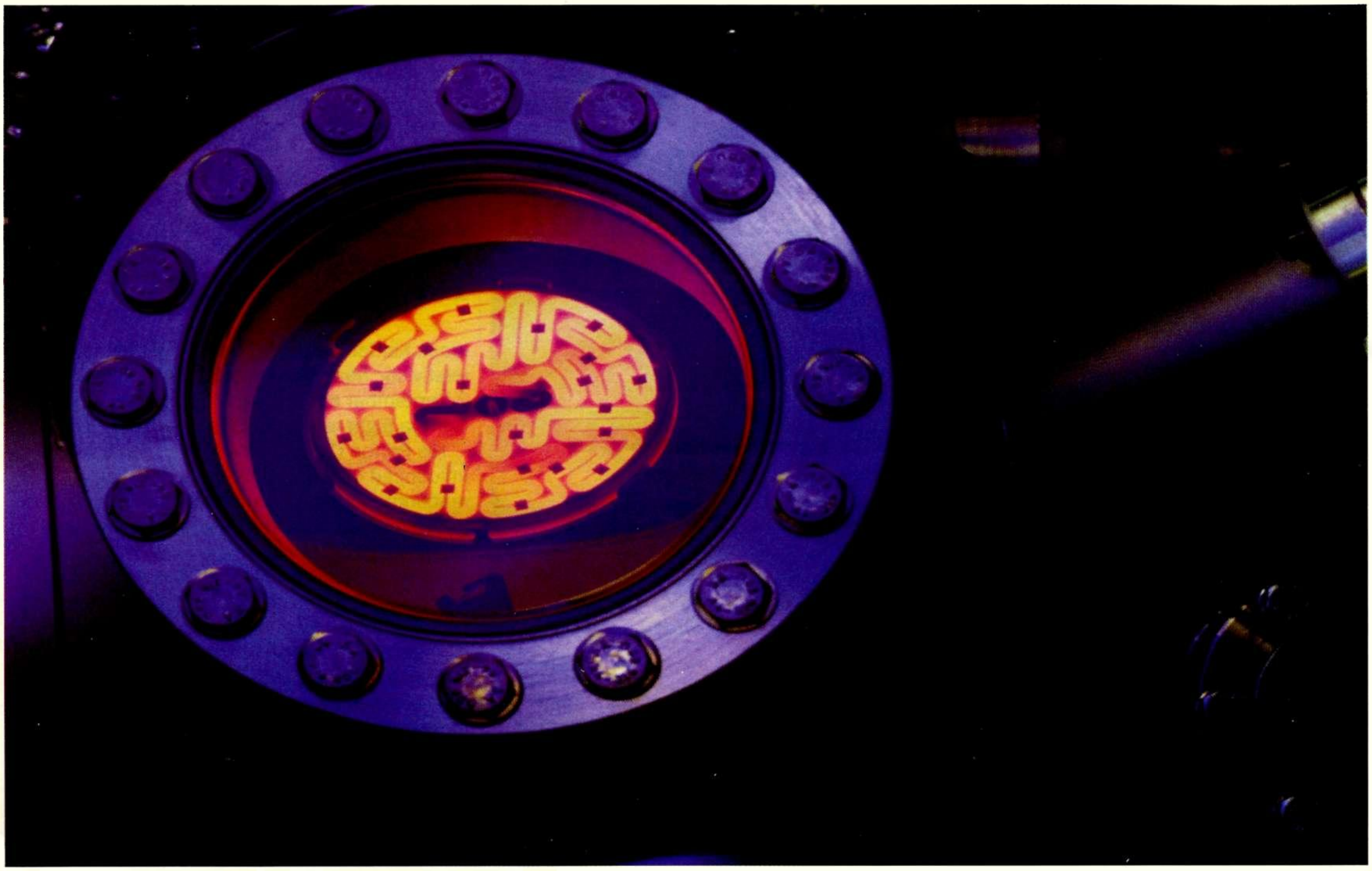
The focus was on phenomenological aspects of M-theory, to find low energy, observable and testable predictions of various theoretical frameworks for this large-scale physics.

M-theory unifies in a phenomenologically successful way all known forces of Nature, including gravity. Thus the longstanding problem of string theory, the mismatch between the gauge coupling and gravity unification scales, is solved. The basic ingredient of this solution is the presence of an extra, fifth, dimension at the energy scale well below the gauge coupling unification scale.

Recent investigations, reported at the meeting, explore other phenomenological consequences of such a five-dimensional world, which opens up at the energy scale 10^{15} GeV (or, as some speculate, even much below). For instance the fifth dimension could be seen via the pattern of soft supersymmetry breaking or in proton decay.

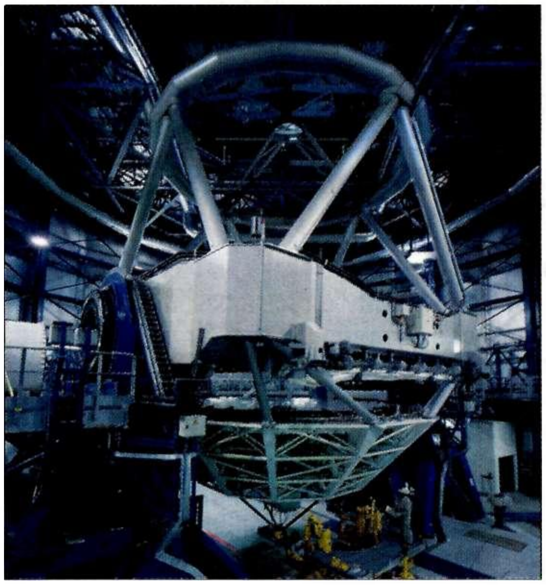
The next meeting in the series will be organized by Bonn and held 19–24 April 1999 in Bad Honnef (Germany). The plans for the year 2000 are to have a meeting in Gran Sasso, organized by the Italian groups.

For further information, see "http://info.fuw.edu.pl/~susy/".



Edited by Emma Sanders

First light at the VLT



The first of the VLT's 8.2 m mirrors.

Observations at Europe's Very Large Telescope (VLT) are off to a successful start. At the end of May, the first astronomical images were taken using the 8.2 m telescope. A second telescope will be installed this autumn.

The European Southern Observatory's VLT at Cerro Paranal in the Chilean Atacama desert should be complete in 2005. Its four 8.2 m telescopes and three 1.8 m telescopes will make up the most sensitive interferometer in the world.

The first telescope has already achieved a resolution equivalent to resolving a car's headlights at a distance of 1200 km. Current telescopes can look back around 94% of the lifetime of the universe (assuming a flat universe). With the VLT, astronomers estimate they will be able to see another 3% further back and are anticipating seeing their first pictures of remote galaxies.

"A key issue is when the dark ages ended, when the first stars and galaxies started to shine," says Cambridge astronomer Sir Martin Rees. He believes if this happened at a redshift of 10, the VLT will see them. The furthest galaxy observed so far has a redshift of 6.

Sir Martin also anticipates direct observations of planetary systems around other stars. "The telescope's large collecting area coupled with its high resolution is ideal," he says. "Planets are very faint and less than an arcsecond from the star."

The telescope's 50 m^2 mirror has a surface which is accurate to 5×10^{-8} m, equivalent to a 1 mm deviation over an area the size of Paris. The surface is continually corrected for the gravitational distortions caused by the telescope's support structure.

A system of adaptive optics will be installed in 2000 to correct observations for atmospheric turbulence. A single star will be imaged 100 times a second to measure how its image changes. This data will be used to deform one of the telescope's mirrors, reducing observational errors and improving image quality.

SOHO back on track

After six weeks lost in space, the Solar and Heliospheric Observatory (SOHO) has been found. The $1 billion satellite was located when it reflected a signal sent into space by the Arecibo radio telescope in Puerto Rico.

SOHO, a NASA/European Space Agency (ESA) collaboration, span out of control on 25 June leaving its solar panels almost edge-on to the Sun and unable to generate power. Since then the panels' position relative to the Sun has slowly changed and now engineers are able to communicate with the satellite for short periods.

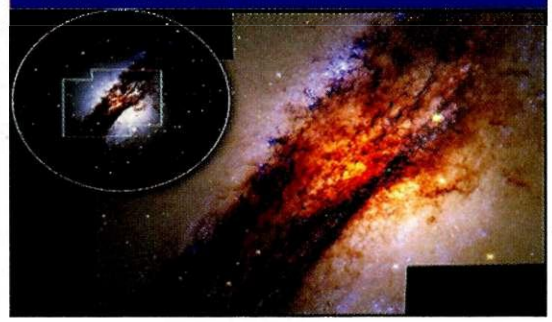
ESA and NASA engineers are working hard to reheat the craft. They need to find a way of storing enough energy in the batteries to unfreeze the fuel tanks so the thrusters can be used to turn the solar panels into the Sun.

SOHO has proved a very popular and versatile observatory. It houses 12 different instruments which have been used to study solar physics and the solar wind. "The mission is in a class of its own," says Giacomo Cavallo, head of science programmes at ESA.

ASTROWATCH

The universe is the ultimate particle physics experiment, and is a wonderful laboratory for effects which make terrestrial efforts seem puny. This new regular round-up of astronews will cover news and new developments in astronomy and astrophysics, with the accent on the physics.

Picture of the month



The Hubble Space Telescope reveals the activity at the centre of Centaurus A, the nearest active galaxy to the Earth. A black hole devouring a small neighbouring galaxy has fuelled a region of intense star formation.

Galactic downsizing

The Milky Way is smaller and slower than astronomers once thought. A group at Southampton, UK, has measured the motions of stars near the Sun and their findings suggest it is 5000 light years closer to the centre of the galaxy than previously thought. Also, the Sun is rotating at 185 km per second about the galactic centre – 35 km per second slower than measured before.

The work may have huge consequences, as astronomical distances are frequently measured in relative terms. Recalibrating this standard "ruler" decreases the distances to other more distant objects, and ultimately, the size of the universe as a whole.

Mars Express

Preparations for ESA's Mars Express are well underway now the spacecraft's scientific instruments have been agreed. One of their main tasks will be to search for frozen water below the planet's surface. Its discovery would shed light on the planet's chemical history and help show if conditions were ever right for life to have existed there. Mars Express will start its 700 million km journey in 2003.

Cosmology comes of age

The easy part is over – experimental cosmology has now reached adulthood. That was the message that emerged from a workshop on cosmology and particle physics held at CERN this summer.

While cosmology is one of the oldest of sciences, it is only this century that it has become truly quantitative, with measurements from ground-based detectors extending beyond the traditional visible window and, more recently, with data from an impressive array of space-borne instrumentation. Underlining the new maturity of the science are the emerging values for the basic parameters of the cosmological equations.

A latter-day Copernican revolution came when Edwin Hubble discovered in the 1920s that the universe is still expanding, subsequently understood to be the aftermath of the initial Big Bang. Ever since, observational cosmology has tried to pin down how this expansion has evolved. The "Hubble constant" – the apparent ratio between expansion velocity and distance – has long been controversial. One typical "result" was the paradox that the universe appeared to be younger than its oldest stars – the "old wine in new bottles" dilemma.

Thanks to new data, including parallax measurements from the Hipparcos satellite (May 1997, p20), the Hubble constant and the age of far-flung objects in the universe are now more compatible. The oldest stars are of the same vintage as our universe.

Talks at the CERN meeting, covering observations from the Hubble Space Telescope and other satellites and from systematic supernova searches, showed that the "world average" Hubble constant now looks to be about 67, with a likely age of the universe about 14 gigayears.

Wendy Freedman of the Hubble Space Telescope team showed that the spectrum of the Hubble flow looks remarkably smooth (with the local "infall" drift towards Virgo subtracted). With reliable new data, statistical fluctuations have largely gone away, and the emphasis turns instead to systematic effects.

Observations of distant supernovae, which exploded when the universe was still young, reveal how the universe has since expanded. For the supernova search teams, Saul Perlmutter and Robert Kirshner demonstrated how the subtle effects now being seen at these extreme distances cannot be fitted by a single Hubble constant, and the idea of a "cosmological constant" – an anti-gravity repulsion – has made a comeback.

According to the basic Big Bang/Hubble picture, the further away an object is, the faster it appears to recede, with the expansion of the universe inexorably slowing as gravity steadily applies the brakes. However, the data from supernovae suggest this is an over-simplified picture, with an anti-gravity effect assisting the expansion, so that the Big Bang can sometimes appear to accelerate.

This reopens the debate on whether the universe is "open", continuing to expand for ever, or "closed", ultimately to disappear in a final "Big Crunch". Neither is yet excluded.

At the CERN workshop, inflation pioneer Andrei Linde showed how an infant universe born in a quantum fluctuation supposedly attained its present proportions due to a brief initial flash of "inflation" which transformed a quantum bubble into a living universe. The incredible rate of this explosion strongly suggests total reconciliation with gravity, so that what we now see should be "flat", neither continually expanding nor destined to recombine.

Achieving a flat universe with the new cosmological data is not ruled out, but the cosmological constant plays an important role. Flatness is not achieved by conventional gravitational pull alone.

