

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 44 NUMBER 1 JANUARY/FEBRUARY 2004



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MUON g-2

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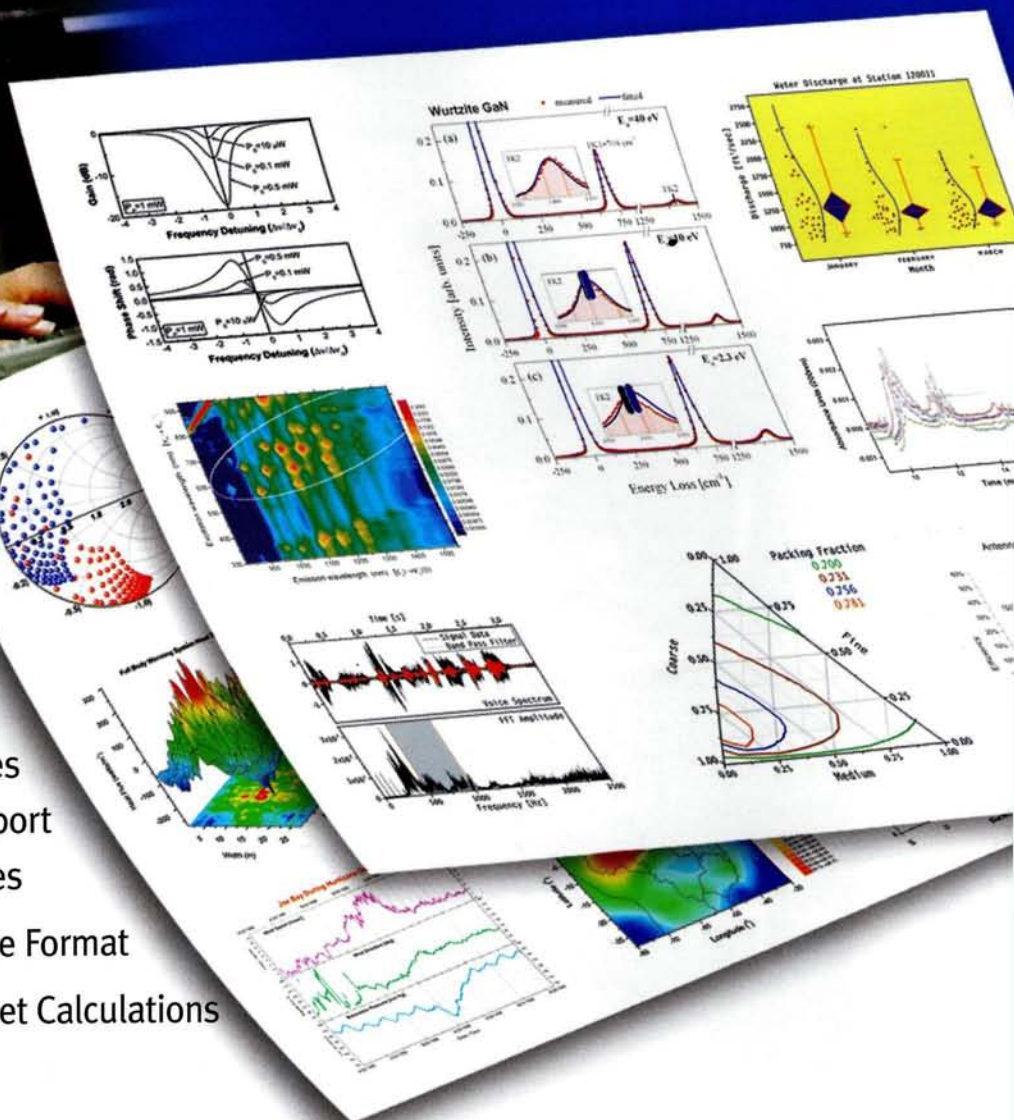
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Produced for CERN by Institute of Physics Publishing Ltd
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General distribution Jacques Dallemagne, CERN, 1211 Geneva 23, Switzerland. E-mail: courier-adressage@cern.ch
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UK Mark Swaisland, CLRC, Daresbury Laboratory, Keckwick Lane, Daresbury, Warrington WA4 4AD. E-mail: m.swaisland@dl.ac.uk
US/Canada Published by *Cern Courier*, 6N246 Willow Drive, St Charles, IL 60175. Periodical postage paid in St Charles, IL. Fax: 630 377 1569. E-mail: vosses@aol.com. Postmaster: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174

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

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

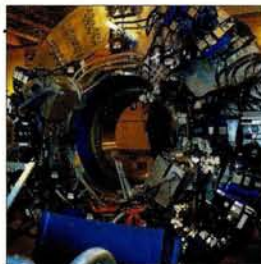
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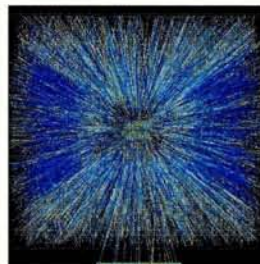


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Cover: Industrially produced cold masses – the heart of the superconducting dipole magnets for the LHC – are now arriving frequently at CERN, as Lucio Rossi describes on p30. This view is along one end of a line of cold masses awaiting installation into cryostats before testing at CERN.



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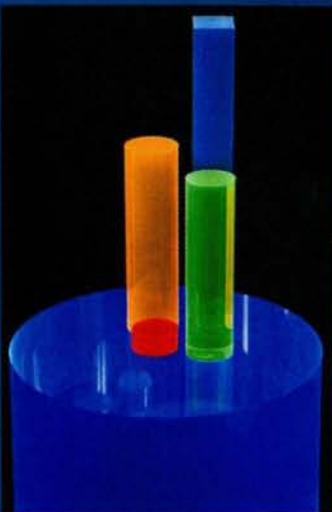
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CERN

CERN Council rings the changes



CERN's new directorate: Robert Aymar, director-general and chief executive officer (centre), Jos Engelen, chief scientific officer (left) and André Naudi, chief financial officer (right). The trio will head up CERN's new structure, which Aymar believes will build on existing strengths.

The CERN Council has formally approved the new structure for CERN, which was presented by the incoming director-general, Robert Aymar, at the Council's meeting on 19 December 2003. The laboratory's directorate will be composed of Aymar as chief executive officer, Jos Engelen as chief scientific officer and André Naudi as chief financial officer. CERN's previous structure of 15 divisions will also be regrouped into a smaller number of departments. Aymar believes that the new structure, which will be implemented from 1 January 2004 for five years, "is well adapted to CERN's current objectives. It ensures continuity and builds on existing strengths."

Aymar comes to CERN from the ITER project, of which he was appointed director in July 1994, before becoming ITER's international team leader in July 2001. He is familiar with the challenges presented by the Large Hadron Collider (LHC) – CERN's most challenging project to date – as he chaired the international scientific committee that assessed and recommended the project for approval in 1996. He also chaired the External Review Committee that was set

Fifty years of CERN

On 29 September 1954 representatives of the 12 founding member states of CERN ratified the organization's convention, paving the way for the establishment of the world's leading particle-physics laboratory.

Many events – both at CERN and in the member states – are planned to



mark the anniversary during 2004. For its part, *CERN Courier* is publishing a number of articles related

to CERN's activities over the past 50 years, starting this month with the story of the Proton Synchrotron (p15). A page of material from the *CERN Courier* archives will also feature each month.

For more information about CERN's 50th anniversary year, see www.cern.ch/CERN50.

up by Council in December 2001 to review the CERN programme. In the new directorate he is joined by Engelen, formerly director of the Dutch National Institute for Nuclear Physics and High Energy Physics, NIKHEF, and Naudi, who was previously CERN's director of finances.

Council was also presented with a review of the year's activities by the outgoing director-general Luciano Maiani, who began with a comprehensive review of the

LHC project. The experiments, ATLAS, CMS, ALICE and LHCb, are all on schedule to be ready for the start up of the LHC in 2007. Maiani pointed out that although challenges continue to be encountered, as is inevitable with such an ambitious scientific undertaking, the experimental collaborations are becoming adept at overcoming them. "Old concerns have been overcome, new ones have appeared," Maiani concluded, "but there are no show-stoppers" ▽

CERN

▷ on the horizon.”

Turning to LHC computing, Maiani congratulated the international team that successfully launched phase 1 of the LHC Computing Grid (LCG-1) in September. The LCG team will be the first concrete example of an operational e-science Grid and a test bed for the Enabling Grids for e-science in Europe (EGEE) initiative, which is funded by the European Union and was launched in 2003.

The LHC machine itself passed a number of important milestones in 2003. The first octant of dipole magnets was completed, the first transfer-line magnet was installed on 17 December, and the first magnets for the LHC itself should be installed in the spring of 2004 (see p30). “It has been a good year for the LHC project,” summed up Maiani. Overall, the project’s cost is stable and its schedule is unchanged, foreseeing first beam in April 2007 with the first collisions following in June.

In reviewing the rest of the year’s activities, Maiani reminded Council that the LHC project now accounts for more than 80% of the laboratory’s budget. Nevertheless, he described a full programme of fixed-target experiments, the highlight of which was the observation by the NA49 experiment of a new exotic particle, possibly a “pentaquark” (*CERN Courier* December 2003 p5).

In bidding farewell to the outgoing director-general at the end of his mandate, delegations from several member and observer states congratulated Maiani on steering CERN through a difficult period. He had, said one delegation, shown remarkable calm in a storm, and the laboratory’s staff had demonstrated the true strength and cohesion of the organization.

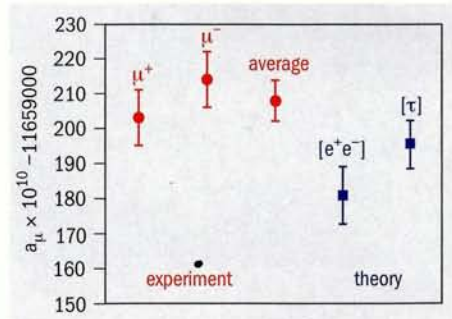
The new president of Council for 2004 was also elected at the meeting. Enzo Iarocci, who is currently president of the Italian National Institute for Research in Nuclear and Subnuclear Physics takes over from Maurice Bourquin of the University of Geneva. Best known for his development, in the late 1970s, of a new type of particle detector – the streamer tube – Iarocci was director of the Frascati Laboratories near Rome from 1990 to 1996, where he played an important role in the construction of the DAPHNE electron-positron storage ring.

BROOKHAVEN

New $g-2$ measurement deviates further from Standard Model

On 8 January the muon ($g-2$) collaboration, E821, which has been working for the past 15 years at the Brookhaven Alternating Gradient Synchrotron to measure the anomalous magnetic moment of the muon, released their final result, their first for the negative muon. The new result, which has been submitted to *Physical Review Letters*, has a relative precision of 0.7 parts per million (ppm), and as expected from CPT symmetry agrees well with the collaboration’s earlier 0.7 ppm measurement for the positive muon (Bennett *et al.* 2004). The combined precision is 0.5 ppm, a factor of 14 more precise than the famous experiments done at CERN in the 1970s, which reached 7.3 ppm. There has been considerable interest in these measurements because of the potential sensitivity to new physics such as supersymmetry, which would show up as a difference between the Standard Model value and the experimental one.

The E821 experiment ran at Brookhaven between 1997 and 2001, and was conducted by a collaboration of scientists not only from the US but also from Germany, Japan, the Netherlands and Russia. It was led by co-spokespersons Lee Roberts of Boston University and the late Vernon Hughes of Yale University (*CERN Courier* July/August 2003 p38). The collaboration’s first precise measurement, which was reported in 2001, differed from the Standard Model value by 2.6 standard deviations (Brown *et al.* 2001). The Standard Model theory for $g-2$ is composed of contributions from the weak, the electromagnetic and the strong forces. While the contributions from the weak and electromagnetic forces can be calculated from first principles, the contribution from the strong force cannot, and must be determined using experimental data. The direct determination uses data obtained by colliding electrons and anti-electrons, and measuring the production of hadrons in the collision. The indirect method uses data from the decay of tau leptons into hadrons, along with the conserved vector-current hypothesis plus the



The new measurement by E821 of $g-2$ for the negative muon, together with the previous measurement for the positive muon, their average, and values calculated from theory.

appropriate isospin corrections. At present the two methods do not agree very well, and in light of this disagreement some physicists use only the direct method to determine the theoretical value.

After the first announcement was made in 2001, many theoretical and experimental physicists took a closer look at the predicted theoretical value for $g-2$. In October 2001 Marc Knecht and Andreas Nyffeler from the University of Marseille found a sign mistake in a piece of the hadronic contribution, which moved theory closer to experiment (Knecht and Nyffeler 2002). Since then, progress has been made on both the experimental and theoretical fronts. The new value for the negative muon differs from the latest direct theoretical value by 2.8 standard deviations, the combined value differs by 2.7 standard deviations (Davier *et al.* 2003), and the difference from the indirect determination is 1.4 standard deviations.

Further reading

- G W Bennett *et al.* 2004 www.arxiv.org/hep-ex/0401008.
- H N Brown *et al.* 2001 *Phys. Rev. Lett.* **86** 2227.
- M Davier, S Eidelman, A Höcker and Z Zhang 2003 *Eur. Phys. J. C* **31** 503.
- M Knecht and A Nyffeler 2002 *Phys. Rev.* **D65** 073034.

DESY

Superconducting cavities exceed 35 MV/m

Development work for the TESLA linear collider has recently made substantial progress. After a surface treatment called electrolytic polishing, four superconducting nine-cell niobium cavities reached accelerating gradients of more than 35 MV/m. This is the performance required for an upgrade of TESLA to 800 GeV (*CERN Courier* November 2003 p22).

TESLA is the only linear collider project based on superconducting technology for particle acceleration. The first stage, with a centre-of-mass energy of 500 GeV, will require an accelerating field of 23.4 MV/m in the nine-cell 1.3 GHz superconducting niobium cavities, which are operated at a temperature of 2 K and a quality factor, Q_0 , of 10^{10} . This performance has been reliably achieved at the TESLA Test Facility (TTF). In the most recent series of 24 industrially produced TTF cavities, the average gradient was 25 ± 2.6 MV/m at $Q_0 = 10^{10}$.

In the TTF cavities a 100–200 μm thick “damage layer” is removed from the inner surface using a chemical etching process called buffered chemical polishing (BCP). The cavities are then subjected to a 1400 °C heat treatment that doubles the thermal conductivity of the niobium at 2 K and increases the gradient by some 5 MV/m. However, after many years of intensive R&D there is now compelling evidence that the BCP process limits the attainable field in multi-cell niobium cavities to about 30 MV/m. This is significantly below the physical limit of about 45 MV/m, which is given by the condition that the radiofrequency (RF) magnetic field must stay below the critical field of the superconductor. For niobium, the maximum tolerable RF field appears to be close to the thermodynamic critical field (190 mT at 2 K).

The upgrade of TESLA to 800 GeV requires an accelerating field of 35 MV/m, which appears inaccessible with the standard cavity preparation technique by BCP. In 1997, however, scientists from KEK reported gradients of up to 40 MV/m in single-cell cavities that had been prepared by electrolytic polishing (EP) of the inner surface. The superiority of electrolytic polishing was then confirmed by an R&D programme on single-cell niobium cavities that was carried out in a collaboration between CERN, DESY and Saclay. These

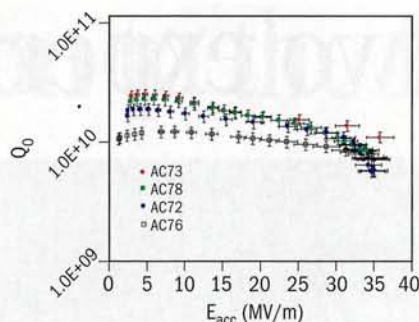


Fig. 1. Excitation curves of the four best nine-cell cavities after electrolytic polishing at Nomura Plating, Japan. The quality factor Q_0 is shown as a function of the accelerating field. The tests were performed at 2 K.

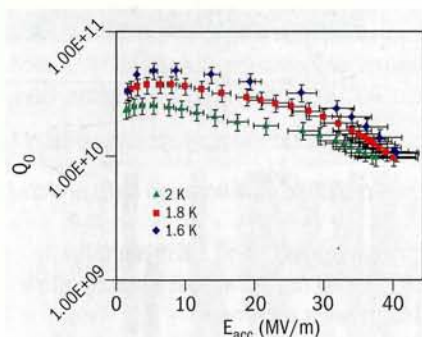


Fig. 2. Test of an initially field-emission loaded cavity after a second electrolytic polishing in the EP facility at DESY. Electropolishing of 40 μm removed the strong field emitter. An excellent result of 39 MV/m at 2 K and 40 MV/m below 1.8 K is achieved. Note that this cavity has not been subjected to heat treatment at 1400 °C, which is an indispensable prerequisite for achieving gradients above 25 MV/m in BCP-treated multi-cell cavities.

successes motivated a joint KEK–DESY programme on the electrolytic polishing of nine-cell resonators. Meanwhile, nine TTF cavities have been electrolytically polished at the Japanese company Nomura Plating and tested at DESY.

