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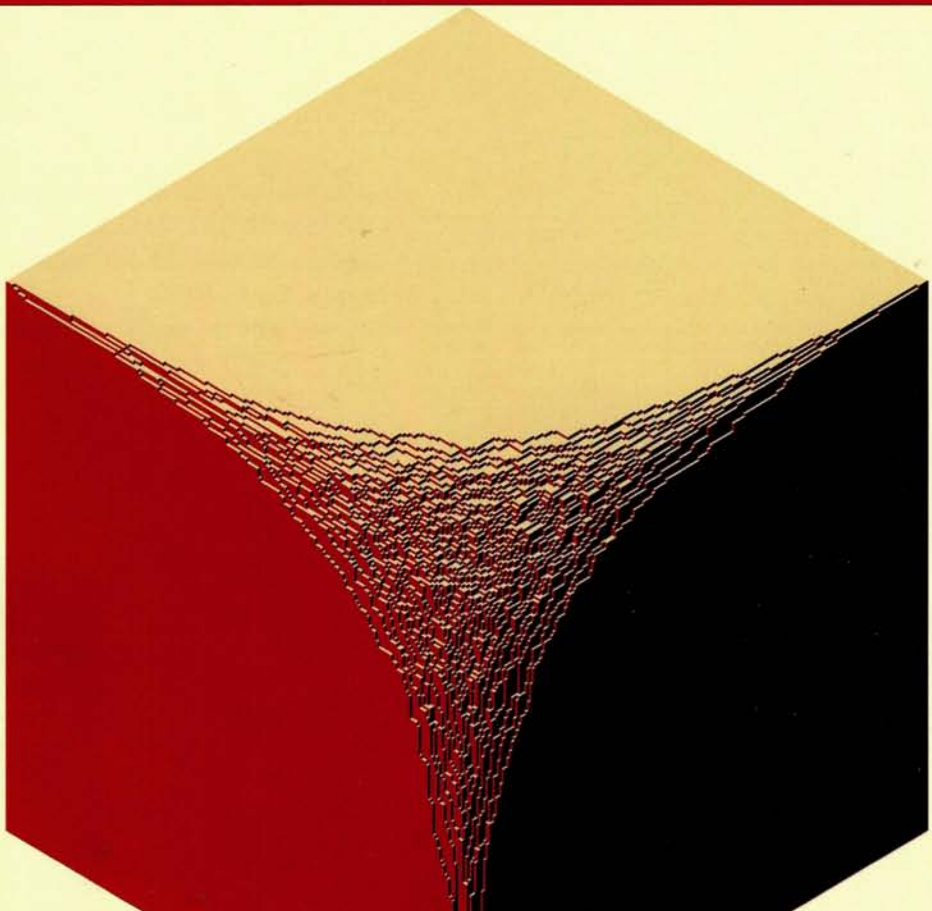

Crystal clue to quantum gravity

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Third appearance for very rare decay p6

1954-2004
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EXOTIC ATOMS
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POWER CONVERTERS

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

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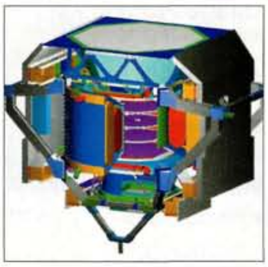
LHC gets ready to cool down p15



A spectrometer for space p18

Forum honours Curien p33

Cover: What does a melting crystal, simulated here, have to do with a quantum description of gravity? The answer lies in the topology and geometry of space–time (p29).
(Image courtesy A Iqbal *et al.* www.arxiv.org/hep-th/0312022.)

NEWS

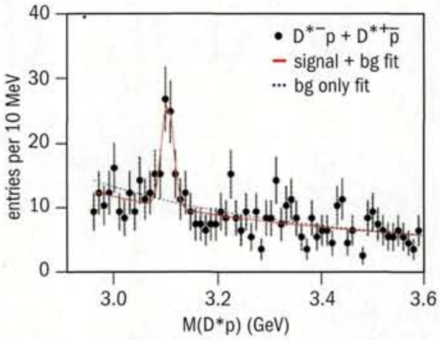
NEW PARTICLES

Has HERA found a charmed pentaquark?

The H1 experiment studying electron–proton collisions at DESY's HERA accelerator may have discovered a new five-quark particle. On 11 March the H1 collaboration reported clear evidence for a charmed pentaquark – a bound state of two up quarks, two down quarks and a charm antiquark (uudd$\bar{c}$), with a mass close to 3100 MeV. However, in a preliminary investigation physicists from ZEUS, the other major experiment at HERA, found no evidence for such a particle in their data. The hunt is now on to discover whether the charmed pentaquark does indeed exist.

The search for the pentaquark became a hot topic in 2003, when several experiments reported evidence for a narrow five-quark state, the Θ^+, containing a strange antiquark (*CERN Courier* September 2003 p5). This immediately raised the question of whether similar states exist, with the strange antiquark replaced by a charm antiquark corresponding to the charmed analogue Θ_c^0 of the Θ^+. Since DESY's electron–proton collider HERA is a copious producer of charm quarks and antiquarks, H1 and ZEUS were quick to take up the search.

The evidence for the new pentaquark in the H1 data is a resonance in the invariant mass combinations of D^{*-} mesons ($d\bar{c}$) with protons (uud) and the antimatter equivalent, D^{*+} mesons with antiprotons. The resonance is remarkably strong and narrow, sitting on a moderate background at a mass of 3099 ± 6 MeV. It is unlikely that it is produced by statistical background fluctuations. The peak contains roughly equal contributions from $D^{*-}p$ and $D^{*+}\bar{p}$ combinations. It survives all reasonable variations in the selection criteria and many other careful tests. A resonance with compatible mass and width is also observed in an independent photoproduction data sample from H1. This makes it more surprising that the ZEUS team could find no such resonance. Both HERA experiments are now carrying out further studies in an attempt to understand the results.



*The effective mass of opposite-charge D*p combinations, as measured in deep-inelastic electron–proton scattering by the H1 experiment at the HERA accelerator.*

Other experiments now have to look in their data for such a state. Its decay to a D* and a proton implies that its minimal quark composition is uudd$\bar{c}$. Not much more is yet known. The exact interpretation will depend on more detailed measurements and theoretical work. Is this the Θ_c^0, or an excited state with spin 3/2 instead of spin 1/2, or something completely different? If the state is confirmed, it is likely to be the first step towards a whole new spectroscopy of charmed pentaquarks, which could lead to an improved understanding of the forces that bind the quarks together.

Further reading

http://de.arxiv.org/pdf/hep-ex/0403017 (submitted to *Physics Letters B*).

INTERNATIONAL RELATIONS

New protocol accords CERN wider international status

CERN's member states have adopted a new protocol on the privileges and immunities of the organization. This brings CERN into line with other European intergovernmental organizations, such as the European Space Agency and the European Southern Observatory, which already enjoy international status in all their member states.

The protocol, which is also open for signature to non-member states that have agreements with CERN, will simplify the movement of personnel and materials between countries involved in projects with CERN. The privileges and immunities granted to CERN are similar to those granted to other international organizations. The protocol will also facilitate any future enlargement of the organization.

CERN already benefits from international status in its two host states, France and Switzerland. Switzerland accorded this status in 1955, as did France after the CERN site was extended across the Franco–Swiss border in 1965. With the new protocol, all member states that sign will recognize CERN's international status.

When it comes into force, the protocol will have important effects for the organization's activities in other countries, particularly those involving contractors or collaborators in other research institutes. For example, by establishing specific privileges and immunities, it will make easier the movement of personnel between countries involved in projects in which CERN is a partner. It will also exempt CERN's purchasing activities from tax (in particular VAT) and customs duties, and thus simplify the transfer of equipment and materials between the various countries that can be involved in a single contract – with the effect of reducing the costs often incurred through successive taxations as goods move between countries.

The protocol also has an important symbolic value for the future of CERN, as it is open for signature not only to CERN's member states, but also to other states that collaborate with CERN, either as associate member states or through co-operation agreements. "Although this seems symbolic today," explains CERN's director-general Robert Aymar, "I believe that in the future, with the increasing globalization of particle physics, this will become a valuable tool in helping CERN to remain a powerful force in science."

Nine member states signed the protocol in a ceremony at CERN on 18 March, bringing to 11 (with France and Switzerland) the number of member states that have now agreed to grant full international status to CERN. The other nine have set in motion procedures that will allow them to sign in the near future. It will come into force once it has been signed and ratified by 12 member states other than the host states.

BROOKHAVEN

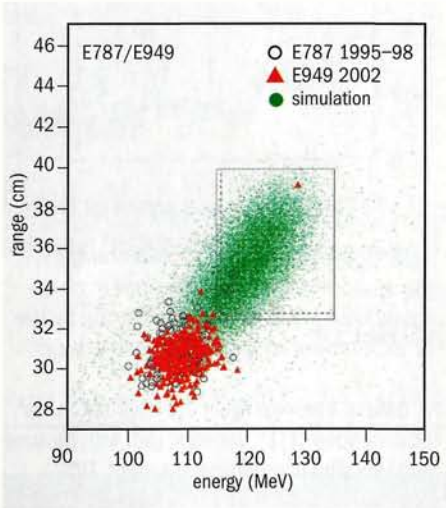
Experiment catches third glimpse of 'one in ten billion' decay

The E949 collaboration at the Brookhaven National Laboratory has reported further evidence for the very rare kaon decay, $K^+ \rightarrow \pi^+\nu\bar{\nu}$. The rate observed for this decay may indicate new forces beyond those in the Standard Model – which predicts the frequency of such decays to be half that observed – although it is still too soon to say if a deviation has occurred.

The decay $K^+ \rightarrow \pi^+\nu\bar{\nu}$ is extremely important due to its sensitivity to the mixing strength V_{td} of the t quark to d quark, which is poorly known, and to many hypothetical new physical effects not accounted for in the Standard Model. $|V_{td}|$ can be extracted from the $K^+ \rightarrow \pi^+\nu\bar{\nu}$ branching ratio with minimal theoretical uncertainty, since the hadronic matrix element can be extracted from the well measured $K^+ \rightarrow \pi^0 e^+\nu$ decay and higher order corrections have been calculated by Andrzej Buras, Gerhard Buchalla and others.

The new result on $K^+ \rightarrow \pi^+\nu\bar{\nu}$ comes from the E949 experiment – an upgraded version of E787, which reported two earlier sightings of the same decay. The two experiments, run by a collaboration of some 70 scientists from Canada, Japan, Russia and the US, have taken place at Brookhaven's Alternating Gradient Synchrotron (AGS), the world's highest intensity proton synchrotron. The improved apparatus of E949 has exploited higher beam intensities and achieved greater detection efficiency than any previous experiment of this type.

Although a neutrino and an antineutrino are emitted in the process $K^+ \rightarrow \pi^+\nu\bar{\nu}$, these particles interact too weakly to be detected. Thus, evidence that one positive pion – and only one positive pion – was produced by the kaon decay had to be proved beyond reasonable doubt, eliminating the possibility that other detectable particles were present. This required the most efficient particle detector system ever built, as well as analysis techniques capable of confirming the required suppression. For example, the detection efficiency achieved for neutral pions was such that fewer than one in a million were missed.



Plot of data from the E787 and E949 study of $K^+ \rightarrow \pi^+\nu\bar{\nu}$, showing the range and energy distributions of charged pions passing all other cuts. The circles represent E787 data and the triangles E949 data. The group of events around E = 108 MeV are due to $K^+ \rightarrow \pi^+\pi^0$ background. The simulated distribution of $K^+ \rightarrow \pi^+\nu\bar{\nu}$ is indicated by dots. The solid line (dashed line) box represents the signal region for E949 (E787).

To establish the validity of the observations, all backgrounds had to be suppressed by a factor of 10^{11}. This was among the first modern analysis efforts to apply carefully "blind" or unbiased analysis techniques, which are now standard practice in high-energy physics (*CERN Courier* March 2004 p22).

Out of all the data analysed, involving nearly 10^{13} kaons, three events explicable by the decay $K^+ \rightarrow \pi^+\nu\bar{\nu}$ have now been seen by E787 and E949. This indicates that the $K^+ \rightarrow \pi^+\nu\bar{\nu}$ process occurs with a branching ratio of $1.47^{+1.30}_{-0.89} \times 10^{-10}$, making it one of the rarest particle decays ever observed. The result continues to suggest a possible discrepancy with the Standard Model, although with only three events it is still consistent with the prediction of $(7.7 \pm 1.1) \times 10^{-10}$.

The goal of E949 was to increase the experimental exposure of E787 by five times. If the E949 findings for $K^+ \rightarrow \pi^+\nu\bar{\nu}$ were to continue at the current pace, 20 or more events would be observed. Such a result could alter our current picture of particle physics, forcing an expanded view of the fundamental constituents of the universe and their interactions. The detector and collaboration are ready to complete the experiment; however, further running is currently not possible because the US Department of Energy discontinued high-energy physics operations at the AGS in 2002, before E949 was completed.

Future work on the related process $K^0_L \rightarrow \pi^0\nu\bar{\nu}$, supported by the US National Science Foundation, is now getting going, with the construction of the KOPIO experiment due to begin at the AGS next year.

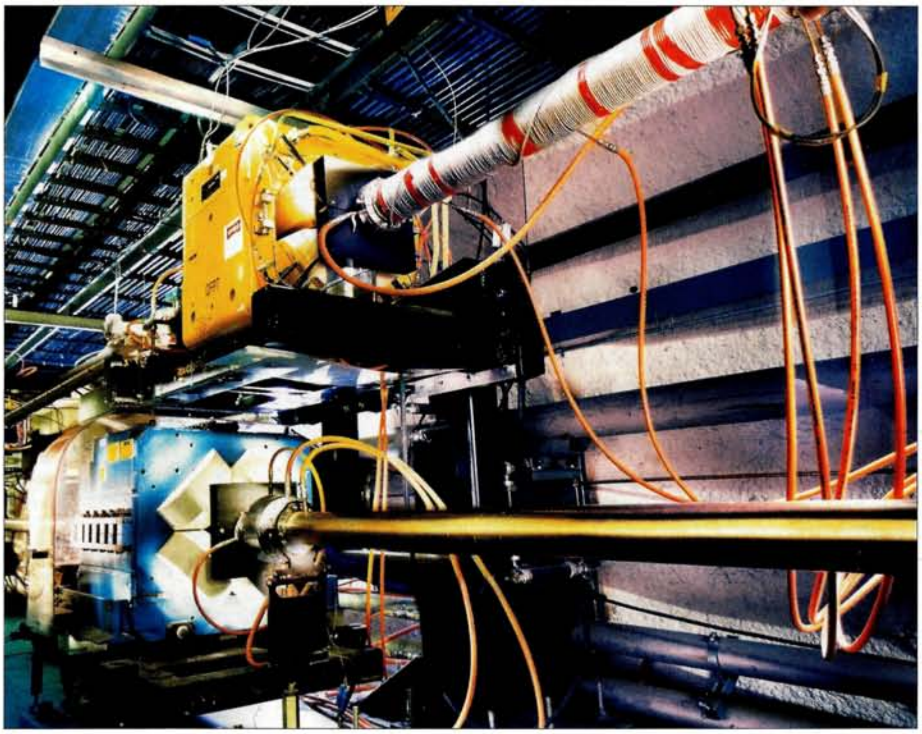
SLAC

Electrons give BaBar a 'trickle treat'

The PEP-II accelerator at the Stanford Linear Accelerator Center (SLAC) reached a new milestone on 11 March by phasing in "trickle injection", a mode of operation that increases the production of B and $\bar{B}$ particles by up to 50%. With the new technique, the BaBar detector can keep taking data virtually uninterrupted while the linear accelerator injects electrons and positrons into the PEP-II storage rings.

Up to 1400 bunches of particles circle around PEP-II's two storage rings at any given time – electrons in the 9 GeV ring and positrons in the 3.1 GeV ring. The linear accelerator periodically injects more bunches to replace those that are used up in collisions inside the BaBar detector. In the old mode BaBar had to be switched off every 45 to 90 minutes to allow for a five-minute "top off" procedure, in other words, the injection of new bunches.

With trickle feed, new bunches are injected continuously, at a rate of up to 10 per second. Initially, the highly energetic newcomers push the other bunches around, thus increasing the amount of background in the detector. However, the researchers have learnt how to teach the unruly bunches to get quickly into line, so that within just one millisecond BaBar can once again take reliable data.



The PEP-II facility, with the positron ring above and the electron ring below. (Courtesy SLAC.)

After more than a year of testing, trickle injection was introduced at the low-energy ring last December, bringing a 30% increase in the B-factory's output. Then in March came what was meant to be a two-day test of trickling into the high-energy ring, to provide another 15% increase. This went so well that the experimenters on BaBar decided to keep it going and the experiment has since been running at its peak luminosity.

The advantages of trickle injection go beyond the numbers, as continuous injection makes the storage of particles more stable so that the PEP-II rings are easier to operate. The success of the whole process is the result of a close collaboration between the BaBar and PEP-II teams.

STRONG INTERACTIONS

Workshop looks to the future of QCD

While quantum chromodynamics (QCD) is considered to be the theory of strong interactions, it is very difficult to use it to make predictions of processes over distances of the order of the size of hadrons. The problem is that the coupling, which determines the strength of the interaction, becomes so large at such "large" distances that it is likely many gluons participate and the calculations diverge. So for the time being large-distance QCD remains one area where experiment can play a leading role and where new and unexpected phenomena may be discovered.

To consider some of the experimental options for the future in this area, Fermilab is hosting a workshop on "The Future of QCD at the Tevatron" on 20–22 May 2004. Its purpose is to evaluate the status of QCD in 2009, when the CDF and D0 experiments at the Tevatron are currently scheduled for completion. The Tevatron is at present the world's highest energy hadron collider, where CDF and D0 are probing QCD at the smallest distances (about 1/10 000th the size of the proton). This frontier will be taken over in 2007 by the Large Hadron Collider (LHC), but many studies, particularly of large-distance QCD, will remain to be done.

The workshop will consider such questions as: what desirable studies are not being done but could be added to the present research programme? What studies will be complementary to the QCD physics that will be performed at the LHC and elsewhere? What can (and cannot) the future Tevatron experiment BTeV, scheduled to start data taking at the Tevatron in 2009, do? All these questions are to be addressed, and it could provide the basis for developing a case for additional experimentation beyond 2009 at the Tevatron, perhaps using CDF or D0 detectors with modest upgrades. For further information, see: http://conferences.fnal.gov/qcdws.

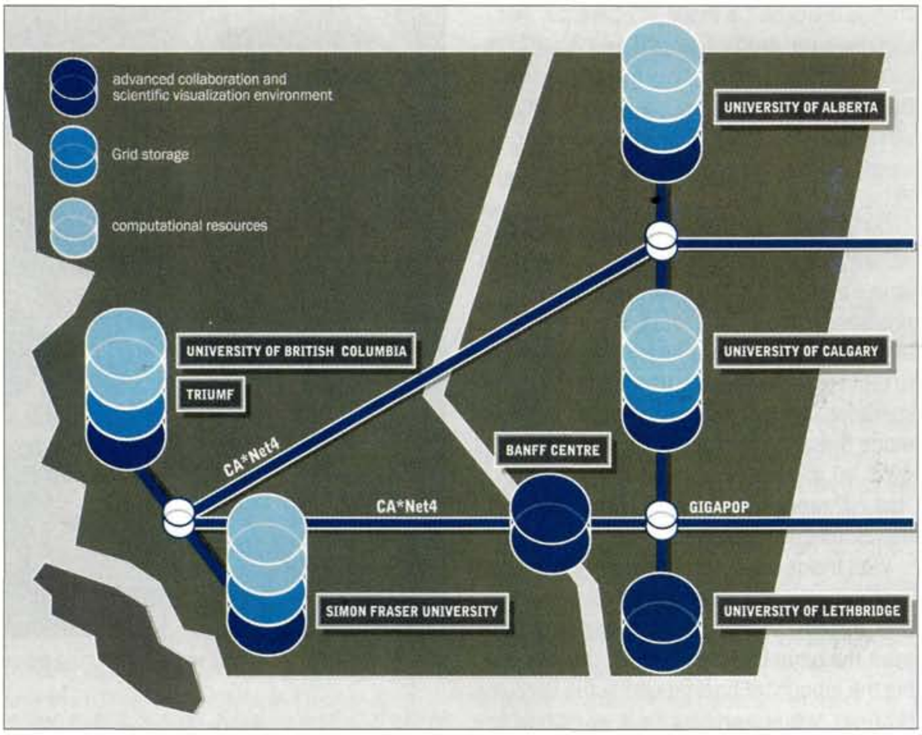
GRIDS

WestGrid team announces completion of computing network in western Canada

Scientists leading the WestGrid project in Canada have announced that the major resources of this $48 million project are available for general use by the research community. Canadian particle physicists have already applied WestGrid successfully to ongoing experiments, and plans are underway at TRIUMF to link the WestGrid Linux cluster to the LHC Computing Grid (LCG).

The aim of the WestGrid project is to provide high-performance computing in western Canada, based on resources at several universities in Alberta and British Columbia, and at TRIUMF. It currently consists of the following: a 256 cpu shared-memory machine (SGI Origin) for large-scale parallel processing at the University of Alberta; a cluster of multiprocessors (36 × 4 cpu Alpha nodes) at the University of Calgary, connected by a high-speed Quadrics interconnect that is also for parallel jobs; a 1008 cpu Linux cluster (3 GHz IBM blades) at the University of British Columbia (UBC) and TRIUMF for serial or loosely coupled parallel jobs; and a network storage facility (IBM) at Simon Fraser University, initially with 24 TeraBytes of disk space and about 70 TeraBytes of tape. As of November 2003, the WestGrid Linux cluster at UBC/TRIUMF ranked 58th in the "TOP500 Supercomputer Sites" rankings.

The Grid-enabled infrastructure also includes major collaborative facilities known as Access Grid nodes, with a total of seven institutions interconnected over dedicated research "lightpaths" on the existing provincial and national research networks.



A schematic view of the WestGrid project, which provides the infrastructure for high-performance computing resources across British Columbia and Alberta, Canada.

The new resources are expected to support advances in research in many disciplines where large amounts of data are typically involved, such as medical research, astronomy, subatomic physics, pharmaceutical research and chemistry.