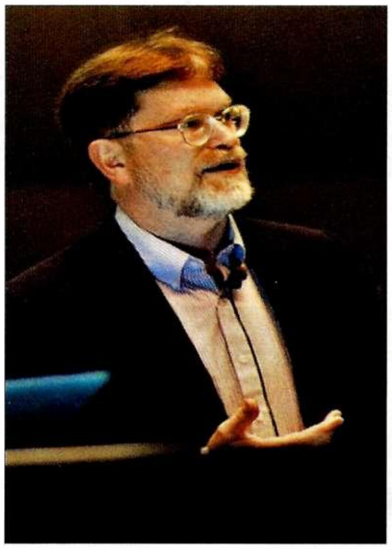
Dark matter

Although inflation practically dictates a flat universe, there is not enough visible matter out there to accomplish the task, and invisible "dark matter" is invoked to provide the extra gravitational pull needed to close the universe. A continuing challenge is to find this missing matter – material we cannot see but which has to be there to explain the gravitational behaviour we do see. However, the arrival of a non-zero cosmological constant provides an additional gravitational effect to help close the universe using less dark matter.

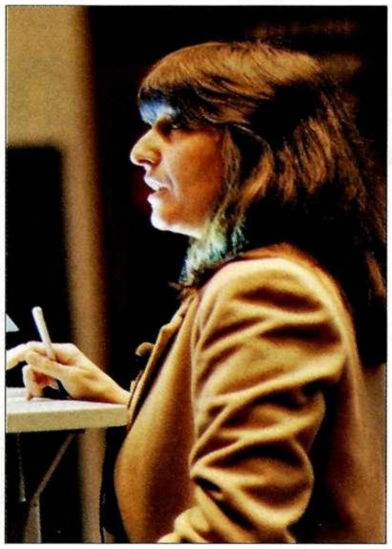
One dark matter candidate is MACHOS – Massive Astrophysical Compact Halo Objects. At the CERN workshop, Michel Spiro summarized the search for MACHOs using gravitational lensing, in which otherwise invisible intervening matter can affect the image of more distant objects as they move across the sky.

A continuing challenge is to find this missing matter – material we cannot see but which has to be there to explain the gravitational behaviour we do see.

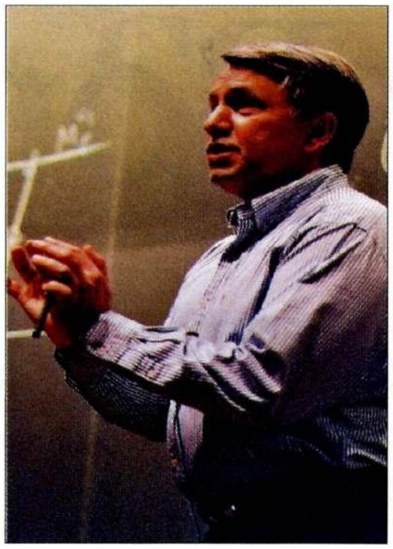
One MACHO-seeking collaboration, itself called MACHO, now has 14 candidates in the direction of the Large Magellanic Cloud (LMC), whose durations range from 15 to 90 days. Another collaboration – EROS – has two, each lasting about four weeks. MACHO cov-



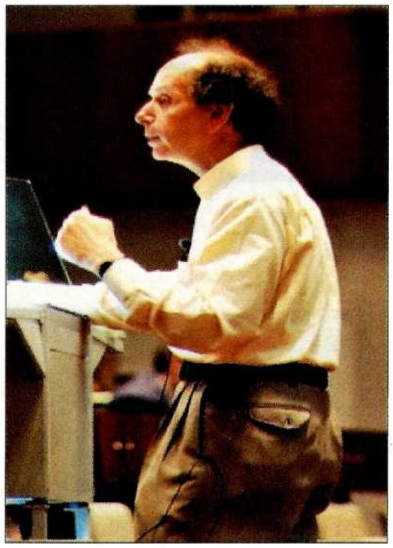
George Smoot, whose COBE team discovered in 1992 that the cosmic microwave background contains tiny temperature fluctuations, a template from which gravity subsequently shaped the large matter structures in our universe.



Wendy Freedman – a smooth Hubble flow from the Hubble Space Telescope.



Andrei Linde – showing how an infant universe born in a quantum fluctuation attained its present proportions due to a brief initial flash of "inflation".



Michel Spiro – looking for dark matter via gravitational lensing.

ers most of the LMC, but with low efficiency, while the complementary EROS search covers a restricted area containing some 150,000 stars with high efficiency. Taken together, these results imply that planetary mass objects account for less than 10% of the halo. Their attention is now also extended to the Small Magellanic Cloud, while other dark-matter searches have also joined the hunt.

Microwave background

The feeble cosmic microwave background radiation is the vestigial rumble of the Big Bang. Even when this radiation was released, the infant universe should have contained some seeds of its present form. After the discovery of this radiation in 1965, theorists were convinced that its superficially smooth envelope would ultimately reveal small irregularities.

In 1992 the COBE satellite team discovered that the cosmic microwave background does contain tiny temperature anisotropies (variations in angle), a template from which gravity subsequently shaped the large matter structures – galaxies and clusters of galaxies – in our universe.

Ever since, COBE and other experiments have sought to enlarge this window. The gravitational "seeds" initially seen by COBE correspond to far larger structures than are visible today. So the aim is to tighten the angular coverage and look for smaller seeds which could have produced visible galaxies and galactic clusters.

At CERN, COBE pioneer George Smoot sketched the ongoing programme of ground-based, balloon-borne and satellite studies, and Dick Bond described the business of extracting meaningful microwave background data from the mess of surrounding effects. The results now cover much smaller patches of sky than the 1992 COBE results. Charles Lineweaver demonstrated how cosmological measurements from microwave background, supernovae and other effects could be combined. The cosmological constant looks to be here to stay.

However, the definitive determination of the cosmological parameters, to better than 1% accuracy, will come from the future satellite missions MAP (due to be launched in 2001) and PLANCK (due 2007).

Making light nuclei

With protons and neutrons available, light nuclei such as deuterium, helium and lithium were formed in the first 1000 seconds or so after the Big Bang. The relative abundances of these nuclei in the universe at large provide another lever to prise apart the Big Bang mechanism.

A researcher who made a major impact on this area was David Schramm, who died in a flying accident last December. He continually emphasized the importance of deuterium as a cosmological mirror, a technique he called "deuteronomy". The nucleosynthesis session at the CERN meeting was dedicated to Schramm's memory.

Speaking in this session was longtime Schramm collaborator Gary Steigman, who pointed out the current "crisis" in the measurements of light nuclear abundances. Fitting these to the standard Big Bang picture requires some ingenuity. The discrepancies could be simply observational, or due to additional physics effects, like an unstable tau neutrino with a mass less than about 20 MeV.

As well as displaying new confidence in observational data, the CERN meeting showed how the veil of cosmological mystery is slowly being pulled aside. The very creation of the universe is being parametrized and processes which only a few years ago were on the theoretical drawing board have become phenomenology.

Gordon Fraser, *CERN.*

How Borexino will

A new ultra-sensitive experiment to detect solar neutrinos is being built underground in Italy. As construction at the Gran Sasso laboratory nears completion, *Gianpaolo Bellini* explains how the Borexino experiment will work, and what it might tell us about the nature of neutrinos.

The energy-dependent deficit of the measured solar neutrino flux compared to the predictions of the Standard Solar Model is often called the Solar Neutrino Problem. In recent years, this problem has become a paradox because the more recent experimental results (from Gallex and Sage), together with the older data (from Homestake and Kamiokande) and the measurement of the solar luminosity indicate a severe suppression of the solar neutrino flux from beryllium-7 reactions, pushing it lower than the neutrino flux from boron-8, which is a product of the reaction involving beryllium-7!

New neutrino physics, in the guise of oscillations, with neutrinos changing their "flavour" (electron-, muon-, or tau-) as they fly through space (September 1998, p1), can fix these problems, which cannot be explained by changing the Standard Solar Model. In addition to this basic vacuum oscillation scenario, additional effects – matter oscillations – are possible due to charged current interactions between neutrinos and the electrons of matter, if the material (the Sun) traversed by the neutrinos is dense.

Measuring beryllium-7 neutrinos

One of the most crucial problems is the behaviour of the beryllium-7 solar neutrinos, whose energy range is below 1 MeV (two monochromatic lines at 384 and 862 keV; the second has by far the higher flux). In addition to measuring the total flux of beryllium-7 neutrinos, time variations of the flux should provide evidence of oscillations, independent of the Solar Standard Model.

Previous experiments (Homestake, Gallex, Sage) able to measure solar neutrinos at low energy were radiochemical experiments, with at most one event per day. A solar neutrino experiment detecting low-energy events in real time at high rate, was needed. Fulfilling the need is Borexino, located underground in the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. The main neutrino reaction detected by Borexino is neutrino–electron elastic scattering, and the main problem dictating the design is natural radioactivity.

Borexino is an unsegmented detector, based on a liquid scintillator, and conceived as a sequence of concentric shells; the more internal the shell, the higher its radio-purity. At least two metres of pure water provides the first shield against gammas and neutrons from the surrounding rock. The water, some 2300 m^3 in total, is contained in a cylindrical stainless steel tank 18 m in diameter and 18 m high in the centre (shown blue in figure 1). An internal stainless sphere, 13.7 m in diameter, supports 2400 phototubes and divides the external water from an internal buffer liquid. 200 outward-pointing phototubes fixed on the external walls of the sphere provide a muon veto. 2200 phototubes are mounted on the internal walls, 1800 of them coupled to optical concentrators. The total optical coverage of the sensitive volume is about 30%.

The Pseudocumene buffer liquid (yellow in figure 1) assures another 2.6 m of shielding against rock emanation and against gammas produced by the phototubes, optical concentrators and related materials (mu-metal, sealing etc).

Finally, the liquid scintillator is contained in a thin, transparent sheet of nylon, 8.5 m in diameter and 300 m^3 in volume. The densities of the scintillator and the buffer liquid are practically the same to assure negligible buoyancy of the nylon vessel.

Borexino design

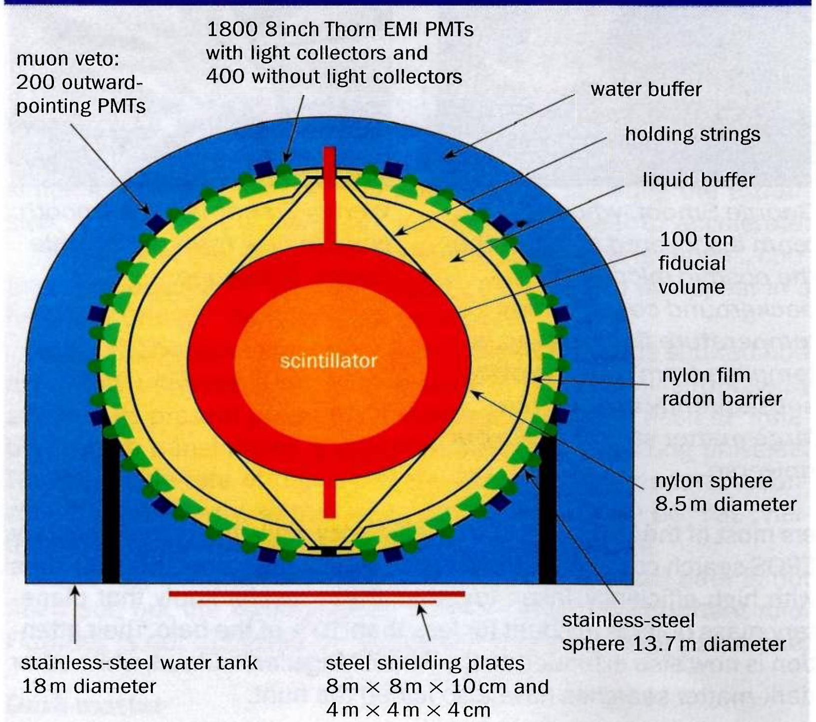


Fig. 1: Layout of the Borexino solar neutrino experiment, contained in a cylindrical stainless steel tank 18 m in diameter and 18 m high in the centre.