In the low-power test in a vertical superfluid helium cryostat, two of these cavities showed strong field emission at 15–17 MV/m and were therefore taken out for a second electrolytic polishing at DESY. The excitation curves of the four best cavities are shown in figure 1. In November 2003 one of the field-emission loaded

cavities was electrolytically polished for a second time in DESY’s new EP facility. The test results of this cavity, shown in figure 2, are excellent: accelerating fields of up to 40 MV/m were reached, a record for multi-cell niobium cavities.

So far, two of the electrolytically polished cavities have been welded into a liquid-helium tank and equipped with a high-power RF coupler, and tests with high RF power have been carried out in a horizontal cryostat at DESY. Both cavities reached the same high gradient as in the low-power test. One cavity was operated for 1100 hours at 35 MV/m and for 57 hours at 36 MV/m without any degradation. These results are clear evidence that the TESLA-800 gradient of 35 MV/m is indeed within reach.

A comprehensive understanding of why EP is so superior to BCP is still lacking, but a few explanations exist. A chemically etched niobium surface has a roughness in the order of micrometres, while an electrolytically polished surface is an order of magnitude smoother. The sharp ridges at the grain boundaries of an etched surface may lead to local enhancements of the RF magnetic field and cause a premature breakdown of superconductivity at these localized spots. A numerical model based on this idea, developed by Jens Knobloch and colleagues at Cornell, can account for the reduction of the quality factor Q_0 at high field. Magnetic field enhancements will be much smaller on the smooth electrolytically polished surface.

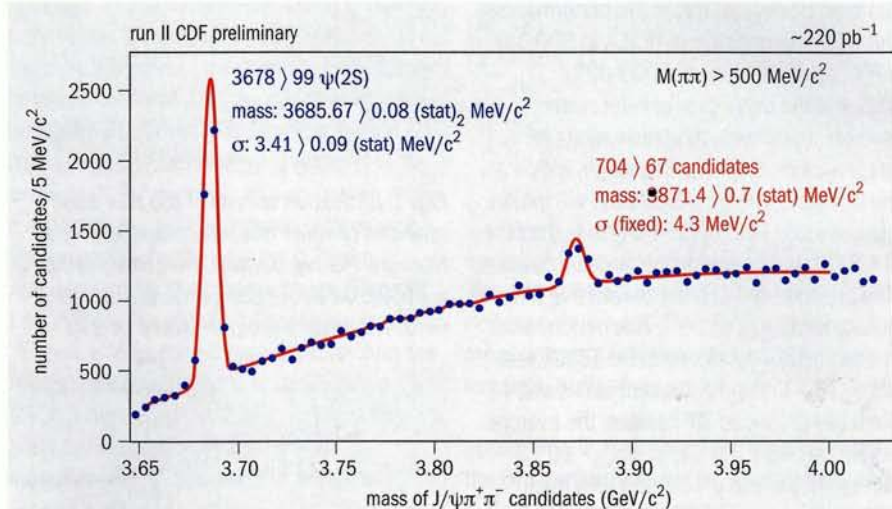
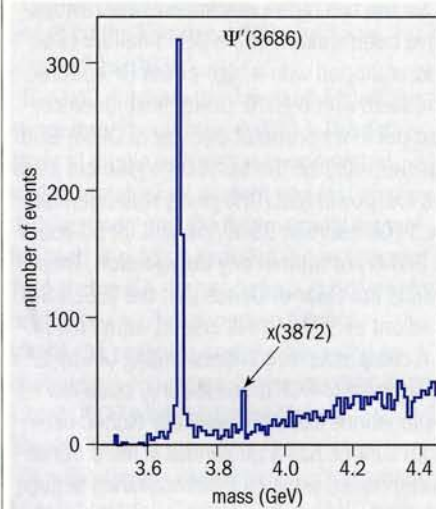
Another advantage of a mirror-like surface is that a so-called Bean–Livingston surface barrier may exist, delaying the penetration of magnetic flux into the niobium, even if the lower critical field B_{c1} (≈ 160 mT for niobium at 2 K) is exceeded. An EP-treated superconducting cavity is likely to remain in the Meissner phase up to an RF magnetic field exceeding B_{c1} by a significant amount, whereas a BCP-treated cavity will allow flux penetration just above B_{c1} , and then suffer from enhanced power dissipation caused by magnetic fluxoids entering and leaving the material.

Further reading

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L Lilje *et al.* 2004 Achievement of 35 MV/m in the Superconducting Nine-Cell Cavities for TESLA NIM A (in press).

NEW PARTICLES

X marks the spot: a new particle appears in two experiments



Plots showing the signals for the X(3872) in data from the Belle collaboration (left) and the Collider Detector at Fermilab (right).

A new and unusual particle – the X(3872) – has been discovered by the Belle collaboration at the High Energy Accelerator Research Organization, KEK, in Tsukuba, Japan, and confirmed by an entirely different experiment, the Collider Detector at Fermilab (CDF), in the US.

Belle operates at KEK's electron–positron collider, KEKB, which is designed to produce large numbers of B mesons at centre-of-mass energies around 10.58 GeV. While investigating the various ways that the B can decay, the Belle team found a small peak near 3.872 GeV in the mass plot for combinations of a J/Ψ with two π mesons – a little higher in energy than the large spike produced by the well known $\Psi'(3686)$, which can decay to the same final state (Choi *et al.* 2003). This indicated the production of a new particle, which has been called the X(3872). Evidently the B

can decay into an X and a K meson. The X(3872) then decays almost instantly into a J/Ψ and two π mesons.

Responding to these results, the CDF team quickly found the X(3872) in the rather different environment of 2 TeV proton–antiproton collisions at Fermilab's Tevatron (Acosta *et al.* 2003). Their observation suggests that the X is produced not only in the weak decays of B mesons but also through the strong interaction, which dominates proton–antiproton interactions. The two observations are also nicely complementary. While Belle has found about 60 X events with little background, CDF has seen about 700 X events with a background of about 6000 events.

As its name implies, the X(3872) particle does not fit easily into any known particle scheme. Belle found the particle while looking for missing states of charmonium (bound

states of a charm quark and antiquark), but the mass and decay properties of the X(3872) do not match theoretical expectations. As a result the X has attracted a considerable amount of attention from the world's physics community, and theoretical physicists are considering a number of alternative explanations. These include the possibility that the X(3872) is a new type of exotic meson made from two quarks and two antiquarks – a multiquark “molecular state” of a D^0 meson bound to an anti- D^{*0} – or a hybrid meson made from a charm quark and antiquark and a gluon.

Further reading

D Acosta *et al.* 2003 www.arxiv.org/hep-ex/0312021
 S-K Choi *et al.* 2003 *Phys. Rev. Lett.* **91** 262001.

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TRIUMF

Canada completes its major contribution to the LHC project

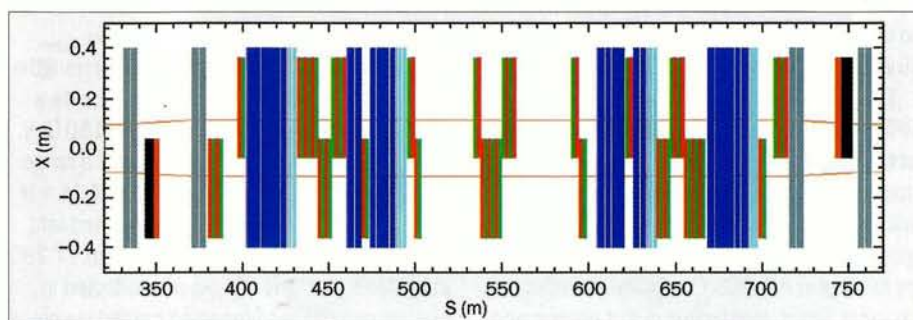
The largest piece of Canada's \$40.5 million (€31.5 million) contribution to the Large Hadron Collider (LHC) was completed in 2003 with the delivery of the last of 52 twin-aperture quadrupole magnets to CERN. These warm magnets (48 plus four spares) will be installed in the two beam-cleaning insertions of the LHC, where heating by lost beam prohibits the use of superconducting coils. The magnets, based on a CERN design, were made by ALSTOM Canada in Tracy, Quebec, with considerable input and design assistance from engineers at TRIUMF and CERN. Their small apertures (46 mm) and high gradient (35 T/m) meant that the 3.4 m long modules had to be assembled with unusually high tolerances to achieve the necessary field quality.

A prototype magnet was completed and shipped to CERN in May 1998 for mechanical and magnetic field measurements. As these measurements showed that the desired field quality had not been achieved, improvements were made in the lamination design, in the punching precision and in welding the stacks of laminations without distortion. Stronger stacking tables and a separate half-magnet assembly table were also constructed. These changes led to the first series magnet, which was completed in March 2001 and fully met the specifications. ALSTOM then proceeded to meet and eventually surpass their planned production rate of two magnets per month. Mechanical measurements were carried out at the factory to qualify the magnets prior to shipping, and detailed magnetic field measurements were made at CERN.

Autumn 2003 also saw the finalization of another feature of the cleaning insertions to which Canada has made a significant contribution – the arrangement of the 48 quadrupole modules and 40 collimators. In collaboration with CERN, TRIUMF has been responsible for developing a computer code to determine the optimum positions for the horizontal, vertical and skew collimator jaws,



The ALSTOM Canada assembly team beside the last of the 52 twin-aperture quadrupole magnets that will be delivered to CERN. (Photo: Yvon Langevin, ALSTOM Canada.)



The layout of the IR7 cleaning insertion (dipoles = grey, quadrupoles = dark blue, collimators: primary = black, secondary phase 1 = red, secondary phase 2 = green). (Image courtesy of R Assmann, O Bruening and D Kaltchev.)

and for certain aspects of the beam optics, including matching to the arcs. An unusual feature is that as each of the focusing quadrupoles is composed of six of the magnet modules, the two beams of the LHC can be tuned independently, by wiring some modules with one beam aperture as F (focus) and the other as D (defocus), and other modules with both apertures acting in the same sense.

The decisions in 2002 to switch from copper to (much longer) graphite collimators to avoid the possibility of meltdown in an accident, and to install only half-length collimators at first, provided last-minute challenges with regard to space, impedance and collimation. Nevertheless, for the standard primary and

secondary collimator apertures, which are six and seven times the rms beam width, respectively, it has been possible to find solutions that keep the collimation inefficiency below the target levels of 0.05 at injection and 0.001 at 7 TeV, with an acceptably low impedance, during phase 1, the first years of LHC physics. Moreover, sufficient space remains for the phase 2 collimators, which will support LHC operation with nominal parameters.

The remaining contributions to the LHC from TRIUMF – the major equipment for the injection kickers, the development of digital acquisition boards for the beam position monitors and beam-beam interaction studies – are also entering their final stages.

HEAVY IONS

STAR prepares to shine a light on spin

A major milestone has been reached for the STAR detector at Brookhaven's Relativistic Heavy Ion Collider (RHIC) with the hoisting of the upper half of the endcap electromagnetic calorimeter (EMC) into place on the "west" STAR magnet poletip. Scientists and engineers looked on with anticipation as this mammoth detector, weighing around 12.5 tonnes, was gently lowered into place, completing the mechanical installation of a key upgrade for the STAR collaboration's spin-physics programme.

Together with the barrel electromagnetic calorimeter, the EMC provides STAR with the capability to probe deeply into the proton's spin structure. Specifically, the EMC will provide forward-angle detection, identification and trigger capability for photons, electrons, positrons and electromagnetically decaying mesons. It is a key element of STAR's plan to use polarized proton beams at centre-of-mass energies up to 500 GeV to study the gluon contribution to the proton spin and flavour-dependence (\bar{u} vs \bar{d}) of the sea-quark polarization.

The main thrust of the spin programme at RHIC is to add significantly to our knowledge of the spin structure of the nucleon. With the addition of electromagnetic calorimetry, STAR will provide important new information on the gluon contribution to the proton spin ($\Delta G(x)$) by looking at the QCD Compton scattering channel, which results in a direct photon and jet. This channel is particularly "clean" in that the only other QCD subprocess that contributes is quark-antiquark annihilation, a relatively small consideration at RHIC energies. The large solid angle of STAR is ideally suited for detecting the jet and photon in coincidence, providing unique kinematic information allowing the extraction of ΔG as a function of the momentum fraction x . The EMC is crucial to reaching the low x portion of $\Delta G(x)$ and also provides essential solid angle for the detection of high-energy electrons from parity-violating W decays, which will allow flavour-separated measurements of the polarization of the up and down antiquark sea.

A traditional lead/plastic scintillator sampling calorimeter, the EMC is about 5 m in diameter and weighs 25 tonnes overall. It consists of 23 layers of lead (laminated with thin stainless steel for strength) between 24 layers



Fig. 1. The detector mounted on the west STAR magnet poletip, with the edges of the layers of lead and scintillator exposed at the upper right. Steve Vigdor (left) is connecting the optical fibre bundles (encased in a black sheath) used to carry the scintillator light to the rear of the poletip for read-out by PMTs. Jim Sowinski (right) is installing scintillator megatiles between lead radiator sheets.

of scintillator, resulting in 21 radiation lengths of material at normal incidence to provide a linear response for energies from 1–150 GeV.

The active area of the EMC covers a range in pseudorapidity of $1.09 < \eta < 2$ ($37.2^\circ > \theta > 15.2^\circ$). The acceptance is segmented into 720 projective towers assembled from 17 280 scintillator tiles. The signals are collected in wavelength-shifting fibres and carried via clear optical fibres (the black cables in the upper left of figure 1) to 720 photomultiplier tubes (PMTs) on the back of the magnet poletip. In addition, the detector provides fast trigger capabilities and pre- and post-shower signals valuable for electron/hadron discrimination.

Photon/ π^0 discrimination in the range 10–40 GeV is critical for measuring $\Delta G(x)$. Thus a shower maximum detector, consisting of two planes of triangular scintillator strips (1 cm wide) with coaxial wavelength shifting fibres, is included. The ~ 9000 shower maximum detector and pre- and post-shower signals are read out with 16-anode PMTs, digitized every 110 ns and stored in a digital delay line. The innovative, miniaturized read-out electronics, incorporating a 12-bit ADC for each channel, mounts directly behind a thin (9 mm) Cockcroft-Walton base on each PMT. Thus 12 PMTs, bases and read-out electronics for 192

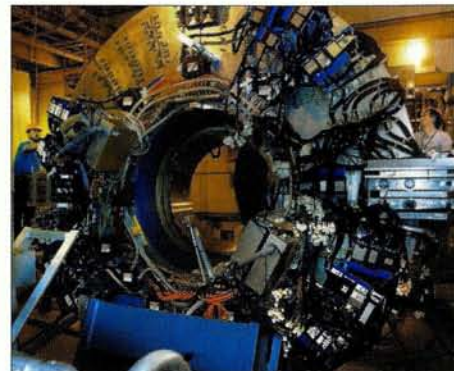


Fig. 2. The back of the STAR magnet poletip is in the process of being completely covered by PMT boxes and read-out electronics for the endcap electromagnetic calorimeter. The routing of the (black sheathed) clear fibre bundles is visible on the right. The PMT boxes (blue) will be placed over these, as has already been done in other regions of the poletip.

channels all reside in a compact magnetically shielded box with a single data fibre output.

The lower half of the mechanical structure and one-third of the tower energy read-out was installed and instrumented in autumn 2002. This was commissioned during the RHIC III run and provided useful tower information. The RHIC IV run began in November 2003 and the full EMC is ready to provide energy signals and triggering. A significant block of the shower maximum and pre/post-shower detectors is also instrumented. These EMC subsystems, as well as the barrel electromagnetic calorimeter, will be completed in the next RHIC shutdown.

The construction of the EMC, funded primarily by the National Science Foundation, has been underway for about three years, led by a group from Indiana University with collaborators from Argonne National Laboratory, Brookhaven National Laboratory, Creighton University, the Joint Institute for Nuclear Research, Kent State University, Michigan State University, Texas A&M University and Valparaiso University.

Further reading

C Allgower *et al.* 2003 *Nucl. Ins. Meth. A* **499** 740.
M Beddo *et al.* 2003 *Nucl. Ins. Meth. A* **499** 725.

James Sowinski, Indiana University.