Two particle-physics experiments, TWIST at TRIUMF and D0 at Fermilab, have already participated in the testing phase at the UBC/TRIUMF site. Both experiments benefited greatly from access to significant computing resources during the tests. For the future, it is planned to connect WestGrid indirectly to the LCG through the LCG site at TRIUMF. Work is ongoing to develop the software necessary to achieve this without the need to install LCG tools on WestGrid itself.

• For further information on the project, see www.westgrid.ca.

CERN COURIER ARCHIVE: 1966

To celebrate the 50th anniversary of CERN, we look back at some of the items in the early issues of *CERN Courier*

ISR PROJECT

The 31st session of the CERN Council

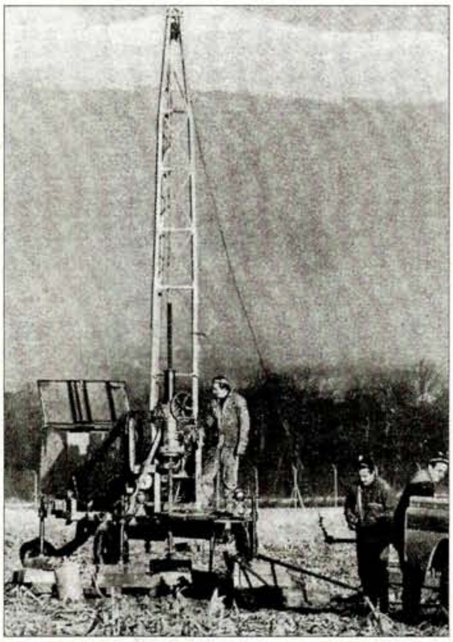
The Council met at CERN on 15 and 16 December 1965. Major decisions on the improvement programme for the existing installations and on the Intersecting Storage Rings (ISR) project were reported briefly in the January [1966] issue of the *Courier*. This article amplifies the information concerning these decisions. [...]

In addition to the basic programme, which comes under the terms of the original CERN convention, there are two supplementary programmes. The first of these is the ISR project. At the Council session in June 1965 the project was approved in principle and in December all the member states, with the exception of Greece, were able to announce that they were willing to participate. A budget of 21.7 million Swiss francs was voted for 1966.

The estimated cost for the full project, over the six years 1966–1971, is 332 million Swiss francs. This covers the building of two intersecting storage rings that will be supplied with protons from the 28 GeV Proton Synchrotron (PS), two colliding beam halls, one 25 GeV experimental hall and all the necessary buildings, laboratories, workshops and other services (power and water supplies, cooling and control equipment, roads, etc.).

Professor Leprince-Ringuet spoke as chairman of the Scientific Policy Committee (SPC), urging the ISR project as "sound and highly recommendable", providing the greatest degree of flexibility that it can be hoped to obtain with this kind of machine. The SPC advised that during the first months of the project, before large sums of money were committed, any possibility of improving the collision structures be pursued, so as to make the final version of the ISR the best conceivable within the limits of the site and the financial provisions.

At present, preliminary work is underway on the newly acquired French site and the area has been fenced off. Drainage works between the PS South Hall and the centre of the ISR, and the first section of the service tunnel on the French site, connecting the main substation with the ISR, are under construction. Early in the summer of this year the major construction work will begin.



A fourth boring being taken at the beginning of January 1966 on the French half of the CERN site, as part of the geological survey for the Intersecting Storage Rings project.

The Intersecting Storage Rings will be a unique facility. It is the only project of its type producing head-on collisions in two high-energy proton beams that is going ahead anywhere in the world. Its uniqueness leads to new and challenging technical problems (beam stacking in the ISR, very stringent vacuum conditions, improved detection methods) and will eventually allow the investigation of extremely high-energy proton interactions that could reveal a new range of phenomena. Authorization for this new development at the CERN site contributes considerably towards ensuring the vitality of CERN in the coming years.

● *Taken from* CERN Courier *February 1966 p23.*

CERN STAMP

Swiss Post issues celebratory stamp

A black and white reproduction of the Swiss postage stamp issued in honour of CERN.

On 21 February the Swiss postal authorities issued a 50 centime postage stamp in honour of CERN. The stamp is one of a series of three, the others being in honour of the International Union for the Preservation of Nature and its Resources (10 centime) and the 50th anniversary of the Swiss Industrial Fair at Basle (20 centime).

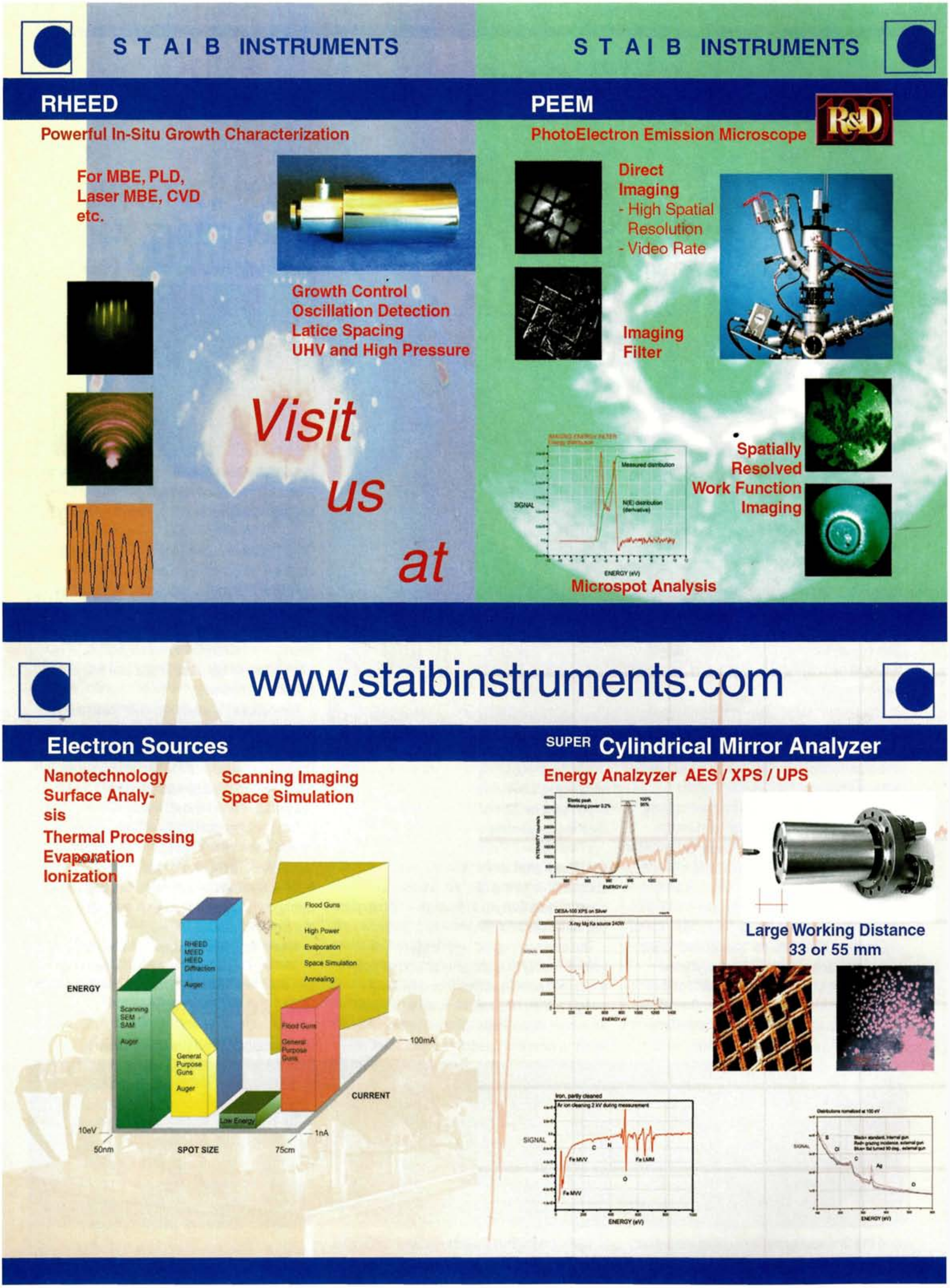
The decision to issue the CERN stamp was taken in 1964 and five Swiss artists, including Marcel Bron from the Site and Building Division, were selected to produce designs. The artists visited the laboratory and were told the story of CERN and shown around the site. [...]

The selected design, by H Kümpel from Zürich, shows the flags of the 13 member states of CERN superimposed on a bubble-chamber photograph. The flags are arranged to represent roughly the outline of the Swiss border.

● *Taken from* CERN Courier *February 1966 p27.*

EDITOR'S NOTE

In December 1965 the CERN Council agreed to proceed with CERN's first proton–proton collider, the Intersecting Storage Rings. Nearly 40 years later and preparations for its successor, the Large Hadron Collider, are well underway (see p15). The same edition also reported the issue of a Swiss stamp in honour of CERN, echoed this year with a new stamp in honour of CERN's 50th anniversary (see p37).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Energy Analzyzer AES / XPS / UPS
Large Working Distance
33 or 55 mm
Iron, partly cleaned
SIGNAL
Fe MVV
Fe LMM
ENERGY (eV)

Compiled by Steve Reucroft and John Swain

Diamonds are made harder than...diamond

What is harder than diamond? One example, perhaps surprisingly, is diamond, provided it has been appropriately "cooked". Chih-shiue Yan of the Carnegie Institute of Washington and colleagues have grown gem-sized single crystals of diamond in a special microwave plasma chemical-vapour deposition technique that produces crystals at very high growth rates, up to 100 times faster than is usual. These diamonds are already very hard, but by applying high-pressure (5–7 GPa) and high-temperature (2000 °C) annealing the hardness increases still further.

The mechanism is not yet understood, but appears to be some kind of work hardening. How much harder are these diamonds than ordinary ones? The answer is not yet known, but they are at least 50% harder than synthetic diamonds produced more conventionally. Some were certainly harder than the tools used to gauge the hardness of lesser stones as they broke the measuring equipment.

Further reading

CS Yan *et al.* 2004 *Physica Status Solidi (a)* **201** R25.

A synthetic-cut single-crystal diamond, about 2.5 mm high, grown by chemical-vapour deposition at the Carnegie Institute. The team at Carnegie have found that these diamonds are the hardest yet. (Photo courtesy of Physica Status Solidi.*)*

Nickel nanolayers lead to better batteries

Most rechargeable batteries are based on a technology that has been available for many years – and almost everyone wishes the batteries were just a little better, whether they are for vehicles or for laptops. Now it seems some clever chemistry could revolutionize everything.

Stuart Licht of the University of Massachusetts in Boston and Ran Tel-Vered of the Technion Institute in Haifa have shown that by replacing nickel ions in the nickel-metal hydride batteries that are popular in portable electronics with superoxidized iron, they can double the charge that can be stored. The idea of using superoxidized iron, which can accept an amazing three electrons per ion (hence the greater charge capacity), is not new, but the electrochemistry has had problems with reversibility. Licht and Tel-Vered, however, have been able to show that fabricating the nickel in nanolayer films can lead to devices that can be recharged 200 times. An added bonus to all this is that the chemical mechanism they propose is not only inexpensive, it is also non-toxic.

Further reading

S Licht and R Tel-Vered 2004 *Chemical Communications* **6** 628.

Towards a new kind of complexity

Stephen Wolfram's book *A New Kind of Science* (*CERN Courier* Jan/Feb 2003 p55) made the case that many complex things could be created by very simple algorithms running as cellular automata. While perhaps philosophically attractive, this is also rather intimidating as it suggests that many things we may want to calculate could just take a very long time to work out. Now, however, Navot Israeli and Nigel Goldenfeld of the University of Illinois at Urbana-Champaign have some good news for those who don't mind if their answers, while not being quite right, are basically correct. In an analysis similar in feel to renormalization, they show that all the cellular automata in Wolfram's classification can be "coarse grained" into much simpler systems that are computationally tractable. While the price is a loss of fine detail, the result is a good description of the large-scale behaviour. One of the automata is equivalent to a universal Turing machine and could compute anything that could be computed, so the claim is very broad and far-reaching.

Further reading

N Israeli and N Goldenfeld 2004 *Phys. Rev. Lett.* **92** 074105.

Tabletop fusion claim is revisited

Two years ago, Rusi Taleyarkhan at Oak Ridge and colleagues made the amazing claim that they had found evidence for neutron emission and tritium production in chilled, deuterated acetone when blasted with sound to produce sonoluminescence (*CERN Courier* May 2002 p11). This was greeted with much scepticism, but in response to comments that suggested the need for various improvements, Taleyarkhan, now also at Purdue, and his team performed a more careful version of the experiment, which seems to confirm the earlier results.

This time the researchers report a "large and statistically significant" emission of neutrons with energies of 2.5 MeV and below, at a rate of up to around 4×10^5 neutrons per second. They also measured the rate of tritium production and found that this was consistent with the observed neutron emission rate, assuming it to be due to deuterium–deuterium fusion. Control experiments using normal acetone did not result in significant tritium activity or in neutron or gamma-ray emissions. Now it remains to be seen how the physics community will respond to these results.

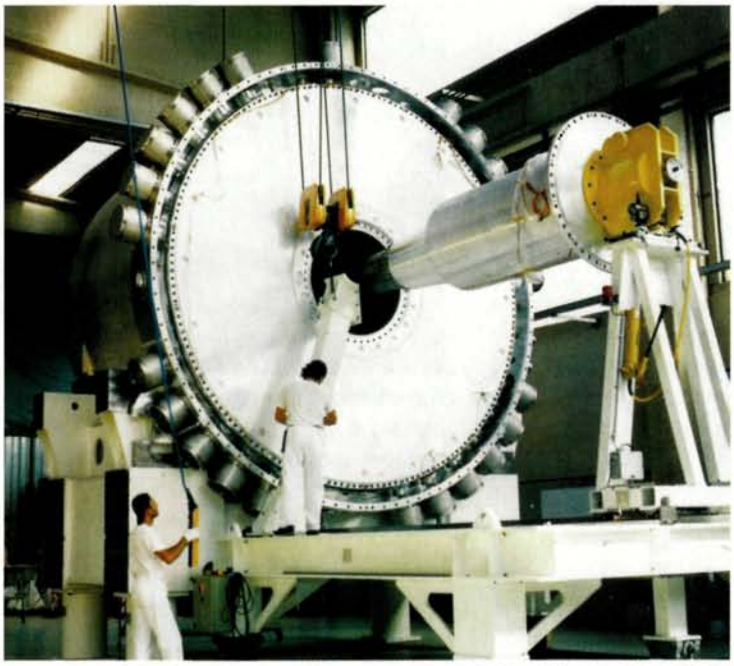
Further reading

R P Taleyarkhan *et al.* 2004 *Phys. Rev. E* **69** 036109.

SIMIC S.p.A.

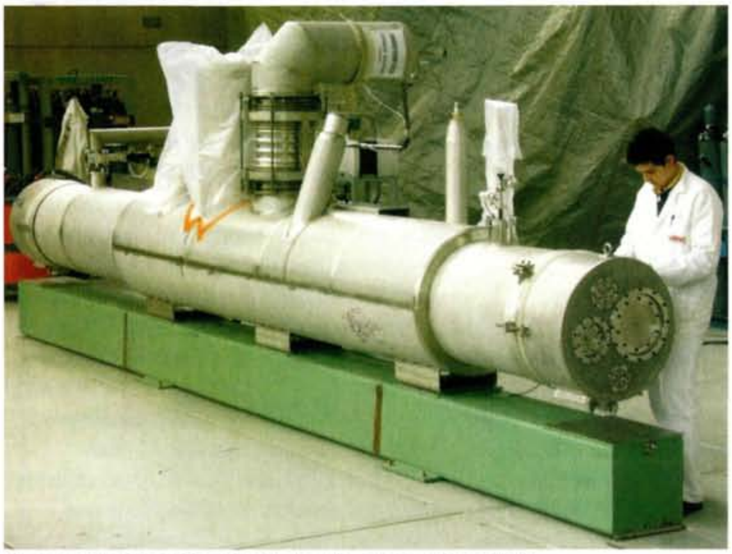
Cryogenics

DESIGN, MANUFACTURING, TESTING AND INSTALLATION OF EQUIPMENT FOR PARTICLE-PHYSICS RESEARCH.
HIGH SPECIALIZATION FOR CRYOSTATS AND HIGH-VACUUM APPLICATIONS.



ENDCAP CRYOSTAT FOR ATLAS EXPERIMENT/LHC PROJECT
MATERIAL: ALUMINIUM AL 5083; THICKNESS: 160 mm;
EXT. DIAM. 5.500 mm; HEIGHT: 3.700 mm; WEIGHT: 30.000 Kg;
TESTS: HYDRAULIC TEST, CRYOGENIC TEST: 90K
He Leak Test (< $1x10^{-8}$ mbar.l/s)

VIEW OF ENDCAP CRYOSTAT AND INTERNAL SUPER-INSULATION
TEST ON SUPER-INSULATION
PERFORMANCE: <$1W/m^{-2}$



SERVICE MODULES FOR QRL, LHC PROJECT
MANUFACTURING INCLUDES: INTSTALLATION OF SUPER-INSULATION, INSTALLATION OF VALVES, HEAT EXCHANGERS, ELECTRICAL WIRES AND INSTRUMENTATION.
MATERIALS: AISI 304 L, ALUMINIUM, Cu-Ni, WEIGHT: 2000 Kg
LENGTH: 6.650 mm,
TESTS: PRESSURE TEST UP TO 25 bar,
He LEAK TEST (<$1x10^{-8}$ mbar.l/s)
DIMENSIONAL TEST, INSTRUMENTATION TEST

SERVICE MODULE (JUMPER)DETAIL
VIEW OF THE INTERNAL STRUCTURE AND SUPER-INSULATION

VIA VITTORIO VENETO, 12072 CAMERANA CN, ITALY
TEL 0039 0174 906611 FAX 0039 0174 906 609
E-MAIL simic@simic.it WEB www.simic.it

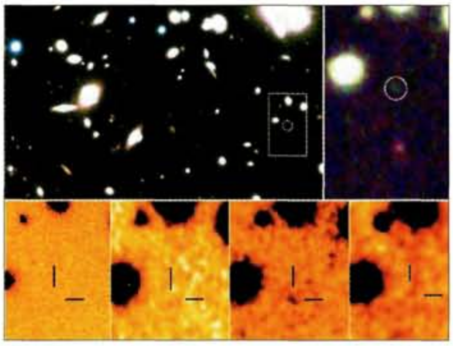
Compiled by Marc Türler

VLT detects farthest known galaxy

The discovery of a galaxy at a redshift of 10.0 smashes the record for the most distant object known in the universe. The detection of this very faint galaxy was made possible by combining the amplification effect of strong gravitational lensing with the power of the 8.2 m Very Large Telescope (VLT) of the European Southern Observatory (ESO).

The quest for the most distant object in the universe has made great progress during the past decade. The advent of telescopes with apertures of 8–10 m has allowed the detection of galaxies and quasars up to a redshift of 6.6. This corresponds roughly with the limit of what can be achieved in the visible domain. To detect higher redshift galaxies, near-infrared instruments are needed because the inter-galactic medium almost completely absorbs the visible flux at shorter wavelengths than the Lyman α line, which is redshifted from the ultraviolet (121.6 nm) into the near infrared.

Using the ISAAC near-infrared instrument on the VLT in Chile, a team of French and Swiss astronomers has now been able to obtain strong evidence for the detection of a galaxy at a redshift of 10.0. This galaxy, named Abell 1835 IR1916, emitted the observed light 13.23 billion years ago. This was at a time when distances in the universe were 11 times smaller than now and the universe was merely 470 million years young.



ISAAC near-infrared image of the core of the lensing cluster Abell 1835 (upper) with the location of the galaxy Abell 1835 IR1916 (white circle). The thumbnail images at the bottom show the location of the remote galaxy in different wavebands from the visible (left) to the infrared (right). (Courtesy ESO.)

This major breakthrough was made possible through light amplification by a factor of 25–100, resulting from strong gravitational lensing of the remote galaxy. This effect results from the bending of light by the huge mass of a galaxy cluster located along the line of sight to the distant galaxy. This natural amplification corresponds to an effective increase of the VLT aperture from 8.2 to 40–80 m.

From the images of the galaxy obtained at various wavelengths, the astronomers have deduced that it is undergoing a period of intense star formation. The total mass of stars already formed in this young galaxy is of the order of 10 million solar masses. This is about 10 000 times smaller than the mass of our galaxy, the Milky Way, and is comparable to the mass of the heaviest globular clusters. As only a small fraction of the mass of a galaxy is in the form of stars, the total mass of Abell 1835 IR1916, including a non-baryonic dark halo, is estimated to be of the order of a billion solar masses. This is in accordance with current cosmological models, as it corresponds to the collapse at a redshift of 10 of slightly more than a 2σ primordial fluctuation.

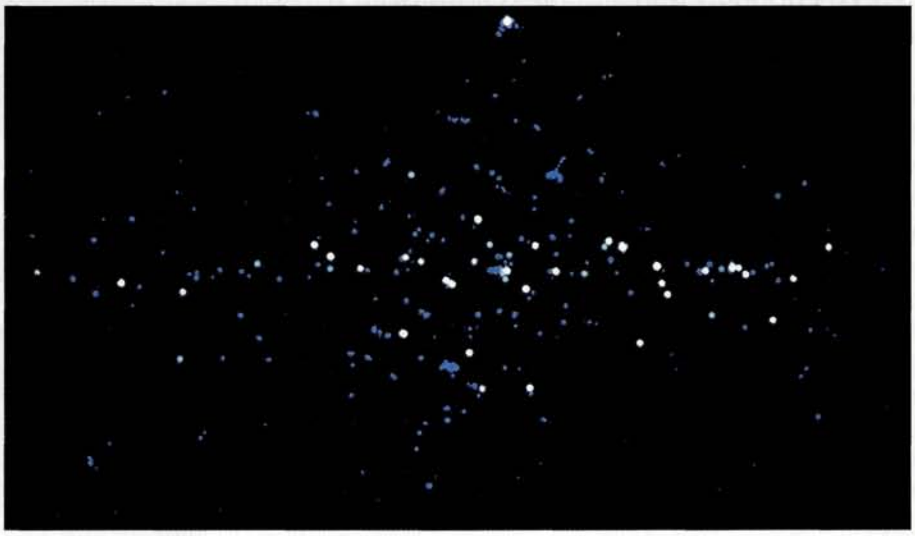
These properties are strong indicators that Abell 1835 IR1916 is indeed one of the building blocks of the large galaxies seen today, thought to have been assembled through the merging of many smaller protogalaxies. These blocks are also thought to be the first light sources to lift the fog over the universe and put an end to the "dark ages" (*CERN Courier* October 2003 p13). The discovery opens the way to explore further this unknown territory at the boundary between the "dark ages" and the "cosmic renaissance", both from the ground and with the James Webb Space Telescope due for launch in 2011.