stare at the Sun

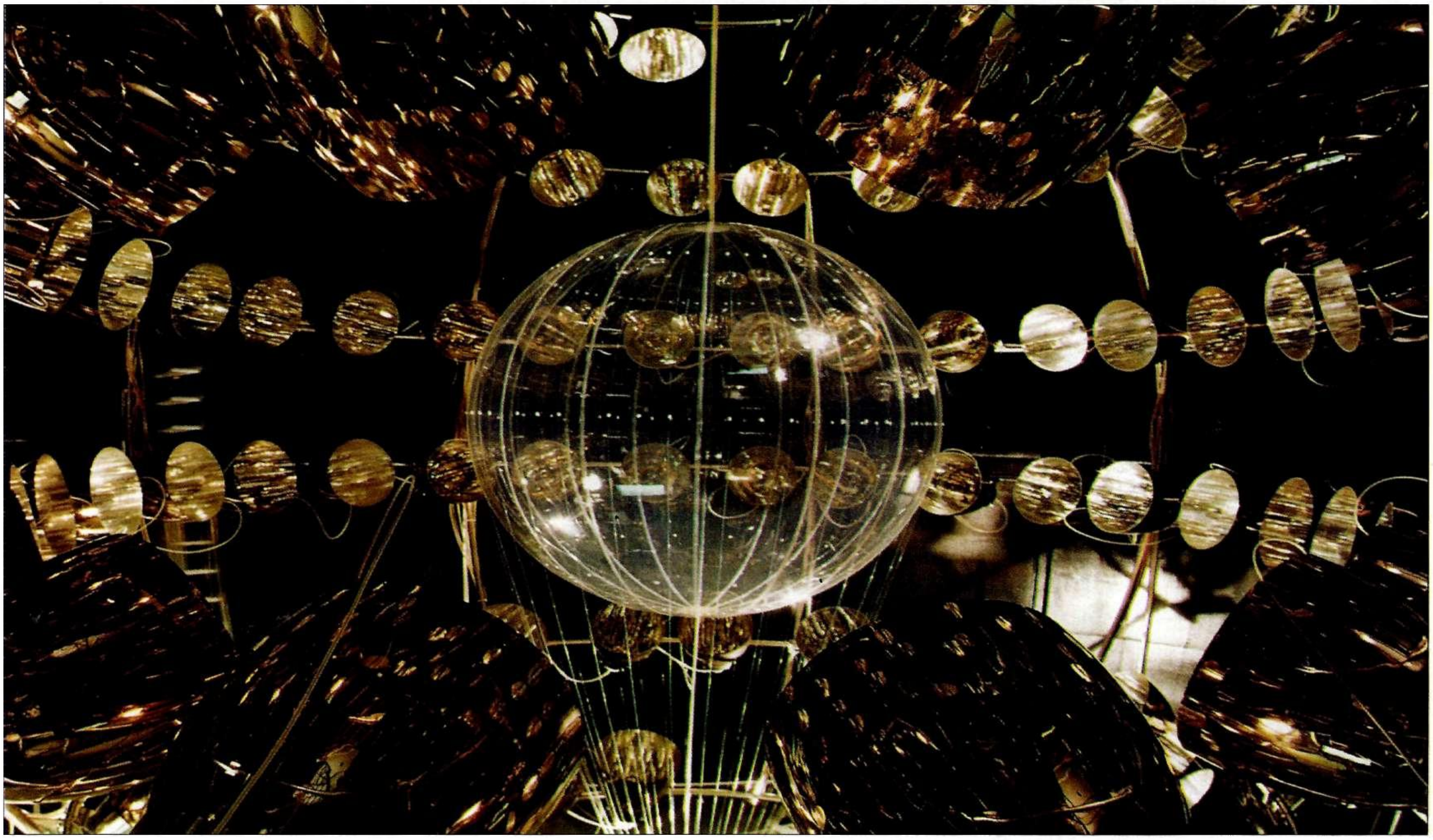


Fig. 2: The CTF is a scaled-down version of Borexino, with a nylon inner vessel containing 4.5 m^3 of scintillator. This shows a detail of the detector within the water tank, with the nylon inner vessel, some phototubes and optical concentrators visible.

Using an inner fiducial volume of 100 m^3, 6 m in diameter (orange in figure 1) provides a further 1.25 m of shielding against emanation from the nylon walls and gammas from the liquid buffer. A further nylon balloon is installed between the stainless-steel sphere and the inner vessel as a barrier against radon emanation from the various materials inserted in the sphere.

Counting Test Facility

The major problem of a real-time experiment such as Borexino, measuring rare events in an energy range below 1 MeV, is background due to the natural radioactivity of the environment and of the construction materials. Stringent radio-purity levels are needed for Borexino. Some of them, as in the case of the scintillator, have never been achieved and there are no standard methods to measure them. The Borexino collaboration therefore carried out initial R&D on the choice of materials and purification methods, and in 1993 decided to construct a very-high-sensitivity detector, the Counting Test Facility (CTF).

This is a simplified and rescaled version of Borexino, with a nylon inner vessel containing 4.5 m^3 of scintillator. An open structure supports 100 phototubes coupled to optical concentrators, while the shielding liquid is highly purified water.

The total water volume of some 1000 m^3 is contained in a cylindrical tank, 11 m in diameter and 10 m high. Auxiliary plants purify the water and the scintillator at ultrapure levels. Figure 2 shows a detail of the detector within the water tank, with the nylon inner vessel, some phototubes and optical concentrators visible. Figure 3 shows the external CTF tank and part of the scintillator handling plant.

Fig. 3: The Borexino CTF tank and part of the scintillator handling plant.

The CTF, installed in Hall C at Gran Sasso, has taken data since January 1995. It is one of the most sensitive large-volume detectors in the world. Without any selection its total counting rate is around 0.03 counts per kg per keV per year, and after a selection based on spatial reconstruction the rate was reduced by two orders of magnitude. The stringent Borexino design goals have been reached, both in the selection of materials and in purification methods. The role of contaminants introduced during scintillator transport and handling was carefully investigated and purification methods successfully removed them.

The CTF is now shut down for refurbishing and upgrading and will start to run again during 1999 as a test facility for the scintillator and the buffer liquid for Borexino. Physics measurements are also planned.

Borexino status

Borexino, approved and funded by the Italian INFN, the US National Science Foundation, and the German BMBF and DFG, is now under construction and is expected to start running in late 2000.

Neutrinos are detected in Borexino via elastic scattering on electrons, the energy of the detected recoil electrons ranging from 250 to 800 keV. The expected daily count rates range from about 12 to 40 or above, depending on the neutrino scenario. A low rate (less than about 16) would indicate neutrino oscillations in matter, and a high rate would indicate a vacuum oscillation hypothesis.

If the vacuum oscillation hypothesis is correct, the time variation of the solar neutrino flux will go beyond the geometrical seasonal variation as the Sun–Earth distance changes during the year. Borexino is favoured also by the energy of the beryllium-7 neutrinos and their monochromaticity. In fact it is able either to measure the 3% seasonal change, connected to the eccentricity of the Earth orbit, or to see a $\pm 30\%$ winter–summer difference, which amounts to exploring all the area allowed by vacuum oscillations.

A Fourier analysis of the predicted experimental signal shows that Borexino is sensitive not only to the first harmonic, but also to the second and third harmonics as well. In the study of possible vacuum oscillations, Borexino is unique.

Seasonal variation would be a clear indicator of vacuum oscillation while the day/night difference would be a signature for matter oscillations. The day/night difference is particularly enhanced in the low energy region, below 1.3 MeV, exactly that measured by Borexino, if the hypothesis of very low mass difference between neutrinos is valid.

Finally, Borexino would also be sensitive to electron antineutrinos, the appearance of which in the solar flux would signal the existence of a neutrino magnetic moment and a neutrino spin-flavour conversion in the solar magnetic fields.

Gianpaolo Bellini *is spokesman for the Borexino collaboration.*

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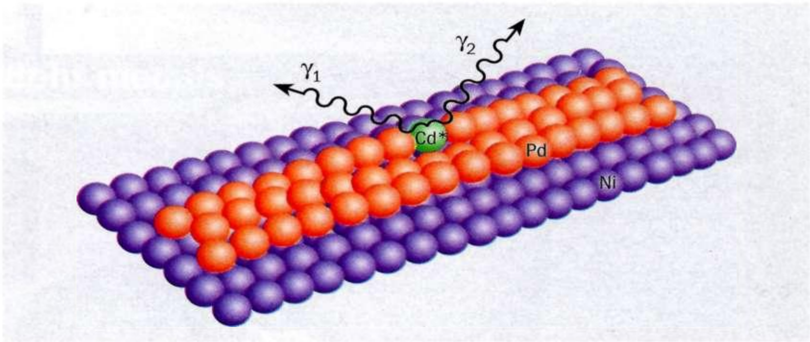
Nuclei as secret agents

Experiments with CERN's on-line isotope separator (ISOLDE) have led to a novel way to probe the interface between magnetic and non-magnetic ultra-thin layers.



Spying on atoms – the Perturbed Angular Correlation (PAC) spectroscopy technique uses probe nuclei with electric and magnetic moments and which decay by emitting two gamma rays nanoseconds apart. This allows PAC nuclei to "spy" on neighbouring atoms. The figure shows a model of Ni(001)–c(16x2)Pd with a radioactive Cd-111 impurity at a bridge site.

ISOLDE is a source of radioactive-particle beams with applications ranging from nuclear medicine to astrophysics. Recent ISOLDE experiments have opened up a new approach to examining the interface between ultra-thin magnetic and non-magnetic layers. The ultra-high vacuum ASPIC (Apparatus for Surface Physics and Interfaces at CERN) chamber takes keV ions from the 1 GeV proton beam bombardment of an ISOLDE ion source target, evaporates them at eV energies onto carefully cleaned surfaces, and studies interactions at the micro-eV scale. Each experiment covers 15 orders of magnitude in energy to study interactions at an atomic scale. Early results have produced some surprises.

The technique used at ISOLDE is called Perturbed Angular Correlation (PAC) spectroscopy. It relies on probe nuclei with two properties: they must have electric and magnetic moments, and they must decay by emitting two gamma rays nanoseconds apart. This combination of characteristics allows PAC nuclei to spy on neighbouring atoms after being "parachuted" onto surfaces, like secret agents. The interaction of the PAC nucleus's electric moment with the electric field gradients on and around the surface allows its precise position to be determined. The coupling between the magnetic moment of the PAC nucleus and the magnetic field it feels – either applied or due to surrounding nuclei – perturbs the correlation between the two gamma rays, allowing information to be gleaned at the atomic scale. This coupling, known as the magnetic hyperfine interaction, gives rise to magnetic hyperfine fields which are often very large.

Surprising result

For example, the magnetic hyperfine field of selenium atoms in bulk nickel is 15 tesla. The first ISOLDE experiment conducted with the ASPIC chamber was designed to investigate whether this was also true for the selenium atoms deposited as relatively loosely bound atoms, called adatoms, on a surface of ferromagnetic nickel. The result came as a surprise, showing that the field is in fact much lower for selenium as an adatom at around 1 tesla. This result prompted a theoretical study which revealed a completely different magnetic behaviour for impurities as adatoms compared to impurities in bulk, in agreement with the experiment.

Because hyperfine interactions are of very short range – from atom to atom – the PAC technique gives resolution to a single atomic layer. Moreover, because the gamma rays have long range, it allows deeply embedded atomic monolayers in a system to be investigated, something which has not before been possible. Furthermore, the technique is extremely sensitive. Only one "spy" atom is needed per thousand atoms on the surface or interface under investigation. Impurities at such a low concentration do not influence the intrinsic properties of magnetic thin layer systems, making PAC atoms the perfect spies.

ASPIC experiments capitalized on these properties by introducing PAC atoms into single atomic layers to investigate the interactions between layers. An isotope of cadmium was incorporated as an impurity into a single layer of palladium on a nickel single crystal. A sample of about 1 square centimetre was used, corresponding to 10^{15} atoms per layer with 10^{12} PAC spies incorporated. Results showed that the nickel induces ferromagnetism in the palladium. Further studies showed that this induced magnetism continued through to a second layer, though with much reduced strength. This observation led ISOLDE researchers to ask what would happen deep in palladium if the palladium was covered by ferromagnetic nickel. Seven atomic layers of palladium were deposited on a palladium crystal, after parachuting the PAC probe atoms on to the crystal surface. These were then covered with two atomic layers of nickel. The result was again surprising, showing that in this case paramagnetic palladium was converted into a superparamagnetic material.

Another curious finding is that isolated cadmium probes choose specific sites, called bridge sites, in a palladium monolayer on nickel. This raises the question of whether a larger number of cadmium atoms occupying all bridge sites would break up the structure of the palladium into cells of sub-nanometre scale. If they do, the consequences for the electronics industry could be profound; state-of-the-art today is nanometre-scale devices.

The application of PAC probe atoms to the study of local magnetic properties in ultra-thin layer systems is in its infancy. But these results from ASPIC clearly indicate the power of the technique to provide detailed information about surfaces and interfaces with single-atom precision.

James Gillies, *CERN.*

Niels Bohr and the 20th century

The international "Niels Bohr and the Evolution of Physics in the 20th Century" meeting earlier this year provided the opportunity to reassess the evolutional impact of Bohr's "Lebenswerk".

Niels Bohr (1885–1962) did not coincide entirely with the 20th century, but was nevertheless one of its great motive powers. The meeting, organized by the Niels Bohr Institute in Copenhagen, brought together about 200 eminent physicists at UNESCO's headquarters in Paris from 27–29 May to consider his scientific legacy.

After presenting the wide variety of Bohr's seminal ideas and paradigms, speakers turned to the present vitality of these concepts at the frontiers of modern physics, emphasizing also the growing symbioses between physics and biology, and between physics and information theory.

The opening talks on Bohr, by biographer Abraham Pais and by Ove Nathan of the Niels Bohr Institute, recalled the deep involvement of science with the everlasting challenge to express ourselves in a way which is both philosophically correct and reflects profound personal integrity.

Examples are the contest early this century between Bohr and Einstein on the interpretation and understanding of the quantum mechanical concepts of measurement and evidence; and the subsequent contests between Bohr and, in turn, Roosevelt, Churchill (who suggested keeping Bohr under house arrest), and later the UN, in the struggle to prevent world politics degenerating into an atomic arms race. Both of these avenues of confrontation remain strikingly topical, as reflected in the talk by Anton Zeilinger on modern quantum information theory, and in the parallel news of the spread of nuclear arms in the East.