SLAC

PEP II gets ready for a data bonanza

Three months into run 4 and the PEP II accelerator, the electron-positron collider at SLAC, is performing beautifully. Recent modifications of PEP II's hardware and operations have allowed it to maintain more intense beams, and it looks to be on course to reach the ambitious goal for run 4: 100 inverse femtobarns. If this goal is reached, the data sample from the first three runs of the BaBar detector will be almost doubled by July 2004. The detector recorded some 125 million $B\bar{B}$ pairs between October 1999 and July 2003, but the physicists are eager for more.

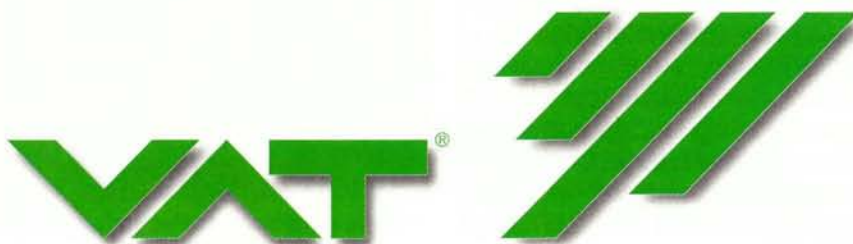
New equipment is one key to the improvements. An eighth radiofrequency (RF) cavity has been added to the accelerator, allowing more particles to be stored in the ring. Another improvement was to solve the problem of unwanted electrons in the positron ring, which are kicked loose from the beam pipe by synchrotron radiation. Their effect is to diffuse the tightly packed positron beam, thus lowering the chance of collisions with the electron beam in the detector. So technicians spent a number of gruelling weeks in a hot tunnel, winding narrow wire tape around every accessible part of the beam pipe in the positron ring. The windings created a solenoid magnet that traps the slower electrons and keeps them out of the positrons' way. Maintenance has been another important ingredient. Over the summer, a vacuum leak in the interaction region was quickly repaired by the Mechanical Fabrication Department, and the Accelerator Maintenance RF group overhauled the entire RF system.

New ways of operating the accelerator have also started to pay off. Previously, PEP II operated with two empty buckets following each filled one. In autumn 2003 the pattern was changed: strings of buckets in which every other one is filled, alternate with shorter strings of empty buckets. Each change to the spacing between bunches affects the beams' behaviour and the new pattern has opened up empty slots to which more particles can eventually be added.

A new approach to keeping the rings full was adopted at the beginning of December. As the beams collide their intensity gradually declines, and previously it was necessary to "top off" the

beams by injecting new particles every 50 minutes or so. During the 5 or 10 minutes required for injection, the detector had to be shut off to avoid the risk of radiation damage. Now a new "trickle injection" scheme in the positron ring adds small pulses of particles as

soon as the buckets begin to be depleted, maintaining the beam at full brightness around the clock. This approach has a double data payoff: the collision rate does not fall off and, as the detector is desensitized for much less time, it can record up to 20% more events.



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INTERNATIONAL COLLABORATION

Components from Iran en route for CMS

The first of a pair of steel tables and shielding superstructures, which will house the two 110 tonne forward hadron calorimeters for the CMS experiment at the Large Hadron Collider (LHC), are due at CERN in January 2004. These large, heavy mechanical pieces (175 tonnes each) are under construction at the Iranian firm HEPCO, located in Arak, an industrial town 200 km west of Tehran. The second set will be completed and shipped to CERN in spring. In addition to these tables and shielding structures, a couple of lead doors and lifting tools are also being manufactured in Iran; they comprise the Iranian in-kind contribution to the construction of the CMS detector.

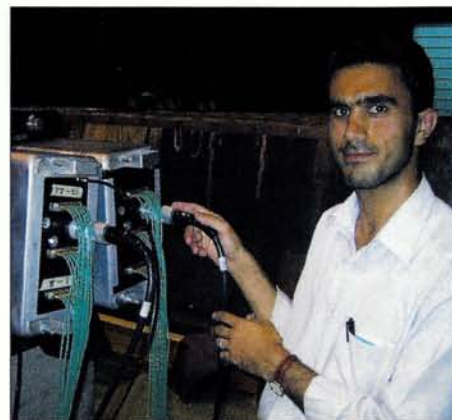
In 2001 a Memorandum of Understanding for co-operation between CERN and Iran was signed, and in the same year the Institute for Studies in Theoretical Physics and Mathematics (IPM-Tehran) joined the CMS collaboration. This was the first step towards developing a high-energy physics programme at the institute, which was traditionally strong



A test assembly of the table and shielding cylinder for the CMS at the Iranian manufacturers HEPCO. (Photo: T de Visser.)

in theoretical physics but has recently begun initiating experimental programmes in nanotechnology, accelerator and particle physics.

There are currently two students from IPM at CERN working on their PhD studies.



Iranian student Saeid Paktina checking a detector in the CMS assembly hall at CERN. (Photo: M Baarmand.)

They are gaining hands-on experience with detector design and construction, and are conducting LHC physics simulations for the CMS. Another Iranian student will join the team at the end of February.

New Zealand signs up to co-operate with CERN

On 4 December 2003 a Memorandum of Understanding (MoU) between CERN and the government of New Zealand was signed in the presence of Peter Hamilton, New Zealand's ambassador to Switzerland. This MoU concerns the further development of scientific and technical co-operation in high-energy particle physics between Ernest Rutherford's birthplace and CERN, which now hosts one of the world's most ambitious scientific endeavours, the Large Hadron Collider (LHC).

In anticipation of the MoU, two New Zealand universities (the University of Auckland and the University of Canterbury in Christchurch) have already joined the CMS collaboration to work on pixel detectors, where they can benefit from the expertise of the pixel group at the Paul Scherrer Institute. These detectors are not only valuable in high-energy particle physics, but also serve medical applications.

As a next step, an international workshop on semiconductor instrumentation for particle



New Zealand's ambassador to Switzerland Peter Hamilton (left) and CERN's director-general Luciano Maiani sign the Memorandum of Understanding on 4 December 2003.

physics, medical physics and astrophysics will be hosted by the Royal Society of New Zealand in Wellington. The University of Melbourne in Australia, which is involved in work on silicon detectors as a member of the ATLAS collaboration, will provide additional participation from the Australasian continent.

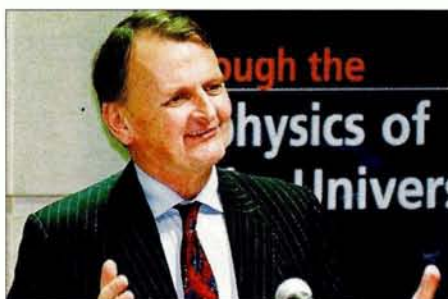
It is expected that this workshop will create synergies between the high-energy particle, medical and astrophysics communities of New Zealand, Australia and the rest of the world. For more information about the workshop, see <http://hep-project-anz-workshop.web.cern.ch>.

RESEARCH POLICY

PPARC announces research agenda for the UK

The UK Particle Physics and Astronomy Research Council (PPARC) has outlined its latest research goals in its Strategic Plan for 2003–2008. Among its aims are to increase UK industrial competitiveness and gain leadership roles in the construction of the next generation of major particle-physics facilities.

Top of the agenda for particle physics is to fulfil the UK's commitment to the Large Hadron Collider (LHC) at CERN, and its contribution to the ALICE, ATLAS, CMS and LHCb experiments. Involvement with the construction of these detectors is essential to maintain PPARC's role in funding research that will improve scientists' understanding of the precise structure of matter, our universe and the forces that bind it together. In recognizing that the future of experimental particle physics lies in global accelerator facilities, PPARC also plans to build up the UK's capacity in accelerator R&D,



Ian Halliday, PPARC chief executive, presents the new strategic plan. (Photo: PPARC.)

enabling UK scientists to play a leading role in their design. As part of the process, PPARC intends to create centres of expertise in particle physics and invite UK universities to host them.

Following the experimental confirmation of neutrino masses and the subsequent need for a neutrino factory to study neutrino properties,

PPARC also intends to increase investment in neutrino R&D. The council hopes that such an effort will create sufficient expertise in the UK to host a neutrino factory facility. Existing UK infrastructure would allow a neutrino factory to be in place by the end of the next decade.

PPARC is also concerned with improving the computing infrastructure required to handle LHC data. In a bid to maintain the UK's competitive edge in high-performance computing, £16 million (€22 million) was announced in December to create a massive computing grid. Known as GridPP2, it will be equivalent to Japan's Earth simulator computer – the second largest in the world – and will eventually form part of the larger European Grid. GridPP2 will thus enhance the overall data-processing capability when the LHC comes online in 2007.

• The five-year strategic plan is available at www.pparc.ac.uk/Pbl/pubs.asp.

ICFA launches selection process

The International Committee for Future Accelerators (ICFA), chaired by director of SLAC Jonathan Dorfan, has announced the members of a 12-person International Technology Recommendation Panel (ITRP) for a future linear collider. The ITRP, with four members each from

Europe, North America and Asia, is charged with recommending which of two leading accelerating technologies will form the best choice for a future international linear collider.

In 2002 ICFA set up its International Linear Collider Steering Committee (ILCSC), chaired by Maury Tigner of Cornell, to guide the community through the R&D phase to construction of a linear collider. However, to commence an international design, the community must decide between two leading linac RF technolo-

gies based on conventional, room-temperature copper cavities or superconducting cavities.

At its meeting in Paris on 19 November, the ILCSC finalized the selection of the ITRP, its chair and charter. Barry Barish of Caltech is to be chair, and the ITRP is to hold its first meeting in January 2004.

• The charge to ITRP, the panel membership and the parameters for a linear collider are in "Recent ICFA Linear Collider Activities" at www.fnal.gov/directorate/icfa/icfa_home.html.

US defines roadmap for science facilities

The US Department of Energy's Office of Science has unveiled its 20 year science facility plan. This is in effect a roadmap for future scientific facilities to support the department's basic science and research missions. The plan prioritizes new, major scientific facilities as well as upgrades to current ones. The 28 facilities listed cover the range of science supported by the Office of Science, including high-energy physics, nuclear physics and advanced scientific computation.

The list begins with 12 facilities that are identified as near-term priorities. Priority one is

ITER, the international collaboration to build the first fusion experiment capable of producing a self-sustaining fusion reaction. Priority two is an UltraScale Scientific Computing Capability, to be located at multiple sites, which would increase the computing capability available to support open scientific research by a factor of 100.

Four facilities tied for priority three, including the Joint Dark Energy Mission, a space-based probe being considered in partnership with NASA; the Linac Coherent Light Source to provide laser-like radiation 10 billion times greater in power and brightness than any existing X-ray light source; and the Rare Isotope Accelerator that would be the world's most powerful research facility dedicated to producing and exploring new rare isotopes not found naturally

on Earth. Six others complete the near-term priorities. These include the 12 GeV upgrade for CEBAF at the Thomas Jefferson Laboratory and the BTeV experiment at Fermilab.

A linear collider operating in the TeV energy region heads the list of eight mid-term priorities. These also include a Double Beta Decay Underground Detector and an upgrade to provide a 10-fold increase in the luminosity of Brookhaven's RHIC II. The eight far-term priorities include a Super Neutrino Beam, 10 times more intense than those currently available, and eRHIC, a project to add an electron accelerator ring to the existing RHIC complex.

• A document describing all 28 facilities and the prioritization process, "Facilities for the Future of Science: A Twenty-Year Outlook", is available at www.sc.doe.gov.

THE INFORMATION SOCIETY

CERN hosts major policy conference

Scientists, policy makers and stakeholders from around the world came together at CERN on 8 and 9 December 2003, when the laboratory hosted The Role of Science in the Information Society (RSIS) conference. Organized by CERN in collaboration with UNESCO, the International Council for Scientific Unions and the Third World Academy of Science, the conference took place immediately prior to the World Summit on the Information Society (WSIS), held in Geneva on 10–12 December.

The conference was organized on the premise that science has a key role to play in broadening the information society (see p58). Basic science made the technologies that underlie the information society possible, and the needs of the scientific community have often driven new developments in information and communication technologies (ICTs), such as the Internet and the World Wide Web. As Ismail Serageldin, director-general of the Library of Alexandria, Egypt, told the conference: "Today, when we stand at the threshold of the new ICT revolution and can barely see the contours of the new organization of knowledge, we must be willing to re-invent ourselves and to think of radical change, not just incremental change."

During the first half-day of the conference, plenary speakers gave their perspectives on the past, present and future of science, ICTs, and society. The following morning, attendees divided into parallel sessions where they explored five areas in more depth: enabling technologies, economic development, health, environment and education. The plenaries then reconvened in the afternoon, when participants heard the results of the parallel sessions, a visionary panel and closing remarks.

Among the key plenary speakers were Princess Maha Chakri Sirindhorn of Thailand, who reminded the conference that there is no single formula for development; Tim Berners-Lee, director of the World Wide Web Consortium (W3C), who articulated the vision that led him to create the World Wide Web while working at CERN; Ismail Serageldin, who described in particular the "hole in the wall"



Princess Maha Chakri Sirindhorn of Thailand reminded participants that, "there is no single formula for development."



Santiago Borrero, secretary-general of the Pan-American Institute for Geography and History, warned that, "Technology itself does not ensure the successful use and application of digital data...Information technology, infrastructure and connectivity do not necessarily equate to information access and a real bridging of the digital divide."

project for bringing the Web to slum children; and Lidia Brito from Mozambique, who emphasized the importance of fair trade in knowledge. Koichiro Matsuura, the director-general of UNESCO, and Yoshio Utsumi, the secretary-general of the International Telecommunication Union, also addressed the conference.

Several general themes emerged and received clear support at RSIS:

- that fundamental scientific information be made freely available;
- that the software tools for the dissem-



United Nations secretary-general, Kofi Annan (left), and Tim Berners-Lee in discussion at the science stand organized by CERN as part of the World Summit on the Information Society at the Palexpo Centre in Geneva.

ination of this information be also made freely available;

- that networking infrastructure for distributing this information be established worldwide;
- that training of people and equipment to use this information be provided in the host nations;
- and that general education underpins all these goals and is an indispensable basis for the information society.

"This event has helped to develop a vision for how information and communication technologies can be applied for the greater benefit of all," said Luciano Maiani, director-general of CERN, in his summary of the conference. Immediately following RSIS, Maiani made a statement at WSIS on behalf of the participants. He was instructed by RSIS to urge the heads of state gathered at WSIS to endorse fully the guidelines that emerged from the RSIS discussions.

CERN also held a Science and the Information Society Forum at the "ICT for Development" platform in Geneva's Palexpo Centre, which was open to the public during the world summit. The forum served as a venue for scientific organizations to exhibit their ICT-related initiatives. Also on display was the first Web server and information about CERN and the RSIS conference. Using the server, United Nations secretary-general Kofi Annan and Tim Berners-Lee sent a message to 800 schools around the world.

We look back at some of the items in the first ever issue of *CERN Courier*

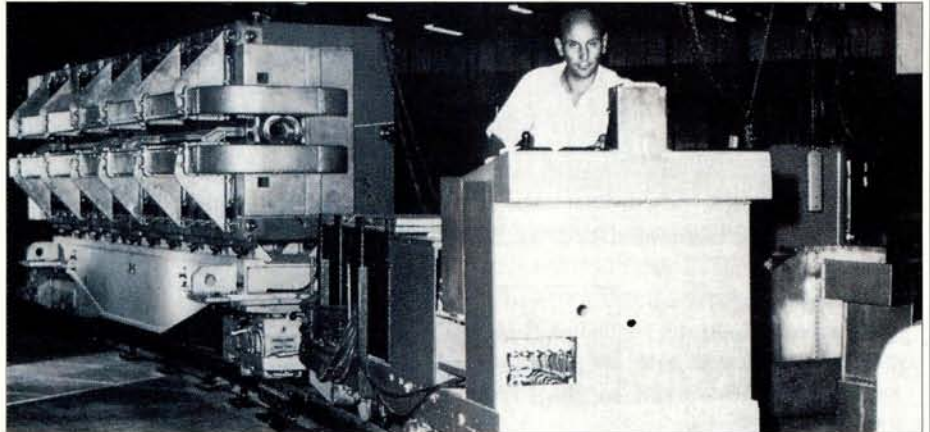
ALL 100 MAGNETS IN POSITION

Making the 'PS' ready for operation

Friday 10 July 1959 was a red-letter day for the Proton Synchrotron (PS) Division. It was on that day, at 3.10 p.m., that the electric locomotive used to bring the magnets to the ring slowly pulled its final load into the tunnel. Now the 100 magnets – each weighing 38 tonnes – that make up the electromagnet are in place, a major construction phase of the PS can be regarded as completed.