Further reading

R Pelló *et al.* 2004 *Astron. Astrophys.* **416** L35.

Picture of the month

The analysis of this image of the central regions of the Milky Way as seen in gamma rays by the INTEGRAL satellite of the European Space Agency (ESA) solves the 30-year-old mystery of the diffuse gamma-ray emission of the galaxy. This was discovered by balloon-borne experiments in the mid-1970s, and attempts to explain it were in terms of emission processes within the interstellar gas. The high sensitivity and resolution of INTEGRAL have revealed that about 100 individual sources contribute to what appeared as a diffuse glow to previous observatories. At least some of the newly detected sources are likely to be obscured binary systems like IGR J16318-484 (*CERN Courier* Dec 2003 p15). (Lebrun *et al.* 2004 *Nature* 428 293. Credit: ESA, F Lebrun; CEA-Saclay.)



CERN's giant fridge

The first stage of the refrigeration system for the Large Hadron Collider is now installed and ready for the initial cooling tests in 2005, as **Laurent Tavian** describes.

Each of the eight 4.5 K refrigerators for the LHC consists of a compressor station (left) and a cold box (Air Liquide, middle; Linde, right).

When the Large Hadron Collider (LHC) begins operation at CERN it will be one of the coldest places on Earth. To keep the protons on course around the LHC and at the same time attain as high an energy as reasonably possible requires powerful superconducting magnets, which will operate at a temperature of 1.9 K – only 1.9 degrees above the absolute zero of temperature and chillier than outer space. While there may indeed be colder places in other laboratories, none will be on the scale of the LHC. The task of keeping the 27 km long structure at 1.9 K will be performed by helium, which will itself be cooled to its superfluid state in a huge refrigeration system.

The choice of the operating temperature for the LHC has as much to do with the "super" properties of helium as with those of the superconducting niobium-titanium alloy in the magnet coils. At atmospheric pressure helium gas liquefies at around 4.2 K, but when it is cooled further it undergoes a second phase change at about 2.17 K to its superfluid state. Among many remarkable properties, superfluid helium has a very high thermal conductivity, which makes it the coolant of choice for the refrigeration and stabilization of large superconducting systems. Indeed, the LHC cryogenic system will carry kilowatts of refrigeration over more than 3 km with a temperature drop from 1.9 to 1.8 K – less than 0.1 K.

From the cryogenic point of view, the LHC is a large distributed helium system operating at a variety of temperature levels down to 1.8 K. As well as being constructed in the tunnel built originally for the Large Electron Positron collider, LEP, to keep costs down the cooling system has been designed around the four 4.5 K refrigeration plants that were used to cool the superconducting radiofrequency cavities for the second phase of the LEP collider, LEP2. (The tunnel is not the only part of LEP to be "recycled" for the LHC!) The design of these refrigeration plants sets the temperature levels for the whole system at 75, 50, 20 and 4.5 K, in addition to the ultimate temperature level produced by the 1.8 K refrigeration system that provides the superfluid helium to the "cold mass" containing the superconducting coils.

The LHC will consist of eight 3.3 km long sectors, with access shafts to services on the surface only at the ends of each sector. The layout for the refrigeration system is therefore based on five "cryogenic islands" – three of which serve two sectors, while two serve a single sector each. Thus each "island" must distribute and recover coolant over a distance of 3.3 km.

Among the main components for this refrigeration system are eight 4.5 K refrigerators – one for each sector – each with a capacity of 18 kW at 4.5 K. Four of these have been recovered from LEP, and they will be upgraded to operate on the sectors with a slightly lower demand for refrigeration. The four high-load sectors will be cooled by new 4.5 K refrigerators, the last of which passed its acceptance procedures towards the end of 2003.

The refrigeration power needed to cool the 4700 tonnes of material of each sector of the LHC is enormous and can only be produced by using liquid nitrogen. Consequently, each 4.5 K refrigerator is equipped with a 600 kW liquid-nitrogen pre-cooler, which will be used to pre-cool a flow of helium down to 80 K while the corresponding sector is being cooled and later filled with helium – a procedure that will take just under two weeks. Using no liquid nitrogen but only helium in the tunnel considerably reduces the risk of oxygen deficiency in the case of accidental release.

The 4.5 K refrigeration system works by first compressing the gas and then allowing it to expand. While it expands it cools by losing energy through mechanical turbo-expanders that run at up to 120 000 rpm on helium-gas bearings. Only two companies in the world provide turbo-expanders with sufficient cooling power – Air Liquide in France and Linde in Switzerland. Each of the refrigerators consists of a helium compressor station equipped with oil and water removal systems and a vacuum-insulated cold box (60 tonnes) ▷

where the process fluid is cooled, purified and liquefied. The compressor station supplies compressed helium gas at 20 bar and room temperature. The cold box houses the heat exchangers and turbo-expanders that provide the cooling capacities necessary at the different temperature levels and liquefy the helium to 4.5 K before it passes to the 1.8 K refrigeration unit. Each refrigerator is equipped with a fully automatic process control system that manages about 1000 inlets and outlets per plant.

The complete system of eight 4.5 K refrigerators takes the cooling capacity at 4.5 K to 140 kW, that is almost 40 000 litres of liquid helium per hour. This is huge progress since LEP2, to say nothing of the days before LEP when most cryogenic needs were for individual experiments (figure 1). An electrical input power of 32 MW (4 MW per refrigerator) will be needed to produce this capacity at 4.5 K.

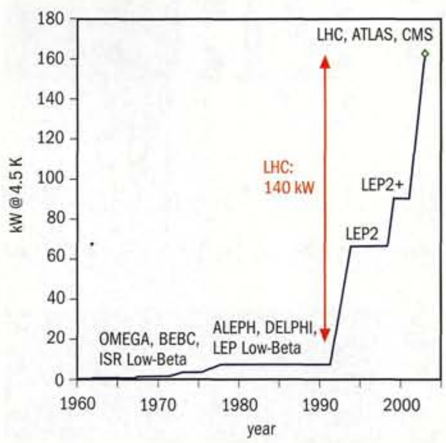


Fig. 1. The cryogenic cooling power at 4.5 K at CERN has increased dramatically since the days before LEP.

The process of bringing together the new 4.5 K refrigerators began in 1998 when contracts were signed with Air Liquide and Linde. The design and industrial engineering phases that followed made it possible for the first deliveries to take place from the middle of 2000, while LEP was still in operation. After a period of intensive tests the first new refrigerator for the LHC, built by Air Liquide, was accepted at Point 1.8 in March 2002. It has since been used to supply the test benches for the superconducting magnets. In December 2002 a second Air Liquide refrigerator was accepted at Point 4, followed by the two refrigerators manufactured by Linde in August and December 2003 at Points 8 and 6.

Of course the story does not end with the installation of the 4.5 K refrigerators. From now on the LHC cryogenic team will focus on upgrading the four LEP refrigerators already in place at Points 2, 4, 6 and 8. Simultaneously, they will finish installing the cryogenic infrastructure and 1.8 K refrigeration units to supplement the 4.5 K system. These installations will gradually be brought into operation to test the other cryogenic assemblies (vertical transfer lines, interconnection boxes, local transfer lines and tunnel distribution lines). This should enable final adjustments to be made and provide the experience necessary to face up to the next challenge, that of cooling the first sector of the machine in 2005.

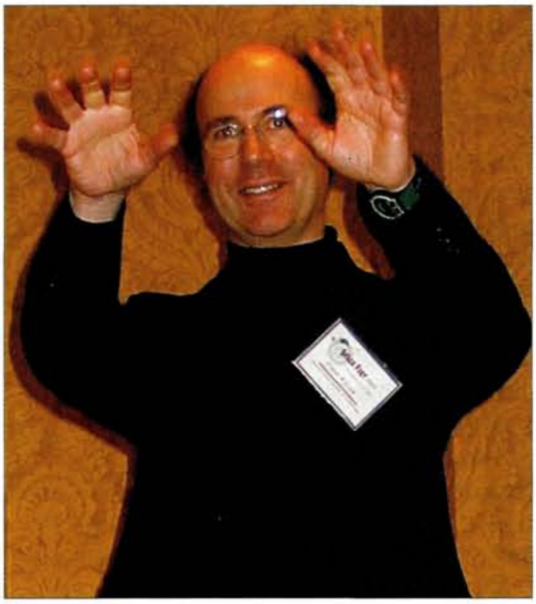
Laurent Tavian, *Cryogenics for Accelerators Group, CERN.*

There's plenty of room at the top

Space is the ultimate laboratory for fundamental physics and the possibility of holding experiments there was the theme of the SpacePart '03 conference. **Roberto Battiston** reports.

The universe is the largest and richest laboratory at our disposal for studying the laws of nature. In it, matter and energy undergo fundamental interactions and endure extreme conditions for infinitesimal times or for billions of years. Using advanced instruments we are able to select signals that reach us from the depths of space and time, and to extract data on fundamental physics that would not be available even with the most complex experiments performed in our laboratories.

To review the potential of particle and fundamental physics in space, a new series of international conferences, called SpacePart, began in 2002 on the Italian island of Elba. Following the success of SpacePart '02, which was sponsored by the Istituto Nazionale di Fisica Nucleare (INFN) and the universities of Pisa and Perugia, NASA played host to the 2003 conference on 10–12 December in Washington, DC, jointly with Stanford's Kavli Institute for Particle Astrophysics and Cosmology, the Massachusetts Institute of Technology (MIT) and INFN. The objective of SpacePart '03 was to explore the possibilities of doing fundamental physics in space during the next 20 years. The meeting was attended by researchers from a number of diverse subfields of physics and astrophysics – from cosmology and gravitation to elementary particle physics – but all of them had a common interest in space-based experiments.



In his keynote speech Frank Wilczek of MIT painted a picture of a universe characterized by numbers that we are unable to explain.

Coming together

Patrick Looney from the US Office of Science and Technology Policy delivered the opening address, representing the presidential science advisor, Jack Marburger. Looney underlined the importance of bringing agencies and research programmes together, in order to talk about the connectedness of the physical sciences and to show its relevance to the broader quest for discoveries in the universe. Indeed, SpacePart '03 was a perfect example of this, as all of the US agencies currently active in space science – NASA (Mike Salamon), the Department of Energy (Ray Orbach) and the National Science Foundation (Mike Turner) – presented their programmes. The major European and Japanese agencies also participated, with representatives from ESA (Oliver Jennrich), INFN (Roberto Battiston), ASI (Simona Di Pippo) and ISAS/JAXA (Tadayuki Takahashi).

Frank Wilczek of the Massachusetts Institute of Technology (MIT) gave an inspirational keynote talk, in which he described the universe as a strange place that is characterized by basic numbers – such as the densities of matter, dark matter and dark energy – that we are completely unable to explain. New theoretical ideas are desperately needed to explain dark energy, as the cosmological constant may not be adequate. In addition, Wilczek pointed out that axions might very well be a better candidate for dark matter than the supersymmetric neutralino.

To try to answer these questions, a number of space-borne experiments are being prepared to study the various components of the cosmic radiation. The charged energetic part – cosmic rays – will be measured up to the TeV region with very high accuracy by the magnetic spectrometers PAMELA (in 2005) and AMS-02 (in 2007). Sam Ting of MIT/CERN gave a status report on AMS-02, the first superconducting spectrometer to be operated in space, which will, by the end of the decade, reach an accuracy of one part in a billion in the search for antimatter nuclei.

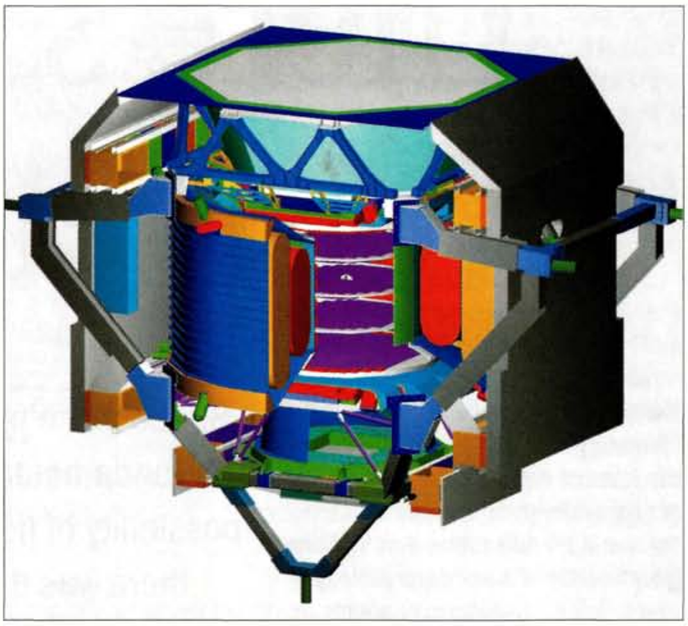
Jonathan Feng of University College Irvine discussed the perspectives for the indirect detection of dark matter in space-based experiments. He reviewed the various possible scenarios for ▷

weakly interacting massive particles (WIMPs): the lightest supersymmetric particle (LSP) based on Bino–Higgsino mixings, Kaluza–Klein dark matter and superWIMP dark matter if the gravitino is the LSP. These models predict a distortion in the spectrum of electrons, positrons and gamma rays, which may be visible with new cosmic-ray experiments such as PAMELA, and in particular with the high statistics expected from AMS-02 and the Gamma Ray Large Area Space Telescope, GLAST.

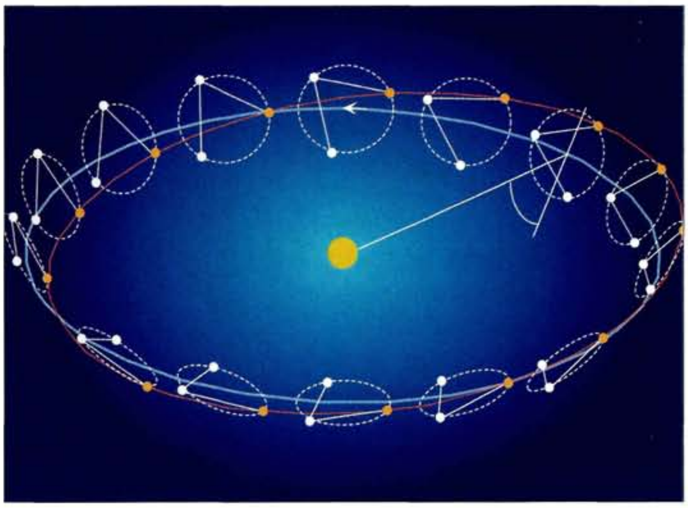
Hard hitters

The region of extremely energetic cosmic rays, above 10^{20} eV, will also be actively pursued because of its scientific interest. Angela Olinto of Chicago reviewed the experimental situation regarding these messengers of the extreme universe – particles that carry the energy of a tennis ball served by a top-class player. Even if we do not yet understand where these particles come from and how they reach such huge energies, "Zevatron" (10^{21} eV) accelerators do seem to exist somewhere in our universe. The advent of the Auger project on the ground, followed at the end of the decade by the Extreme Universe Space Observatory on the International Space Station, will open the way to cosmic-ray astrophysics, as the highest energy particles are so energetic they can traverse vast regions of the universe without significant deflection. Perhaps more exciting, but still more uncertain, would be the possible detection of extremely energetic neutrinos, as discussed by Tom Weiler from Vanderbilt who stressed how significantly the rate predictions are affected by the uncertainty in the neutrino cross-section at these energies.

Neutron stars have been known of for some time now, but we are still not completely sure whether some of them could be made of strange matter instead of neutrons. A fragment of a strange star – a strangelet – would behave like a cosmic ray with an anomalously low charge-to-mass ratio. Jack Sandweiss of Yale reviewed the status of strangelet searches. A strangelet could be detectable in a particle spectrometer such as AMS-02, and indeed one event compatible with the strangelet hypothesis was observed by AMS-01 during the successful 1998 STS91 mission. A strangelet would, however, also have a peculiar interaction with the Earth, giving rise to a unique pattern of "epilinear" seismic signals that would indicate a linear source. Such events have been searched for: in more than a million seismic events recorded in the years 1990–1993, one puzzling event that could be compatible with the passage of a strange-matter nugget through the Earth has been found.



The Alpha Magnetic Spectrometer, AMS-02, will be the first superconducting spectrometer to be operated in space, and will search for antimatter nuclei. (R Becker, MIT.)



The LISA mission will be a three-spacecraft interferometer that will observe passing gravitational waves. The spacecraft will maintain a triangular configuration, even though each one will be separately orbiting the Sun. This image highlights the motion of one of the spacecraft. (ESA/NASA.)

By the light of the Moon

Our pale satellite, the Moon, has been a source of poetical inspiration for thousands of years. It is possibly less well known, however, that since 1969 the Moon has also been a source of high-precision tests of general relativity through reflections of a laser beam from mirrors located on the lunar surface. Advances in detector technology will allow a tenfold gain in sensitivity in these measurements in the coming months. The APOLLO experiment at the 3.5 m telescope at the Apache Point Observatory in New Mexico will perform lunar ranging with millimetre resolution. Each pulse to the Moon will contain 1600 laser photons within a 95 picosecond jitter, of which about one photon will be detected back on Earth with a timing accuracy corresponding to a resolution of about 20 mm. Millimetre sensitivity can be obtained within one minute, a time that should be short enough to beat systematic effects. Among other things, this accuracy would be sufficient to test the weak equivalence principle in the 10^{-14} region. Next summer, laser ranging from Apache Point will also include tests using the Mercury Orbiter spacecraft, while in future additional improvements in accuracy might come from a laser-ranging experiment on Mars.

A major improvement in sensitivity is expected from a new NASA mission under review, the Laser Astrometric Test of Relativity (LATOR), which was presented at the conference by Slava Turyshev

Sam Ting of MIT/CERN described the various components of AMS-02, which will reach an accuracy of one part in a billion by the end of the decade.


The SpacePart '03 conference included a lively symposium in honour of Nobel laureate Riccardo Giacconi (second from right). The symposium was held at the Smithsonian America History Museum, and participating with Giacconi were (from left to right): Sam Ting from MIT/CERN, Gunther Hasinger from MPI and Duccio Macchetto from the Hubble Space Telescope.

from the Jet Propulsion Laboratory. LATOR will be based on inter-spacecraft laser ranging, and is aiming to improve dramatically the accuracy on the γ factor from about 2×10^{-5} (the already precise result obtained in 2003 using the Cassini spacecraft) to the interesting sensitivity region of 10^{-8}. A test of the LATOR concept is also planned on the International Space Station.

A "cool" subject at SpacePart '02 had been the cosmic microwave background (CMB). However, with the Wilkinson Microwave Anisotropy Probe now operating and the increase in sensitivity with its successor, PLANK, still awaited, the new hot topic at SpacePart '03 was CMB polarization. Matias Zaldarriaga of Harvard presented recent data from the DASI instrument, showing that the CMB is weakly polarized. Polarization of the CMB, due to Thomson scattering at the recombination time, links matter density-fluctuations to gravitational wave and lensing effects. Since the power spectrum of cosmological gravitational waves depends on the inflation mechanism, measurements of the CMB polarization should give a glimpse, through the recombination time, into the very early phases of the universe.

Emerging technologies

At the beginning of the next decade the direct detection of gravitational waves by LISA, the three-satellite ESA–NASA interferometer with arms that are five million kilometres long, will open up a new kind of astronomy that is able to see through very dense regions of our galaxy and even behind the recombination shroud. Stefano Vitale of Trento discussed the status of ESA's LISA pathfinder mission, SMART2, which is planned in 2006 to test basic technological aspects of this ambitious project.

A special session was devoted to emerging technologies that should further improve the physics reach of astroparticle physics in space. Mark Kasevich of Stanford reviewed the prospects for Bose–Einstein interferometry in space, which would allow the construction of ultra-sensitive accelerometers to test gravitational effects to an outstanding level of accuracy. This technology is developing at an incredible pace because of the many applications in the more mundane field of navigation systems and geodesy measurements. Gert Viertel of ETH Zürich presented results from a prototype synchrotron radiation detector flown on the STS108 mission on the space shuttle *Endeavour*. This detector makes use of the X-ray emission from TeV electrons/positrons interacting with the magnetosphere to measure the flux and charge of these particles in a high-energy window that is not covered by magnetic spectrometers.

Il Park of Ewha Woman's University in Korea presented a new concept of adaptive optics for a large field of view based on micromachined movable mirrors, which are capable of following rapidly changing light sources in real time, to monitor for example the emission of an extremely energetic cosmic-ray shower in the atmosphere. Tadayuki Takahashi of ISAS/JAXA also stressed the role of micro and nanotechnologies for future astroparticle-physics experiments in space in building and exploiting cheaper, smaller satellites with a faster turnaround time.

Easier access to space is certainly needed for the growth of this exciting field if it is to attract young talents and exploit new ideas. Indeed, astroparticle physicists have only started to scratch the surface of the potential of space for fundamental physics, and there is still, to paraphrase a well known saying, "plenty of room at the top". SpacePart '04 is to be held in Beijing at the end of 2004 and will be sponsored by the Chinese Ministry of Science and Technology. See you there!

Further reading

Information about SpacePart '03, including downloadable copies of the talks, can be found at www-lns.mit.edu/SpacePart03.

Roberto Battiston, *director, INFN Sezione of Perugia, Italy.*

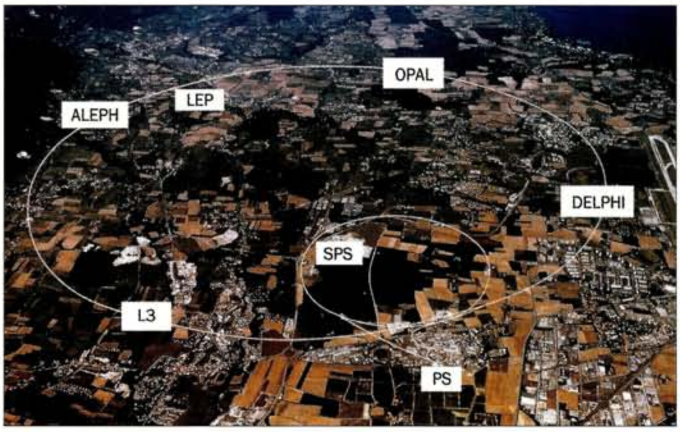
The W and Z at LEP

The Large Electron Positron collider made significant contributions to the process of establishing the Standard Model as the basis for matter and forces, and also built a platform for physics scenarios beyond the model.