Distinguished physicist, author and Bohr biographer Abraham Pais spoke on "Niels Bohr, man and physicist".

Turning to the present frontiers of science first embraced by Bohr and other monumental personalities of the 1920s, the younger contemporary observer must feel more comfortable with the development of a much wider physics community.

Here an enormous interpersonal web of co-operation and exchange of ideas and resources, aided by public revenue support still driven by the evolutionary spirit of the scientific revolution at the dawn of the century, supports a complex of frontier projects.

This encompasses not only the spectacular "big science" effort as exemplified by the Hubble Space Telescope, CERN's LHC proton collider, or Japan's Superkamiokande underground detector, but also the international communities pushing the underlying theoretical understanding beyond the standard models of their respective disciplines.

Bohr medals

At the "Niels Bohr and the Evolution of Physics in the 20th Century" meeting, four distinguished scientists were awarded Niels Bohr–UNESCO gold medals for their important achievements in basic science and their efforts to shorten the bridge between science and society: S Chandrasekhar of the Centre for Liquid Crystal Research, Bangalore, India; Vitaly Ginzburg of Moscow's P.N. Lebedev Institute; Walter Kohn of the University of California, Sanata Barbara; and Alexander Polyakov of Princeton (pictured).

Small science

And there is modern table-top science – "small is beautiful" – splitting photon states for quantum teleportation, fixing single atoms in nano-Kelvin states to measure time to an accuracy of 10^{-19} (to check the time variation of Nature's "constants"), developing DNA strains to catalyse organic manufacture of photomasks for quantum-level semiconductor chips, and synthetic muscular mini-machines built from multi-polymeric "soft matter" complexes.

These specialist subjects are vibrant with excitement, both for the open horizon of learning about the universe of Nature, and the transition from an initial qualitative to a precision quantitative understanding of the quantum world, inorganic and organic.

Astrophysics left a particularly strong impression, with new results from Hubble on the dark matter problem (Martin Rees), and with Superkamiokande's tentative evidence for neutrino oscillations (John Bahcall) giving the first hints of physics beyond the Standard Model.

The symposium was a memorable experience for participants, achieving its basic but ambitious objective of surveying the evolution of phyics this century. It was in some ways a modern revival of the dramatic meetings held at the beginning of the century, such as the historic 1911 Solvay Conference, but with a small number of insular scientific luminaries replaced by a host of enthusiastic heirs.

Notably absent were the prophets of doom, predicting the imminent end of science. Regrettably, as the symposium would have convinced them otherwise.

Reinhard Stock, *Frankfurt.*

Precision beams for

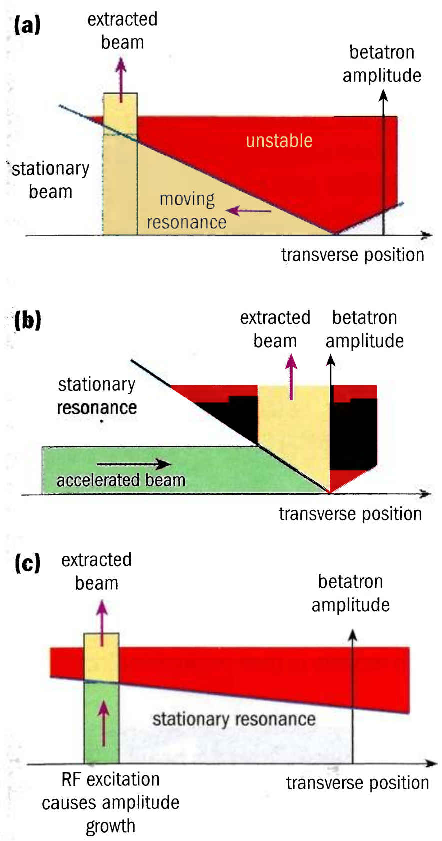


Fig. 1 – *how a particle beam can be moved into the unstable region of a resonance for extraction.*

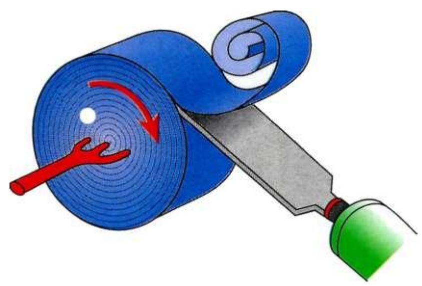


Fig. 2 – *the quadrupole-driven extraction of figure 1(a) is analogous to turning a piece of wood on a lathe.*

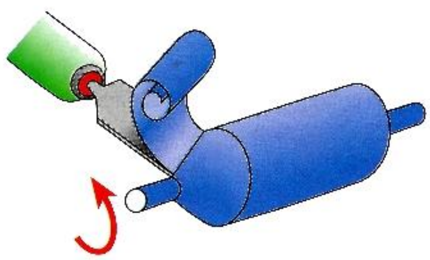


Fig. 3 – *the acceleration-driven extraction of figure 1(b) is analogous to a different kind of wood turning, with shavings from all radii.*

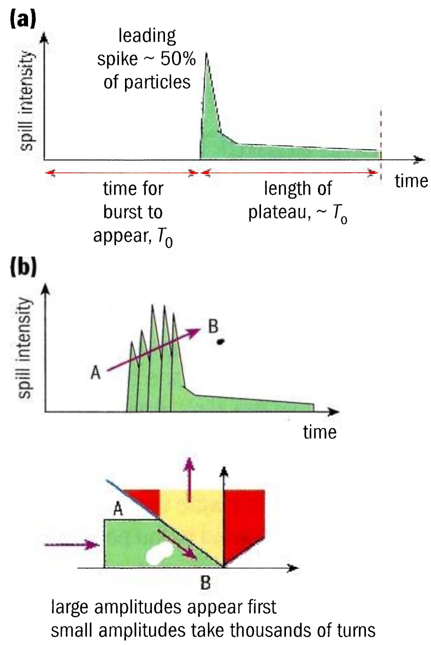


Fig. 4 – *acceleration-driven extraction mixes different initial amplitudes, the spikes becoming blurred and the resultant beam more smooth.*

CERN is host to the Proton-Ion Medical Machine Study (PIMMS), a multinational collaboration that is looking at how particle physics can benefit medical treatment.

Increased life expectancy goes hand in hand with support from science. At present, about one in three of us will have an encounter with cancer and, in developed countries, about one in eight will have this treated by a linear accelerator.

Conventional accelerator-based treatments use spread-out photon or proton beams collimated to the tumour shape. However, some tumours are more radio-resistant while others have complex shapes and are lodged around vital organs such as the optic nerve.

For these requirements of higher radiobiological efficiency and higher precision, the next generation of hadron therapy accelerators are arming themselves with light ions (probably carbon) and high-precision voxel (volume pixel) or raster scanning techniques that maintain millimetre precision over complex volumes.

The expertise of accelerator labs like CERN helps point the way to further progress in this fast-growing applications area of particle physics. For example, the accelerator has to deliver the beam smoothly and controllably. Resonant slow extraction can be used from a synchrotron, but how can the legendary sensitivity of the spill be stabilized?

Figure 1 shows how a beam can be moved into the unstable region of a resonance for extraction. Scenario (a) is the classic quadrupole-driven extraction that "pushes" the resonance across the beam. Scenario (b) shows the acceleration-driven extraction (used successfully at CERN's LEAR low-energy antiproton ring) that instead moves the beam across the resonance. Finally, scenario (c) (from Japan) blows up the oscillation amplitudes until the particles reach the resonance.

The quadrupole-driven extraction (a) is analogous to turning a piece of wood on a lathe, as illustrated in figure 2. However, in particle extraction the "wood" shaving is more important than the remaining wood. The wood turns about one million times to com-

hadron therapy

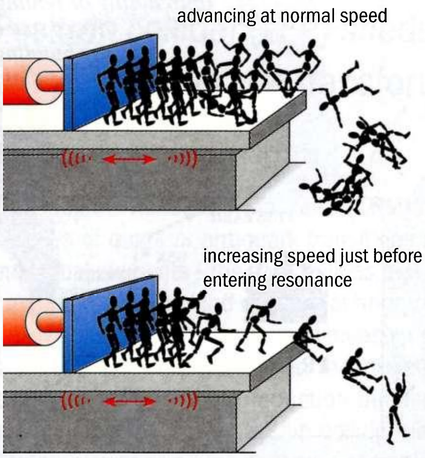


Fig. 5 – *illustrating the technique of "front-end acceleration". Victims on a shaking cliff being slowly pushed towards the edge by a ram will fall randomly, but if ordered to take a running jump, their increase in velocity compared to the floor movement makes their lemming-like exodus more uniform.*

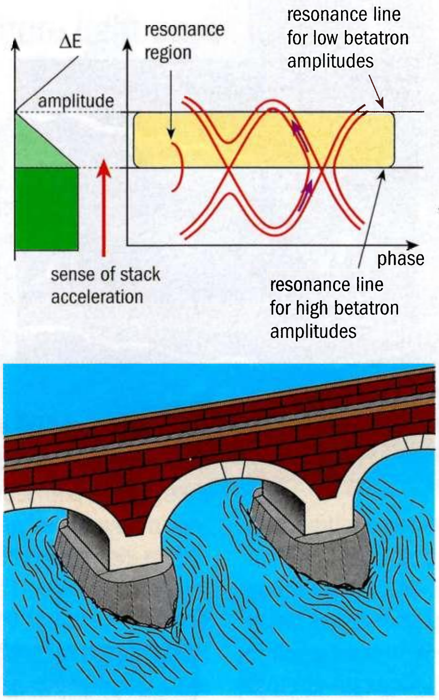


Fig. 6 – *if the longitudinal phase space between resonance and beam is partially blocked by radio-frequency "buckets" (stable areas in phase space), then the beam must dodge round them, rather as the water in a river rushes more quickly past the piers of a bridge.*

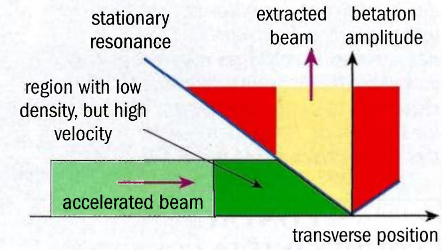


Fig. 7 – *a suitably modified version of the extraction scheme of figure 1(b).*

plete the extraction and the resultant wafer-thin shaving is easily destroyed by the slightest vibration.

With this classic technique, a sharp movement between the beam and the resonance for particles with a given amplitude leads to a burst of particles in the spill with a leading peak and a flat plateau. The time needed for this burst to appear depends on the initial oscillation amplitude. The first remedial step is to adopt acceleration-driven extraction, illustrated in figure 3 by analogy to a different kind of wood turning. In this case, the shaving is composed of wood from all radii. By mixing different initial amplitudes, the spikes are blurred. Figure 4 shows the resultant smoothing effect.

The next remedial step – "front-end acceleration" – is more active. Imagine a crowd on a shaking cliff being slowly pushed towards the edge by a ram (figure 5). The victims will fall randomly, but if ordered to take a running jump, their increase in velocity compared to the floor movement would stabilize them and the lemming-like exodus would be more uniform.

This can be done with a slow extraction and has been demonstrated in the CERN proton synchroton. If the longitudinal phase space between resonance and beam is partially blocked by radio-frequency "buckets" (stable areas in phase space), then the beam must dodge round them, rather as the water in a river rushes more quickly past the piers of a bridge (figure 6).

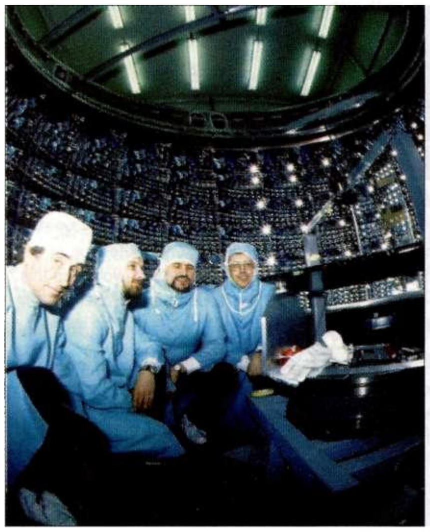
To accelerate the beam, a betatron core is an ideal choice for a smooth spill and has the great advantage that all other parameters in the machine can be kept constant during the extraction. These refinements modify the extraction of figure 1(c) into figure 7.

CERN is hosting and supporting PIMMS (Proton-Ion Medical Machine Study), where these and other ideas are being developed. PIMMS is a fruitful collaboration between the national organizations Med-AUSTRON in Austria, Onkologie 2000 in the Czech Republic and the TERA Foundation in Italy. The study group has also benefited from close contacts with the GSI laboratory, Darmstadt, where beams of carbon ions are already being used for therapy.

Philip Bryant, *CERN.*

LEP helps fill CKM matrix

New evidence from CERN's Large Electron–Positron collider (LEP) sheds more light on the way quarks can transform.



Thinking RICH. At the Delphi experiment at CERN's LEP electron–positron collider, the Ring Imaging Cerenkov, RICH, detector, seen here during installation, plays a vital role in measuring W-boson decays into a charm and a strange quark. The RICH allows s quark-containing particles to be identified.