In the south experimental hall, the test bed used to measure the magnetic properties of the 100 magnets has been removed from its concrete support, while the railway used to carry the magnets to the accelerator has been dismantled. Some said that the PS had “burnt its boats”, however, that is not the case as there is a permanent track running inside the accelerator ring from the tunnel to the northern experimental hall. Nevertheless, the dismantling of these elements symbolizes the confidence within the PS Division after submitting each of the sub-assemblies to meticulous tests.

Could this be seen as marking the completion of the installation of the magnets? Not really, especially as far as the geodesics team in charge of the final positioning of the electromagnets was concerned. On average, two hours are needed to position each of the



The last magnet unit being towed towards the ring of the Proton Synchrotron.

100 magnets with a radial tolerance of one-tenth of a millimetre on a ring with a 200 m diameter. This provides an insight into the scale of the geodesics team's task. The fact is that once the magnets have briefly been powered up, new tests and adjustments will be necessary. Subsequently, the team will have to take advantage of two annual shut-downs to redo the measurements.

Regulars in the “ring” will not have failed to notice the presence of a sign stating “Tunnel blocked at the 46th magnet”. What was the

reason for this warning, punctuated by the incessant flashing of two red lamps? It is important to note that before the magnets are powered up for the first time on 27 July, there will be a final check of the connections and surfaces to ascertain that no tools or other foreign bodies that may be influenced by the magnetic field remain on the magnets or in the gaps. The ring has been blocked off to ensure that these checks can be carried out properly.

● This extract is translated from the article in French, see *Courier CERN August 1959 p4*.

OTHER PEOPLE'S ATOMS Stanford University stirs excitement

Stanford University in California is one of the leading players in the linear accelerator field. It operates a sizeable collection of these machines, some of which are used for medical purposes. Its 75 m long machine produces 700 MeV electrons and its energy is to be increased to 1050 MeV.

At the end of May this year, Stanford again made the headlines with a linear accelerator. Taking the floor at a scientific symposium in Manhattan, President Eisenhower stated that he would be recommending the US Congress to fund “a new linear electron accelerator...a machine measuring over three kilometres long, making it by far the largest ever built”.

If Stanford acquires such a machine, it will

be one of the world's most spectacular atom smashers. Two parallel tunnels, each nearly three kilometres long, would have to be excavated in the rock of a hill near Palo Alto. This natural protection would, of course, act as a barrier against any dangerous radiation likely to be produced. The tunnel with the smaller diameter would house the accelerator itself, while the larger tunnel would be used for services needed to maintain the machine.

The new Stanford accelerator would first produce 15 BeV (GeV) electrons, but there is talk of a possible subsequent energy increase to 40 BeV. It is estimated that machine construction will take six years and cost 100 million dollars. At the time of going to press, the only remaining hurdle to the project's approval is the decision to be taken following the debate by Congress in July.

● Translated from *Courier CERN August 1959 p7*.

EDITOR'S NOTE

While CERN began in 1954, the first edition of the *CERN Courier* did not appear until August 1959, with the subtitle “Monthly published for the CERN staff”.

The early editions were certainly more like an amalgamation of the current *Courier* and the weekly *Bulletin* (see <http://bulletin.cern.ch/>). Only with volume 2, in January 1962, did the *Courier* come to resemble closely its current form. But it is interesting to see that even the first edition carried news of other laboratories – and that the major story about the PS (only part of which appears here) is reflected in this month's article on the LHC (p30).

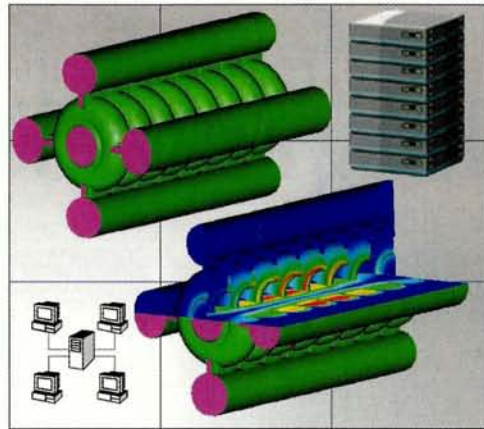
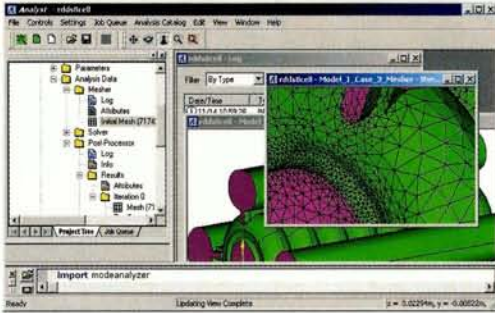
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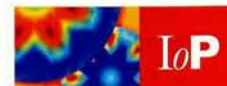
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Compiled by Steve Reucroft and John Swain

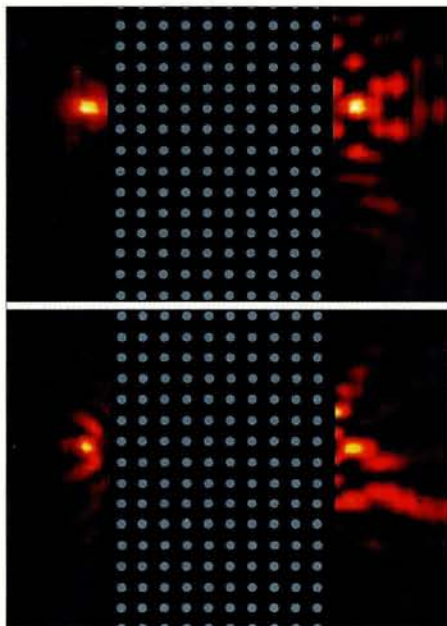
Photonic crystal makes flat lens

Lenses are usually thought of as being made of curved dielectrics, but must this always be the case? Rather surprisingly, the answer is "no", as Srinivas Sridhar and colleagues at Northeastern University in Boston, US, have demonstrated.

The key to creating the flat lens lies with the recent advent of materials – photonic crystals – that effectively have a negative index of refraction. A flat slab of such a substance can have an index of refraction that depends on the angle at which radiation hits it. The slab can then act as a lens, with the amazing property that there is no preferred axis and no restriction in aperture size. As the Northeastern researchers point out, the tricky part in creating the flat lens is in designing a photonic crystal with negative refraction over a wide range of angles – and low absorption.

The two pictures on the right show that they succeeded with a structure composed of cylindrical aluminium rods. In the upper picture an image of a point source of microwaves, at a frequency of 9.3 GHz, is created on the far side of the slab. In the lower picture the source has been moved up by 4 cm and the image has moved correspondingly. This illustrates that the flat lens does not have a single optical axis and limited aperture.

While this lens works only with microwaves – and in fact only for a narrow range of



A flat lens formed from an array of cylindrical aluminium rods creates an image (right) of a microwave source (left). In the lower picture the image has followed the 4 cm upward movement of the source.

frequencies, from 9.0–9.4 GHz – the principle could herald a revolution in optics.

Further reading

P V Parimi *et al.* 2003 *Nature* **426** 404.

Quintessence drives inconstant constant

The idea that the fine structure "constant" α might vary with time is an old one, but has been bolstered by observations of distant quasars that suggest α could have been dramatically smaller some 10 billion years ago. On the other hand, terrestrial measurements suggest only a very slow variation (if any!), which seems to be incompatible with the quasar work (*CERN Courier* March 2003 p15).

Now Luis Anchordoqui and Haim Goldberg of Northeastern University, US, have shown that these pictures can be reconciled by linking the variation in α not just to the passage of time, but also to the evolution of the dynamical scalar field known as "quintessence". This has been proposed to

explain the "dark energy" that appears to control the expansion of the universe (*CERN Courier* September 2003 p23). In particular, Anchordoqui and Goldberg have considered the model of Andreas Albrecht and Constantinos Skordis, in which the quintessence field has rapidly slowed in the recent past. They found that they obtained agreement with all the data on α . So it does indeed seem that while most of the things in the universe fly away from each other, protons and electrons – as if to defy the expansion of space – hold ever tighter to each other as α increases.

Further reading

L Anchordoqui and H Goldberg 2003 *Phys. Rev. D* **68** 083513.

New random way to immunize

Whether one worries about limited supplies of vaccines during the flu season, or about what might be needed in the event of a biological attack, it seems a good idea to think about how to optimize the distribution of such protection. Reuven Cohen of Bar-Ilan University in Israel and colleagues have made an amazingly simple suggestion: choose, at random, a sample of the population, ask them to name one acquaintance and then vaccinate those acquaintances.

The idea is that the people who are most likely to spread the disease, due to their large number of associates, have a high probability of being named. This overcomes the problem that those who have many acquaintances tend to be fewer in number and therefore unlikely to be chosen in a random trial. While this is clearly of medical interest, its application in protecting computers from viral attack by distributing suitable patches is also clear.

Further reading

R Cohen *et al.* 2003 *Phys. Rev. Lett.* **91** 247901.

Doppler reversed in radio waves

When does the frequency of a source increase, rather than decrease, as it moves away from you? One place is in Bristol, UK, in a laboratory at BAE Systems, where Nigel Seddon and Trevor Bearpark have demonstrated this remarkable effect with radio waves. The idea is to have waves in a nonlinear medium that can exhibit anomalous dispersion. In this case – which as it turns out has been known since the 1940s – the effect occurs as the incoming waves strike the boundary between a region of anomalous dispersion that is moving away and a region of normal dispersion that has not yet been made anomalous. The backscattered component then comes back shifted not down, but up in frequency. This work offers a whole new way of thinking about how to generate frequencies in traditionally difficult regions of the spectrum.

Further reading

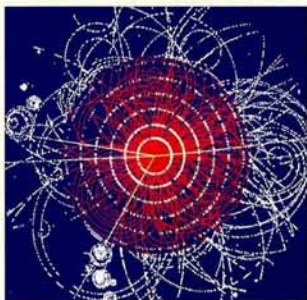
N Seddon and T Bearpark 2003 *Science* **302** 1537.



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Image shows a simulation by the ATLAS experiment of the decay of a Higgs boson into four muons (yellow tracks).

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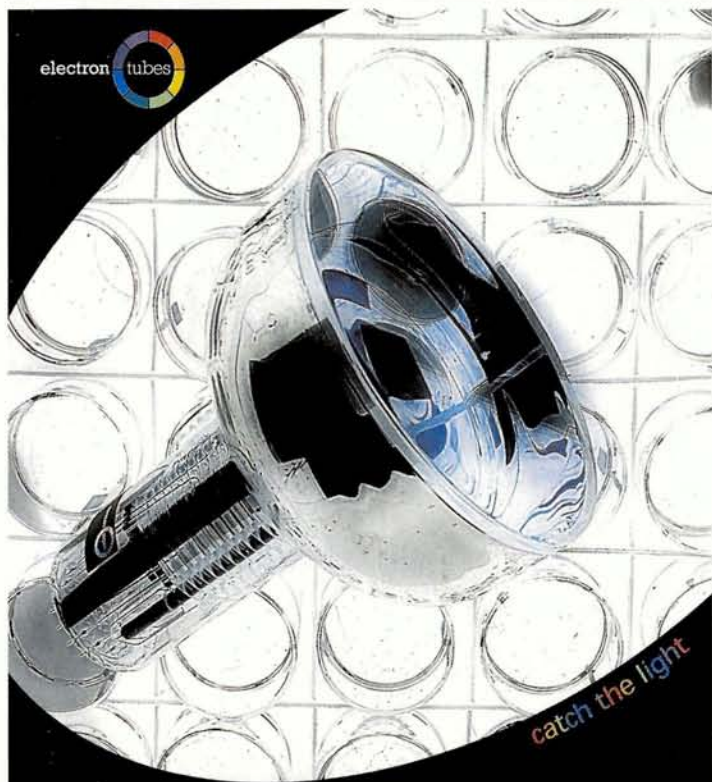
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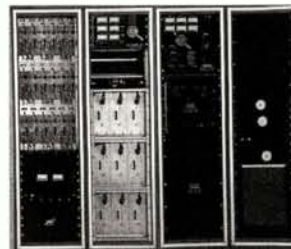
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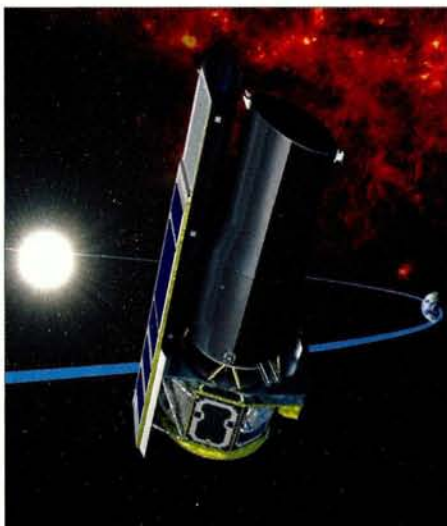
Compiled by Marc Türler

Spitzer Space Telescope delivers first pictures

On 18 December 2003 a new window to the universe opened with the release of the first dazzling images from NASA's newly named Spitzer Space Telescope, formerly known as the Space InfraRed Telescope Facility. The telescope was renamed after Lyman Spitzer (1914–1997), a renowned astrophysicist who first proposed placing telescopes in space in the mid-1940s.

The Spitzer Space Telescope was launched by a Delta II rocket from Cape Canaveral, Florida, on 25 August 2003. It is the fourth and last mission of NASA's suite of Great Observatories, which includes the Hubble Space Telescope, the Compton Gamma-Ray Observatory and the Chandra X-ray Observatory. Consisting of a 0.85 m telescope and three cryogenically cooled science instruments, Spitzer is larger than the 0.6 m European Infrared Space Observatory, which was in operation from November 1995 until May 1998.

The Spitzer Space Telescope is devoted to observing infrared radiation at wavelengths between 3 and 180 μm . This is mainly heat emission from celestial bodies that have a temperature between roughly 10 and 1000 K. Such objects include small stars that are too



An artist's impression of the Spitzer Space Telescope in its Earth-trailing orbit around the Sun. The telescope observes infrared radiation between 3 and 180 μm . (NASA/JPL-Caltech.)

dim to be detected by their visible light, extrasolar planets and giant molecular clouds. However, infrared radiation also has the advantage over visible light of being able to penetrate the dense clouds of gas and dust

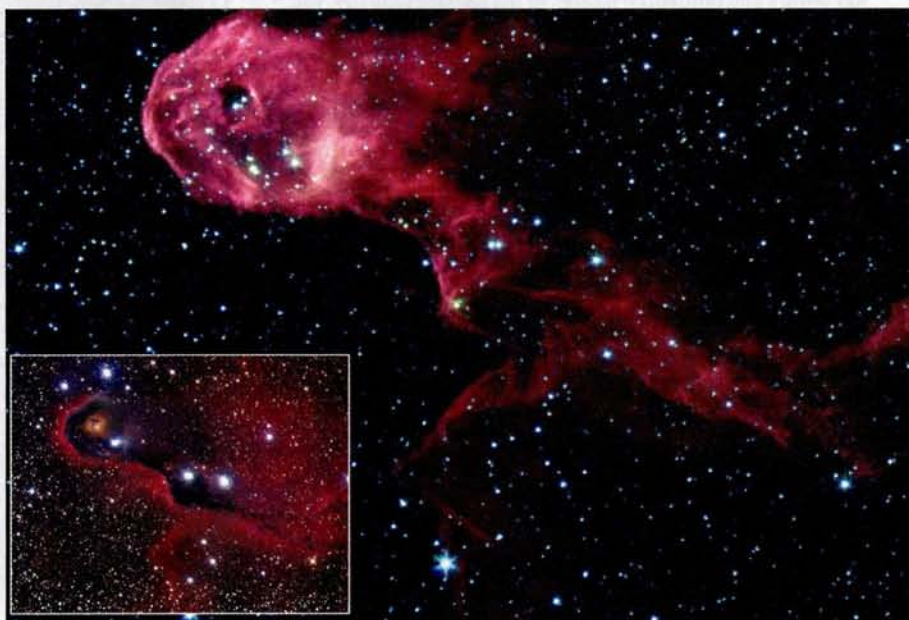
that block our view. Spitzer therefore allows us to peer into regions of star formation, the centres of galaxies and into newly forming planetary systems, which are hidden from optical telescopes. Its spectral capabilities can detect the unique signatures of the many molecules in space, including those that are organic.