The Standard Model of particle physics is arguably one of the greatest achievements in physics in the 20th century. Within this framework the electroweak interactions, as introduced by Sheldon Glashow, Abdus Salam and Steven Weinberg, are formulated as an SU(2) x U(1) gauge field theory with the masses of the fundamental particles generated by the Higgs mechanism. Both of the first two crucial steps in establishing experimentally the electroweak part of the Standard Model occurred at CERN. These were the discovery of neutral currents in neutrino scattering by the Gargamelle collaboration in 1973, and only a decade later the discovery by the UA1 and UA2 collaborations of the W and Z gauge bosons in proton–antiproton collisions at the converted Super Proton Synchrotron (*CERN Courier* May 2003 p26 and April 2004 p13).

Establishing the theory at the quantum level was the next logical step, following the pioneering theoretical work of Gerard 't Hooft and Martinus Veltman. Such experimental proof is a necessary requirement for a theory describing phenomena in the microscopic world. At the same time, performing experimental analyses with high precision also opens windows to new physics phenomena at much higher energy scales, which can be accessed indirectly through virtual effects. These goals were achieved at the Large Electron Positron (LEP) collider.

LEP also provided indirect evidence for the fourth step in this process, establishing the Higgs mechanism for generating mass. However, the final word on this must await experimentation in the near future at the Large Hadron Collider.



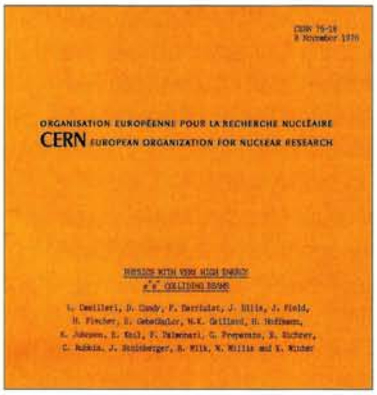


Fig. 1. The cover page (left) of the seminal CERN yellow report 76–18 on the physics potential of a 200 GeV e^+e^- collider, and the eventual facility as realized in LEP at CERN (top), including the four universal detectors ALEPH, DELPHI, L3 and OPAL.

The beginnings of LEP

Before LEP started operating in 1989, the state of the electroweak sector could be described by a small set of characteristic parameters. The masses of the W and Z bosons had been measured to an accuracy of a few hundred MeV, and the electroweak mixing parameter $\sin^2\theta_W$ had been determined at the percent level. This accuracy allowed the top-quark mass to be predicted at 130 ± 50 GeV, but no bound could be derived on the Higgs mass.

The idea of building such an e^+e^- collider in the energy region up to 200 GeV was put forward soon after the first highly successful operation of smaller machines in the early 1970s at energies of a few GeV. The physics potential of such a high-energy facility was outlined in a seminal CERN yellow report (figure 1).

LEP finally started operation in 1989, equipped with four universal detectors, ALEPH, DELPHI, L3 and OPAL. The machine operated in two phases. In the first phase, between 1989 and 1995, 18 million Z bosons were collected, while in the second phase, from 1996 to 2000, some 80 000 W bosons were generated at energies gradually climbing from the W-pair threshold to the maximum of 209 GeV. The machine performance was excellent at all the energy steps.

Phase I: Z physics

The Z boson in the Glashow–Salam–Weinberg model is a mixture of the neutral isospin SU(2) and the hypercharge U(1) gauge fields, with the mixing parameterized by $\sin^2\theta_W$. The Z boson interacts with vector and axial-vector currents of matter. The Z-matter couplings, including the mixing angle, are affected by radiative corrections so that high-precision analyses allow both tests at the quantum level and extrapolations to new scales of virtual particles.

The properties of the Z boson and the underlying electroweak theory were studied at LEP by measuring the overall formation cross- ▷

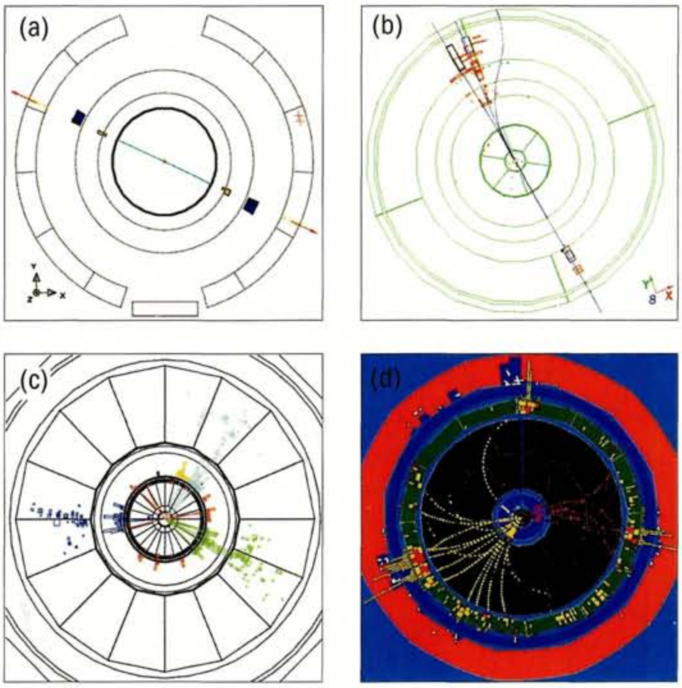


Fig. 2. Typical events recorded in the four LEP experiments: (a) $\mu^+\mu^-$ pair at OPAL; (b) $\tau^+\tau^-$ pair at DELPHI; (c) three-jet event at L3; and (d) W^+W^- event at ALEPH.

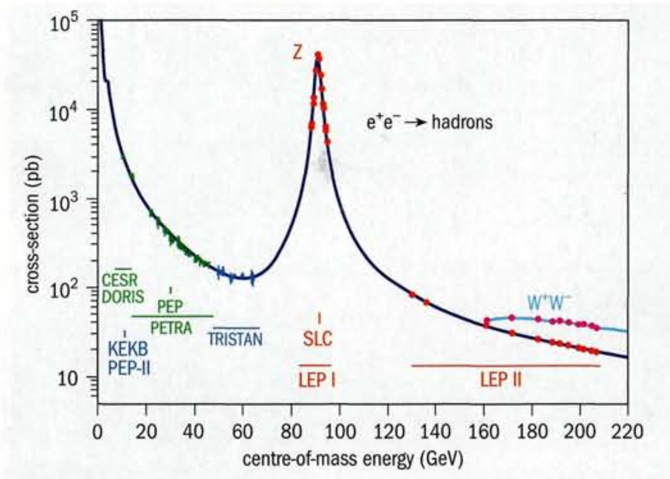


Fig. 3. The e^+e^- annihilation cross-section to hadrons, from initial low energies in early colliders to the maximum energy at LEP.

Equation 1

$$M_Z = 91\,187.5 \pm 2.1\ \text{MeV}$$
$$\Gamma_Z = 2495.2 \pm 2.3\ \text{MeV}$$
$$\sin^2\theta^l_{eff} = 0.23147 \pm 0.00016$$

section, the forward–backward asymmetries of the leptons and quarks, and the polarization of tau leptons. Outstandingly clear events were observed in each of the four detectors (see figure 2). As a result, the experimental analyses of the Z line-shape (see figure 3) of the decay branching ratios and the asymmetries were performed with a precision unprecedented in high-energy experiments (see equation 1 for all Z data, including SLD).

Thus, the electroweak sector of the Standard Model successfully passed the examination at the per-mille level, as highlighted by global analysis of the electroweak mixing parameter $\sin^2\theta_W$. This is truly in the realm where quantum theory is the proper framework for formulating the laws of nature. Figure 4 shows the observables that were precisely measured at LEP. The picture is uniform in all the observables, with deviations from the average line a little above and below 2σ only in the forward–backward asymmetry of the b-quark jets, and the left–right polarization asymmetry measured at the Stanford Linear Collider facility.

However, beyond this most stringent test of the electroweak theory itself, Z physics at LEP allowed important conclusions to be drawn on several other aspects of the Standard Model and potential physics beyond.

The first of these concerned the three families of leptons in the Standard Model. The number of light neutrinos could be determined by comparing the Z width as measured in the Breit–Wigner line-shape with the visible lepton and quark-decay channels. The ensuing difference determines the number of light neutrino species to be three: $N_\nu = 2.985 \pm 0.008$. Thus, LEP put the lid on the Standard Model with three families of matter particles.

The physics of the top quark was another real success story at LEP. Not only could the existence of this heaviest of all quarks be predicted from LEP data, but the mass could also be predetermined with amazing accuracy from the analysis of quantum corrections – a textbook example of the fruitful co-operation of theory and experiment. By analysing rate and angular asymmetries in Z decays to b-quark jets at LEP and complementing this set with production rates at the lower energy collider PETRA, the isospin of the b-quark could be uniquely determined (figure 5). From the quantum number $I^L_3 = -1/2$, the existence of an isospin +1/2 partner to the bottom quark could be derived conclusively – in other words, the top quark.

There was more than this, however. Virtual top quarks affect the masses and the couplings of the electroweak gauge bosons, in particular the relation between the Fermi coupling G_F of beta decay, the Sommerfeld fine-structure constant α, the electroweak mixing $\sin^2\theta_W$ and the mass of the Z boson, M_Z. This correction is parameterized in the ρ parameter and increases quadratically in the top-quark mass: $\Delta\rho \sim G_F m_t^2$. This led to the prediction of $m_t = 173^{+12}_{-13}{}^{+18}_{-20}$ GeV, before top quarks were established at the Tevatron and their mass confirmed by direct observation. This was truly a triumph of high-precision experimentation at LEP coupled with theoretical high-precision calculations at the quantum level of the Standard Model.

Beyond the electroweak sector

Z physics at LEP has also contributed to our knowledge of quantum chromodynamics (QCD), the theory of strong interactions in the complete SU(3) x SU(2) x U(1) Standard Model. As was already apparent from the study of PETRA jets at DESY, the clean environment of electron–positron collisions enables these machines to be used as precision tools for studying QCD. At LEP several remarkable obser-

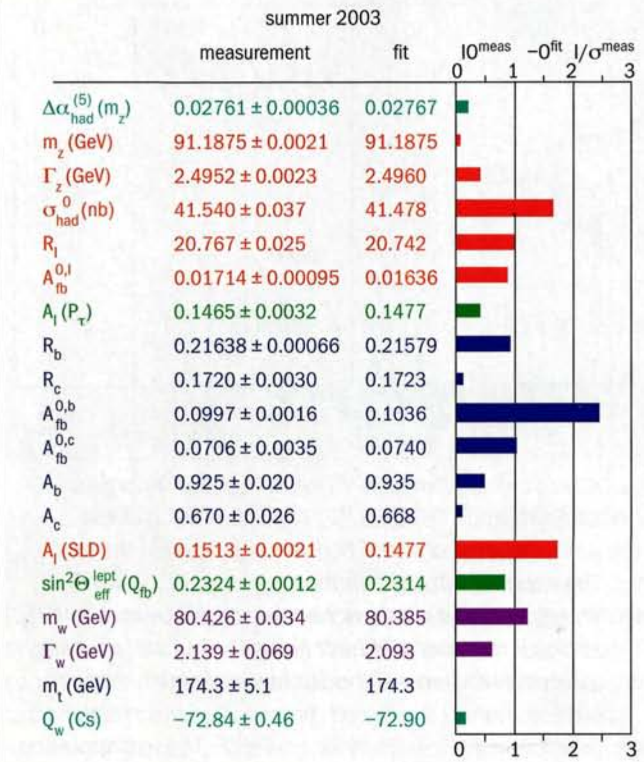


Fig. 4. Precision observables of the electroweak part of the Standard Model, measured at LEP and elsewhere.

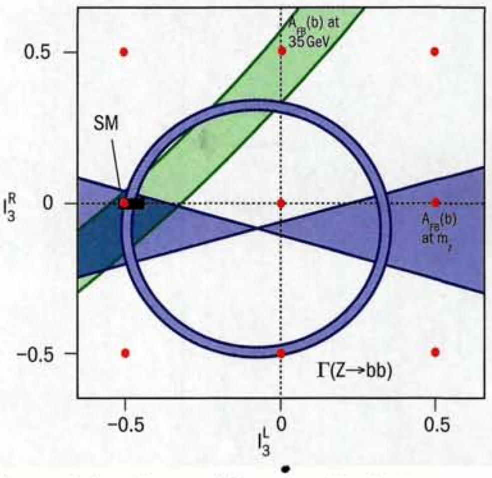


Fig. 5. Determining the weak isospin of the bottom quark. The blue circle represents the partial Z decay width to $b\bar{b}$ pairs at LEP; blue wedges are the forward–backward asymmetry at LEP; and the green strip is the cross-section at PETRA. All measurements cross the point $[I^3_L, I^3_R] = [-1/2, 0]$, so an isospin partner to the b-quark with $[I^3_L, I^3_R] = [+1/2, 0]$ should exist, i.e. the top quark.

Equation 2

$$M_W = 80.412 \pm 0.042 \text{ GeV [world average]}$$
$$\Gamma_W = 2.150 \pm 0.091 \text{ GeV}$$

vations contributed to putting QCD on a firm experimental basis.

Firstly, with the measurement of the QCD coupling $\alpha_s = 0.1183 \pm 0.0027$ at the scale M_Z and the jet analysis of the running from low energies at PETRA to high energies at LEP, the validity of asymptotic freedom could be demonstrated in a wonderful way (see figure 6a). Secondly, the observation of the three-gluon self-coupling in four-jet final states of Z-boson decays enabled QCD to be established as a non-abelian gauge theory (see figure 6b). With the measured value $C_A = 3.02 \pm 0.55$, the strength of the three-gluon coupling agrees with the predicted value $C_A = 3$ for non-abelian SU(3), and is far from the value of zero in any abelian "QED type" field theory without self-coupling of the gauge bosons. Thirdly, in the same way as couplings run, quark masses change when weighed at different energy scales, induced by the retarded motion of the surrounding gluon cloud. This effect was observed in a unique way by measuring the b-quark mass at the Z scale (see figure 6c).

There is one further triumph of the Z-physics programme. When extrapolating the three couplings associated with the gauge symmetries SU(3) x SU(2) x U(1) in the Standard Model to high energies, they approach each other but do not really meet at the same point. This is different if the particle spectrum of the Standard Model is extended by supersymmetric partners. Independently of the mass values, so long as they are in the TeV region, the new degrees of freedom provided by supersymmetry make the couplings converge to an accuracy close to 2% (see figure 7). This opens up the exciting vista that the electromagnetic, weak and strong forces of the Standard Model may be unified at an energy scale close to 10^{16} GeV, while at the same time giving support to supersymmetry, a symmetry that may be intimately related to gravity, the fourth of the forces we observe in nature.

Phase II: W physics

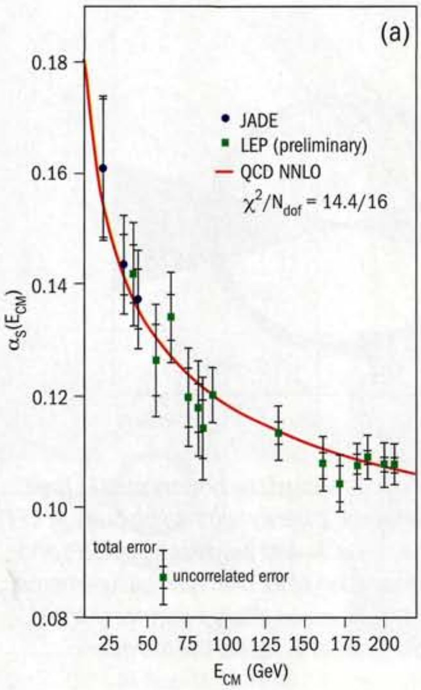
Gauge field theories appear to be the theoretical framework within which the three fundamental particle forces can be understood. The gauge symmetry theory was introduced by Hermann Weyl as the basic symmetry principle of quantum electrodynamics; the scheme was later generalized by C N Yang and R L Mills to non-abelian gauge symmetries, before being recognized as the basis of the (electro) weak and strong interactions.

One of the central tasks of the LEP experiments at energies beyond the W-pair threshold was the analysis of the electroweak three-gauge-boson couplings, predicted in form and magnitude by the gauge symmetry. A first glimpse was also caught of the corresponding four-boson couplings.

Charged W^+W^- pairs are produced in e^+e^- collisions by three different mechanisms: neutrino exchange, and photon- and Z-boson exchanges. From the steep increase of the excitation curve near the threshold and from the reconstruction of the W bosons in the leptonic and hadronic decay modes, the mass M_W and the width Γ_W can be reconstructed with high precision (see equation 2).

This value of the directly measured W mass is in excellent agreement with the value extracted indirectly from radiative corrections.

Any of the three production mechanisms for W^+W^- pairs, if ▷



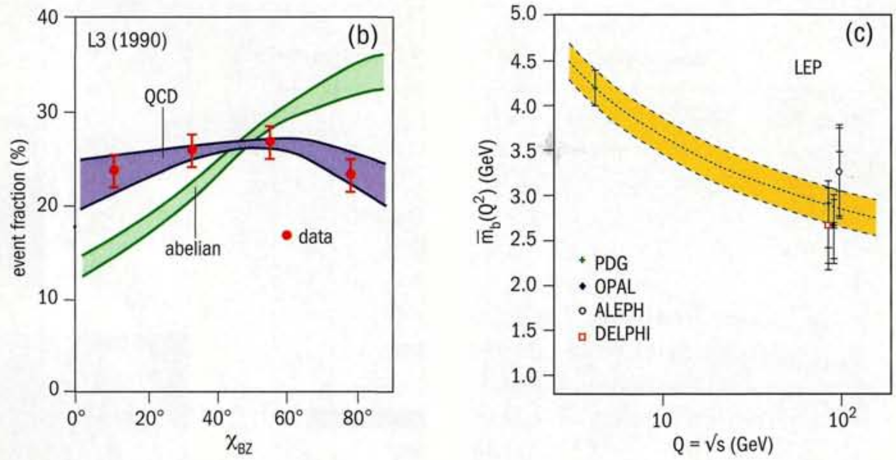


Fig. 6. (a) The running of the QCD coupling from low PETRA to high LEP energies compared with the prediction of asymptotic freedom. (b) The distribution of the azimuthal angle between the planes spanned by the high-energy jets and the low-energy jets in four-jet events. The experimental distribution is compatible with QCD, involving the self-couplings of the gluons, but it cannot be reproduced by an abelian "QED type" field theory of the strong interactions without gauge-boson self-coupling. (c) The change in the bottom-quark mass when weighed at low and high energies.

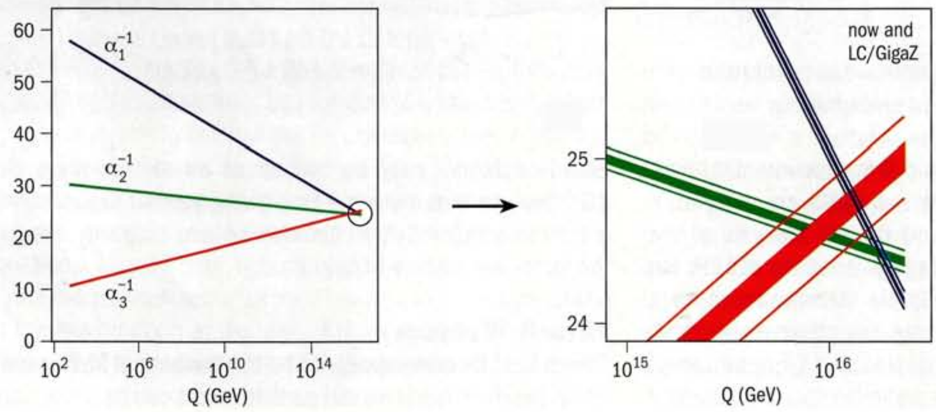


Fig. 7. The extrapolation of the SU(3), SU(2) and U(1) gauge couplings to high energies in the minimal supersymmetric extension of the Standard Model; they approach each other near 2×10^{16} GeV at a level of 2% – indicative of the grand unification of the three-gauge interactions.

evaluated separately, leads to a cross-section that rises indefinitely with energy. However, the amplitudes interfere destructively as a result of the gauge symmetry, and the final cross-section is damped for large energies. The prediction of gauge cancellations is clearly borne out by the LEP data (see figure 8), thus confirming the crucial impact of gauge symmetries on the dynamics of the electroweak Standard Model sector in a most impressive way.

The role of the gauge symmetries can be quantified by measuring the static electroweak parameters of the charged W bosons, i.e. the monopole charges (g_W), the magnetic dipole moments (μ_W) and the electric quadrupole moments (q_W) of the W bosons coupled to the photon and Z boson. For the photon coupling $g_W = e$, $\mu_W = 2\times e/2M_W$, $q_W = -e/M_W^2$ and for the Z coupling analogously. These predictions have been confirmed experimentally within a margin of a few percent.

Studying the quattro-linear couplings requires three-boson final states. Some first analyses of $W^+W^-\gamma$ final states bounded any anomalies to less than a few percent.

Hunting the Higgs

The fourth step in establishing the Standard Model experimentally – the search for the Higgs particle – could not be completed by LEP. Nevertheless, two important results could be reported by the experiments. The first of these was to estimate the mass of the Higgs when acting as a virtual particle. By emitting and reabsorbing a virtual Higgs boson, the masses of electroweak bosons are slightly shifted. In parallel to the top quark, this effect can be included in the ρ parameter. With $\Delta\rho \sim G_F M_W^2 \log M_H^2/M_W^2$, the effect is however only logarithmic in the Higgs mass, so that the sensitivity is reduced considerably. Nevertheless, from the celebrated "blue-band plot", a most probable value of about 100 GeV in the Standard Model, though with large error, is indicated by evaluating the entire set of established precision data (see figure 9). An upper bound close to 200 GeV has been found in the analysis shown in equation 3a.