The Cabibbo-Kobayashi-Maskawa (CKM) matrix codifies the probabilities of quark or antiquark transitions in weak interactions. Its individual elements – the probabilities that a quark or antiquark will turn into a different kind of quark or antiquark in a weak interaction – are not predicted by theory, and measuring them has been a major preoccupation of physicists in recent years. With the step up in energy to the W-boson production threshold at LEP in 1996, the experiments at CERN's flagship collider have begun to make their contribution to this important area of particle physics. Results from LEP's first two years of W-boson running were presented at this year's major particle physics conference, ICHEP'98, in Vancouver in July.

The CKM matrix owes its origins to the phenomenon of CP-violation, a subtle difference between Nature's treatment of matter and antimatter. CP-violation was discovered by James Cronin and Val Fitch at Brookhaven in 1964. At the time, physicists knew of just three quarks, up, down and strange, whose transitions were described by Nicola Cabibbo. His picture did not allow CP-violation since the transition probabilities for quarks and antiquarks were identical, putting matter and antimatter on equal footing.

Extended matrix

To accommodate Cronin and Fitch's observation, the Japanese physicists Makoto Kobayashi and Toshihide Maskawa extended Cabibbo's ideas to six quarks with the resulting 3×3 CKM matrix whose nine elements govern the transition probabilities between these quarks or their antiquarks. Since the CKM formulation does not specify whether these probabilities are the same for quarks and antiquarks, it opens the door to CP-violation.

To a good approximation, the CKM elements on the diagonal, which relate quarks of the same family, up and down, charm and strange, and top and bottom, are expected to be close to one. In other words quarks prefer to keep things in the family, the probability of changing into a quark or antiquark from a different family being small.

Up to now, most CKM measurements have been made by studying the weak decays of quarks, but many have been hampered by the fact that it is generally not a quark which is observed to decay but a hadron. As a consequence, assumptions about the behaviour of the hadron have to be folded in with the experimental measurement in order to extract a result.

The best measured CKM element, V_{ud}, which gives the probability that an up quark will become a down quark, does not suffer from this problem. It is measured to a few parts in a thousand by comparing beta decay with muon decay, processes which do not involve assumptions about hadron structure. The next element on the diagonal however, V_{cs}, does suffer from hadronic uncertainties. It is measured only to an accuracy of around 16% from the decays of c quark-containing D mesons into s quark-containing kaons.

The advent of W-boson production at LEP has opened up a new route to measuring V_{cs} without relying on hadron decays. LEP's four experiments, Aleph, Delphi, L3, and Opal, identify and count particles containing c quarks emerging from W decays. They then divide this number by the total number of W decays producing hadrons. Since there are six known quark combinations a W-boson can decay to, three of which involve c quarks, the resulting ratio is expected to be a half. Any deviation could indicate that W-bosons can decay in ways unknown to the Standard Model (the theory which encapsulates our current knowledge of elementary particle interactions). Combining the results from all the experiments, however, yields a ratio of 0.506 with an uncertainty of 12%. Good news for the Standard Model.

The LEP measurement of V_{cs} comes from combining this ratio with previously measured values of the other CKM elements. This yields a value of 0.987 with an uncertainty of under 12%, a marked improvement on the previous 16% measurement. However, the LEP result is still dependent on measurements of other matrix elements. An alternative analysis, which requires more data to become competitive, aims to overcome this hurdle. By simultaneously identifying particles containing c quarks and particles containing s quarks, the aim is to measure V_{cs} directly from W decays into a c and an s. As more data are analysed, the LEP experiments hope to reduce the uncertainty on V_{cs} to a few percent. If this matrix element can be so accurately measured, perhaps it will shed light on hadron models instead of the other way round.

Further reading

See Vladimir Obraztsov, *W->c(s) BRs and V_{cs}*, in parallel session 1 at the ICHEP'98 Web site: "http://ichep98.triumf.ca/main.asp". Proceedings to be published by World Scientific.

QED: surviving the bad press

"How in the world can you make any money out of a theory like this?" asked Steven Weinberg. But quantum electrodynamics has proven a robust theory, and researchers are still pushing at its frontiers – as a workshop in Bulgaria revealed.

Weinberg's irreverent remark about quantum electrodynamics (made in his 1986 Dirac Memorial Lecture) is just one among many made by such luminaries as Dirac, who suggested that the remarkable agreement between QED calculations and experiment was a "fluke", and Feynman, who described such calculations as a mathematical "hocus-pocus" (and who suspected that the renormalization technique that produces the agreement is not mathematically self-consistent).

In spite of this bad press, QED has not only survived but prospered – after more than 50 years it has become the prototype against which every other quantum field theory is measured, and its status as the most successful theory we have ever had in physics remains unchallenged.

To some particle physicists, this very success seems to have excluded the notion that there might still be a QED scientific frontier. In fact, at least three of them could be discerned at a workshop held in June in Sandansky, Bulgaria, entitled "Frontier tests of QED and physics of the vacuum".

The first concerns such exotic atomic systems as metastable antiprotonic helium (a helium atom with an antiproton substituted for one electron), singly-charged heavy ions such as uranium-91^{+}, muonium (a bound state of a muon and an electron), and antihydrogen (an antiproton with an orbital positron). Beyond a certain level of experimental precision, each of these hydrogen- and helium-like systems is a testbench atom for one QED aspect or another.

The second frontier is the study of macroscopic consequences of QED, with effects like vacuum polarization (spontaneous transient particles) and zero-point energy (the "dressing" surrounding a bare particle); hence the weak birefringence acquired by a vacuum under a magnetic field (a consequence of vacuum polarization) and the Casimir force between objects in the vacuum, this being related to the change of zero-point energy when the vacuum's domain of quantization is restricted by boundaries. (The Casimir force between two parallel plates is proportional to the inverse fourth power of their separation and has magnitude of about 0.2×10^{-5} newtons for 1 cm^2 plates separated by 0.5 microns – equivalent to a mosquito standing on one of the plates.)

Finally there is what might be called the Popperian frontier – the line beyond which QED might yet be found lacking. The holy grail of researchers in this latter domain is to discover some effect that does not agree with the predictions of Feynman's hocus-pocus.

As with geographical frontiers, there is some mystery and not a little argument about where QED frontiers begin, end, and overlap. The first of them is perhaps of most interest to particle physicists, much of the research having been done at CERN and other accelerator laboratories. Thus, several Sandansky talks dealt with experimental and theoretical aspects of the antiprotonic helium atom, which has been investigated spectroscopically by experiment PS205 at CERN's LEAR low-energy antiproton ring. The steady advance in the measurement precision of spectral lines reported by H A Torii and E Widmann (Tokyo) has led this work into the parts-per-million domain where QED and spin effects must be taken into account in calculating expected transition frequencies. These calculations were discussed by D Bakalov (Sofia) and V I Korobov (Dubna). The experiments will be taken yet further by the ASACUSA experiment at CERN's AD Antiproton Decelerator (May 1997, p1). Its first results, expected in summer 1999, should inspire theorists to make still more refined QED calculations.

Sandansky workshop organizers take a break from their duties. (Photo J Reinhardt.)

Also coming into sight at the AD are spectroscopic experiments on antihydrogen. As the underlying concepts of local field theory assert that there is no difference between the QED of hydrogen and antihydrogen atoms, laser spectroscopy can provide extremely precise tests by comparing identical spectral features in the two atoms.

The status of ATRAP, which is one of the two AD antihydrogen experiments, was discussed by G Gabrielse (Harvard), who also announced the latest results of his group's ever-more precise determination of the antiproton charge/mass ratio. Other topics were improved measurements of the the muon magnetic moment (V Hughes, Yale) and of the hyperfine structure of the muonium atom (K Jungmann, Heidelberg). Muonium, containing no strongly interacting particles, is free of complications arising from hadron charge and magnetic form factors.

Frontiers

C Guaraldo described an imminent experiment at DAFNE, Frascati, in which transitions between neighbouring levels in kaonic hydrogen and deuterium (in both of which the electron is replaced by a negative kaon) will be precisely measured. In similar vein, Detlev Gotta (Juelich) reported on studies at LEAR and the Swiss PSI laboratory of the fine and hyperfine structure of transitions between neighbouring levels of antiprotonic hydrogen (protonium – where the electron of hydrogen is replaced by an antiproton, as distinct from antihydrogen) and antiprotonic deuterium, as well as the experiment proposed at PSI to determine the pion–nucleon coupling constant to 1% via spectroscopic studies of pionic hydrogen.

Franz Kottmann (ETH Zurich) pointed out that spectroscopy of muonic hydrogen now appears feasible, and should supply essential information on the proton form factors, uncertainty about which currently limits the accuracy of QED calculations for the hydrogen atom.

Finally, the supercritical regime of QED was discussed by T Cowan (Livermore) and others. Supercriticality should appear with nuclei whose atomic number Z approaches the reciprocal of the fine-structure constant, α, $^1/_{137}$. $Z\alpha$ is then no longer a small number and new phenomena should appear – the so-called "sparking of the vacuum".

The obvious candidates for this condition are heavy atoms from which all electrons but one have been removed, but it can also be satisfied in high-energy photon–photon inelastic scattering experiments such as those described by A C Melissinos (SLAC).

At the macroscopic QED frontier, approaches at Florence and Padova to detect and measure the Casimir force, and at Legnaro and Fermilab to observe field-induced vacuum birefringence were presented. In the latter studies, a linearly polarized light beam will be sent through the kind of large dipole magnet familiar to particle physicists as elements of high-energy beamlines, but with a resonant optical cavity enclosed between the poles. After many cavity traversals, the light beam should acquire a measurable elliptical polarization. R Pengo (Legnaro) and F Nezrick (Fermilab) described how this may be detected via its modulation when a constant-field dipole magnet is physically rotated, or when the field undergoes extremely low-frequency oscillations.

The conditions to challenge QED demand stratospherically high levels of precision. While agreement between theory and experiment in quantum chromodynamics (the field theory of quarks and gluons) is at best about 1%, the ultimate in QED tests requires parts in 10^{12}. This frontier is constantly being pushed back by improvements in the precision of spectral line measurements for simple atoms such as hydrogen. In this respect, T W Hänsch (Munich) presented the latest experimental results on the hydrogen 1S–2S transition frequency, now known with a precision of a few parts per trillion. Such advances must be complemented by improved theoretical techniques, a further subject of heated discussions at Sandansky.

John Eades, *CERN.*

Physics in Bulgaria

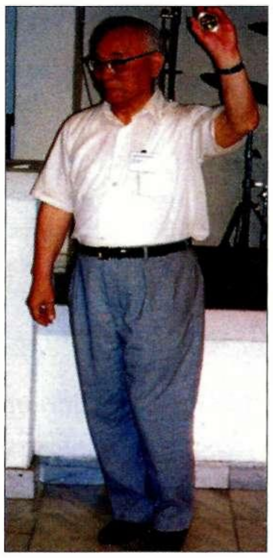
Sandansky, a resort town in south-western Bulgaria, was the birthplace of Spartacus the gladiator. In Spartacus's time it was known as Medius, but now the town is named after a key figure in early 20th century Bulgarian history, Janne Sandansky.

Bulgaria might seem an unlikely venue for a physics conference. However, as some 50 participants at the "Frontier tests of QED and physics of the vacuum" workshop found, Bulgarian physics is strong, healthy and in good hands, in spite of difficult economic conditions. The faultless organization of Dimitre Bakalov, Carlo Rizzo and the local committee complemented the programme committee's success in attracting many of the world's foremost workers in the QED field to Bulgaria, and made the workshop a highlight among meetings in any country in recent years. The Proceedings volume is expected by October as a result of a high-speed undertaking arranged with the Bulgarian Heron Press.

Bulgaria is a member of the Joint Institute for Nuclear Research, Dubna, and during a recent visit by a CERN delegation, CERN Research Director Lorenzo Foà had a series of talks with various members of the Bulgarian Council of Ministers in connection with Bulgaria's application to become the 20th CERN Member State.

The largest physics research centre in Bulgaria is the Institute of Nuclear Research and Nuclear Energy (INRNE) of the Bulgarian Academy of Sciences, which has a scientific staff of about 375. Its activities include high-energy physics (V Gentchev leads a Bulgarian team in the CMS experiment for CERN's LHC collider) and theoretical physics. The theory group includes I T Todorov (who has made important contributions to quantum field theory and has spent extended periods at MIT, the Princeton Institute for Advanced Study and Dubna), D Stoyanov and D Bakalov, chairman of the Sandansky organizing committee.

Other important institutions are the Sofia Faculty of Physics, which also takes part in CMS and has a theory group led by M Mateev, and the American University in Bulgaria (located in the provincial city of Blagoevgrad), which concentrates mainly on teaching.



Toichiro Kinoshita of Cornell displays the SUN-AMCO medal of the International Union of Pure and Applied Physics awarded at the Sandansky workshop. The medal recognizes his contribution to the precision determination of fundamental constants via his work in QED. (Photo D Bakalov.)

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Institute of Physics is pleased to announce that The Internet Pilot to Physics (TIPTOP) has been transferred to the Institute of Physics Web site so that it may be maintained and imaginatively developed within the Institute's award-winning electronic publishing department.

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SLC perched on a high

The Stanford Linear Collider has generated its last Z particle – unless the US government provides more money. But it crowned its act with a flourish.