Because infrared is primarily heat radiation, the telescope must be cooled to near absolute zero so that it can observe infrared signals from space without interference from the telescope's own heat. To reduce the amount of cryogen used to cool the instruments as much as possible, the spacecraft is protected by a solar shield, while its innovative Earth-trailing heliocentric orbit keeps it away from the heat released by our planet.

After the two-and-a-half-year Spitzer mission, the next infrared space telescope will be European. The Herschel mission of the European Space Agency, formerly called the Far InfraRed and Submillimetre Telescope, is scheduled for launch in February 2007. With a mirror of 3.5 m it will detect much fainter sources than Spitzer but at longer (80 to 670 μm) wavelengths, so covering the full far-infrared and submillimetre waveband.

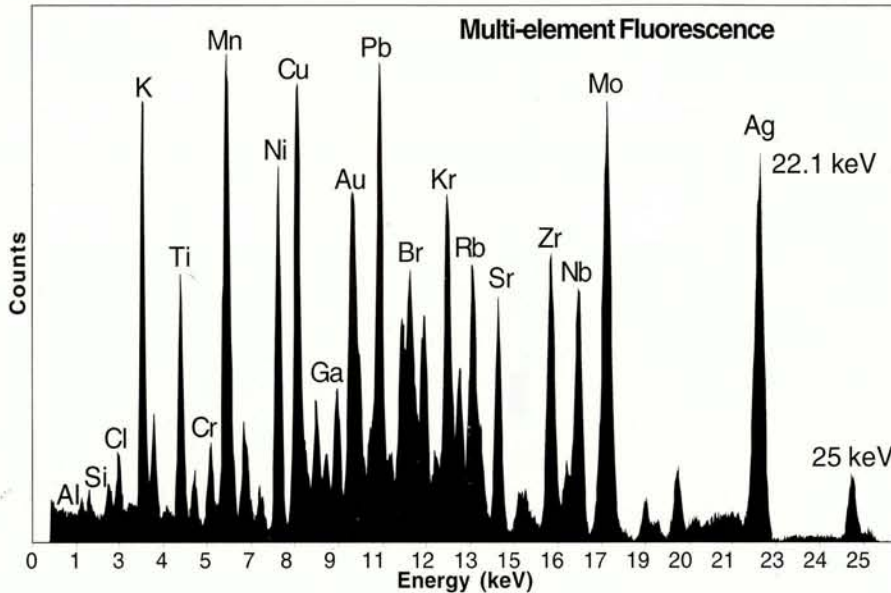
Picture of the month

One of the very first images from the Spitzer Space Telescope provides a spectacular contrast to the opaque cloud seen in visible light (inset, bottom left). Spitzer has transformed this dark globule – known as the Elephant's Trunk – within the emission nebula IC 1396 into a glowing stellar nursery that resembles a creature on the run with flames streaming behind it. Spitzer's infrared detectors unveiled the brilliant hidden interior of this opaque cloud of gas and dust, exposing for the first time young stars being formed in the densest parts of the cloud. The image is a four-colour composite of infrared light, showing emission from wavelengths of 3.6 μm (blue), 4.5 μm (green), 5.8 μm (orange) and 8.0 μm (red). (NASA/ JPL-Caltech/W Reach (SSC/Caltech).)



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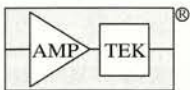


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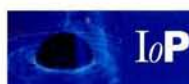
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The quest for higher gradients

A workshop at Argonne on high-gradient RF cavities attracted 90 participants, with contributions from CERN, KEK, SLAC, Argonne and Fermilab. **Jim Norem** reports.

For some years the Muon Collaboration – a group of particle and accelerator physicists from the US, Europe and Japan interested in neutrino factories and muon colliders – has been looking at the problems associated with operating high-gradient radiofrequency (RF) cavities at low frequencies (~ 200 MHz). In addition there has recently been considerable progress in the development of high-frequency, high-gradient cavities for linear colliders. So in order to review the common problems, whilst also aiming to communicate with the materials-science community, the idea of a workshop on high-gradient RF at Argonne National Laboratory began to form. Although we initially expected about 40 participants, almost 90 attended on 7–9 October 2003. The aim of the workshop was to try to identify the effects limiting gradients in a wide variety of different applications, and to connect these with the properties of the materials involved. Although most of the research in achieving high gradients in RF cavities has been in support of linear-collider proposals, similar challenges exist for klystrons and photoinjectors, and, more recently, the low-frequency cavities required for muon cooling.

While much of the discussion at the workshop concerned copper cavities, talks from KEK and DESY outlined the state of the art for superconducting RF. These talks implied that RF cavity surfaces could be made good enough to avoid breakdown processes, but that the procedures involved were expensive and the applicability to normal cavities was not always clear, as breakdown events seem to be produced from clean, smooth surfaces.

In a later session, measurements of direct current (DC) breakdown from Cornell, which resulted in “starbursts” identical to those seen in superconducting RF cavities, were shown. These events seem to connect the phenomena seen in DC, normal conducting and superconducting RF. There were also presentations of new data from Argonne

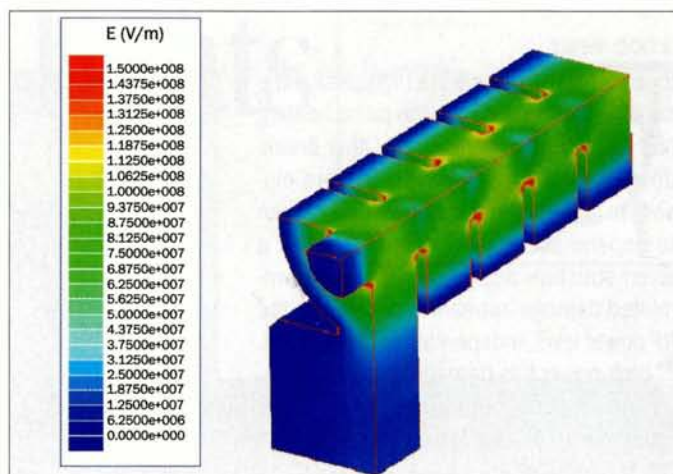


Fig. 1. The distribution of electric fields in an 11.4 GHz prototype cavity for the NLC, showing high fields at irises and low electric fields near the coupling port, where many breakdown events occur. (V Dolgashev, SLAC.)

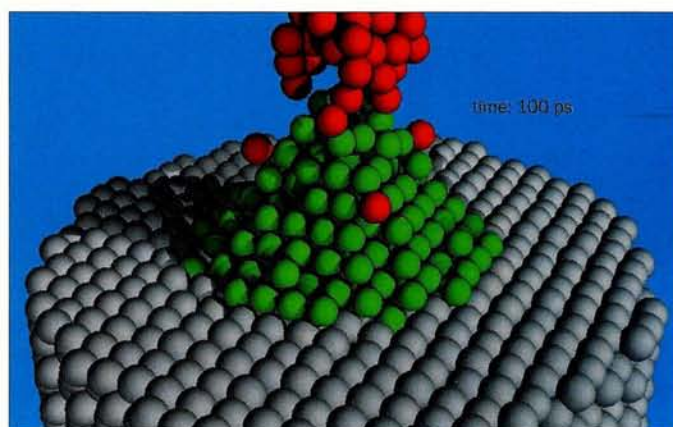


Fig. 2. Ions (red) and neutral atoms (green) being pulled apart by 10 GV/m electric fields, in a process similar to field evaporation. (Z Insepov, Argonne.)

on dielectric acceleration structures, and theoretical discussions on multipactoring in these structures.

Most of the workshop, however, was devoted to summaries of results from groups working on linear-collider development. The CLIC team from CERN reported the results of studies of refractory materials (molybdenum, tungsten), which seem to be able to survive higher fields than the copper usually used, but require much longer to condition (*CERN Courier* March 2003 p6). They also reported the frequency and temperature dependence of breakdown, showing data indicating that these two parameters do not have a strong effect.

Participants from SLAC and KEK described the efforts being made for the Next Linear Collider (NLC) and Global Linear Collider (GLC) projects, respectively, to develop 11.4 GHz structures (figure 1) that operate stably at 65 MV/m with 400 ns pulses. Although the performance of these structures is approaching that required for a linear collider, the gradient limits are not fully understood. One limitation that has been overcome is thought to originate from pulse heating at the sharp-edged waveguide openings to the coupler cells. Pulse temperature increases above 100 °C appear to cause stress-related fracturing of the copper surface, which leads to breakdown. Rounding ▷

these edges to reduce the high peak magnetic fields that enhance the pulse heating has eliminated these events. Other breakdown mechanisms have been more elusive. In general the breakdown rate is seen to depend strongly on surface field for a given structure design, while breakdown-related damage appears to depend on the RF power level, independent of the design. At high power this damage leads to breakdowns on subsequent pulses (so-called "spitfests"), preventing further increases in gradient. For the three generations of structure designs that have been evaluated, this mechanism has limited input power levels to 60–80 MW, while the surface fields at this limit have varied by almost a factor of two (110 MV/m to 195 MV/m). The structure design efforts have therefore focused on reducing the input power for a given gradient, which is difficult due to efficiency and wakefield constraints.

KEK also reported on methods of surface treatment for the new S- and C-band accelerator structures they are building. The relative merits of diamond turning, chemical etching, electropolishing, vacuum baking, hydrogen baking and water rinsing are being systematically studied as part of their programme to upgrade the injector linac. A new method of smoothing, almost to the level of single atoms, was proposed by Epion Corporation. Gas-cluster ion beams (for example argon clusters at kilovolt energies) can produce very smooth surfaces on a variety of materials, with respectable erosion rates and coverage.

The Muon Collaboration reported on recent measurements in Lab G at Fermilab, which showed much new detail on dark-current production, as well as plans for the development of 201 MHz cavities, which are required by the Muon Ionization Cooling Experiment. In addition new data on high gradients in high-pressure cavities was presented by Muons Inc – a small business that was set up to perform R&D for muon cooling. A unique feature of this facility is the ability to produce very high magnetic fields in a variety of geometries.

Talks on modelling breakdown, from SLAC, Cornell and Argonne, looked at the process from a variety of directions. The most complete description of the development of RF breakdown events, which relies on an artificial injection of ions to get the process started, is a model that has been under development at Cornell for some time. Perry Wilson from SLAC summarized the many different mechanisms that have been shown to be involved in breakdown. Plasmas have been seen in many cavities and DC structures, and dark currents are known to be present at some levels in high-gradient cavities. Surface treatments affect the behaviour of the cavities, at least until the by-products of previous breakdown events dominate the surface, and surface heating due to wall currents and perhaps dark currents is known to contribute. In addition the plasma physics of ions, atoms and surfaces in high, rapidly changing electric fields is quite complex.

It seems that while many applications are limited by the same mechanisms, these mechanisms are not well understood. The designs for the SLAC/KEK 11.4 GHz NLC, CERN's 30 GHz CLIC linac



Fig. 3. This graphic shows surface damage associated with grain boundaries, perhaps as a result of localized ohmic heating. (S Harvey, SLAC.)

and the Muon Collaboration's 805 and 200 MHz cavities seem to be affected by breakdown at operating fields consistent with the production, by field enhancements, of local surface electric fields of 5–10 GV/m. In addition to this mechanism, a separate failure mode connected with the local current density in the walls can occur – the phenomenon known as pulse heating. While breakdown in lower frequency cavities seems to be dominated by the high electric fields, pulse heating is more of a concern at higher frequencies.

There was considerable interest in isolating a "breakdown trigger". In a session on modelling, there seemed to be some agreement that the missing element was a mechanism that would propel large numbers of atoms and ions into the volume of the cavity, to mix with the field-emitted

electrons that are known to be there already.

Work at Argonne over the past year has been aimed at identifying the breakdown trigger(s). Detailed measurements on dark currents at Fermilab have shown local fields of around 10 GV/m at emitters. Such fields can produce tensile stresses close to the tensile strength of copper, where fragments could break off and fly into the cavity. Also, some preliminary but very photogenic modelling of field evaporation (figure 2, p21), seems to show that large fluxes of single atoms, ions and clusters could be injected into the cavity volume at the appropriate electric field and temperature. The effects of grain boundaries and defects also seem to be important (figure 3). At the high current densities present in high-frequency cavities, the resistivity of defects would produce very high local ohmic heating densities (and electric fields) in the surface of the material.

The surfaces that exist in cavities are complex, both structurally and chemically, and not completely understood, so continued effort will be required to progress further. Although the priorities are not entirely clear, it seems as if a variety of material-science measurements could begin to provide useful information on how some of the proposed trigger mechanisms for breakdown might actually work. There was some talk about the measurements that should be made and who might be involved in them. There was also discussion of the scope of current experimental and theoretical programmes that are aimed at improving cavity performance.

While a complete description or explanation of breakdown remains to be found, the workshop began to show how processes at surfaces and surface properties could influence the phenomenon. Ultimately, the relevant question is how much control is it possible to have over breakdown, and the answer will require some aggressive multidisciplinary research and development.

Further reading

Talks from the workshop are available at www.hep.anl.gov/RF.

Jim Norem, Argonne National Laboratory.

CERN's heart beats as strong as ever



Günther Plass looks back to the very beginnings of the Proton Synchrotron in the 1950s and its subsequent career as the centrepiece of CERN's accelerator complex.

The timely construction and commissioning, in November 1959, of CERN's Proton Synchrotron (PS) clearly demonstrated both the ability of the young European laboratory to turn a new concept into reality and the wisdom of the decision, taken as early as October 1952, to build an alternating-gradient synchrotron. Nobody involved could have imagined that the PS would remain the backbone of CERN's scientific activities for more than 50 years.

The origins of the PS date back to May 1952, when the provisional CERN Council decided to build a 600 MeV synchro-cyclotron (similar to the one at Liverpool in the UK) and a "high-energy" PS (similar to the 2 GeV Cosmotron at Brookhaven), and to set up "SC" and "PS" groups. The initial members of the PS group were: Hannes Alfen (Sweden), Odd Dahl (Norway), D W Fry (UK), Wolfgang Gentner (Germany), Frank Goward (UK), Kjell Johnsen (Norway), F Regenstreif (France), Chris Schmelzer (Germany) and Rolf Wideröe (Switzerland).

Concept and design

The PS group set out to work on a synchrotron of the weak-focusing type, similar to the Cosmotron at Brookhaven, but with an energy of 10 GeV. Three members of the group, Dahl, Goward and Wideröe, went to Brookhaven in August 1952 for discussions with the Cosmotron's designers. The American scientists, however, presented their visitors with a revolutionary concept for the design of future high-energy accelerators. Alternating the magnetic-field gradients while increasing them as much as possible would afford strong focusing of the beam, as occurs in a sequence of optical lenses, allowing smaller beam apertures and magnets for the synchrotron. Conversely, for a given magnet mass of a synchrotron, substantially higher particle energies could be obtained. This proposal became at once the subject of intense discussions with the inventors Ernest Courant, Stanley Livingston and Hartland Snyder. (This principle had been proposed independently by Nicholas Christophilos two years earlier.)

Two problem areas soon emerged: very high gradients would lead to very strong sensitivity to magnetic-field or alignment errors, and at a critical energy level – the "transition" energy – total beam loss would occur unless countermeasures were found. All the same, only two months later, in October 1952, the PS group convinced Council



Since the PS started up in 1959, the intensity of its proton beam has increased a thousandfold and it has accelerated many other kinds of particles. Rejuvenated and upgraded, the PS is still the central workhorse of CERN's accelerator complex.



An aerial view of the CERN site, as it was in spring 1957; the circular structure of the PS is visible to the right.

to launch a feasibility study of an alternating-gradient PS of "about 30 GeV" as the main project of the new laboratory. That demonstrated extraordinary insight as well as foresight and courage. The scene was thus set for the successful history of CERN as it developed – it surely would have been quite different had they opted for the old, "safe" way. In that session Council also selected Geneva as the seat of the laboratory. (We really should have celebrated CERN's 50th anniversary two years earlier!)