Thus, in the framework of the Standard Model and a large class of possible extensions, LEP data point to a Higgs mass in the moderately small, intermediate mass range. This is corroborated

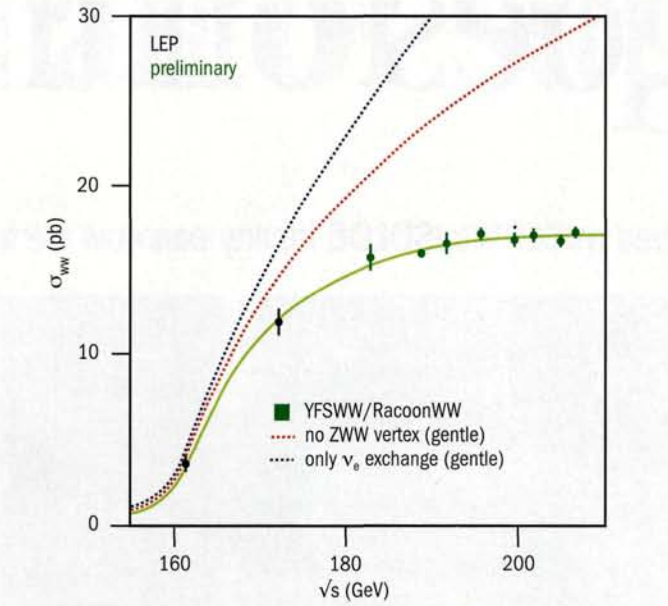


Fig. 8. The total cross-section for W-pair production $e^+e^- \rightarrow W^+W^-$ at LEP in the Standard Model. The measurements are also confronted with ad hoc calculations in which three-boson self-couplings are switched off. The gauge symmetries are apparently crucial for the understanding of the measurements.

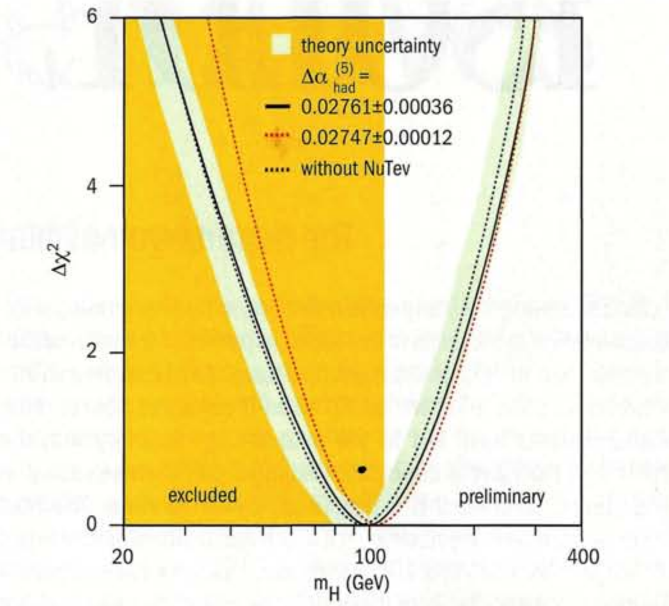


Fig. 9. Probability of the Higgs-mass value in the Standard Model as extracted from radiative corrections to electroweak precision data (maximum probability at minimum of the band). The yellow region is excluded by the (unsuccessful) direct search for the Higgs boson at LEP.

Equation 3a

$$M_H = 91 + 58 - 37 \text{ GeV}$$
$$M_H < 202 \text{ GeV [95\% CL]}$$

Equation 3b

$$M_H > 114.4 \text{ GeV at 95\% CL}$$

by individual analyses of all the observables, except the forward–backward asymmetry of b-jets. (This indirect evidence for a light Higgs sector is complemented by indirect counter-evidence against a large class of models constructed for generating mechanisms of electroweak symmetry breaking by new strong interactions.)

The direct search for the real production of the Higgs particle at LEP through the "Higgs-strahlung" process, $e^+e^- \rightarrow ZH$, set a stringent lower limit on the mass of the particle in the Standard Model (see equation 3b). However, we have been left with a 1.7σ effect for Higgs masses in excess of 115 GeV, fuelled by the four-jet channel in one experiment. "This deviation, although of low significance, is compatible with a Standard Model Higgs boson in this mass range, while also being in agreement with the background hypothesis." (LEP Higgs Working Group.)

LEP's legacy

Based on the high-precision measurements by the four experiments, ALEPH, DELPHI, L3 and OPAL, and in coherent action with a complex corpus of theoretical analyses, LEP achieved an impressive set of fundamental results, the traces of which will be imprinted in the history of physics. LEP firmly established essential elements of the Standard Model at the quantum level. It provided indirect evidence for the existence of a light Higgs boson of the type required by the Standard Model. The extrapolations of the three gauge couplings measured at LEP point to the grand unification of the individual gauge interactions at a high-energy scale – compatible with the supersymmetric extension of the Standard Model in the TeV range.

In addition, the precision analyses performed at LEP probed the many physics scenarios beyond the Standard Model, constraining their parameters in the ranges between the upper LEP energy to the TeV and multi-TeV scales. These studies have led to a large number of bounds on masses of supersymmetric particles, masses and mixings of novel heavy gauge bosons, scales of extra space–time dimensions, radii of leptons and quarks, and many other examples.

• The figures and the experimental numbers are from the four LEP experiments, the LEP Electroweak Working Group, the LEP Higgs Working Group, G Altarelli, S Bethke, D Haidt, W Porod, D Schaile and R Seuster.

This article is based on a talk given by Peter Zerwas at the symposium held at CERN in September 2003 entitled "1973: neutral currents, 1983: $W^\pm$ and Z^0 bosons. The anniversary of CERN's discoveries and a look into the future." The full proceedings will be published as volume 34 issue 1 of *The European Physical Journal C.* Hardback ISBN: 3540207503.

Christine Sutton, *CERN, and* **Peter Zerwas**, *DESY.*

ISOLDE goes on the

The superlarge nuclei studied at CERN's ISOLDE facility can now vie for attent

Foremost among the many open questions in nuclear physics is the determination of the limits of the basic properties of the nucleus. For example, just what is the heaviest nuclear system possible and into what forms does it distort itself? When it comes to nuclear size, measurements have led to the astonishing discovery that the lightest nuclei have a curious tendency to puff themselves up in importance, imitating their bigger (and heavier) relatives. The most famous example is the nuclide ^{11}Li, which has a radius almost equal to that of ^{208}Pb and yet is 20 times lighter. ^{11}Li has such a surplus of neutrons – eight, for only three protons – that the last two are pushed far from the core, forming a so-called halo. This nuclide, which still defies theoretical description, even by the most advanced nuclear models, has recently come under intense scrutiny at the ISOLDE facility at CERN.

The heaviest elements of the periodic table, now reaching at least to $Z=115$, have been discovered recently at JINR in Dubna and at GSI in Darmstadt (see *CERN Courier* April 2004 p6). They are located well beyond the heaviest known stable elements of lead (Pb, $Z=82$) and bismuth (Bi, $Z=83$), across the gulf of spontaneously fissioning actinides, which is dotted by a small archipelago consisting of stable thorium (Th, $Z=90$) and uranium (U, $Z=92$). The new region being explored in Darmstadt and Dubna is known, naturally, as the "island" of superheavy elements. [The naming of these elements is an issue in itself, which is subject to stringent verification by the International Union of Physics and Applied Chemistry (IUPAC). At a recent ceremony the discoverers of $Z=110$ were granted their wish to name their foundling darmstadtium (Ds) after the city of their institute, GSI (see *CERN Courier* December 2003 p6).]

Shape shifters

Another example of nuclear extremes concerns shape and is a consequence of nuclear deformation – the departure from a normal, spherical shape. Some nuclides, particularly those with unbalanced proton-to-neutron ratios, are more comfortable assuming some type of contortion, typically a cigar shape (prolate) or a disc shape (oblate). A recent trend in experiments in nuclear physics was to create nuclei with the highest possible angular momentum. The consequence of so much spin was a nucleus that was so distorted it was classed as superdeformed. Such nuclei were studied by a very special type of spectroscopic footprint: a comb-like energy spectrum produced by a series of cascading gamma-ray decays as the whirling nucleus shed its enormous excess of rotational energy (Walker and Dracoulis 1999).

CERN's online isotope mass-separator facility, ISOLDE, does not have the beam energy necessary to produce either superdeformed or superheavy nuclides. However, ISOLDE does have the capacity to produce nuclides of another superlative character – the superlarge. To do this ISOLDE must be pushed to its limit: the neutron drip line (see figure 1). Imagine producing heavier isotopes of an element by adding neutrons to a given number of protons to the point

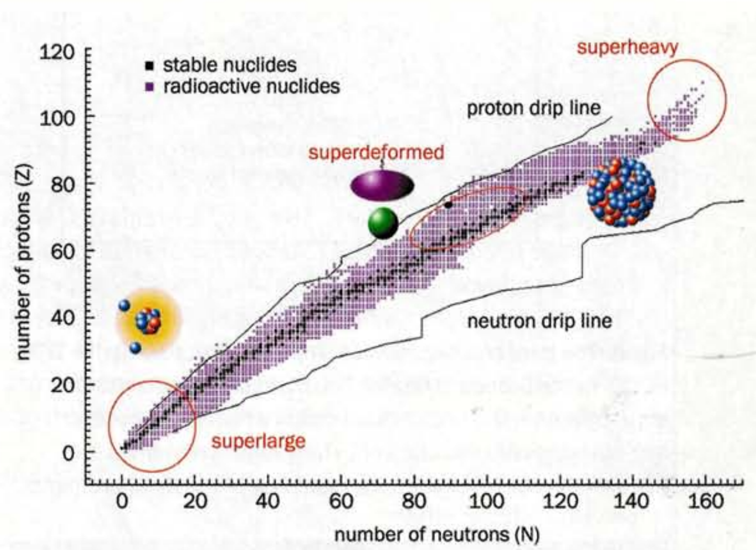


Fig. 1. The table of known stable and radioactive nuclides, showing the regions that are inhabited by the superheavy, superdeformed and superlarge nuclei, as well as the drip lines, which have been calculated using the Hartree–Fock–Bogoliubov plus Gogny method.

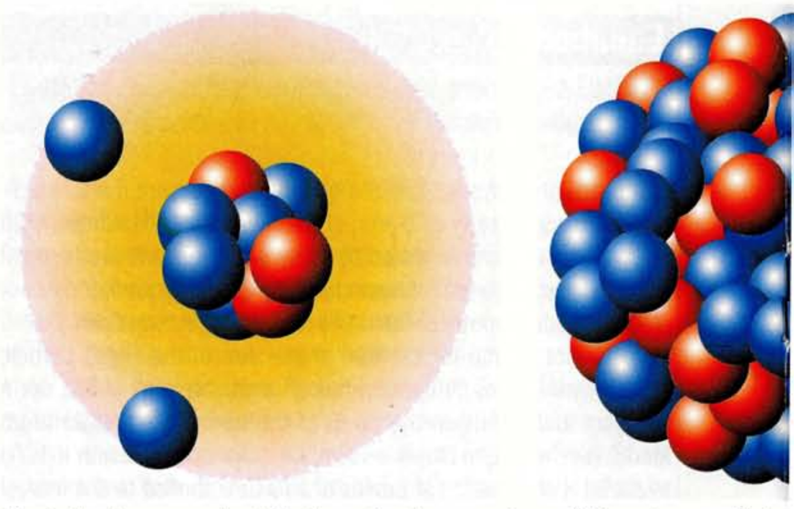
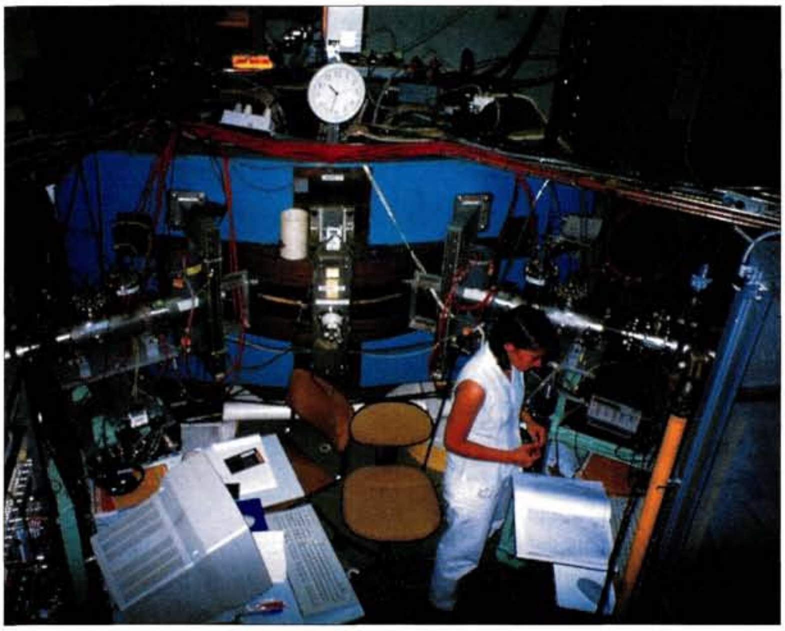


Fig. 2. The image on the left shows the the superlarge ^{11}Li nucleus – a ^{9}Li cc two-neutron halo. The right-hand image shows the ^{208}Pb nucleus, which is a than ^{11}Li yet practically the same size due to the extended reach of the halc

trail of superlatives

tion with the superdeformed and the superheavy, as **David Lunney** explains.



A general view of the MISTRAL precision mass spectrometer at work. The ISOLDE beam arrives from the right side of the instrument.

re with an orbiting lmost 20 times heavier neutrons in ^{11}Li.

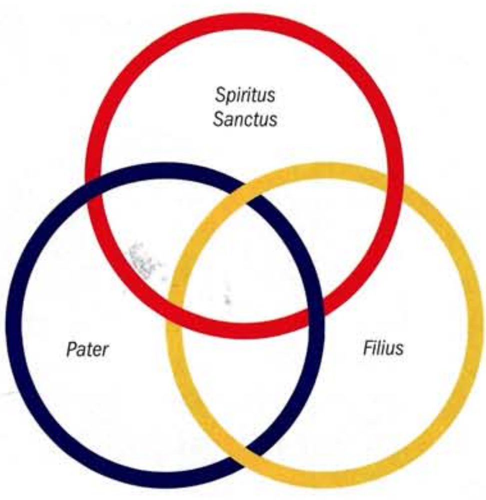


Fig. 3. Borromean rings, like the two-neutron halo nucleus, are linked in such a way that removing any one ring frees the other two.

where the neutron-saturated nucleus cannot hold any more. Like a water-soaked sponge, the nucleus *drips* neutrons.

Nuclides at the drip line exhibit behaviour that is unlike that of stable or even mildly radioactive species, and as such warrant special study. One interesting example is when loosely bound neutrons stray from a more equilibrated cohesive core to form what are called halo nuclei. These wayward neutrons considerably extend the nuclear radius, making it much larger than a nucleus in which the neutrons do not so greatly outnumber the protons – hence the term "superlarge".

Superlarge nuclides are a conundrum to theorists as the halo radii are in fact larger than the range of the strong interaction that binds the protons and neutrons within the nucleus. The case of ^{11}Li, where the halo is formed from two neutrons, is particularly curious (see figure 2). Not only is the two-neutron subsystem unbound, but so is the ^{10}Li subsystem, which consists of a ^{9}Li core plus a neutron – an example of a nucleus that drips one neutron. So if one of the halo neutrons is removed from ^{11}Li then the other comes away too. These systems have been dubbed Borromean (of Italian nobility) after the heraldic symbol of three rings which are connected in such a way that the removal of any one ring frees the other two (see figure 3).

In 2003 two experiments at ISOLDE were devoted to the most important fundamental properties of ^{11}Li – its size and its weight. In fact these two quantities are related, as the binding energy (from the mass) determines the radial extent of the system. But given the particular behaviour of the outer, valence neutrons, the recipe is not so straightforward.

Mass measurements and laser spectroscopy

The MISTRAL experiment (*CERN Courier* September 1997 p20) recently measured the mass of ^{11}Li. MISTRAL is a precision mass spectrometer that is particularly adapted to measurements of very-short-lived nuclei, and with a half-life of only 8.6 ms ^{11}Li was extremely well suited to MISTRAL's rapid measurement technique. Though previously known, the mass value was considerably improved and in fact slightly modified by about 70 keV. While this is small compared with the total mass of the system of around 11 GeV, it is significant with respect to the two-neutron binding energy of only 300 keV (Bachelet 2004).

The radial extent – and shape – of superlarge nuclei can also be determined by laser spectroscopy (*CERN Courier* December 1999 p20). This is an elegant marriage of atomic and nuclear physics techniques that probes the subtle effect of the small but finite nuclear volume on the distant electron orbitals. The measured quantity in this case is the nuclear quadrupole moment which, like the mass, was previously known but with insufficient precision to constrain the ever-increasing sophistication of theoretical models (Borremans 2004).

In the past, the two neutrons forming the ^{11}Li halo were considered with respect to a ^{9}Li core, which was regarded as inert. The results of these new measurements, especially that of the quad- ▷

rupole moment, will have an important bearing on the polarization of the core by the halo neutrons – an effect that is only now starting to be treated by theory (Jensen *et al.* 2004).

Given the importance of superlarge nuclides, ISOLDE, in collaboration with the Rutherford Appleton Laboratory in the UK, has invested considerable effort in the development of specialized targets for the production of such nuclei. A prime example is the target constructed by pressing together more than 100 tantalum foils only 2 μm thick. ^{11}Li is produced in the target by fragmentation of the tantalum nuclei by the proton beam from the PS Booster at CERN. The thinner the foils constituting the target matrix, the faster the short-lived drip-line nuclides can diffuse out to be ionized and transported to the experiment (Bennett *et al.* 2002).

^{11}Li is not the only superlarge nuclide that is produced at ISOLDE. Others include, for example, ^{14}Be, which has a two-neutron halo, and ^{19}C, which has a one-neutron halo. ^{17}Ne has also been the subject of study by laser spectroscopy due to its interest as a nuclide with a one-proton halo, and it will come under scrutiny again in 2004 when its mass is measured by MISTRAL's sister experiment ISOLTRAP (*CERN Courier* March 2004 p5).

MISTRAL's new RF modulator is mounted so that the ^{11}Li experiment can be performed.

The superlarge ^{11}Li has, meanwhile, been the subject of a myriad of experimental and theoretical studies, with two recent reviews (Jonson and Jensen *et al.* 2004) chronicling the superlarge saga. It will fall to nuclear theory to fit all the pieces into place, hopefully reconciling all the superlative behaviour of the nuclear system after the fashion of supersymmetry, supergravity and superstrings: a veritable supermodel.

Further reading

C Bachelet 2004 PhD Thesis, Université de Paris Sud.
J R J Bennett *et al.* 2002 *Nucl. Phys. A* **701** 327.
D Borremans 2004 PhD Thesis, University of Leuven.
X Jensen *et al.* 2004 *Rev. Mod. Phys.* **76** 215.
B Jonson 2004 *Physics Reports* **389** 1.
P Walker and G Dracoulis 1999 *Nature* **399** 35.

David Lunney, *CSNSM-IN2P3/CNRS, Université de Paris Sud, Orsay.*

Space goes quantum at Stony Brook

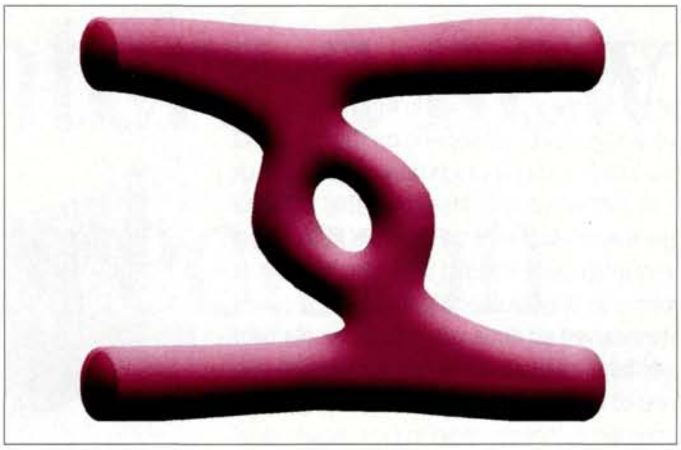


Fig. 1. Quantum strings splitting, exchanging and recombining. (Image courtesy of M Roček and T Moll-Roček.)

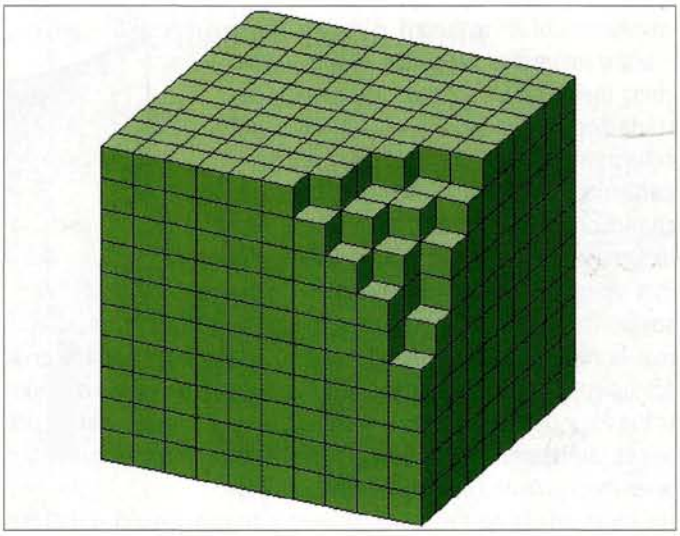


Fig. 2. A depiction of an ideal crystal as it begins to melt. (Image courtesy of Iqbal et al. *2003.)*

Does a melting crystal provide the key to developing a quantum description of gravity? Advances at the first Simons Workshop point to a connection.

Like players on a stage, most forces act in a fixed, pre-existing space, but in Einstein's classical theory of general relativity gravity is the dynamic shape of space. When classical forces enter the quantum arena the stage plays a new and more visible role: in its usual formulation quantum theory demands a ground state. The ground state is a fixed vacuum, above which excitations – which we can calculate and often measure to astonishing accuracy – propagate and interact. Because the vacuum is fixed it is not a surprise that for decades there was no convincing way to apply quantum principles to gravity.