Just before noon on 8 June, operators at the Stanford Linear Accelerator Center (SLAC) shut down the SLC Stanford Linear Collider for what may have been the last time. It had been a record-breaking year-long run in which the world's first-ever linear collider more than tripled its collision rate, or luminosity, and generated over 350,000 massive Z particles for physicists on the SLD experiment collaboration to study. But unless the US Department of Energy provides the funding for an extension, the 1997–98 run will have been the SLC's last hurrah.

The data-taking phase of the run had begun slowly in July 1997. Although the peak luminosity matched that of prior years, it was not quite up to the levels of the 1996 run. Accelerator physicists and operators were taking extra time to tune the machine carefully in preparation for the long run.

In October and November the collider really hit its stride, however, often exceeding a hundred hours of successful operations and 10,000 Zs per week. After recovering from the Christmas shutdown, the machine surpassed even those levels, occasionally delivering over 20,000 Zs per week during the rest of the run.

Under the leadership of Nan Phinney, who was aided by the untiring efforts of Pantaleo Raimondi and Tracy Usher, the SLC performed beyond expectations. Often working through the night, this pair found clever solutions to long-standing problems and helped achieve large luminosity gains without any major hardware upgrades.

Disruption

With beam profiles at the interaction point as small as 0.65 by 1.5 microns (rms half height and width), physicists finally began to observe the long-awaited phenomenon of "disruption", in which a bunch is compressed by the macroscopic electromagnetic fields of the bunch it passes through. According to estimates, this enhancement doubled the peak luminosity, leading to the high values attained toward the end of the run. Experimenters marvelled at occasional events in which they could clearly discern the crossing of two Zs produced in a single bunch.

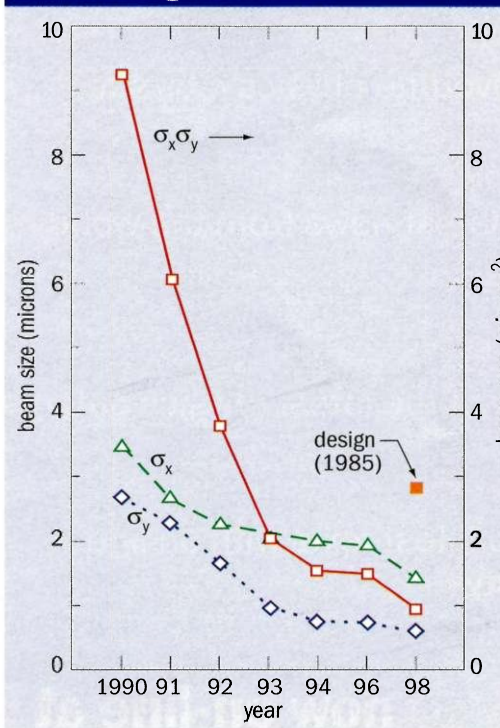
The collider was roaring along, generating 5300 Zs in the previous 24 hours, when a vacuum failure in the positron source forced its premature shutdown a week early. At the time the SLC was spewing out about 300 Zs per hour, or a peak luminosity of about 3×10^{30} per sq cm per s – half its design value.

The number of Zs the SLC produced in the 1997–98 run is nearly twice that generated in all previous runs, bringing the cumulative total to more than half a million. When combined with electron beam polarization levels of 73%, this bonanza means that SLD physicists will have plenty of work in the coming months extracting the world's best measurement of the weak mixing angle. And using the SLC's narrow beams together with what is the world's most sophisticated vertex detector, the collaboration may also be able to uncover other unique physics results – such as measuring the mass difference that determines the frequency of particle–antiparticle mixing in B_s mesons.

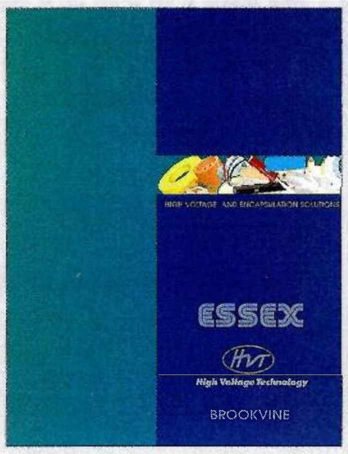
Undoubtedly there will be important questions left unanswered, however, and collaboration leaders are already lobbying for a final SLC run to raise the total number of Zs to more than a million. Another run could also allow them to boost its peak luminosity above the design value to 10^{31}, Phinney estimates. Such an achievement would help advance the state of the linear collider art in preparation for the TeV-scale linear collider that many now agree is the next major project for high-energy physics.

Whatever else happens, the SLC will go down in history as the machine that proved the feasibility of the linear collider concept. Although outgunned by CERN's LEP collider ring in terms of the sheer output of Z particles, physicists at SLAC fought back successfully by emphasizing narrow beams and polarization as important tools for doing precision physics measurements. With nearly twice the beam polarization originally planned, the SLC has now essentially achieved the overall performance goals set for it more than a decade ago – despite falling a bit short on the luminosity front. And even that shortcoming could be erased in a final run.

Shrinking beams



By compressing the size of the electron and positron beams at the interaction point (IP), the SLC has substantially increased its luminosity, a measure of the electron–positron collision rate. σ_x and σ_y are the rms beam half width and height, respectively; their product is a measure of the cross sectional area of the beam at the interaction point.



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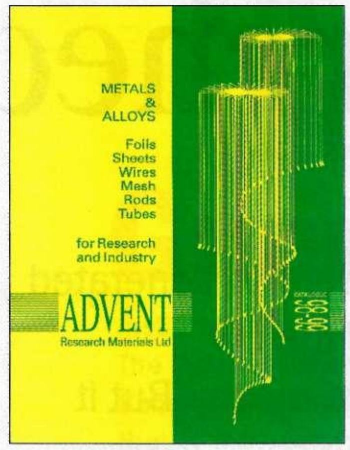

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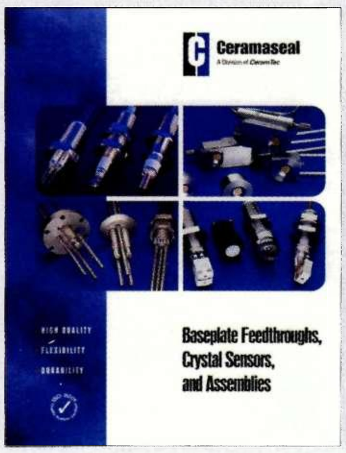

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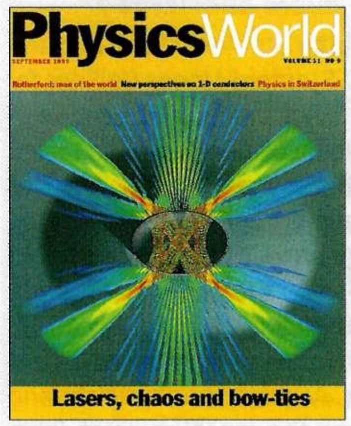

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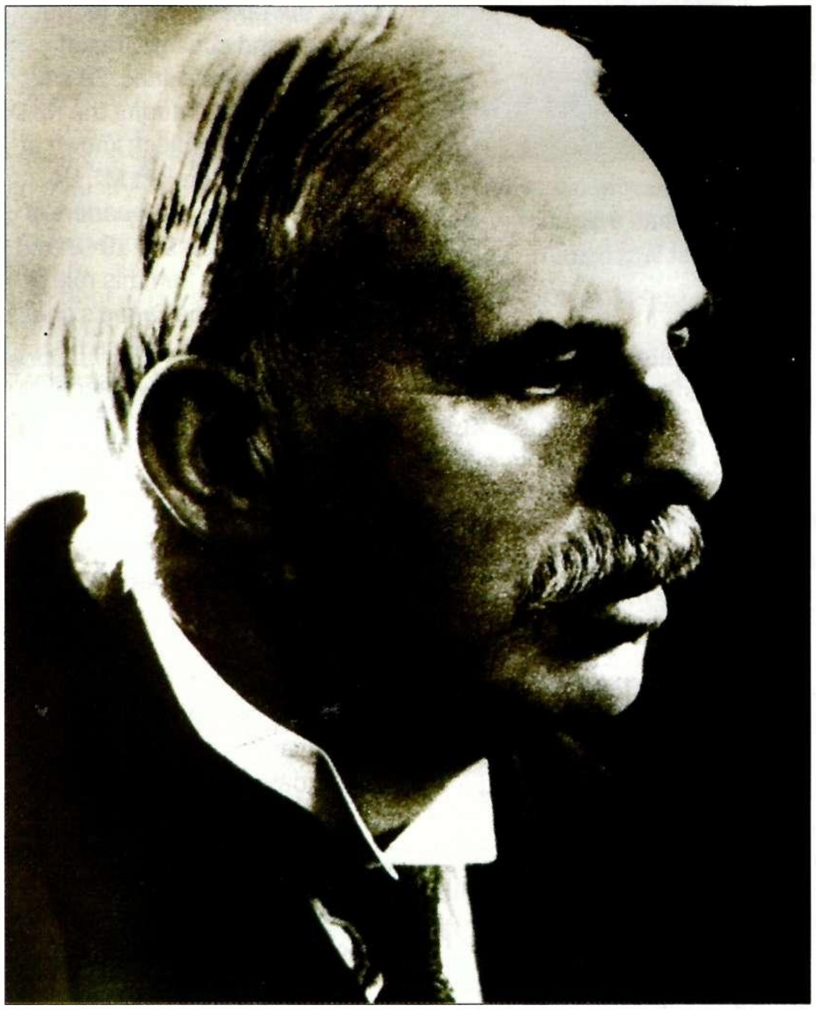
A hundred years ago...



One hundred years ago, Ernest Rutherford discovered that radioactivity has alpha and beta components.

In 1895, a chance discovery by Wilhelm Conrad Röntgen changed the face of science. It was the dawn of a new branch of physics – the investigation of subatomic phenomena. Following the centenary of the Röntgen discovery in 1995, an occasional series of articles in *CERN Courier* looks back at what happened one century ago.

Röntgen's discovery of X-rays in 1895 startled the world of science and immediately motivated other researchers to investigate fresh paths. In the Cavendish Laboratory in Cambridge, J J Thomson ordered a general mobilization of research effort on the new Röntgen phenomena. The result was that Thomson himself discovered the electron in 1897 and a young New Zealand student called Ernest Rutherford stopped playing about with his electromagnetic wave generator and turned to the new subatomic physics instead.

In 1896, the discovery by Henri Becquerel that uranium emitted mysterious radiation had provided fresh physics stimulation. However, in contrast to the immediate impact of the earlier Röntgen discovery, the implications of Becquerel's radioactivity breakthough took longer to appraise. Becquerel himself turned to the investigation of another new discovery, the Zeeman effect.

In Paris, one resolute young researcher was continuing with the study of Becquerel rays – Marie Curie. Working with her husband, Pierre, she showed that the ability of uranium compounds to emit the rays was a property of uranium itself, and went on to coin the name "radioactive". During 1898, in a heroic analysis of uranium-rich minerals, Marie and Pierre Curie identified two new radioactive substances – polonium and radium.

Marie Curie, the driving force in this work, did not finish her PhD thesis until 1903, that same year sharing the Nobel Physics prize with her husband and with Henri Becquerel for their work on radioactivity. Pierre Curie was killed in a Paris traffic accident in 1906, and Marie succeeded him as Sorbonne professor.

On the other side of the Channel, Rutherford had been working with Thomson, studying the gas ionization generated by X-rays and developing the parallel-plate electroscope. In 1898 the young New Zealand student turned to the ionization produced by Becquerel rays. While previously Rutherford had been looking at the effects of radiation ("the electrified gases from Röntgen's rays"), this time he focused on the nature of the radiation itself.

Setting the style for his subsequent work, simple but incisive methods produced remarkable insights. By covering his sources with layers of foil, Rutherford showed that Becquerel rays were inhomogeneous, with at least two distinct components, one of which was absorbed by just a few foils, which he called alpha-radiation, the other – beta-radiation – being more penetrating.

Rutherford's initial paper on radioactivity was completed at Cambridge on 1 September 1898, just before he left to take up the MacDonald Chair of Physics at McGill University, Montreal, where he was to continue his epic studies of radioactivity.

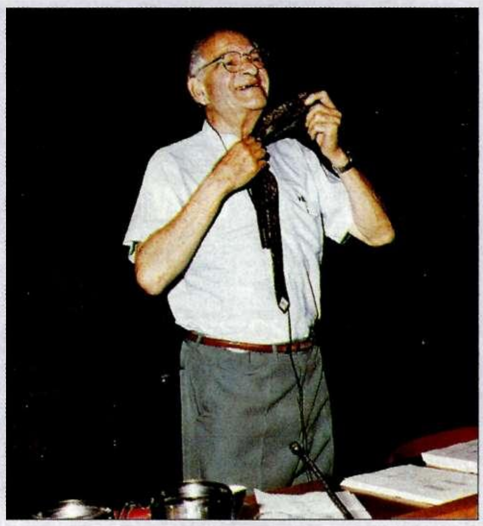
One hundred years later, the Curie–Rutherford nomenclature of radioactivity and alpha particles remains in everyday use.