Things proceeded with extraordinary speed in the following months. While the design of an alternating-gradient machine took ▷

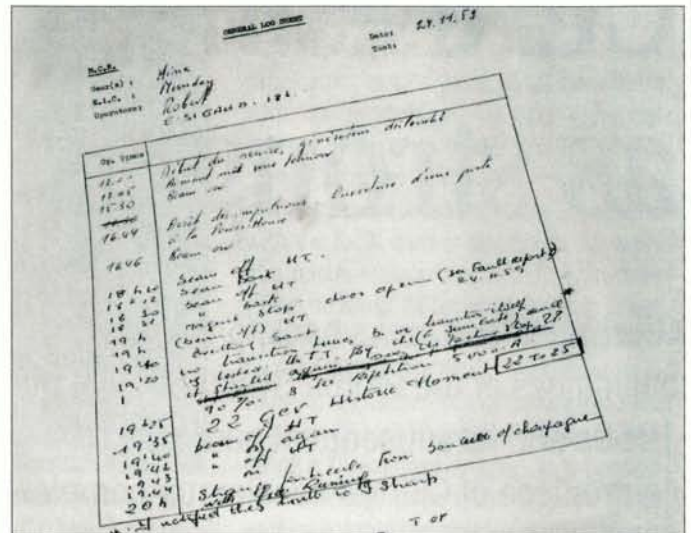


Completed magnets in the South Hall wait to be installed in the PS ring in October 1958 – a view comparable to that of today’s stock of “cold masses” for the Large Hadron Collider (p33).

shape in intense collaboration between the European and Brookhaven teams, diplomats, administrators and several eminent scientists worked hard on pushing the convention for the new international laboratory, in itself something never heard of before, through governments and parliaments to ratification.

In October 1953 the first members of the PS group, up to then split between half-a-dozen national laboratories, moved into preliminary premises at the Institut de Physique in Geneva, and at the end of the month a Conference on the Alternating-Gradient Proton Synchrotron was held there. Good progress in solving the problems inherent in the alternating-gradient principle was reported, and a conceptual machine design presented by the CERN group proved to be surprisingly similar to the PS as built six years later.

On 17 May 1954 ground was broken in Meyrin on the site proposed by Switzerland, and soon afterwards – with the formal beginnings of the European Organization for Nuclear Research on 29 September (see p5) – staff could be recruited and contracts for equipment awarded on a firm basis. It may be hard in today’s world to imagine the excitement of those lucky enough to be recruited by CERN. It was an extraordinary privilege to collaborate on a truly pioneering European project and to work in one team with colleagues from neighbouring countries on, in the PS division, an almost unbelievable project: a high-precision machine of 200 m diameter that stretched technologies to their very limit and presented a need for initiative and invention in many areas. New arrivals experienced the continued hospitality – including a beautiful view from the rooftop at tea time – of the Institut de Physique, where some temporary buildings had been set up to cope with the numbers. These were wooden barracks, which only enhanced the feeling of being real pioneers. Time and again bursts of laughter pervaded the corridor, coming from the office of the leader of the magnet group, Colin Ramm, when ways were being discussed both to produce and reduce the cost of the thousands of tonnes of equipment that had to be purchased. In February 1956 the southern end of Lake Geneva (known as “la rade de Genève”) froze up – the last time this occurred during the 20th



The PS log book for the evening of 24 November 1959 with its announcement of full energy at 19.35, followed by champagne!

century! – and so did the heating pipes in those temporary barracks.

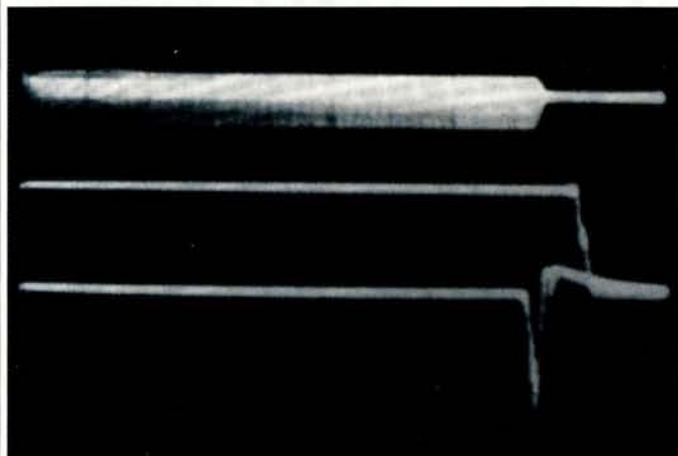
In June 1956, when the community gathered for the Symposium on High Energy Accelerators and Pion Physics, the viability of strong focusing was beyond doubt, though it had only been tested on a small-scale model at Brookhaven. The basic design of the PS was ready, staff numbers in the PS division were approaching 140, many of the important contracts with industry were being prepared and Kees Zilverschoon’s construction schedule (handwritten, since there were no computers yet) was established for finishing the project before the end of 1959.

Surprisingly, a Russian delegation (including a taciturn “expert” whose name nobody had ever heard before or after) obtained permission to participate in the symposium. Its members contributed a number of interesting proposals for advanced accelerating techniques, and above all, a good quantity of the drinks any Russian is brought up with – plus the quantity of caviar necessary to accompany them. Ivan Chuvilo of the Institute of Theoretical and Experimental Physics (ITEP) in Moscow never forgot his struggle with the Swiss customs about his “diplomatic” luggage, and surely all the conference participants will remember the Russian party at Hotel Metropole of 18 June (the day this author joined CERN).

First operation

Early in 1957 staff and laboratories moved to the new buildings at the Meyrin site. As from January, with parts of the roof still missing, the South and North Halls were fitted out for two years of testing, assembly, re-testing and storage of the accelerator components produced by industry in various member states. On 3 February 1959 the first of 100 magnet units was installed in the PS tunnel and the assembly of the synchrotron was finished by the end of July 1959 (see p15). The injector – the 50 MeV linear accelerator – produced beam at the end of August, and beam circulating in the PS was obtained on 16 September, but all acceleration tests resulted in erratic beam behaviour for several weeks.

On 24 November, a memorable date indeed, Wolfgang Schnell



Oscilloscope traces indicating that the PS had accelerated protons to an energy of 25 GeV. The top trace corresponds to the beam circulating without energy loss, the middle trace shows the magnet voltage, and the bottom trace gives a signal at the end of the acceleration cycle, when the beam is lost.

installed new “phase lock” electronics in the beam-control system, with the grudging consent of Schmelzer, the RF group leader. (The original Nescafé tin containing the essential circuits is still available in his office.) When beam tests were resumed, the beam was accelerated at once, and even went through transition energy without difficulty; moreover, the team present (see photo, above right) hardly believed their eyes as they watched acceleration continue right through to 24 GeV. Finally on 8 December, after they corrected for magnet saturation, the peak energy of 28.3 GeV was attained.

The PS thus became the highest energy accelerator in the world for seven or eight months. Then its sister machine, the Alternating Gradient Synchrotron (AGS) at Brookhaven, was ready, which was somewhat larger and hence of higher energy capability. However, for the PS at CERN this was only the beginning of an extraordinary “career” of improvements and modifications, such that it has remained for 50 years the central member – the real heart – of the ever-increasing system of accelerators that has made CERN such a unique laboratory worldwide.

Improvements and new functions

While the machine was being carefully coached into routine operation and delivered first beams from internal targets, additional facilities and always higher intensities were already requested. A “fast” (short-pulse) ejection system was developed for neutrino experiments in the South Hall (soon to be relocated to a dedicated area). Also, to keep up with the steep increase in the number of users, another experimental area, the East Hall, was built, for which a “slow” (very long pulse) ejection system was needed for experiments on very rare or short-lived particles. Then, in 1965, when the Intersecting Storage Rings (ISR) project, designed to collide high-energy protons from the PS, was authorized as CERN’s first major extension, a second fast-ejection system and a dedicated transfer line were implemented.

Later in the 1960s, the construction of the “Booster” synchrotron was initiated to raise the injection energy to 1 GeV, and hence increase the beam intensity accepted by the PS, in response to con-



The scene on 24 November 1959 in the RF control room in the centre of the PS ring. From left to right: John Adams, Hans Geibel, Hildred Blewett, Lloyd Smith, Chris Schmelzer, Wolfgang Schnell and Pierre Germain.

tinued requests. Simultaneously a programme to replace most of the first-generation subsystems of the PS was launched (see box, p26). The 50 MeV Linac could by then no longer provide the necessary intensity nor the reliability, and had to be replaced during the mid-1970s by an improved machine (Linac 2).

Also, just to make sure that no trick was missed, a working group at the time investigated whether different magnet structures for the PS tunnel, such as separate function magnets, might provide improved capabilities. The result was unambiguous: the machine as designed 20 years previously was the best to satisfy all requirements – an excellent job had been done.

In the late 1960s a 300 GeV Super Proton Synchrotron (SPS) became seen as a necessary step by European physicists, although finding a suitable site seemed like an imbroglio of geotechnical and political considerations impossible to solve, until in 1970 the proposal (dating from 1961) was resuscitated to build the machine under land adjacent to the original CERN site. After due discussion the proposal was formally submitted to Council in December 1970, and a special session approved it in February 1971, not least because the use of the PS as injector (and of other existing infrastructure) emerged quite naturally as an additional benefit. New beam-ejection and transfer modes, a dedicated acceleration system and delicate beam-matching procedures had to be developed for the PS in parallel with the improvement programme outlined above. Computer control then became a necessity, and refined operation procedures were conceived so that the ISR and the SPS, as well as the secondary beams, could run simultaneously.

Thus towards the end of the 1970s the intensity per cycle had been increased from about 10^{10} to more than 10^{13} protons, the cycle time had been shortened by a factor of three and machine availability had reached more than 95% of scheduled time. Operated and maintained by a superb team of competent and dedicated staff who were enthusiastic about the intricate system of accelerators and beam lines under their responsibility, the PS clearly was fit for even more demanding years ahead. ▸

All these programmes were not quite finished when Carlo Rubbia, in 1976, brought forward the proposal for proton-antiproton experiments, which implied new challenges again for the PS. For anti-proton production a 26 GeV proton beam of the highest intensity and density had to be provided, with all the beam concentrated in one-quarter of the PS circumference. Furthermore, the antiprotons from the antiproton accumulator were to be brought back to the PS for acceleration and transfer to the SPS.

The PS thus became a central element of the experiments in which the W and Z bosons were discovered, bringing the first Nobel prizes to CERN staff, with the awards in 1984 to Carlo Rubbia and Simon van der Meer (*CERN Courier* May 2003 p26). Also in the 1980s the PS became an antiproton decelerator supplying the Low Energy Antiproton Ring (LEAR). It still provides the high-intensity primary proton beam for LEAR's successor, the Antiproton Decelerator (AD), where delicate experiments continuing the tradition of LEAR are running today.

A universal accelerator

For some time, ideas for a programme of research with heavy ions had been looming in the physics community. Early in the 1970s tests with deuterons and alpha particles were run in the "old" Linac 1, which was dedicated to ions after the construction of Linac 2. Equipped with a new front end, Linac 1 provided beams of oxygen and sulphur ions for acceleration in the PS, so that by the mid-1980s experiments with these ions could run at SPS energies.

Eventually Linac 1 was replaced by a dedicated heavy-ion Linac (Linac 3) constructed by a collaboration involving CERN, GANIL, GSI, IAP (Frankfurt), Indian institutes and INFN (Lugnano), as well as financial contributions from the Czech Academy of Science, and the Swedish and the Swiss delegations. Since 1994 the PS has therefore been fit for providing ions as heavy as lead for experiments at the SPS and, in future, the Large Hadron Collider (LHC).

The 1980s and 1990s were the main decades for CERN's Large Electron Positron collider (LEP). This was originally planned to have a dedicated injector synchrotron for electrons and positrons, but when Council put the brakes on the budget, people's minds turned once again to the PS.

It turned out that the combination of the PS and the SPS, equipped with suitable acceleration systems, would make an adequate injector for LEP. Space was made available near the PS circumference for the electron and positron sources and pre-accelerators, to which the Laboratoire de l'Accélérateur Linéaire (LAL) at Orsay made significant contributions. New inflectors, a new vacuum chamber, wiggler magnets and a dedicated acceleration system for electrons and positrons had to be installed in the PS so that, for a dozen years or so, it became the universal accelerator for all stable charged particles.

Finally, protons and heavy ions for the LHC will of course come from the PS (through the SPS). The beam current will have to be increased once more with a new front end for Linac 2. To accommodate the increased current, the transfer energy from the booster to the PS has been raised to 1.4 GeV, and both machines need, among a number of other adaptations, to be equipped with new acceleration systems synchronized to the acceleration systems of the SPS and the LHC.

For 45 years this machine has been adapted successfully to the

A first round of improvements

The PS improvement programme of the late 1960s included:

- a new main generator (later replaced by a solid-state system) and a new acceleration system to shorten the magnet cycle;
- improved magnetic-field correctors redesigned for improved saturation correction and to liberate straight-section space for new requirements;
- a "transition jump" system conceived for the smooth passage of the critical transition energy at high intensities;
- the vacuum system being refitted with state-of-the-art equipment to lower the pressure;
- sophisticated controls, beam observation and measurement systems indispensable for the simultaneous operation of several beam users.



In April 2003, for the first time in 45 years, two magnets and a bus-bar connection in the PS were found to be faulty during high-voltage tests at the end of the accelerator shutdown. A team of mechanics, technicians and engineers worked at full speed to replace the faulty magnets, and the accelerators' spring start-up was only two weeks late. Here one of the replacement magnets is being prepared.

requirements of the physics programme, while both in the minds of people and in fact (its basic focusing structure has remained untouched), it is still "the PS". Understanding the physics of beams in accelerators, refined beam observation and measurements, ingenious inventions, powerful computers for beam simulation and controls, as well as a few decades of general progress in many technologies (vacuum, electronics, RF, high stable and fast power sources, materials, etc), along with motivated staff, were all necessary ingredients for this development.

Young physicists of the 21st century, as enthusiastic to work at CERN as those of 50 years ago, will surely not hesitate to teach the old lady a few new tricks. When one day, maybe quite remote, the PS finally faces retirement, people should remember CERN's founding fathers and the participants in the historic Council session in October 1952 for their courageous decision, and the original machine designers for their excellent job.

Günther Plass joined CERN in June 1956. Now retired, he was most recently director of accelerators from 1990–1993.

The challenge of the LHC

The Large Hadron Collider project has had to overcome challenges at every stage.

Lyn Evans focuses on the three phases of approval, construction and operation.

It is generally considered that the starting point for the Large Hadron Collider (LHC) was an ECFA meeting in Lausanne in March 1984, although many of us had begun work on the design of the machine in 1981. It took a very long time – 10 years – from this starting point for the project to be approved. During most of this time Giorgio Brianti led the LHC project study. However, we should not forget the enormous debt we owe to Carlo Rubbia in the second half of that decade for holding the community together behind the LHC against all the odds.

The first project approval came in December 1994, although under such severe financial constraints that we were obliged to make a proposal for building the machine in two stages. This would have been a terrible thing to do, but at that point we had no alternative. However, after a major crisis in 1996, when CERN had a rather severe budget cut, at least the constraints on borrowing were relaxed and a single-stage machine was approved. The first operation of the LHC is now foreseen for spring 2007. It has been a very long road indeed.

It is clear that building the LHC is a very challenging project. It is based on 1232 double-aperture superconducting dipole magnets – equivalent to 2664 single dipoles – which have to be capable of operating at up to 9 T. We were doing R&D on these magnets in parallel with constructing the machine and the experimental areas. This was not just a question of building a 1 m scale model with the very skilled people here at CERN, but of being able to build the magnets by mass production, in an industrial environment, at an acceptable price. This is something we believe we have achieved.

The machine also incorporates more than 500 “two-in-one” superconducting quadrupole magnets operating at more than 250 T/m. Here, our colleagues at Saclay have taken on a big role in designing and prototyping the quadrupoles very successfully. There are also more than 4000 superconducting corrector magnets of many types. Moreover, operating the machine will involve cooling 40 000 tonnes of material to 1.9 K, when helium becomes superfluid. An additional challenge has been to build the machine in an international collaboration. Although usual for detectors, this was a first for the accelerator community, and it has proved to be an enriching experience.

The production of the superconducting cable for the dipoles has driven the final schedule for the LHC, because we have to supply the cable to the magnet manufacturers. We could not risk starting magnet production too early when we were not sure that we could follow it with cable production. Figure 1 shows the ramp-up of cable pro-

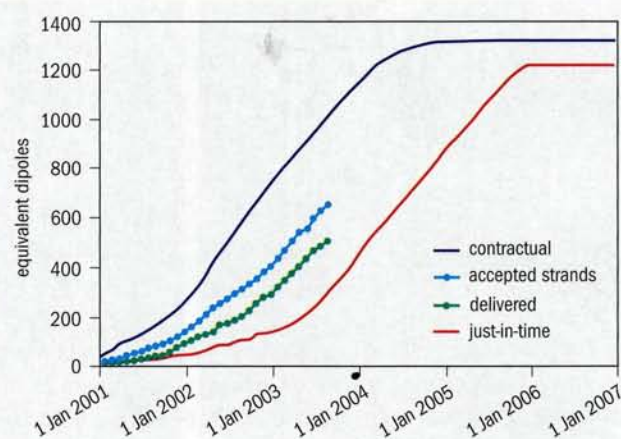
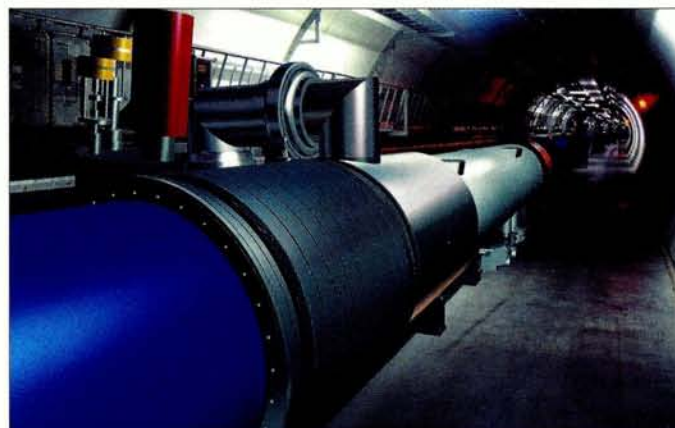


Fig. 1. The delivery of the superconducting cable for the LHC continues to lie comfortably above the “just-in-time” line.