Attempts were made to use the techniques of quantum field theory, which successfully quantizes light, to quantize Einstein's theory. In this approach, just as light is described by a particle, the photon, gravity is described by a particle, the graviton. This is already a compromise as the graviton is a quantum ripple in a pre-assumed space that is not quantized. More drastically, the quantum field theory for the graviton fails because what should be small quantum corrections overwhelm the classical approximation, giving uncontrollable infinite modifications of the theory.

String theory solved part of this problem. In string theory the graviton is a string vibrating in one of its possible patterns, or "modes". As the string moves through space it splits and rejoins itself (figure 1). These bifurcations and recombinations are the "stringy" quantum corrections, which are milder than those in quantum field theory and give rise to a quantum theory of gravity that is well defined and finite as a systematic expansion in the number of splittings. But the strings still move in space rather than being a part of it; they are quantized, while space itself remains stubbornly classical. Furthermore, it is not known if this expansion around Einstein's classical theory can be summed to give a completely defined quantum theory.

Even before string theory John Wheeler suggested that at the Planck scale, the distance where the quantum corrections to gravity become large, the topology and geometry of space–time are unavoidably subject to quantum fluctuations (Wheeler 1964). This idea of a space–time quantum "foam" was explored by Stephen Hawking but has remained mysterious (Hawking 1978). New developments from an unexpected direction, however, have now given hints of an underlying, fundamentally quantum theory of strings that realizes these ideas: a mapping has been found to the theory of how crystals melt. In this picture classical geometry corresponds to a macroscopic crystal and quantum geometry to its underlying microscopic, atomic description.

These ideas grew out of discussions between a string theorist, Cumrun Vafa of Harvard, and two mathematicians, Nikolai Reshetikhin of UC Berkeley and Andrei Okounkov of the Institute for Advanced Study. They were brought together at the first of a series of interdisciplinary workshops held at the C N Yang Institute for Theoretical Physics and supported by the Simons Foundation at Stony Brook University in the summer of 2003.

The full theory of strings is still not understood well enough to formulate the problem of strings moving in a quantum space in complete generality. Instead, Okounkov, Reshetikhin and Vafa studied a part (or "sector") of string theory called "topological string theory". For concreteness, they focused on topological strings moving in a special class of spaces known as Calabi–Yau (CY) spaces. ▷

Topological string theory is a simplification of the full theory of strings in which the motion of strings does not depend on the details of the space through which they move. As such it is mathematically more tractable than the full theory. At the same time, CY spaces are very interesting in string theory. In part this is because they are candidates for the as yet unobserved six dimensions that complement our familiar three dimensions of space and one of time. A widely discussed string-theory scenario is that the familiar four-dimensional space–time and a six-dimensional CY space combine to make up the 10-dimensional space–time that is required for the self-consistency of string theory.

Many interesting properties of topological string theory on CY spaces have already become known through the work of Vafa and collaborators over the past few years. In particular they have shown that quantum corrections can be computed. These corrections are given by the relative likelihoods that strings split and join as they move in the space. The potential for one string to split or join is measured by a number called the "string coupling". This is actually a measure of the force between strings – in string theory forces are generated between two strings when one splits and one of its parts joins with the other. The larger the string coupling the more likely it is that this will happen and the stronger the force. These calculations are fine as long as the string coupling is small, but they become unmanageable when the coupling gets too large.

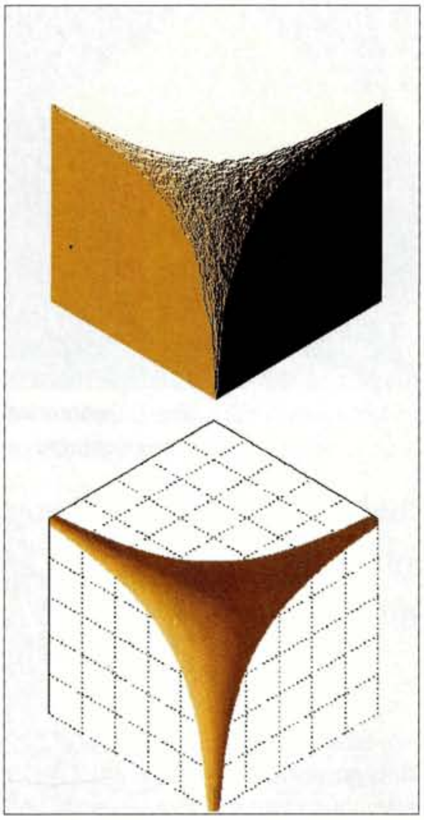


Fig. 3. As the crystal melts (top), it becomes a smooth surface, which is the projection of a CY space (bottom). (Image courtesy of Iqbal et al. *2003.)*

The crystal connection

At last summer's Simons Workshop, Okounkov, Reshetikhin and Vafa realized that a formula describing the topological string splitting on a CY space also has a completely different interpretation involving a crystal composed of a regular array of idealized atoms (Okounkov *et al.* 2003). When they identified the temperature of the crystal with the inverse of the string coupling, the likelihood of an atom leaving the lattice became the same as that of a string splitting. Once this connection is made, the same formula that describes the splitting of the strings describes the melting of the crystal (figure 2).

At high temperatures the idealized crystal melts into a smooth surface with a well-defined shape. This surface is a two-dimensional portrait of a CY space, called a "projection" of the space (figure 3). At these temperatures the string coupling is small and topological strings can be described in terms of the calculable quantum corrections. However, as the string coupling and hence the force between strings increases, the strings split so often it is unclear how to compute their behaviour in string theory. But increasing string coupling means decreasing temperature, and at low temperatures the crystal theory comes to the rescue. The crystal becomes simple at low temperatures, with most atoms fixed in their positions in the lattice. This means that the smooth surface of the melted crystal is replaced by the discrete structure of the lattice. The CY space naturally becomes discrete.

This led Okounkov, Reshetikhin and Vafa to conclude that topological string theory and crystal theory are "dual" descriptions of a single underlying system valid for the whole range of weak and strong string coupling, or equivalently, high and low temperatures, respectively. In particular when the string coupling is small, quantum fluctuations appear only at scales much smaller than the natural size of the strings themselves, and the picture of smooth strings remains self-consistent.

The new picture that emerges from this duality is that of a "quantum" CY geometry. To understand what this means it is worth recalling that in a classical space of any kind each point is specified by a set of numbers, or co-ordinates. Examples of co-ordinates are the longitude and latitude of the Earth's surface. In the quantum CY space the co-ordinates are no longer simple numbers to be specified at will. Rather they obey the Heisenberg uncertainty principle, which relates the position and momentum of a quantum particle. For the quantum CY spaces of Okounkov, Reshetikhin and Vafa's dual description of topological string theory, the long-standing dream of replacing a smooth classical space with a discrete quantum substructure is thus realized. In this system the emergence of a classical geometry out of a quantum system can be clearly controlled and understood. As is shown in further work by Vafa *et al.*, this gives an explicit and controllable picture of the Wheeler–Hawking notion of topological fluctuations – or "foam" – in space–time (Iqbal *et al.* 2003). The fluctuations of topology and geometry actually become the deep origin of strings. They extend rather than reduce the predictive power of the quantum theory of gravity.

Of course many challenges remain before a full theory of this kind can be realized. Chief among these is the extension of the picture from topological strings to full string theory. A possible path has been identified, however, suggesting that in string theory, as in Einstein's gravity, the distinction between forces and the space in which they act melts away.

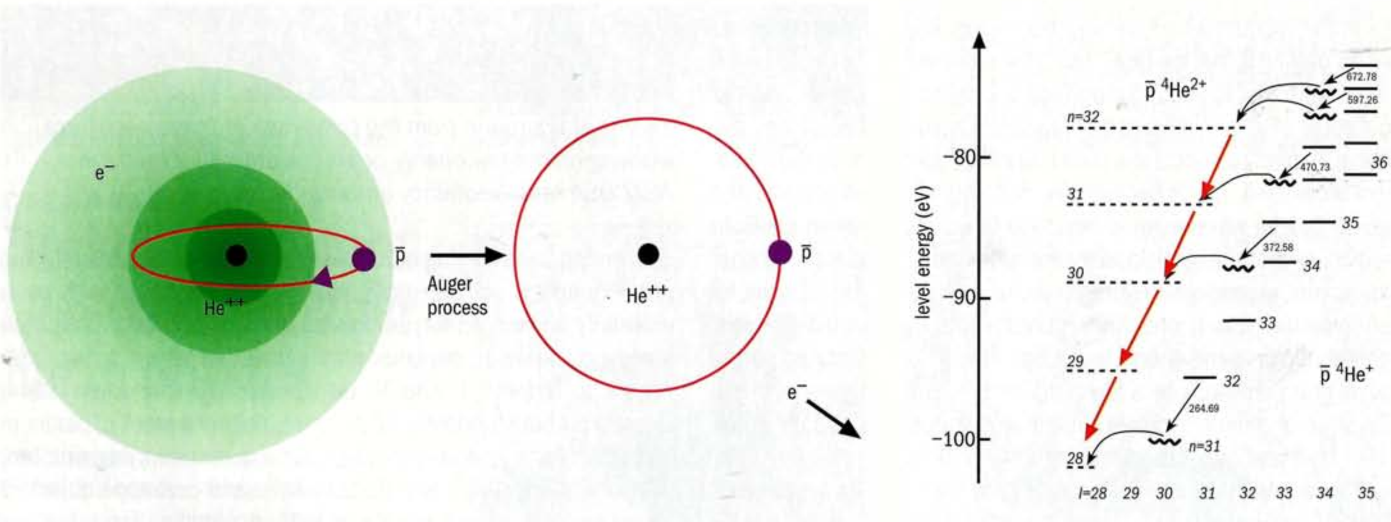
Further reading

S W Hawking 1978 *Nucl. Phys. B* **144** 349.
A Iqbal *et al.* 2003 www.arxiv.org/hep-th/0312022.
A Okounkov, N Reshetikhin and C Vafa 2003 hep-th/0309208.
J A Wheeler 1964 *Relativity Groups and Topology* Eds B S and C M De Witt (Gordon and Breach, New York).

Martin Roček *and* **George Sterman**, *C N Yang Institute for Theoretical Physics, Stony Brook University.*

ASACUSA enters a new world of precision

The antiproton may soon be better known than the proton, and an ion that is more hydrogen-like than hydrogen may become the subject of high-precision laser spectroscopy experiments. John Eades describes an exotic future.



Left: Auger decay of the $\bar{p}He^{+}$ three-body system to the $\bar{p}He^{++}$ ion. Right: energy-level diagram of the neutral three-body system (solid and wavy lines) and the ion (broken lines). The curved arrows symbolize Auger transitions emitting an electron and the straight arrows radiative transitions emitting photons. n *and* l *represent the principal and angular quantum numbers, respectively.*

For some years now, the Japanese–European ASACUSA collaboration at CERN has been tightening the limit on the antiproton charge (Q) and mass (M) relative to the values for the proton (see *CERN Courier* January/February 2003 p27). Any difference, however small, would indicate that the CPT-theorem, which under certain axiomatic conditions guarantees identical properties and behaviour for matter and antimatter, is in some way deficient. Such an eventuality would be of earth-shattering importance for our understanding of the physical world.

The latest result from ASACUSA is that any proton–antiproton charge or mass difference must be smaller than one part in 10^8 (Hori *et al.* 2003). As in the past, this limit was obtained by combining the ratio of the proton and antiproton Q/M values with their Q^2M values. The former was obtained from previous measurements by the Harvard group of the proton and antiproton cyclotron frequencies in a Penning trap (Gabrielse *et al.* 1999), and the latter from the frequencies of laser-stimulated transitions in antiprotonic helium – that is, atomic helium in which an antiproton replaces one of the two orbiting electrons.

The improved precision was made possible through the use of a radiofrequency quadrupole decelerator to reduce the kinetic energy of antiprotons from the Antiproton Decelerator (AD) from 5.3 MeV to 65 keV (*CERN Courier* July/August 2003 p30). The lower energy ensured a much smaller variation in the position at which the antiprotons came to rest in low pressure (1 mb), low temperature (10 K) helium gas. This in turn allowed an adequate number of antiprotonic helium atoms to be formed in a volume small enough to be irradiated by the laser beams. Much of the art of high-precision experimentation lies in accounting for minute systematic errors, and in such a low-density environment systematic shifts in the resonant laser frequencies associated with collisions between "antiprotonic" and "ordinary" helium atoms could be better estimated and corrected for.

Further experiments completed in 2003 are about to bring another exciting new prospect into sight. These experiments ▷

showed that it is possible to create antiprotonic helium ions – with a single antiproton rather than a single electron orbiting the helium nucleus – in a state suitable for the kind of laser spectroscopy described above. The important thing here is that this $\bar{p}He^{++}$ ion is a two-body system, while the neutral atom $\bar{p}He^{++}e^-$ comprises three bodies. The properties of two-body systems are in principle exactly calculable mathematically, while those of three-body systems can only be solved approximately using extremely complex calculations with powerful computers. The results of these calculations are consequently subject to their own errors, which beyond a certain level of precision can exceed those of the experimentally determined resonant laser frequencies. This sets a practical limit to the precision that is available with the neutral antiprotonic helium atom – which may indeed be reached after ASACUSA returns to the fray in 2004 with a new, higher precision laser system.

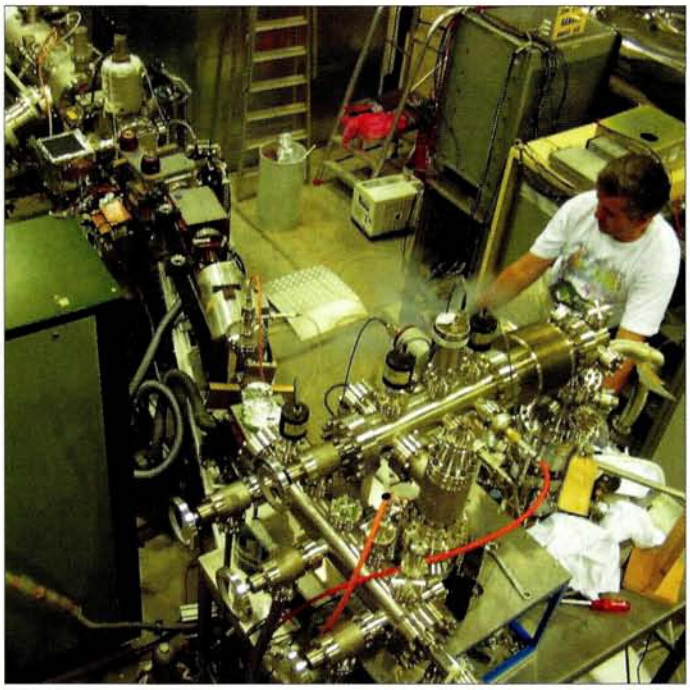
By performing experiments on the two-body ion instead of the neutral atom, this calculational roadblock can be circumvented. The experiments will be difficult, not least because the frequencies involved lie in the vacuum ultraviolet spectral region. What makes the game worth playing is that the $\bar{p}He^{++}$ ion is the nearest thing to the standard Bohr atom that is used to introduce undergraduate students to the concepts of atomic physics that physicists have ever had at their disposal. In many respects it is even more like hydrogen than the hydrogen atom itself. This is because the antiproton is non-relativistic and its de Broglie wavelength is some 40 times smaller than the Bohr radius, so that the semiclassical approximation, which is rather poor for normal, ground-state hydrogen atoms, turns out to be excellent for antiprotonic helium ions. All this means that the spin-independent contributions to the energy levels can literally be calculated on the back of an envelope to a few parts in 10^9. For comparison, in the 2p-state of atomic hydrogen, relativistic corrections appear at the 10^{-5} level and quantum electrodynamic corrections at 10^{-6}.

At the same time, even experiments with the "conventional" neutral antiprotonic atom may lead ASACUSA into a fascinating new regime in 2004. If we assume CPT-invariance, we can relate the mass of the antiproton to the electron mass instead of the proton mass. If ASACUSA is able to achieve a precision some 40 times better than the current 10 ppb, then the antiproton will become an even better known fundamental particle than the proton itself. This seemingly paradoxical situation comes about because no "protonic antihelium" counterpart to the antiprotonic helium atom is available with which the corresponding proton experiments could be made.

In the proton case, the limit on the charge neutrality of bulk matter has to be combined with the ratio of proton and electron cyclotron frequencies, ω_p and ω_e measured in the same Penning trap. While the charge neutrality limit is phenomenally precise (parts in 10^{20}), small corrections have to be applied to the measured ratio ω_p/ω_e because the two frequencies differ in magnitude by the large factor of the proton/electron mass ratio. One important consequence of this is that relativistic corrections, negligible for the proton, must be applied to the electron value. Taking this into account severely limits the precision obtained for the proton mass to about 0.5 ppb.

At this point we are confronted by some rather deep questions concerning the meaning of experimental results. In measuring any given quantity, we are really making a comparison with some arbitrarily chosen prototype object. The significance of that measurement, however, depends on the question we are trying to get nature to answer. It should be no surprise that when asking questions about fundamental particles, neither a block of platinum-iridium in Paris (the standard kg) nor a current-carrying wire loop (defining the MeV/c^2) is a particularly useful prototype object. Of much greater interest are the values of particle properties with respect to those of other particles, these being the prototypes chosen, in a sense, by nature herself. Thus, choosing the proton as the prototype for the antiproton is clearly meaningful when asking questions about CPT invariance. Choosing the basic leptonic constituent of stable matter, the electron, as a prototype for the mass of the proton – the basic hadronic constituent – evidently has some fundamental significance in the larger picture of particle physics. Plausible though this choice may be, no theoretical basis yet exists within the Standard Model to predict what the hadron/lepton mass ratio should be.

If ASACUSA achieves the expected new precision for this ratio with the antiproton, it will then still be necessary to wait until some theoretical prediction arrives to put the result in the wider general context. We might also suggest that experimentalists find some way of doing a better job on the proton mass!



Eberhard Widmann from the University of Tokyo seen here working on the low-energy beamline emerging from the ASACUSA radiofrequency quadrupole decelerator.

Further reading

G Gabrielse *et al.* 1999 *Phys. Rev. Lett.* **82** 3198.
M Hori *et al.* 2003 *Phys. Rev. Lett.* **91** 123401.

John Eades, *Tokyo.*

EUROPE

Forum Engelberg pays tribute to Curien

The 2004 Forum Engelberg paid tribute to its president, Hubert Curien, who will celebrate his 80th birthday this year. Curien is a former French minister for research and was president of the CERN Council during the crucial years 1994–1996, when the Large Hadron Collider project was approved. He is also known as one of the strongest promoters of European collaboration in science and technology.

The highlights of the 2004 conference, which was held in Lucerne on 1–4 March, included an interdisciplinary scientific programme with the theme "Science on the Agenda of European Politics", a young-scientists programme and a session on e-science and the Grid.

Hubert Curien during a visit to CERN in 2002.

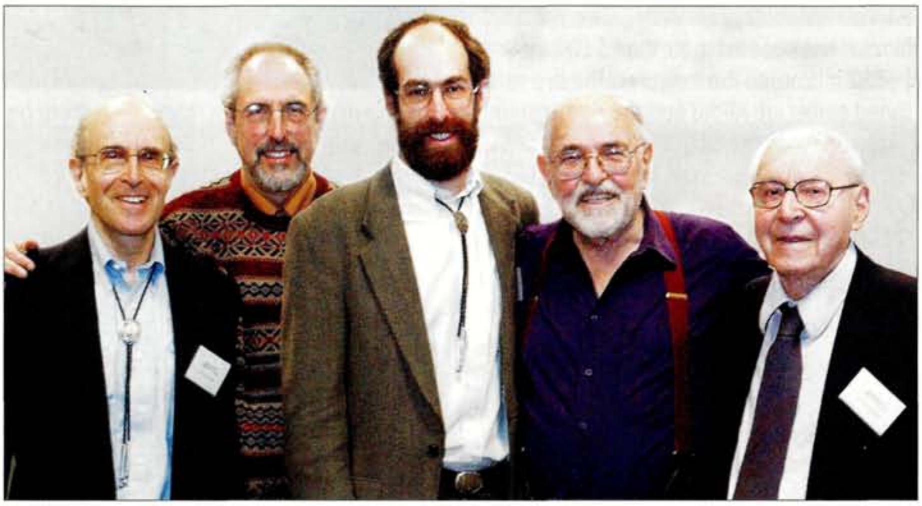
Under the patronage of the European commissioner for research, Philippe Busquin, and with the participation of present and former director-generals of the EIROforum research organizations (CERN, EFDA, ESA, ESO, EMBL, ESRF and ILL), along with government officials, ministers, friends and colleagues, the two-day colloquium covered presentations on European research-policy issues, present and planned research activities and projects, the dissemination of science, science and ethics, and the best practices for technology transfer.

The conference chairman, Luciano Maiani, concluded after the two days of interesting talks that: "Europe badly needs many more Hubert Curiens". For the full 2004 programme, see www.forum-engelberg.org.

CELEBRATION

Berkeley honours Gerson Goldhaber's life in physics

On 21 February the Lawrence Berkeley National Laboratory celebrated Gerson Goldhaber's 80th birthday with a "Gersonfest", which also marked the 50th anniversary of his arrival at the laboratory. The day-long symposium was organized around what one of the organizers called "the phase changes of Gerson's career", each of which corresponded to his favoured experimental techniques. These included deuterium-loaded photographic emulsions beginning in the 1940s, the hydrogen bubble chamber beginning in the 1950s, the solenoidal detector at SPEAR in the 1970s, and what George Trilling wryly described as the most dramatic phase change of all: "In the late 1980s Gerson decided to join the Supernova Cosmology Project, while I went into the Superconducting Super Collider. You can draw your own conclusions." During the festive dinner Maurice Goldhaber also recalled that his younger brother was so identified with the discovery of the charmed quark, that at a conference where both were speaking Maurice was introduced as "the Goldhaber without charm."



Goldhaber physicists at the Gersonfest (from left): Alfred Scharff Goldhaber, Michael Goldhaber, David Goldhaber-Gordon, Gerson Goldhaber and Maurice Goldhaber (Gerson's older brother). Alfred and Michael are Maurice's sons and David is Alfred's son.