This summer, CERN Director-General Chris Llewellyn Smith unveiled a sign naming the **Route Abdus Salam** on CERN's Meyrin site. The road passes near the site of the Gargamelle bubble chamber which discovered neutral currents in 1973, 25 years ago, and provided the first experimental confirmation of electroweak unification, of which Salam was a major architect. Soon after learning of his 1979 Nobel award for this work, Salam dutifully hastened to CERN to pay tribute to CERN's neutrino physics achievements. Also at the brief ceremony were some of those who contributed to these and subsequent physics developments at CERN, and for whom Salam's name has a special meaning: left to right – Maurice Jacob, John Ellis, Don Cundy, Chris Llewellyn Smith, Horst Wachsmuth, Luigi Di Lella, Alan Ball, Gregoire Kantardjian, Gordon Fraser, Guy Acquistapace.

At **Brookhaven** during the recent annual meeting of users of the laboratory's Alternating Gradient Synchrotron (AGS) and RHIC relativistic heavy ion collider – left to right; RHIC Project Director Satoshi Ozaki, AGS User Committee Chairman David Hertzog of Illinois, Brookhaven High Energy and Nuclear Physics Associate Director Tom Kirk, US Department of Energy High Energy and Nuclear Physics Associate Director Peter Rosen (seated).

The venerable AGS has recently produced some notable example of rare events, while the new precision experiment to measure the muon magnetic moment continues to make good progress. Next year sees the commissioning of the 3.8 kilometre RHIC collider ring.

Victor Weisskopf celebrated his 90th birthday on 19 September. Weisskopf's career has spanned and helped mould the entire history of modern physics, his contributions ranging from fundamental quantum mechanics in Göttingen in the late 1920s, to pioneer quantum chromodynamics in the early 1970s. He has also been a key player in some of the great dramas which unfolded during the 20th century. A truly world citizen, he served as Director-General of CERN from 1961–65 and in a number of key responsibilities in the US. In all these roles as a scientist and a scientist-administrator he has left a mark. As Chairman of CERN's Scientific Policy Committee from 1964–66, the eminent French physicist Louis Leprince-Ringuet said of Weisskopf, "the spirit of CERN is his creation". MIT, where Weisskopf worked for many years, marked the event by a private dinner for him at the American Academy of Arts and Sciences.



Edward Ginzton

Stanford Linear Accelerator Center pioneer Edward Ginzton died in August at the age of 82 from complications following surgery. During the 1950s, he headed a team of Stanford physicists in the design of a 1 GeV linear accelerator that was the take-off point for the design and construction of SLAC's two-mile linac. Ed was SLAC's director during the R&D phase of the project, known at that time as "Project M". He was one of the six founders of Varian Associates in 1948 and stepped down from his role at SLAC to become Varian's chairman in 1961. As well as his driving role in SLAC, his many contributions to the development of high-power klystrons and accelerators are also widely acknowledged.

Web pioneer rewarded

World Wide Web pioneer Tim Berners-Lee, Director of the World Wide Web Consortium at MIT, becomes a Fellow of the prestigious MacArthur Foundation.

Blois Workshop

An International Conference on Elastic and Diffractive Scattering (the VIIIth "Blois Workshop") will be held at the Institute for High Energy Physics, Protvino, Moscow Region, Russia, from 28 June to 2 July 1999.

The main topics will be: the Pomeron and Odderon, QCD and soft and hard diffraction, together with current experiments (Fermilab, HERA, Cosmic rays), and new projects (RHIC, TOTEM).

Secretariat: Alexei Prokudin, EDS99 Organizing Committee, IHEP, Protvino, 142284 Russia. Fax: +(095)-230-2337. E-mail: blois@mx.ihep.su. Web: http://www.ihep.su/~blois/

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The Institute for High Energy Physics (IHEP) at Ruprecht-Karls Universität Heidelberg has an immediate opening for a

Scientific Staff Position in Technical Computer Science

(Wissenschaftlicher Angestellter) at the Lehrstuhl für Hardware Informatik, a newly formed research group. Immediate activities of this group include the design of high-performance trigger processors for LHC experiments which includes the implementation of trigger algorithms in both hard and software.

The successful applicant is to participate in both the scientific and educational activities of a German *Lehrstuhl.* Besides collaboration with industry, the scientific projects include long term activities such as the design and implementation of a fast trigger processor for LHC experiments at CERN. These projects include hardware and software design using the latest state of the art tools and equipment. The research group has access to an in-house ASIC laboratory.

Candidates should have experience with hard and software. Experience with modern digital design methodology (VHDL, Verilog synthesis) is very favourable. The candidate should be familiar with common operating systems such as Windows NT and Unix and should have experience with C and C++.
The position requires a Ph.D and includes a substantial benefits package. The appointment will be initially for two years with a possible extension up to 5 years. Superior performance in the position would offer the possibility to confer qualification as a university lecturer *(Habilitation).*

Applications: Ref: VOL_2A, are invited to be sent to Prof. Volker Lindenstruth before 31.10.98, e-mail: voli@ihep.uni-heidelberg.de, phone: 0049 62 21 54 43 03. Ruprecht-Karls-Universität Heidelberg, Institute for High Energy Physics, Schröderstrasse 90, D-69120 Heidelberg, Germany.

Disabled applicants with equal qualifications will be preferred.
The Heidelberg University encourages especially women to apply.

UNIVERSITY OF CALIFORNIA, RIVERSIDE

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The D-zero group at the University of California, Riverside has an immediate opening for a postdoctoral physicist. The successful applicant will be based at Fermilab and is expected to play a major role in the design and implementation of reconstruction software for the D-Zero silicon tracker and to exhibit a leadership role in the analysis of data from the high luminosity Tevatron run beginning in Spring 2000. Experience with object-oriented design and C++ is preferred but not essential.

The Riverside group consists of two faculty (John Ellison and Stephen Wimpenny), one research faculty (Ann Heinson), two post-docs and two students. The group is making important contributions to the design and construction of the silicon tracker and has leading roles in analysis of D-Zero data in the areas of top quark and electroweak physics.

Interested persons should send the following application materials to **Yvonne Ayers, Department of Physics, University of California, Riverside, CA 92521-0413**:

- a resume
- a description of research experience
- names and addresses of at least three referees (the candidate should arrange to have the letters of recommendation sent directly to the address above).

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The University of Geneva particularly encourages women to apply.

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Topic of the first event: cyclotron operation and magnetic spectrometer, 23 nov. - 12 dec., 1998.

We invite PhD researchers and postdoctoral fellows in various fields of science (not only nuclear physics!) We offer a hands-on introduction to the principles of accelerator-based nuclear-physics research. Participants will become familiar with accelerator operation and detection equipment. Experimental activities will be accompanied by lectures and student seminars on the underlying physics concepts. The number of participants is limited to 25. The participation fee is 200-EU per event. For detailed information consult http://www.kci.nl/ under the topic TMR. Applications and requests for financial support should be sent before November 1st to the organiser: Prof. dr. H. Löhner, KVI, Zernikelaan 25, NL-9747 AA Groningen, The Netherlands, e-mail: loehner@KVI.nl.

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The Department of Physics at the University of California at Davis invites applications for a tenure-track faculty position as Assistant Professor in theoretical or observational cosmology which will be available July 1, 1999.

This position is the second of four new positions created for our cosmology program. The current cosmology group consists of Professors Andreas Albrecht and Robert Becker. The cosmology program will benefit from overlapping interests with our strong departmental programs in nuclear physics, condensed matter and quantum gravity, and especially with our particle physics program. Outstanding persons in all areas of cosmology will be considered. Faculty at UC Davis have full access to both Lick and Keck Observatories. The successful candidate will have a Ph.D. in physics or astrophysics and will be expected to teach at the undergraduate and graduate levels and to conduct an active research program in cosmology.

This position is open until filled; but to assure full consideration, applications should be received by November 16, 1998. To initiate the application process, request an application package by writing an e-mail message to *forms@physics.ucdavis.edu.* Those who do not have access to e-mail should send curriculum vitae, publication list, research statement, and the names (including address, e-mail, fax, and phone number) of three or more references to:

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SCIENTIFIC STAFF POSITIONS

A research center focusing on the physics program of the Relativistic Heavy Ion Collider (RHIC), hard QCD/spin physics, lattice QCD and relativistic heavy ion physics has been established by the Institute of Physical and Chemical Research, Japan (RIKEN) at Brookhaven National Laboratory. The members of the center will be Research Associates (two-year appointments), RIKEN BNL Fellows (up to five-year appointments) and Visiting Scientists. Frequent workshops are planned. Several positions for theorists in the above categories are expected to be offered for the fall of 1999. Members of the Center will work closely with the existing high energy and nuclear physics groups at BNL.

Scientists with appropriate backgrounds who are interested in applying for Research Associate positions should send a *curriculum vitae* and three letters of reference to Dr. T. D. Lee, Building 510A, Brookhaven National Laboratory, P.O. Box 5000, Upton, Long Island, NY 11973-5000, before January 1, 1999. BNL is an equal opportunity employer committed to work force diversity.

BROOKHAVEN NATIONAL LABORATORY
on the frontier of science and technology

The Institute for High Energy Physics (IHEP) at Ruprecht-Karls Universität Heidelberg has an immediate opening for a

Permanent Position in Technical Computer Science

The successful applicant is to play a major role within a new and growing research group, and is to participate in both the scientific and educational activities of a German *Lehrstuhl*. Besides collaboration with industry, the scientific projects include long term activities such as the design and implementation of a fast trigger processor for one of the LHC experiments at CERN. These projects include hard and software design using the latest state of the art tools and equipment. The research group has access to an in-house ASIC laboratory.

Candidates should have experience in the design, implementation and debugging of digital hardware including PC board level design and FPGA design. Background in ASIC design and experience with modern digital design methodology (VHDL/Verilog synthesis) is very favourable. The candidate should be familiar with Windows NT and Unix and should have experience with C and C++. Background in the development of firmware or embedded real-time software as well as knowledge about NT/Unix driver development are highly regarded. Familiarity with real-time operating systems such as Linux, VxWorks and OS9 are useful.

Applications: Ref: VOL _IB are invited to be sent to Prof. Volker Lindenstruth before 31.10.98, e-mail: voli@ihep.uni-heidelberg.de, phone: 0049 62 21 54 43 03. Ruprecht-Karls Universität Heidelberg, Institute for High Energy Physics, Schröderstrasse 90, D-69120 Heidelberg, Germany.

Disabled applicants with equal qualifications will be preferred.
The Heidelberg University encourages especially women to apply.

RIKEN BNL Research Center
Brookhaven National Laboratory

TENURE TRACK
STRONG INTERACTION THEORY
RHIC Physics Fellow Positions

The RIKEN BNL Research Center (RBRC) at Brookhaven National Laboratory, together with university partners, invites applications for a new program of cooperative fellowships in strong interactions theoretical physics motivated by the experimental program of the Relativistic Heavy Ion Collider soon to be operating at BNL. Each RHIC Physics Fellow will be jointly selected and supported for 5 years, beginning September 1999, by the Center and one of the cooperating universities, and will hold a tenure track faculty appointment (or equivalent) in that university's Physics Department. Each fellow will spend about half time at RBRC and the remaining time at the university. Candidates should have a Ph.D. degree in theoretical nuclear or particle physics and be interested in pursuing theoretical research within a broad range of hadron physics, such as high energy nuclear theory, RHIC physics, QCD (perturbative and lattice), hadronic spin physics, hadronic spectra and their transition matrix elements.

Scientists with appropriate backgrounds who are interested in applying should send a *curriculum vitae* and three letters of reference to: Dr. T. D. Lee, Director, RIKEN BNL Research Center, Building 510, Brookhaven National Laboratory, P.O. Box 5000, Upton, Long Island, NY 11973-5000 before January 1, 1999. Additional information, including a list of participating universities, is available by sending an email request to: rhic_fellows@bnl.gov or writing to the above address. BNL is an equal opportunity employer committed to workforce diversity.

BROOKHAVEN NATIONAL LABORATORY
on the frontier of science and technology

University of Chicago
Postdoctoral Research Associate

The high-energy physics group at the University of Chicago has an immediate opening for a research associate to work on the ATLAS and OPAL experiments. This allows physics analysis with an operating experiment as well as challenging technical work on the preparation of a next-generation collider detector.

The position would be based at the University of Chicago during the first two years, with special emphasis on the ATLAS work. Trips to CERN would be needed to participate in meetings, and test beam studies. In subsequent years the individual could be based at CERN, with more emphasis on OPAL.

We seek an individual with a recent PhD in experimental particle physics. Experience with both physics analysis and detector hardware would be an asset, but not absolutely essential for a talented individual. The position is renewable for up to four years.

For enquiries or more information contact Jim Pilcher. E-mail pilcher@uchep.uchicago.edu. Phone No. 00-1-773-702-7443.

Applications with a CV, publication list and three confidential letters of recommendation should be sent to: Professor J. Pilcher, Enrico Fermi Institute, University of Chicago, 5640 S. Ellis Avenue, Chicago, IL 60637.

LEAP AHEAD OF THE REST.....PLACE YOUR RECRUITMENT MESSAGE IN FRONT OF A QUALIFIED AUDIENCE

For further information
on recruitment advertising in the
CERN Courier please contact Chris Thomas

Tel: +44 (0)117 930 1031
Fax: +44 (0)117 930 1178
E-mail: chris.thomas@ioppublishing.co.uk

EXPERIMENTAL CONDENSED MATTER PHYSICS
University of Utah

The Physics Department at the University of Utah is seeking highly qualified candidates for an assistant professor tenure track position in experimental condensed matter physics. Research specialties of particular interest include the physics of nanostructures, quantum electronics, optics and acoustics. We seek candidates with strong commitments to both teaching and research. Successful candidates will be expected to teach undergraduate and graduate courses in Physics.