A computer-generated image of the Large Hadron Collider.

duction, which has now reached the required plateau. The final schedule for machine start-up in spring 2007 was fixed once we were confident of reaching this goal. This schedule is also well-matched to the construction of the detectors.

The next step is the serious production of the dipoles, with installation in the tunnel starting in January 2004 and finishing in summer/autumn 2006. The “collared coils” – more than half the work on the dipoles – are now being made at the rate we need. These are assembled into the cold masses, which are delivered to CERN where they are installed in their cryostats, tested and stored. More than 100 dipole cold masses are now at CERN, and we are confident that we will be very close to the final date for installation.

At the same time the infrastructure of the tunnel is being prepared for the installation of the superconducting magnets. Sector 7-8, the first sector to be instrumented, now has its piping and cabling installed. The next step is the installation of the cryoline, to provide the liquid-helium refrigeration. We are now looking forward to as smooth a passage as possible from installation into commissioning. ▽

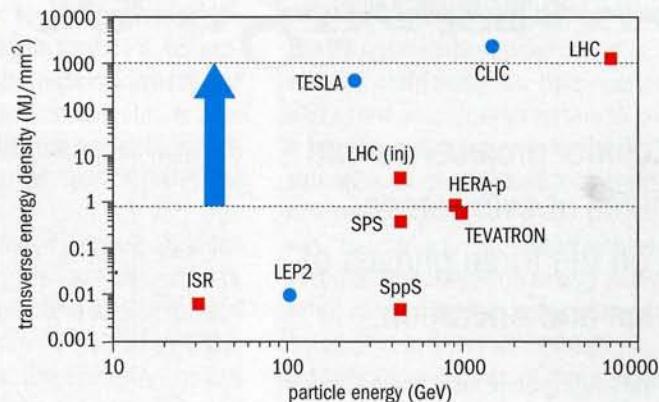
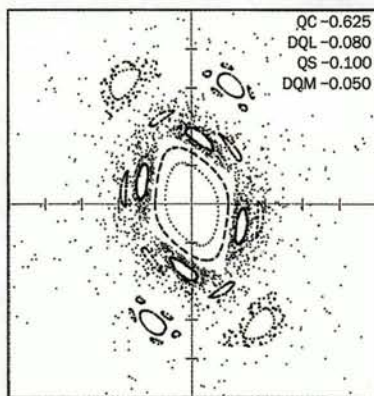


Fig. 2 (left). Simulation showing the chaotic effect of the beam-beam interaction on the position-velocity space of a particle in one of the beams.

Fig. 3 (right). At less than 1% of nominal intensity the collimation system enters new territory. The collimators must survive under very punishing conditions.

The LHC is a very complicated machine, and its operation presents many challenges. The most fundamental concern is the beam-beam interaction and collimation. In designing a particle accelerator, we try to make sure that the magnets have as little non-linearity as possible: that is, they have pure dipole and quadrupole fields. We then introduce controlled non-linearities – sextupoles to control chromatic aberrations and octupoles to give beam stability (Landau damping). We want smooth, distributed non-linearity, not a “lumped” linearity at one point in the ring. So we take a great deal of care, but then we are stuck with what we absolutely do not want – the beam-beam interaction itself. When the beams are brought into collision, a particle in one beam sees the Coulomb field of the other beam, which is strongly non-linear and is lumped – in every revolution the particle sees the beam-beam interaction at the same place. This produces very important effects, which I shall describe.

First, however, I should mention that the conversion of the Super Proton Synchrotron (SPS) into a proton-antiproton collider was a vital step in understanding this phenomenon. Indeed, it is not generally known what a step into the unknown we took with the collider. In this machine the strength of the beam-beam interaction, which we call the beam-beam “tune shift”, was very large, much larger than at the Intersecting Storage Rings (ISR). The collider was to operate in a domain where only electron-positron machines had worked, and these machines have the enormous advantage of strong synchrotron-radiation damping: particles that go through large amplitudes are “damped” into the core of the beam again. So we were going to operate a machine with no damping and a strong beam-beam effect. (Indeed, tests at SPEAR at lower and lower energies with reduced damping showed catastrophic effects, which when extrapolated indicated that the proton-antiproton collider could never work!)

Figure 2 shows the effects in a simulation of the transverse phase space (the position-velocity space) of a particle in a perfect machine, apart from the beam-beam interaction. Because of the strong nonlinearity of the beam-beam interaction, particle motion can become chaotic and unstable at large amplitude. This was a real worry at the proton-antiproton collider, which proved to be an absolutely essential prototype for defining the parameters of the LHC. We have designed the LHC to beat this effect by sitting in a very small corner of “tune space” with very precise control in order

to stay away from high-order resonances, although the beam-beam interaction will always be a fundamental limit.

A second major challenge of operating the LHC concerns collimation, which is needed to remove halo particles from the beams to avoid their touching the superconducting magnets, and to control the background in the detectors. We also need collimation to protect against fault conditions – the stored energy in the nominal LHC beam is equivalent to 60 kg of TNT! If there is a fault the beam will be kicked out, and for that there is a 3 μ s hole in the bunch spacing to allow the field in the kicker magnets to rise. If there is a misfiring particles will be lost as the kickers rise, and the collimators can melt, so they have to be very carefully designed.

Already, at less than 1% of its nominal intensity, the LHC will enter new territory in terms of stored energy. It is two orders of magnitude more in stored beam energy, but the beam-energy density is three orders of magnitude higher (figure 3) because as the beam is accelerated it becomes very small. To cope with this we have designed a very sophisticated collimation system. At injection the beam will be big, so we will open up the collimators to an aperture of about 12 mm, while in physics conditions the aperture of the beam will be 3 mm – the size of the Iberian Peninsula on a €1 coin. The beam will be physically close to the collimator material and the collimators themselves are up to 1.2 m long.

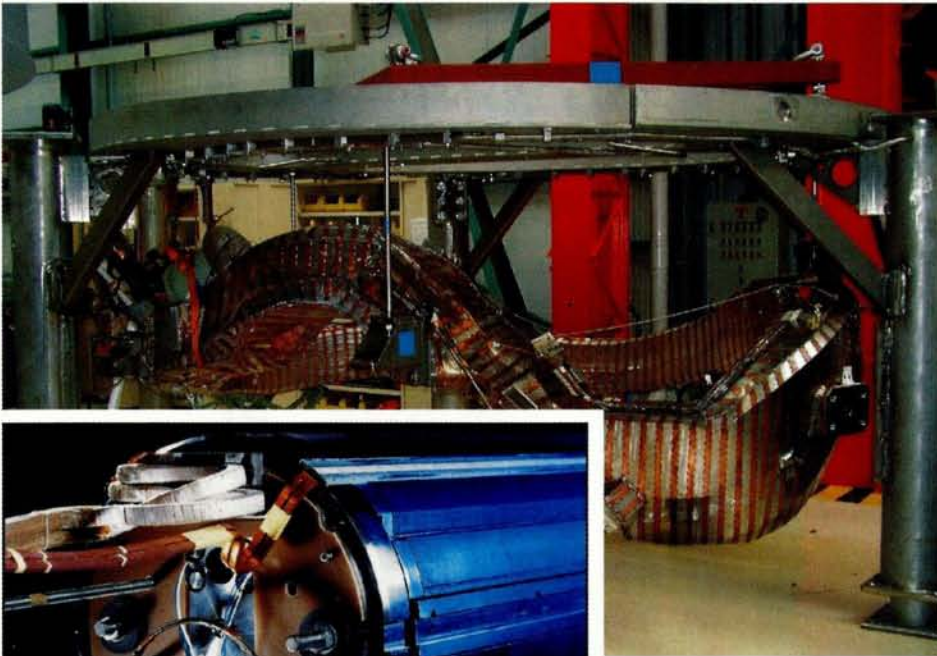
We are now on the final stretch of this very long project. Although there are three-and-a-half years to go, they will be very exciting years as we install the machine and the detectors. It is going to be a big challenge both to reach the design luminosity and for the detectors to swallow it. However, we have a competent and experienced team, and we have put into the design 30 years of accumulated knowledge from previous projects at CERN, through the ISR and proton-antiproton collider. We are now looking forward to the challenge of commissioning the LHC. It will be there in spring 2007.

• This article is based on a talk given at the symposium held at CERN in September 2003, “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.

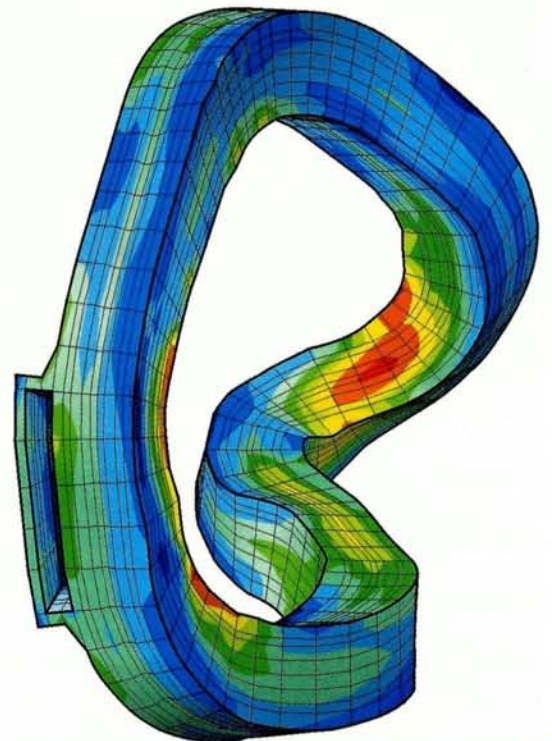
Lyn Evans, LHC project leader, CERN.

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LHC dipole product

By early December 2003 CERN had taken delivery of 154 superconducting dipole magnets – enough for the first octant of the LHC. This indicates that industrial production is now both on course and in full swing, as **Lucio Rossi** describes.

Since autumn 2003 people travelling between CERN's two main sites in France and Switzerland have begun to notice a number of strange traffic jams, which are increasingly testing the nerves of impatient drivers. Lorries 16 m long with special cradles to transport 30 tonnes of equipment are now routinely entering Point 18 to unload their precious cargo: the main superconducting dipole magnets that will eventually fill more than 20 km of the 27 km ring of the Large Hadron Collider (LHC), and which will operate at fields in the range 8–9 T at 1.9 K. Following an R&D phase of more than 10 years, the ramping up of dipole production, which was long awaited by many and never even believed possible by the sceptics, has definitely begun with a pace that is now more than one magnet per working day. The last week of October 2003 scored the record so far, with eight dipoles being delivered between the Monday and the Friday.

Production overview

Three companies are charged with the construction of the LHC's superconducting dipoles: the French consortium Alstom MSA-Jeumont, the Italian firm Ansaldo Superconduttori and the German company Babcock Noell Nuclear. Each has been engaged to provide CERN with one-third of the main dipole "cold masses" (figure 1). CERN is providing all the main components, some of the main construction tools and testing instruments, and the necessary engineering and technical support to make sure that the work done in industry complies with the tight technical specifications.

The process of magnet manufacturing can be split into two main activities: the production of the collared coils and the cold-mass assembly. The collared coils consist of eight coil layers that are wound with NbTi superconductor – the heart of the LHC – together with the collars that contain most of the magnetic forces, the cold-bore tubes where beam circulates and the heaters that protect the coil after a quench (the irreversible transition that brings the conductor to a resistive, normally conducting state). Once assem-

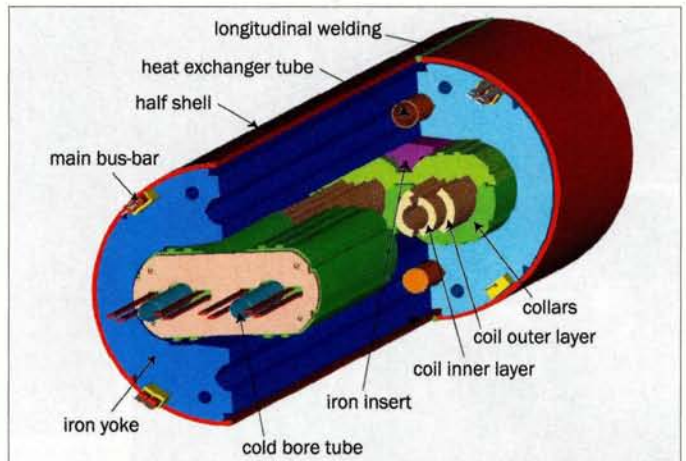


Fig. 1. Artistic sketch of the LHC dipole cold mass. All the components indicated in the picture are provided by CERN.

bled, the coils are subject to magnetic measurements and stringent electrical checks.

The magnetic circuit is completed by assembling the flux return iron yoke around the collared coils and enclosing everything in the outer shrinking cylinder, which also serves as a superfluid helium vessel. Operations are then performed on the magnet extremities, including the electrical connections, the assembly of the corrector magnets, the insertion of the heat exchanger tubes that remove heat from the superfluid helium bath, the welding of the end covers that constitute the helium enclosure in the longitudinal direction, and many other welding and finalization operations. Finally, electrical tests, magnetic and curvature measurements, and leak tests are mandatory before the magnet can be dispatched to CERN.

One of the problems with the industrialization of the LHC dipole construction is the long lead time between the decision to implement a change and its validation in a cold test. This was more than two years during the prototype phase and more than one year in the so-called "preseries" phase. The last major design change was the choice of austenitic steel for the collars, in 1999, but further improvements such as the final design of the end spacers came as late as 2001. So the strategy for reaching a reasonable price both for CERN and the companies was to sign first contracts in 2000 for 3 × 30 preseries dipoles, with a tender for the series production in 2001. The tender process ended in spring 2002 with the signing of three contracts for the series production of 3 × 386 dipoles. Together with the preseries magnets, this makes a total of 1248 magnets, of which 1232 are destined for the tunnel, to be delivered by summer 2006. By summer 2001 only a few magnets had actually been built, and companies were not at all comfortable quoting for the series. However, through a collaborative negotiation, CERN and the companies arrived at a reasonable solution, although

Production begins to take off

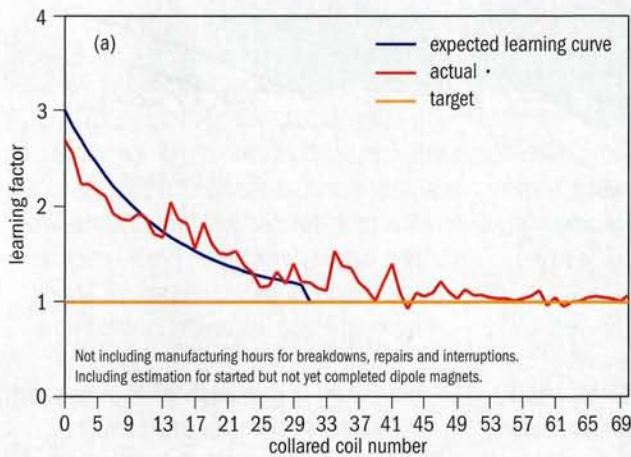


Fig. 2. (a) The actual and expected learning curves for the manufacture of a complete dipole collared coil at Babcock Noell Nuclear in Würzburg, Germany. Values are normalized to the final target. (b) Coils waiting for pole assembly at Ansaldo in Genova, Italy.