RESEARCH FUNDING

New Kavli institutes to advance research in cosmology, nanoscience and neuroscience

The philanthropist Fred Kavli has announced the formation of seven new scientific research institutes at leading universities in the United States and Europe. This announcement comes just one year after he inaugurated the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) at SLAC in March 2003 (*CERN Courier* June 2003 p9). The network of Kavli institutes will address major challenges in the fields of cosmology, nanoscience and neuroscience. The new institutes will include the Kavli Institute for Cosmological Physics at the University of Chicago. Led by Bruce Winstein, it will investigate a wide range of modern cosmology, from the nature of dark energy and dark matter to the connections between cosmology and string theory. Kavli himself has donated more than $100 million (~€82 million) to the institutes. The two established earlier are KIPAC and the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara, led by David Gross.

Fred Kavli (centre) with Roger Blandford (left), the director of KIPAC, and Michael Turner, the National Science Foundation's assistant director for mathematical and physical sciences, at the recent announcement of the seven new Kavli institutes.

COMPUTING

Programming-language pioneer visits CERN

A workshop set up to explore the potential for scientific computing of the Oberon programming language was held at CERN on 10 March and included the originator of the language, Niklaus Wirth, along with various experts, all of whom gave presentations. Wirth, who celebrated his 70th birthday in February this year, founded the influential school of computer science at ETH, Zurich, where he was professor from 1968 until his retirement in 1999. He is best known as the designer of the programming languages Pascal (1970), for which he received the Turing Award in 1984; Modula-2 (1980), which is a language of choice for industrial control applications; and Oberon (1988), which incorporates support for object-oriented programming and automatic memory management in a remarkably small package. Oberon greatly influenced the design of the popular Java and C# programming languages, and has opened up new options for the design of algorithms for scientific applications. For further information about the Oberon workshop, see: http://cern.ch/oberon.day.

Influential program designer Niklaus Wirth, who celebrated his 70th birthday this year.

AWARDS

Top suppliers for CMS win Crystal and Gold

The fifth annual CMS awards ceremony was held at CERN on 15 March. This year, six of the approximately 1000 companies who work for CMS were honoured with the Gold Award for demonstrating excellence by providing parts on schedule, within budget and within specification. Two of the prize-winners also received the Crystal Award, which is given to a company that has taken further efforts to develop new designs, explore novel technologies and collaborate in research and development programmes with CERN, even when such action holds no direct benefit for the company.

The IBM Technology Group earned their Crystal Award by collaborating over the application of microelectronic technology to instrumentation for CMS. During the course of its continuing relationship with CERN, IBM has provided consultation expertise on the design and manufacture of silicon chips, helping CERN to develop its own design libraries. In addition, IBM solved a complex problem resulting in a high yield and overall cost savings to CMS. Ansaldo Superconduttori of Italy received their Crystal Award for achievements in the development and construction of modules for the CMS superconducting coil (*CERN Courier* March 2003 p6). The company proposed an innovative construction method that simplified the process by dividing the coil into five modules and also undertook the delicate task of impregnating modules in epoxy resin.

Gold Awards were also presented not only to IBM and Ansaldo but also to EEI of Italy, EMPA of Switzerland, Lenoir Elec of France and TPA Brianza of Italy. EEI was selected for their achievements in the production of the power converter for the CMS magnet. EMPA developed a new ultrasound checking system to control fabrication of the superconductor. They also introduced a process for immediate detection and visualization of welding flaws on line. Lenoir Elec adapted contact breakers especially for the needs of CMS. It is essential that these are very reliable to prevent damage to the magnet. Finally, TPA Brianza received their award for efforts in the development and construction of the winding line for the superconducting coil. To prevent damage to the insulation tape around the conductor, the company developed an innovative tool that works on the same principle as human hands. The device clamps the conductor during the push-up phase and releases it afterwards to prevent friction damage. A seventh Gold Award will be presented to the Iranian company HEPCO in June 2004.

Representatives of the companies receiving CMS Gold Awards on 15 March, pictured in front of the first superconducting coil module at the experiment construction site.

Riccardo Ranieri (left) receives the 2003 CMS Thesis Award from Lorenzo Foà, the chairperson of the CMS collaboration board, at the awards ceremony.

At the same ceremony, the 2003 CMS Thesis Award was presented to Riccardo Ranieri for his PhD thesis "Trigger selection of $WH \rightarrow \mu\nu b\bar{b}$ with CMS". Ranieri received his PhD from the University of Florence and was supervised by Carlo Civinini. In total, nine theses were nominated for the award, which was judged on originality, impact within the field of high-energy physics, impact within CMS and clarity of writing.

PRIZES

EPS rewards work in accelerator physics

Vladimir Shiltsev and Igor Meshkov have been announced as the winners of the 2004 accelerator prizes awarded by the European Physical Society's Interdivisional Group on Accelerators (EPS–IGA). The prizes will be given out and the award winners will talk about their work during the forthcoming 9th European Particle Accelerator Conference, EPAC '04, on 8 July 2004 in Lucerne, Switzerland (see p38).

Shiltsev, from Fermilab, receives the prize for an individual in the early part of their career who has made a recent significant and original contribution to the field of accelerator research. Specifically, his award was announced as being for: "many important contributions to accelerator physics, which include theory, beam simulations, hardware development, hardware commissioning and beam studies, and in particular for his pioneering work on electron-lens beam–beam compensation."

Meshkov, from JINR, Dubna, is awarded the prize for an individual with outstanding work in the accelerator field. He receives his prize for: "seminal contributions to numerous advances in accelerator science over the past 40 years, in particular for his development and implementation of the techniques that have allowed the original brilliant idea of electron cooling to become a hardware reality and an accelerator tool; and in addition for his devotion to and promotion of international collaboration in accelerator physics."

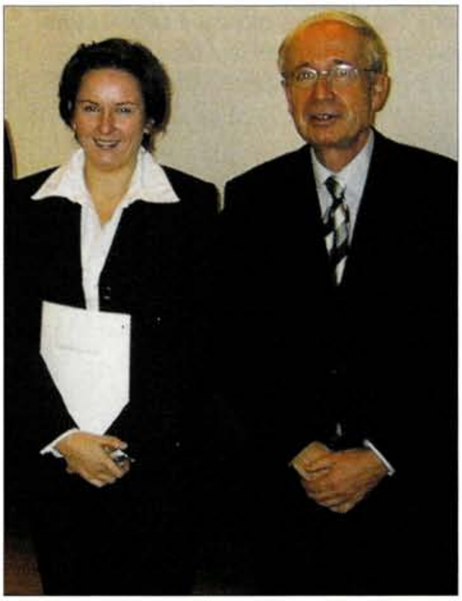

Vladimir Shiltsev (left) and Igor Meshkov, winners of the EPS–IGA 2004 accelerator prizes.

Prize awarded for radiation-protection research at CERN

Sabine Mayer from CERN has received the 2003 Zakovsky prize from the Austrian Radiation Protection Association for her PhD thesis on "Measurement of dose equivalent in radiation fields at high-energy accelerators". Awarded every two years, the Zakovsky prize acknowledges outstanding scientific contributions by young scientists to the field of radiation protection.

The investigations and work for the thesis were carried out in the Radiation Protection Group of CERN, where Mayer worked on her thesis in the framework of the Austrian Doctoral Student Programme. She shares the 2003 prize with Christian Kirisits from the University of Vienna, whose thesis dealt with radiation protection at therapy units in hospitals.

The award of the prize to Mayer illustrates the importance of the Austrian programme for PhD students at CERN. This programme supports work in all fields of applied physics and technology relevant for CERN. It is financed by the Austrian Federal Ministry for Education, Science and Culture, and forms part of the CERN Doctoral Student Programme. Approximately 10 new students are accepted per year and so far more than 50 students have obtained PhDs through the programme.



Prize-winner Sabine Mayer (left), with Hannes Aiginger, her thesis supervisor at the Vienna University of Technology.

PARTICLE PHILATELY

Swiss Post Office produces stamp to commemorate 50 years of CERN...

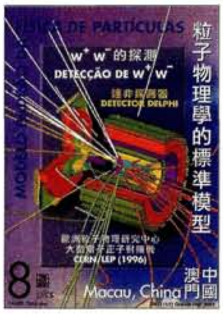
From left to right: CERN's director-general, Robert Aymar, together with Elsa Baxter from the Stamps and Philately Unit at the Swiss Post Office, and the two artists who designed the stamp, Christian Stuker and Beat Trummer. They are shown here at the press conference to mark the official start to CERN's 50th anniversary celebrations.

On 9 March a commemorative stamp dedicated to CERN's 50th anniversary went on sale in post offices and philatelic centres throughout Switzerland. Designed by Swiss artists Christian Stuker and Beat Trummer, the stamp aims to convey the spirit of CERN in an area no larger than 28 by 33 mm. "We wanted to get away from existing CERN imagery and create something symbolic for this anniversary," Christian Stucker explained. The radiating design portrays an opening, a spreading out towards infinity, which reflects CERN's fundamental goals of research and the transmission of knowledge. The Swiss Post Office also issued a "first-day cover", which is an envelope for collectors to receive franked on the first day of issue.

The stamp was unveiled at a press conference at the Geneva Press Club, which announced the programme of events planned to mark CERN's 50th anniversary. Elsa Baxter, head of the Swiss Post Office's Stamps and Philately Unit, said at the press conference: "I am delighted to offer you this special stamp, which commemorates your laboratory's 50 year history and pays tribute to its achievements, its pioneering spirit and its perseverance."

...while Macau's stamps celebrate the Standard Model

Particle-physics themes on stamps are probably more common than you might imagine. The Macau Post Office, China, recently published a set of stamps on "Science and Technology – Standard Model of Particle Physics". The Macau Post Office, which publishes several series of stamps each year, contacted particle physicists in Portugal with a proposal for a series on the Standard Model. Jorge Dias de Deus, Mário Pimenta and Sofia Andringa were involved in the draft design and scientific content, while Daniel Dias was responsible for the design and graphic composition. The final designs give special emphasis to the contributions made by the Large Electron Positron (LEP) collider at CERN. Six stamps for 1.5 patacas illustrate various aspects of the Standard Model: electroweak unification (shown here), symmetry breaking, Higgs diagrams, the three families of quarks and leptons, quantum chromodynamics and grand unification. In addition, a souvenir sheet includes one stamp for 8 patacas that shows the first W^+W^- pair detected at the LEP in the DELPHI detector.



Stamps from Macau illustrating electroweak unification (left) and the first W^+W^- pair.

CERN

China and CERN renew co-operation agreement for a further five years

During a visit to CERN on 17 February, Liu Yanhua, the vice-minister of science and technology of the People's Republic of China, signed a new co-operation agreement with the laboratory. The agreement, which is valid for a period of five years and is renewable, lays down the framework for the development of scientific and technological co-operation between CERN and China. This includes China's participation, as a non-member state, in CERN's research projects as well as in its main programmes.

Yanhua's visit included a tour of the test halls for the LHC's superconducting magnets, the assembly hall for CMS, the ATLAS cavern and the CLIC (Compact Linear Collider) test facility.

Liu Yanhua (left), vice-minister of science and technology of the People's Republic of China, and Robert Aymar, CERN's director-general, shake hands on the new co-operation agreement.

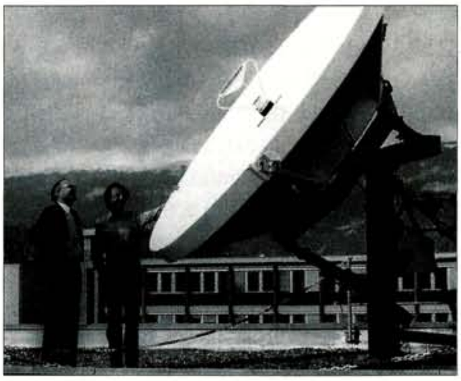
LETTERS

CERN Courier welcomes letters from readers. Please e-mail cern.courier@cern.ch. We reserve the right to edit letters.

STELLA days

It was a pleasure to recognize Mervyn Hine standing on the left of the picture in the STELLA project box on page 14 of the March 2004 issue of *CERN Courier*. STELLA was a pioneering project. An important aim in those days was to test the reliability in the transmission of large volumes of data over long distances, as would soon be required by experiments. Mervyn was responsible for the CERN part of the project. Those who had the privilege of working close to him in one of his many activities at CERN, remember well his prompt wit, his vast culture and his inquisitive, uncompromising mind. His attitude on the photograph is so characteristic of him, almost a signature.

Franco Bonaudi, Commugny, Switzerland.



MEETINGS

SEESAW 25, the International Conference on the Seesaw Mechanism and the Neutrino Mass, will be held on 10–11 June at the Institut Henri Poincaré in Paris, France. The aim of the conference is to assess progress since the invention of the seesaw mechanism 25 years ago, in 1979. For an online registration form and for more information about the meeting, see http://seesaw25.in2p3.fr.

Lattice 2004, the XXII International Symposium on Lattice Field Theory is to be held on 21–26 June at the Fermi National Accelerator Laboratory. For more information, see http://lqcd.fnal.gov/lattice2004.

EPAC 2004, the 9th biennial European Particle Accelerator Conference, will take place on 5–9 July at the Lucerne Congress Centre, Lucerne, Switzerland. The conference is organized by the European Physical Society's Interdivisional Group on Accelerators (EPS–IGA). For further information, see www.epac04.ch.

The 16th Annual Summer Nuclear Institute at TRIUMF, TSI2004, will be held on 15–16 July. The institute will provide short courses in topics in nuclear astrophysics from both a theoretical and experimental point of view. It will also be an excellent introduction to the symposium NIC8, which takes place the following week. Experimental and theoretical physics students are urged to attend. For more information, see www.triumf.ca/snit.

NIC8, the 8th International Symposium on Nuclei in the Cosmos will be held on 19–23 July at TRIUMF in Vancouver, Canada. This conference is the foremost biannual meeting of theoretical and observational astrophysicists, nuclear physicists, cosmochemists and others interested in the creation of energy and elements in the universe. For further details, see www.triumf.ca/nic8/.

OBITUARY

George Hampton 1920–2004

George Hampton at CERN in 1963.

George Hampton, who died recently, was CERN's director of administration in the 1960s and an important member of the team who managed the growth of CERN as it left the construction period and became a world-class physics laboratory.

To be a good director of administration at CERN is not easy. This was doubly so in the 1960s when the laboratory was just starting its main research activities after the intense period of construction of the big accelerator, the Proton Synchrotron (PS). CERN was passing through a major budget crisis and the new director-general, Viki Weisskopf, was faced with a completely new structure that was set up by his predecessor John Adams, and which included 12 divisions for running the laboratory, all reporting directly to him, and four directors. In addition, the CERN staff were proud of their success in building the PS in their own way, in the planned time and close to the forecast cost. They were therefore anxious not to be subjected to the kind of bureaucracy that administrators in their home countries might well want to set up in the face of such self-sufficiency.

With the renewal of the position of director of administration in 1963, Weisskopf selected George Hampton from the candidates from the member states. George came from the UK Atomic Energy Authority, but had earlier worked as a delegate to the International Civil Aviation Organization. Viki, I believe, picked him for his character rather than his administrative experience. Indeed, Viki himself when being chosen as director-general was asked if he had any administrative experience, to which he firmly replied "No", adding that he considered that to be an advantage.

George's position at the start was to help the director-general with foreign affairs and general administrative policy, but in 1965 the new director-general, Bernard Gregory, gave his directors direct authority over the appropriate divisions. In George's case, these were finance, personnel, site and buildings, and the directorate services, whose leaders previously had direct access to the director-general.

George met these challenges remarkably well. For example, although he naturally represented CERN administration in discussions with the finance committee, he gave me a free hand in writing the long-term budget papers and presenting them to the committee, which involved my routinely invading the territories of finance and personnel.

Henri Laporte, then head of site and buildings, recalls: "On the face of it, we weren't exactly made to get along with each other, given that we had such different origins and professional and academic backgrounds. But in spite of everything, we did get along and never failed to respect each other or provide mutual support. George had his feet firmly on the ground and knew where his limits lay. When we first met, he told me that he didn't want to interfere with the technical matters handled by my division, but he did ask me to advise him as to which issues I thought I should consult him on, in particular those relating to the proper administration of CERN. He was quite comfortable if I let weeks go by without consulting him if there was no reason to do so, and was never offended by the direct contacts I sometimes enjoyed with other directors, outside authorities or member-state delegations."

This summarizes well George's way of working inside CERN with his collaborators. His contacts with the scientific and technical divisions were less direct, instead going through finance and personnel, but his good humour and pragmatism were known and appreciated. His particularly British sense of humour was illustrated by a memo he sent to division leaders during discussion of a reorganization: "It seemed that every time we were beginning to form up into teams, we would be disbanded. I was to learn later in life that we tend to meet any new situation by reorganizing; and a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency and demoralization. *Petronius Arbiter 57 AD.*"

In dealing with the outside world, George had to be more active, and was a strong defender of the laboratory. Laporte again recalls: "I remember on one occasion there had been a serious accident on the site and certain sections of the Swiss media were trying to aggravate the situation. As soon as George found out about this he went straight down to Geneva and, using his good contacts with the political authorities and newspaper editors, made sure that the whole business was dealt with correctly. As far as I'm concerned, George Hampton had true nobility, and I have good memories of the many years we worked together."

George was equally strong in dealing with the CERN Council and finance committee members. Towards the end of his period as director, when the finance committee no longer had members with the same enthusiasm for CERN as in the early days, his directness annoyed some people, which was a pity. He was a very effective director of administration, a good man to work with, and in my view the best CERN has ever had.

Mervyn Hine, Founex, Switzerland.

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MICHIGAN STATE UNIVERSITY

POSTDOCTORAL POSITIONS
EXPERIMENTAL/COMPUTATIONAL CONDENSED MATTER PHYSICS
MICHIGAN STATE UNIVERSITY

Applications are invited for one or more post-doctoral research positions in condensed matter physics. The successful candidate will carry out x-ray and neutron scattering experiments and computer simulations to study the structure of nanostructured materials.

Applicants with a strong background in x-ray or neutron scattering, or computational physics are particularly encouraged to apply. Review of applicants will begin after April 1st 2004 and continue until the position is filled. Candidates must have a Ph.D in physics, materials science, chemistry or a related field.

Please send applications by paper mail, including a vita, statement of research, copy of one of your papers and at least two letters of recommendation, to **Prof. Simon J. L. Billinge, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824**.

More information about the research can be found on the group web-page at **http://www.pa.msu.edu/cmp/billinge-group.**

Michigan State University is an affirmative action/equal opportunity institution. Women and minorities are especially encouraged to apply. Persons with disabilities have the right to request and receive reasonable accommodations.

CAREER POSITION IN EXPERIMENTAL PARTICLE ASTROPHYSICS

The Lawrence Berkeley National Laboratory's Nuclear Science Division is seeking a scientist with outstanding promise and creative ability in experimental particle astrophysics. The appointment will be a career position as Staff Physicist. The successful candidate will have at least 5 years of experience beyond the PhD in major collaborative research in nuclear or particle physics and will be expected to assume a leadership role in the neutrino physics/astronomy program at LBNL.

The successful candidate initially will assume a major role in the group at LBNL that has a key role in IceCube, a neutrino detector to be installed at the South Pole. IceCube will survey the neutrino sky in the energy range 10**12 - 10**16 eV in search of galactic and cosmological neutrinos from a variety of potential sources. LBNL has major responsibility for the DAQ system, which will acquire data from 4800 optical modules located deep in the polar ice cap.

Applicants are requested to e-mail a curriculum vitae, list of publications, statement of research interests, and the names of at least 5 references, no later than June 1, 2004, to gensciemployment@lbl.gov and to jnmarx@lbl.gov. Please reference job number NS/016961/JCERN in your cover letter. Berkeley Lab is an EEO/AA employer.

BERKELEY LAB

POSTDOCTORAL POSITIONS IN EXPERIMENTAL PARTICLE PHYSICS

The Fermi National Accelerator Laboratory (Fermilab) has openings for postdoctoral Research Associates in experimental particle physics. The Fermilab research program includes experiments with the 2 TeV proton - antiproton collider, neutrino oscillation experiments, fixed target experiments and astroparticle physics experiments. There are positions for recent Ph.D.s to join the Tevatron Collider program. There are also opportunities to join the neutrino oscillation experiments MiniBooNE and MINOS, and the Cryogenic Dark Matter Search. Opportunities also exist to participate in the future BTeV and LHC-CMS experiments. Positions associated with the experimental program are also available in the Computing Division for candidates interested in modern computing techniques applicable to HEP data acquisition and analysis.

Successful candidates are offered a choice among interested Fermilab experiments, and typically have the opportunity to participate in detector development and commissioning in addition to experiment operation and data analysis. Appointments are normally for three years with the possibility of extension.

Applications and requests for information should be directed to:
Dr. Michael Albrow, Head Experimental Physics Projects Department, Particle Physics Division (albrow@fnal.gov), Fermi National Accelerator Laboratory, MS 122, P.O. Box 500, Batavia, IL 60510-0500.
Applications should include a curriculum vita, publication list and the names of at least three references. EOE M/F/D/V.

Fermilab

UNIVERSITAS BERNENSIS

The Faculty of Science of the University of Bern
invites applications for a position of

Full Professor of Experimental High Energy Physics and Head of the Laboratory for High Energy Physics

opening March 1, 2006 at the Laboratory of High Energy Physics of the Physics Institute, University of Bern, Switzerland. Current research activities of the Laboratory include work at CERN especially on the ATLAS experiment at LHC, as well as the physics of neutrino oscillations (OPERA) and dark matter (ORPHEUS).

Candidates should have a proven first rate research record in experimental high energy physics. This may include participation in large experiments and the development of novel experimental techniques.
She/he should also be prepared to participate actively in the teaching of physics at both the undergraduate and graduate level. As Head of the Laboratory, the successful candidate has overall responsibility for about 30 collaborators and will be a member of the Board of Directors of the Physics Institute.

The University of Bern especially encourages women to apply for this position.

Letters of application, including curriculum vitae, a list of publications, copies of the most important publications, and an outline of past and future research (all in English) should be sent before September 15, 2004 to
Prof. G. Jaeger, Dean of the Faculty of Science,
Sidlerstrasse 5, CH-3012 Bern, Switzerland.

Further information about the Laboratory can be found at **http://www.lhep.unibe.ch** and enquiries about this position can be made by contacting
Prof. W. Benz, Physikalisches Institut,
Sidlerstrasse 5, CH-3012 Bern, Switzerland,
Tel: +41 31 631-4403, Fax: +41 31 631-4405,
e-mail: wbenz@phim.unibe.ch

Senior Science Experts

(FIXED-TERM APPOINTMENTS)

SWINDON, WILTSHIRE

The Particle Physics and Astronomy Research Council (PPARC) is the UK's strategic science investment agency for particle physics and astronomy and it directs and funds research in national and international programmes across these areas. The PPARC delivers world-leading science, technologies and people for the UK.