Candidates should submit their curriculum vitae, list of publications, and three letters of recommendation by February 15, 1999 to:

CONDENSED MATTER SEARCH COMMITTEE
Department of Physics
115 South 1400 East, Room 201
University of Utah
Salt Lake City, UT 84112-0830

University of Utah is an Affirmative Action Equal Opportunity Employer. It encourages applications from women and minorities and provides reasonable accommodations to the known disabilities of applicants and employees.

UNIVERSITY OF CALIFORNIA, SAN DIEGO

DEPARTMENT OF PHYSICS

The Department of Physics at the University of California, San Diego, invites applications from outstanding candidates for a Postdoctoral Research position in experimental High Energy Physics. UCSD is a member of the BABAR experiment at the PEP II B Factory at SLAC. The goal of BABAR and PEP II is to explore CP violation in B decays as a precision test of the Standard Model, beginning with first collider data in 1999. The successful applicant will participate in the commissioning of the BABAR detector, and thereafter in data taking and physics analysis. It is expected that UCSD will contribute to the ongoing operation of the Drift Chamber, as well as to tracking and reconstruction software development. Candidates with interest and experience in these areas and in data analysis are particularly encouraged to apply. A Ph.D. in particle physics or a related field is required. Applicants should send a copy of their curriculum vitae, including a statement of physics interests, and arrange for three letters of recommendation to be sent to:

Professor David MacFarlane
Physics Department, 0319
University of California at San Diego
9500 Gilman Drive, La Jolla, CA 92093-0319
e-mail: dbmacfarlane@ucsd.edu
phone: + (619) 822-1452
fax: + (619) 534-0173

The nominal deadline for the receipt of the application is December 1, 1998. But the search will continue until the position is filled.

UCSD is an equal-opportunity, affirmative-action employer.

UNIVERSITY OF VICTORIA

POSTDOCTORAL RESEARCH ASSOCIATE POSITIONS IN EXPERIMENTAL HIGH ENERGY PHYSICS

The University of Victoria invites applicants for Research Associate positions in Experimental High Energy Physics. The positions will either be based at CERN or at the University of Victoria, working on the OPAL and ATLAS experiments. The positions have a two-year term with a possible one year extension. The positions are available immediately.

The University of Victoria group is currently pursuing research at LEP II with the OPAL collaboration. The group already has a significant role in searches for new phenomena, triple gauge coupling measurements and several aspects of physics with tau leptons. The group is also responsible for operating the OPAL online data reconstruction facility.

The University of Victoria Group is responsible for the construction of cryogenics feedthroughs for the ATLAS liquid argon calorimeter. The group also has responsibilities in the ATLAS endcap hadronic calorimeter beam tests and installation.

Candidates should have a recent Ph.D. in particle physics. Interested candidates should, prior to 15 January 1999, send a curriculum vitae, a description of research interests, and arrange for two letters of recommendation to be sent to:

Dr. M. Lefebvre or Dr. R. Sobie
Department of Physics and Astronomy
University of Victoria
Box 3055 Stn CSC
Victoria, British Columbia
V8W 3P6
E-mail: lefebvre@uvic.ca or rsobie@uvic.ca
FAX: (250) 721-7752

In accordance with Canadian immigration regulations, priority will be given to Canadian citizens and permanent residents. All qualified individuals are encouraged to apply.

POSITIONS AT THE NSCL MICHIGAN STATE UNIVERSITY

The National Superconducting Cyclotron Laboratory at Michigan State University has openings for top quality candidates to be post-doctoral fellows and assistant research professors. The appointments are typically renewable up to three years and are for research in nuclear or accelerator physics, both experimental and theoretical. The experimental nuclear physics program includes studies approaching the driplines with radioactive beams, nuclear astrophysics, and nucleus-nucleus reaction dynamics using the K1200 cyclotron system that can produce heavy ion beams in the 10 - 200 MeV/nucleon range.

Further descriptions of the research opportunities can be found on our web-site http://www.nscl.msu.edu/ Please send a CV with a list of publications and arrange for three letters of reference to be sent directly by post to Prof. D.J. Morrissey, NSCL, Michigan State University, East Lansing, MI, 48824, or e-mail to morrissey@nscl.msu.edu

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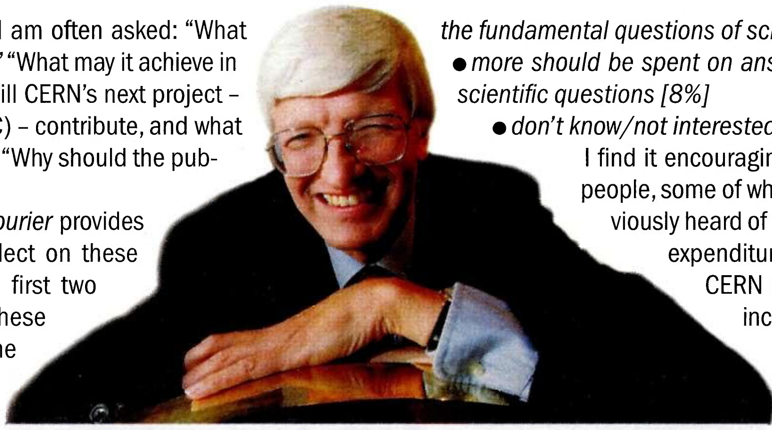
The public and particle physics



The first of two articles in which, as his five-year mandate as Director-General of CERN nears its end, *Chris Llewellyn Smith* reflects on what particle physics has achieved, where it is going and why it deserves support.

As Director-General of CERN, I am often asked: "What has particle physics achieved?" "What may it achieve in the future, what in particular will CERN's next project – the Large Hadron Collider (LHC) – contribute, and what may come after the LHC?" and "Why should the public support particle physics?"

The launch of a new-look *Courier* provides an opportune moment to reflect on these questions. I will consider the first two questions in the second of these essays, which will survey the achievements of the past and argue that prospects for the foreseeable future are excellent, especially at CERN where the LHC will be the world's front-line facility for exploring the fundamental properties of matter in the first two decades of the next century. Here I consider the arguments that we particle physicists use when explaining the importance of particle physics to the public.

The primary argument is the intrinsic interest of understanding the nature of the matter of which the universe is made, to which I will return in my second essay. Readers of the *Courier* have been exposed to the fascination of the science, and also to the fact that particle physics has many important secondary benefits. These include spin-offs (devices developed to do particle physics that turn out to have other uses, such as the World Wide Web, or particle detectors and accelerators now used in medicine), stimulation of the technological capabilities of industry, training and the creation of networks between young scientists and engineers who go on to work in industry, and the ability to excite the interest of schoolchildren in science and technology. All these are of course very important, and it is also conceivable that particle physicists will discover new laws of Nature that can be exploited in novel and important ways (see my article at "http://www.cern.ch/Public/bs_1.html" for a general discussion of the importance of basic scientific research). These factors are, however, secondary in justifying support for particle physics – the science must come first.

What does the general public think? Two years ago a British newspaper published a poll which asked (responses added in brackets):

"Each year, the UK contributes £55m towards CERN, a European project based in Geneva where scientists are trying to understand what matter is made of and the basic laws of Nature. What do you think of the UK's spending money in this way? Do you think that

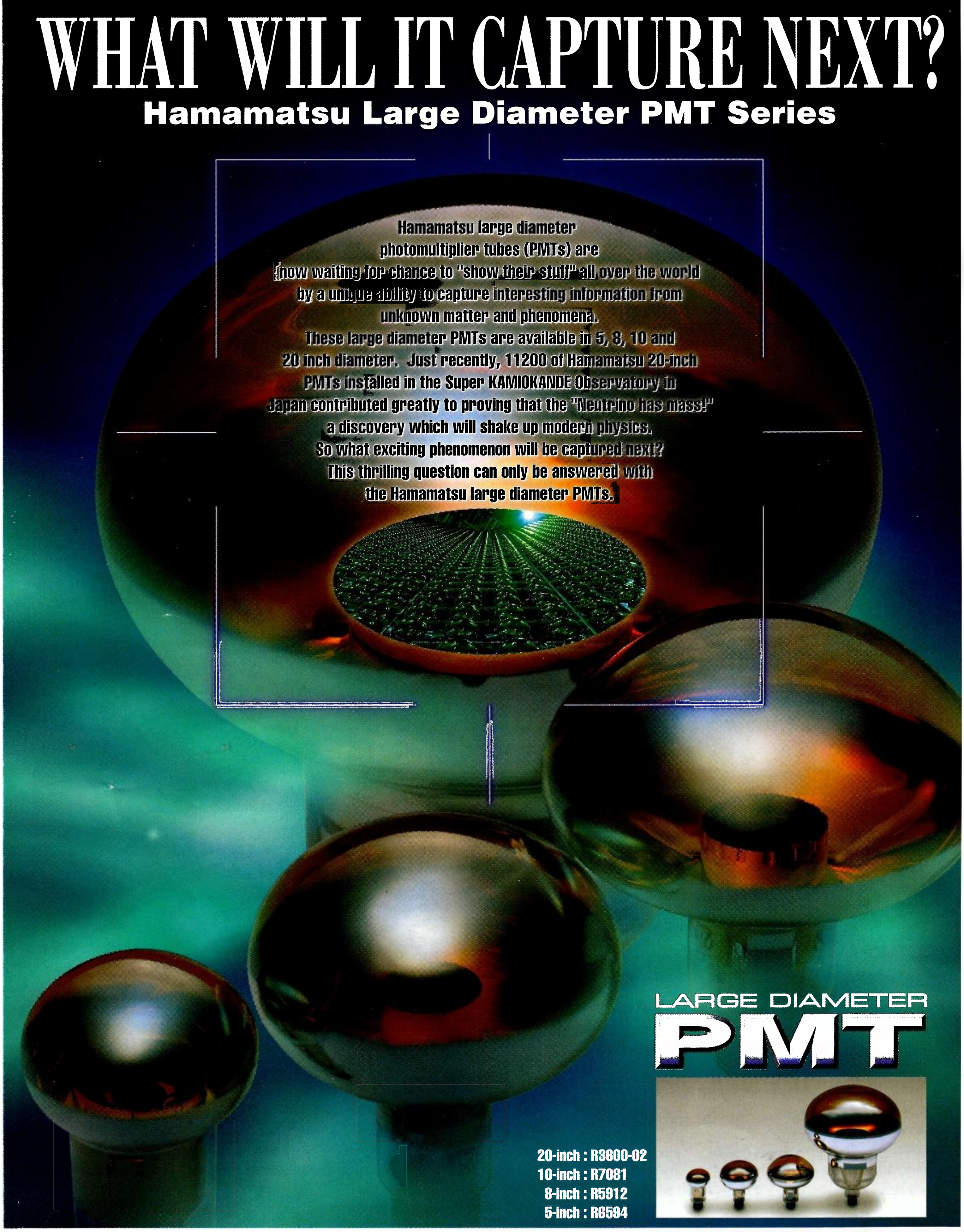
- *this should not be funded because no public money should be spent on science [5%]*
- *this money would be better spent on more practical issues such as health and transport [56%]*
- *it is very important that public money is spent on trying to answer the fundamental questions of science [22%]*
- *more should be spent on answering these and other basic scientific questions [8%]*
- *don't know/not interested [8%]."*

I find it encouraging that in a random sample of people, some of whom had presumably never previously heard of CERN, 30% thought that public expenditure on research such as that at CERN is justified, or should even be increased. Furthermore, those who felt that the money would be better spent on health might have expressed a different opinion if they had known that one person in eight in the developed world will at some time or other be treated for cancer with accelerators originally developed for research in nuclear and particle physics (see page 20), and that if they need a PET scan it is quite likely that the detectors in the scanner will use the BGO crystals developed originally for the L3 experiment at CERN's electron–positron collider, LEP.

In fact, in my experience, most people are interested in the discoveries of particle physics, and are ready to accept that mankind as a whole should continue to explore the fundamental nature of matter. The fact that the LHC will be a unique facility and that construction of the collider itself and the detectors is a collaborative global effort helps the case, and those who start with the erroneous idea that the cost of particle physics is going up are reassured to discover that this is not the case. In fact, despite the increasing sophistication of CERN's facilities, the CERN budget – corrected for inflation – is actually 20% less than it was twenty years ago, while gross national products in the CERN Member States have typically gone up some 60% in real terms in this period.

Presenting the arguments

However, although the importance of particle physics in general, and the LHC in particular, is generally accepted by those to whom it has been explained, their number is limited. It is the job of particle physicists to present the arguments as widely, as well, and as fairly as they can. In fact, I believe that we particle physicists have an obligation to try to share the excitement of our science, which I view as a contribution to culture, with the public that supports us. I am therefore very pleased to see the increasing effort devoted to promoting public appreciation of particle physics worldwide, and in particular I welcome the launch of the new-look *CERN Courier*. I hope these initiatives will allow a greater number of people to share the excitement of the discoveries that lie before us in further unravelling the secrets of Nature.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