In a new initiative to enhance its operations, the PPARC wishes to appoint a small number of high calibre science experts to work closely with the Chief Executive, Director Programmes and other senior members of the PPARC team in defining, developing, implementing and monitoring its future science priorities and programmes. These senior appointments, which will typically be for a fixed-term linked to specific projects or initiatives, will provide additional knowledge and expertise to complement that already available in-house and through the PPARC's existing peer-review and advisory structure.

The PPARC has four main science areas covering its remit; particle physics, particle astrophysics, astronomy and solar system science and it is envisaged that the experts will have a role in shaping the science strategies and priorities within these broad themes. Three projects requiring specific support and drive in science, policy and international negotiations are the Linear Collider, the ESA Aurora Programme, and Extremely Large Optical Telescopes coupled with the Square Kilometre Array. Expressions of interest in other areas of the PPARC's programme will also be welcome however.

The role and responsibilities taken by an expert will depend upon their skills and expertise and also, crucially, on the PPARC's science requirements in a specific area. Typically, however, the role is expected to encompass:

- Responsibility for development of a major project, including full delegated responsibility for the budget, liaison with other funding agencies, and interaction with the UK community.
- Advice and support to Director Programmes, Chief Executive and Science Committee on the development of PPARC's long term scientific strategy.
- Advice and support to the appropriate PPARC Programme Manager on matters relating to a particular subject theme area including liaison with the community.
- General support and advice to PPARC's Peer Review System.

To fill these exciting and challenging roles successfully individuals will need to be acknowledged experts in the PPARC theme area on which they wish to work. They must also be able to demonstrate experience in the development and management of major science projects / programmes at a national if not international level as well as a broad understanding of the definition and implementation of science policy and associated strategy within the UK research system. They must also be able to demonstrate that they can shape and set the agenda in the UK's strategic interests.

Effective communication (both written and oral) and political skills will be crucial to the role as will the ability to interact effectively with a wide range of senior people in the academic, industrial and government sectors both in the UK and abroad. High level negotiation and representation skills are a prerequisite. The role will require a substantial amount of travel to meetings around the UK and overseas and the need to work flexible and sometimes extended hours.

The nature and terms of appointment will be subject to negotiation depending upon the circumstances of the selected candidate and the role agreed. However, the PPARC envisages that the roles will typically be filled on a fixed-term basis linked to specific projects or initiatives with the individual subsequently returning to their former employment or similar. Applications involving a secondment or sabbatical arrangement are, therefore, particularly encouraged.

The salary offered will depend on qualifications and experience but will likely fall in the PPARC Band 2a range of £41.5k to £51k p.a. The PPARC also offers a final salary pension scheme and a generous non-pay benefits package. The role will require a commitment to work from the PPARC Swindon Office for a significant proportion of the allotted time. Assistance with relocation expenses of up to £5k may be payable in appropriate circumstances.

No agencies.

The PPARC is operating an equal opportunities policy, which ensures that all job applicants are treated fairly regardless of gender, ethnic origin or disability.

Suitably qualified individuals are invited to register their interest by submitting a copy of their CV with a covering letter indicating their area of interest to the Personnel Management Section, PPARC, Polaris House, North Star Avenue, Swindon SN2 1SZ or via e-mail to pms@pparc.ac.uk. Potential applicants are encouraged to contact Professor Ian Halliday, PPARC Chief Executive, e-mail Ian.Halliday@pparc.ac.uk or Professor Richard Wade, PPARC Director Programmes, e-mail Richard.Wade@pparc.ac.uk for an initial discussion about the work before registering their interest formally.

Expressions of interest should be sent by 14th May 2004 following which they will be considered by the PPARC with a view to arranging formal interviews with suitable applicants. It is hoped that successful candidates will take up appointment by October 2004.

PPARC

Particle Physics and Astronomy Research Council
www.pparc.ac.uk

the physics of the universe

hmi

The Hahn-Meitner-Institut Berlin (HMI)

Member of the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren
invites applications for the appointment as

Head of the Ion Beam Laboratory ISL Berlin

(BAT I)

HMI is a research center with some 800 employees, research focussed on structure investigations utilizing neutrons, ions and synchrotron radiation and photovoltaics.

As a national large scale facility ISL provides particle accelerators and irradiation facilities to utilize fast ions in solid state physics, materials research and medicine. The accelerator complex combines a sector cyclotron with two injectors, a Van de Graaff and a RFQ structure, both equipped with modern ECR ion sources. Research at ISL ranges from a broad programme in basic research to applications of fast ions in medicine and technology (cf. also www.hmi.de).

Candidates with a PhD in Physics or Engineering and an international reputation for expertise on

- particle accelerators
- modern high efficiency ion sources
- applying fast ions in materials research or medicine

are invited to apply.

The successful candidate is expected to be a motivating team leader and to inspire all efforts to support the high standard of reliability and precision of the beams provided to the users. She/he is expected to recruit new users and new applications, and to keep ISL matching the demands of both the external and internal research projects. Recruiting and supporting third-party funded projects is of ever rising importance.

HMI is seeking to increase the quota of women scientists. Therefore, women are especially encouraged to apply. Handicapped applicants will be given preference over others of equal qualification.

Applications including our reference no. **SF 2004/4** must be received no later than 4 weeks after posting, and should be addressed to Prof. Michael Steiner, Scientific Director, HMI, Glienicker Straße 100, D-14109 Berlin. Further information may be obtained via phone (049 / 030 / 8062 2762).

University of Zurich

The Faculty of Science (Mathematisch-naturwissenschaftliche Fakultät) of the University of Zurich invites applications for a

Professorship in Theoretical Physics

at the Institute for Theoretical Physics, to commence on March 1, 2006. The new professor is expected to establish and lead a successful research group, contribute to the Masters program in Theoretical Physics and to undergraduate teaching. She or he will find a very stimulating environment in many areas of theoretical physics and major experimental activities at the University, the ETH and PSI. Current research interests at the institute include particle physics, quantum field theory, astrophysics and cosmology.

We are looking primarily for a theoretical cosmologist or particle-astrophysicist to complement our activities, however the main priority is to identify candidates with excellent scientific standing and applications from other fields will also be considered.

Applicants are invited to submit by July 31, 2004 a curriculum vitae, a publication list, and a summary of their research interests to Prof. Dr. P. Truöl, Dean of the Faculty of Science (MNF), University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland. The application material should also be submitted in a single Word or PDF file to jobsmnf@zuv.unizh.ch.

For further information, contact Prof. D. Wyler, Institute of Theoretical Physics, phone +411 635 5817, email: wyler@physik.unizh.ch, or visit the homepage at www.theorie.physik.unizh.ch.

Deutsches Elektronen-Synchrotron DESY

Particle Physics

DESY is world-wide one of the leading accelerator centres exploring the structure of matter. The main research areas range from elementary particle physics over various applications of synchrotron radiation to the construction and use of X-ray lasers.

The DESY-Group –H1– is involved in the operation and upgrade of the H1 detector at the ep collider HERA as well as in physics analysis of the collected data. We have an opening for an

Experimental Particle Physicist (Ph.D)

You will develop the software environment of the H1 experiment towards optimal physics analysis and will actively participate in the H1 physics program.

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Salary and benefits are commensurate with public service organisations. DESY operates flexible work schemes, such as flexitime or part-time work. DESY ist an equal opportunity, affirmative action employer and encourages applications from women.

Deutsches Elektronen-Synchrotron DESY
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email: personal.abteilung@desy.de

Deadline for applicants: 16th May 2004

POSTDOCTORAL FELLOW - ATLAS

The Physics Division of the Lawrence Berkeley National Laboratory (LBNL) is seeking a Postdoctoral Fellow to participate in the ATLAS Experiment at the Large Hadron Collider (LHC) at CERN. The ATLAS Group at LBNL has important roles in the silicon tracking detectors and in physics simulation and preparations for data analysis for ATLAS.

The successful applicant is expected to be involved in the production and commissioning of the ATLAS pixel detector and in analysis of the first data from the LHC. This is a 2-year term position with the possibility of renewal up to a total of 5 years. To qualify, you should have a PhD in Experimental High Energy Physics or equivalent experience and demonstrated strong potential for outstanding achievement as an independent researcher.

Interested applicants should submit via email (our preferred method) a curriculum vitae, publication list, and 3 letters of recommendation to gensciemployment@lbl.gov or mail to Lawrence Berkeley National Laboratory, Attn: Merrill Martin, 1 Cyclotron Road, MS 937-0600, Berkeley, CA 94720-8152. Applications should reference job number PH/016923/JCERN. Questions related to job content and responsibilities should be directed to M. Gilchriese at MGGilchriese@lbl.gov. Applications will be accepted until the position is filled. LBNL is an Affirmative Action/Equal Opportunity Employer committed to the development of a diverse workforce.

BERKELEY LAB

INDEX TO DISPLAY ADVERTISERS

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BOOKSHELF

Books received

Frontiers of Science: In Celebration of the 80th Birthday of C N Yang by Hwa-Tung Nieh (ed), World Scientific. Hardback ISBN 9812384073, £78 ($106). Paperback ISBN 9812384146, £41 ($55).

The proceedings of the International Symposium on Frontiers of Science, which was held in June 2002 to celebrate the 80th birthday of Chen Ning Yang, this book is a collection of the presentations made at the symposium, including fifteen plenary talks, seven of which are by Nobel laureates. It covers a wide range of topics that mirror Yang's research and intellectual interests. The range of fields encompasses high-energy, condensed-matter, mathematical, applied, bio-, astro-, atomic and quantum physics.

Mathematical Perspectives on Theoretical Physics by Nirmala Prakash, Imperial College Press. Hardback ISBN 1860943640, £87 ($118). Paperback ISBN 1860943659, £43 ($58).

Subtitled "A journey from black holes to superstrings", this new printing of a book that was originally published by Tata McGraw-Hill presents the basics of mathematics that are needed for learning the physics of today. It describes briefly the theories of groups and operators, of finite- and infinite-dimensional algebras, the concepts of symmetry and supersymmetry, and then delineates their relations to theories of relativity and black holes, classical and quantum physics, electroweak fields and Yang–Mills. The book concludes with a chapter on strings and superstrings, and their link to black holes.

Beyond Measure: Modern Physics, Philosophy and the Meaning of Quantum Theory by Jim Baggott, Oxford University Press. Hardback ISBN 198529279, £45 ($74.50). Paperback ISBN 198525362, £20 ($34.50).

The aim of this book is to bridge the gap between specialist textbooks on quantum theory, which are often filled with complex jargon, and popular presentations, which emphasise "weirdness" and contain no mathematics at all. Discussion of the theory's problems is grounded directly in its mathematical formalism, in a way that undergraduates and others can follow. The book also brings the reader up to date with the results of experimental tests.

Remnants of the Fall: Revelations of Particle Secrets by William B Rolnick, World Scientific. Hardback ISBN 9812380604, £36 ($48). Paperback 9812381465, £15 ($20).

Interspersed with interludes of poetry, this book by William Rolnick takes the reader on a journey through the modern understanding of the building blocks of nature and their interactions. The descriptions for the general reader have no equations and are punctuated with original verses. In particular, the central role of symmetry is explained in a manner that is suitable for the general science reader.

Smaller institutes look to gain from scientific fallout

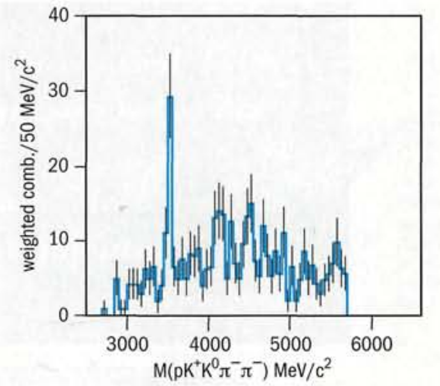
Alexandru Mihul believes that the distribution of data from large laboratories to smaller institutes for longer term analysis has benefits for all.

Large laboratories obtain scientific data in vast quantities and usually use this material for rapid research being driven by competition. The majority of important results are collected in as short a time as possible. When new data appear older data lose their importance and are abandoned or placed at the disposal of smaller labs that could make use of them.

This has been the case in the past with data obtained at laboratories such as CERN, Fermilab and JINR, which came in such quantities that they could not be exhaustively analysed by the researchers there. The data were therefore given to various universities and other smaller laboratories, which over a long period of time have analysed the events in question and sometimes made valid discoveries.

More recently, data from the CDF and D0 experiments at Fermilab have become available via the web. A more leisurely analysis phase is also happening with data obtained from experiments at LEP, whose activity is slowing down. Thus it gives the possibility of allowing researchers at smaller scientific institutions to follow up the work and make new findings. For example, institutes in the "Post L3" collaboration are currently analysing some LEP data in their own time and have no obligation to provide results by a specific deadline.

The pictures made in the late 1960s with the CERN 2 m hydrogen bubble chamber show the possible importance of this approach. Its films ended up in various universities, either for further analysis or for didactic purposes, because bubble-chamber pictures are useful for students. Consequently, during the 1970s, the University of Bucharest and JINR in Dubna obtained 125 000 pictures courtesy of CERN. The pictures were found to contain a number of interesting items that had earlier been overlooked because in the principal analysis they had been viewed with different criteria in mind.



Was this a pentaquark? The $pK^+K^0_s\pi^-\pi^-$ mass distribution from 16 GeV/c π^-p interactions in CERN's 2 m bubble chamber shows a significant peak at 3520 MeV.

In one particular example, V M Karnauhov, V I Moroz, C Coca and A Mihul were able to report on finding a resonance in π^-p interactions at 16 GeV, having a mass of 3520 ± 3 MeV/c^2 and a width of 7^{+20}_{-07} MeV with eight standard deviations (Karnauhov *et al.* 1992). At the time this seemed very strange, as most physicists were not particularly interested as the resonance corresponded to a five-quark particle (uud c$\bar{c}$), which did not fit then into any theoretical framework.

During the past year, however, evidence for several exotic resonances has been reported. A real "gold rush" for similar phenomena – the "pentaquarks" – has begun, even though there are few, if any, irrefutable theoretical explanations. Their masses have not yet been calculated due to the lack of a theoretical basis. These include the Θ* (1540 MeV and a width of 17 MeV) and the Ξ (1862) baryon with S = −2, which have still to be established with high accuracy. They appear like states of five quarks (pentaquarks), i.e. four quarks and one antiquark, so yielding a system without colour, which is necessary to be observable.

The 2 m bubble-chamber data suggested long ago that at least one more baryonic exotic state was found with a mass of 3520 ± 3 MeV/c^2, a width of 7^{+20}_{-07} MeV and S = 0. This was a pentaquark baryon with neutral strangeness. The essential difference between the Θ*and Ξ (1862) and what was found long ago is that the old resonance was formed by quarks including a c$\bar{c}$ pair, while the new ones contain s ($\bar{s}$) quarks, giving a substantial difference in the final mass. Other teams have also reported possible sightings of pentaquarks in data from the 2 m chamber (*CERN Courier* April 2004 p31), and now the H1 experiment at DESY has evidence for a uudd$\bar{c}$ state with a mass of 3100 MeV/c^2 (p5).

So what can we learn from this experience? The distribution of data to smaller institutions, which perhaps have more time to follow different or unfashionable lines of analysis, must continue. Besides the benefits that this activity can bring to the institutes themselves, the long-term process also has the benefit of bringing fresh minds to the analysis as younger physicists, who may bring new approaches, replacing older ones.

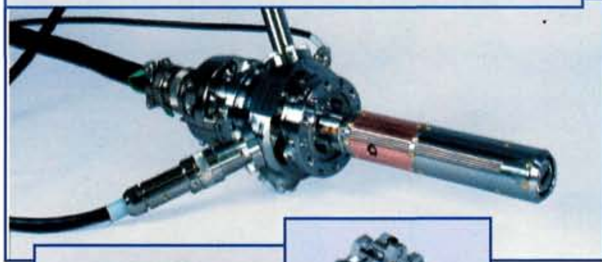
The Grid should also be able to overcome some of the difficulties of the past. It aims at providing a global computing facility, which will allow the smaller laboratories to participate in the primary research. However, the Grid is being developed to provide enormous computing power; it will not be able to provide the thinking time that is necessary for the best job to be done. This can only be provided by the researchers performing long-term analysis generally in the smaller laboratories.

Further reading

V M Karnauhov *et al.* 1992 *Phys. Lett.* **B281** 148.

Alexandru Mihul, University of Bucharest.

Electron and Ion Guns / Systems
UHV Components, Vacuum Chambers

UHV Electron Guns/Systems
UHV Ion Guns/Systems

Beam energies: <1 eV to 100 keV.
Beam currents: femtoamps to amperes
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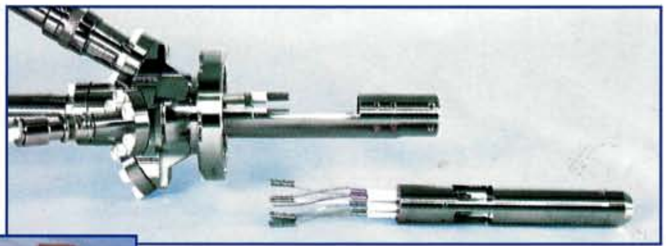







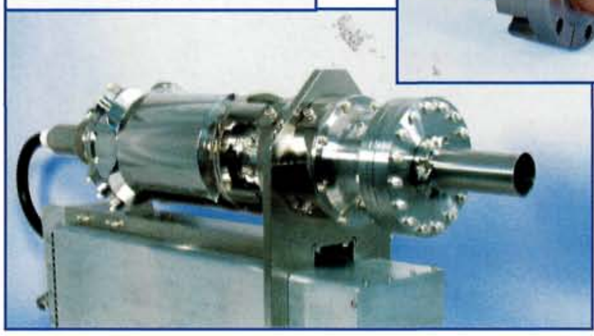


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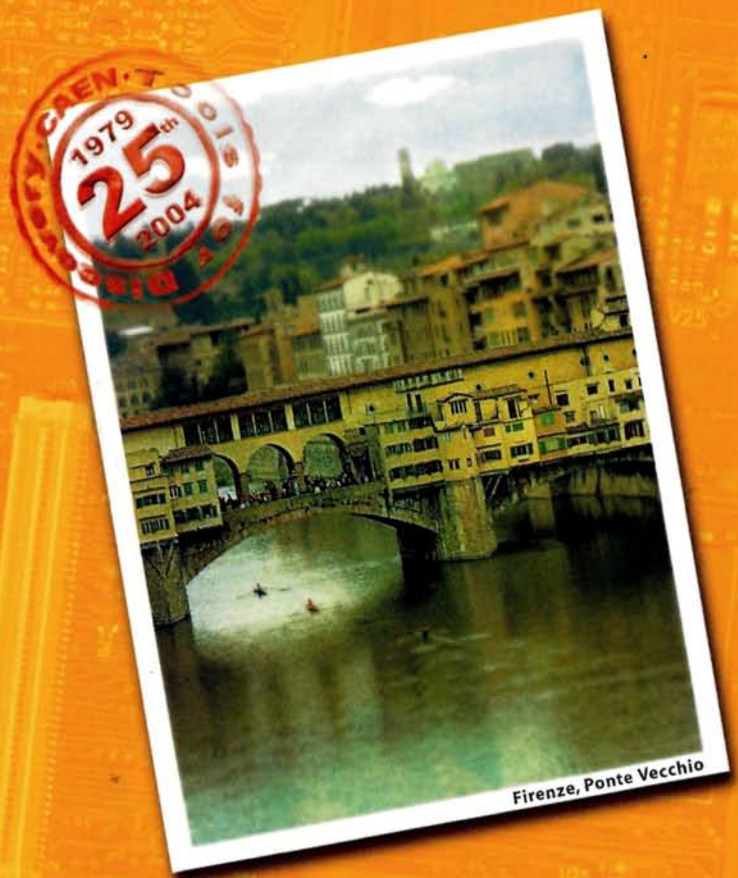

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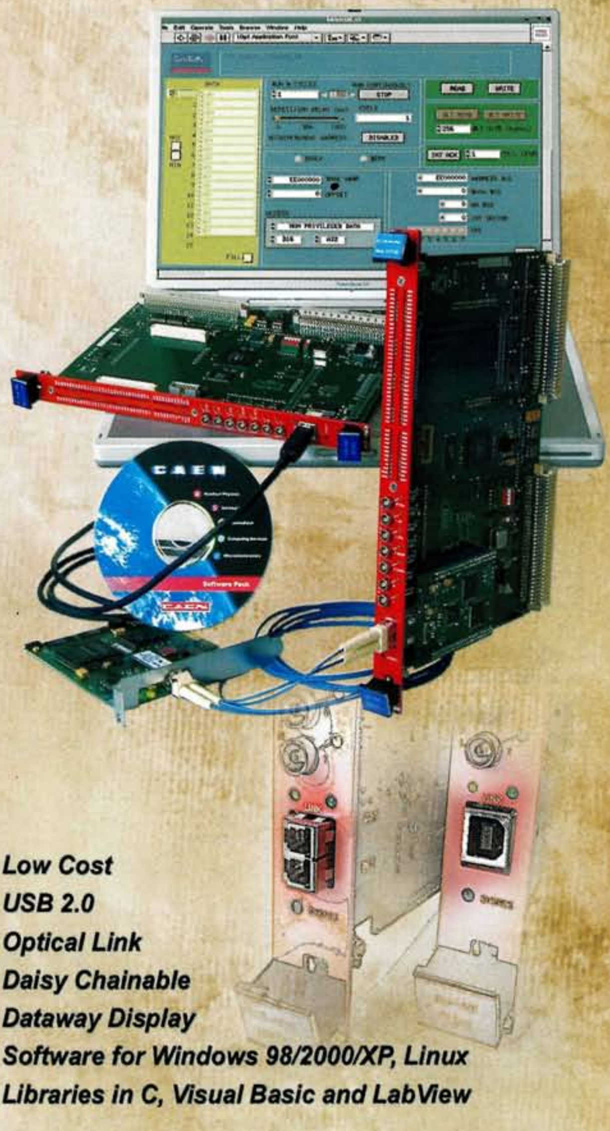

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