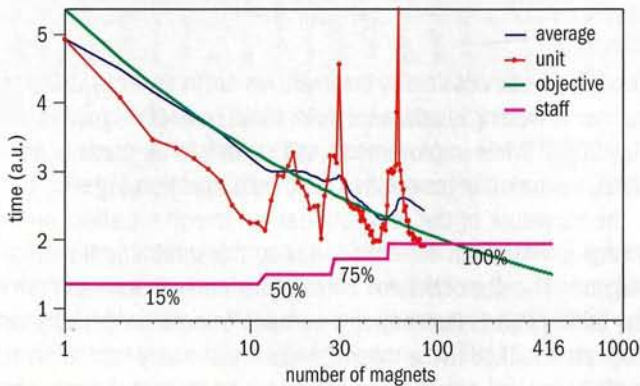


Fig. 3. The actual and expected (objective) learning curves for the manufacturing of a full pole at Jeumont in France (part of a consortium with Alstom). The jumps in time are very well correlated to the increase in and training of new staff.

the figures for the various operations were at the time more of an educated guess than a proven reality.

Now the preseries production is over and all three companies are well inside the series contract, so it is interesting to review where we are in terms of the industrialization of the process. Figure 2a shows the time needed for one company to complete a collared coil, compared with the so-called learning curve predicted at the time of the tender. On average, the process follows the prediction remarkably well. This is a sign that the process is well under control, which is of paramount importance for two reasons. First the collared coil is the heart of the magnet. Quench performance and field quality depend mainly on this part of the assembly. This point is made even more important by the time lag between collared-coil construction and the cold test (which is on average 10 months at present). Second

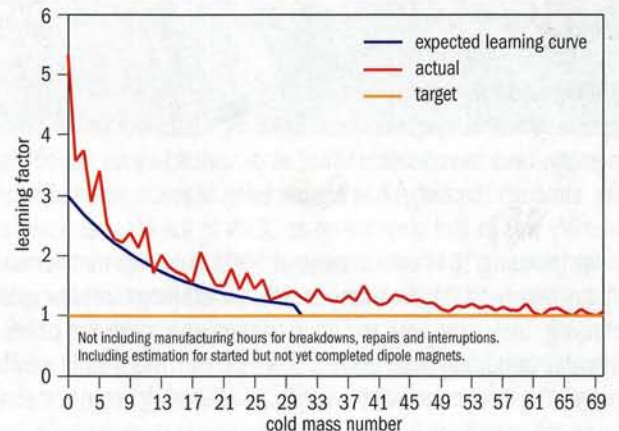


Fig. 4. Actual and expected learning curves for the manufacture of the cold-mass assembly (from collared coil to delivery) at Babcock Noell Nuclear in Zeitz, near Leipzig, Germany.

the collared coils represent about 60% of the assembly cost and more than 70% of the total value of a dipole (mainly because of the superconducting cable cost).

The good performance shown in figure 2a, and the impressive stock of coils now at the suppliers (see figure 2b), is the fruit of a long R&D process in which the collared coils were always manufactured by industry. The continuity of the work on this part of the magnet system made this quick ramping up of production possible, while maintaining good quality – a marriage that is not at all automatic. The effect of training new people for the increased production is quickly absorbed, as shown in figure 3, where the construction time of one pole for one manufacturer is indicated. Coil quality shows some correlation with the recruitment of new staff and with the introduction of new tooling. ▽

Welding and curving the half shells

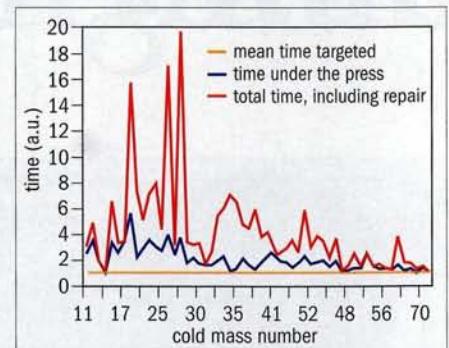
The welding procedure for the LHC dipoles combines the STT process (Surface Tension Transfer, invented by Lincoln Electric) for the root pass and the pulsed-MIG (metal inert gas) process for the three filling passes. STT is an advanced GMAW (gas metal arc welding) process adapted for making root passes in pipes and sheet welding. For the LHC dipole shells it allows a high-quality weld to be made at the root side with a simple chamber and reasonable tolerances on the welding gap, without having to use a backing strip to support the weld puddle. The process is based on fast electronic control of the arc current to achieve the instantaneous requirements of the arc during the entire process. This is possible thanks to the use of a new generation of inverter-based power sources.

The welding press is equipped with a sophisticated control system that measures



One cold mass during welding, with another waiting behind the press, at Alstom in Belfort, France. The two welders controlling the welding remotely can be seen on the left.

the welding gap of the assembly with a laser sensor, calculates optimum welding parameters as a function of the measured gap and provides the necessary input to the welding generators. In this way, the welding parameters are optimized automatically by



The time needed for a longitudinal weld of a dipole (time under press) and the total time, including repairs, at Alstom, normalized to the target for the series.

the system to guarantee the highest quality. Welding the cold-mass shells under constraint in the press allows the magnets to be curved according to the requested sagitta (the difference from a straight line between the ends and the centre).

Welding and curvature

Figure 4 shows the graph comparable to figure 2a but for cold-mass assembly. Here the situation is not as advanced as for the collared coils, although the target has almost been reached. The cold-mass assembly was in fact undertaken at CERN in the Magnet Assembly Facility (building 181) until the end of 2001, and was transferred to industry only in 2002. Needless to say, transferring the appropriate technology took more time and effort than planned, with two points in particular impeding a smooth progression to the manufacturing process. The first concerned the longitudinal welding of the half shells around the yoke (see figure 1). This welding is done under a large press where the magnet is bent and so curves slightly downwards, i.e. it is rotated by 90° with respect to the final position in the tunnel. Secondly, the extremities of the magnets are very demanding and must be accurately positioned to allow fast and safe interconnections to be made by an automated procedure in the tunnel. This means that the curvature of the magnet has to stay within tight tolerances.

The longitudinal welding of the 10 mm thick half shells is carried out in four passes, the first being done with Surface Tension Transfer (STT) technology (see "Welding and curving the half shells" box, above). This rather new process invented by Lincoln Electric is a world first for this type of welding. While the process was selected using a prototype machine in the Magnet Assembly Facility at CERN, it could only be set up on the actual presses in 2002. A CERN task-force worked intensively on this problem with the dipole manufacturers and welding experts, and now the time for longitudinal welding has been significantly reduced. One company has shown itself to be capable of routinely welding 4.5 magnets a week; to remain within the LHC delivery plan the required weekly peak rate is three to four. This progress has

also been made possible by the improvement in welding quality: the number of welding repairs went down by an order of magnitude after May 2003. While improvements still remain to be made in some areas, we think that the solution adopted is finally paying off.

The curvature of the magnets has an important effect on the quality of the beam deflection, due to the small aperture of the magnets. The size of the coil bores of 56 mm is much less than in any other project. Furthermore, we need to position the corrector magnets attached to the magnet ends within a very tight tolerance of ± 0.3 mm. However, a study carried out on magnet alignment has slightly revised the end tolerances and established that about one-third of the magnets can have a tolerance in the body larger than was first thought. So the only open problem left is the accurate control of the position of the correctors, an issue for which several different solutions are under investigation.

The measurement of the geometry inside the 16 m long, 53 mm diameter cold-bore tubes has involved a special laser tracker developed by Leica in Switzerland, with the use at CERN contributing to its "debugging". Both tubes are measured on each side four times during the construction of the magnet. At the time of the tender the duration of this operation had a large margin of uncertainty and initially the long time needed was an area of concern, both for the possible extra cost and timing of the project. Today the situation is much better and is steadily improving towards the objective.

Quality control and delivery

The LHC dipoles are built following a strict quality-control based on an inspection and test plan containing 25 control points. In particular the magnetic measurements serve two different functions, with



Fig. 5. In room-temperature measurements of the magnetic field of more than 220 magnets at the main dipole manufacturers, three cases of bad assembly procedures have been found and cured (by November 2003): a missing shim of 0.8 mm thickness (left), a coil presenting some turns not glued to the inner layer, leading to cable displacements of 1 mm (centre), and a double coil-protection sheet of 0.5 mm thickness (right).

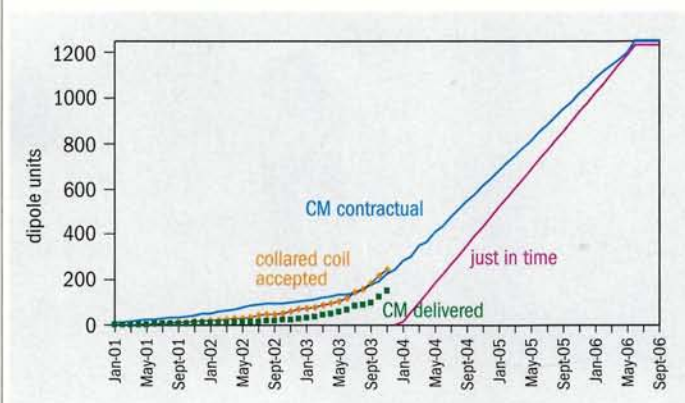


Fig. 6. Dipole cold-mass (CM) delivery, updated 28 November 2003, where the collared-coil production is shown with the “just-in-time curve” of the installation plan, as defined in September 2002.



Fig. 7. The stock of finished and almost finished cold masses at the Babcock Noell Nuclear workshop in Zeitz.

separate thresholds and modality of intervention. First the magnetic tests must steer the production of the magnets so that the bending strength and harmonics of the magnetic field remain inside the tough control limits imposed by the beam dynamics. The 10 month delay between construction of a collared coil and the low-temperature testing of the cold mass means that measurements must be made at ambient temperature in industry. This required fine tuning of the collared-coil cross-section during production, with two different interventions, to optimize the field harmonics.

The magnetic tests must also intercept assembly or component faults. While the warm tests cannot reveal all the faults – for example deficits in the critical current of the superconducting cable – so far three magnets have been disassembled based on field analysis and the predicted defect found (figure 5). The monetary value saved is already more than the whole investment in the warm magnetic measurements for the production so far. For this reason the magnetic measurements of the collared coils is a holding point, i.e. manufacturers can proceed with assembly only upon CERN’s explicit approval.

The performance in terms of the maximum field reached without a quench is good. More than half the magnets perform better than required, i.e. they are suitable for operation even at 9T without needing systematic “re-training” in the tunnel. The other magnets do not have any problems in reaching the nominal field of 8.3T without quenching, and only six magnets out of the 85 tested so far have

lower performance (i.e. they may require training to reach nominal field). This is a mere 8%, which we hope to bring down to the target of 2% in the series production.

The delivery plan for the LHC dipoles depends critically on the timely delivery of the CERN-supplied components, beginning with the 1200 tonnes of superconducting cable at the heart of the accelerator. Figure 6 compares the delivery according to the contract (March 2002) with the actual results for approved collared coils and cold-mass delivery. Meeting the schedule is certainly a very difficult task, which can be jeopardized by many factors (first cables, and also collars, laminations and half shells are on the critical path). However, the changes in delivery slope last spring for collared coils and after summer for cold masses, show that magnets are really arriving at CERN, with the first octant having been delivered by 3 December 2003. Figure 7 shows the stock of cold masses that are almost ready at one of the manufacturers, blocked only by a temporary bottle-neck in transport. We had all better be prepared!

Further reading

The progress on the components and magnets of all types for the LHC can be found on the “LHC dashboard” at <http://lhc-new-homepage.web.cern.ch/lhc-new-homepage/DashBoard/index.asp>.

Lucio Rossi, Magnets and Superconductors Group leader, CERN.

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LHC interconnections: searching for reliability

The reliability of the LHC will depend not only on the superconducting magnets but also on the interconnections between magnetic sections, as **Blazej Skoczen** explains.

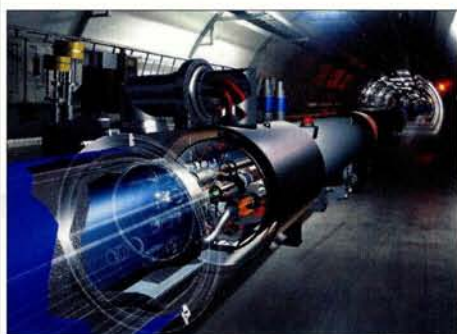


Fig. 1. A schematic of the LHC installed in the tunnel, showing one of the interconnection zones.

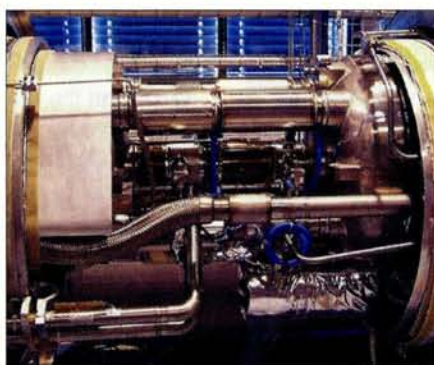


Fig. 2. The crowded interconnection zone in the LHC prototype string.

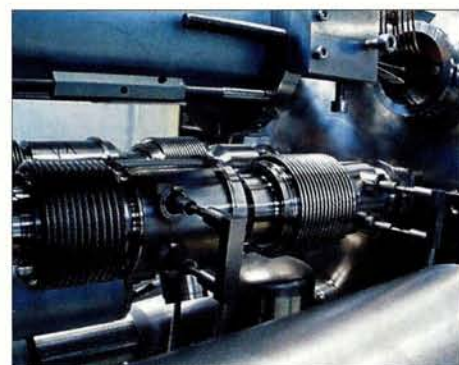


Fig. 3. The expansion bellows for the beam vacuum system.

The classic “FODO lattice” – the basic combination of magnets that is repeated around the ring of most modern synchrotrons – contains not only focusing/defocusing magnets (main quadrupoles) and bending magnets (main dipoles) but also drift spaces between the magnets where the particles simply coast. These drift zones fulfil a very fundamental function, providing space for all the necessary connections for the beam chambers and power supplies, and also for the cryogenic systems, thermal shielding and vacuum vessels in the case of superconducting machines such as the Large Hadron Collider (LHC). However, because the drift space does not provide beam bending strength, it is wasted space in terms of achieving the highest beam energy in the ring. So one of the design requirements for circular accelerators and storage rings that are optimized for high beam energy is to minimize the ratio of drift-to-magnetic length in the machine arcs. This implies strong constraints on the systems located in the drift spaces, such as the thermal contraction/expansion compensation system, the radiofrequency (RF) contacts between the beam screens, the joints of the superconducting bus-bars, etc.

In the LHC, despite the machine’s complexity, the interconnections have been optimized to the extent that they will occupy only 3.7% of the accelerator length in the arcs and associated dispersion suppressors. (The machine consists of eight bending arcs, generally with dispersion suppressor sections located at either end of the arc to reduce the horizontal dispersion in the beams.) Figures 1 and 2 show the crowded interconnection region planned for the final machine and as already implemented in a prototype.

Such an achievement has had its price, however. As a result of a tight mathematical optimization, the components of the thermal contraction/expansion compensation system – the expansion bellows, which are composed of very thin corrugated shells (figure 3) – have been pushed to operate beyond the elastic limit, where plastic deformation occurs. Thus, for the first time in the history of accelerators, the interconnection bellows “plastify” with every cycle of cool-down (to 1.9 K) and warm-up (back to 293 K), whereas the magnets stay “elastic”. This process is associated with the evolution of plastic strain fields in the “concertina” of the bellows convolutions, which is accompanied by micro-damage and, at low temperatures, a strain-induced phase transformation (from a face-centred-cubic to a body-centred-cubic material structure). To minimize the intensity of this phase transformation, the bellows convolutions are made from a special “medical” grade of stainless steel. Figure 4 shows typical hysteresis curves, indicating the dissipation of energy due to plastic deformation during cycling between room and low temperatures. To obtain a reliable performance of the expansion bellows, these phenomena were all carefully modelled and tested at room and cryogenic temperatures. As the number of these components in the LHC exceeds 20 000, a statistical check of their reliability is performed, based on accelerated life testing of 1% of the components.

Another important feature of the interconnection zones concerns the joints between the superconductors. These joints, or splices, comprise connections both between the Rutherford-type superconducting cables powering the main magnets and between the

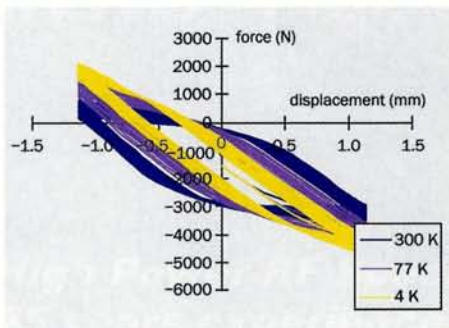


Fig. 4. The dissipation of energy due to inelastic deformation in the convolutions of an expansion bellows.

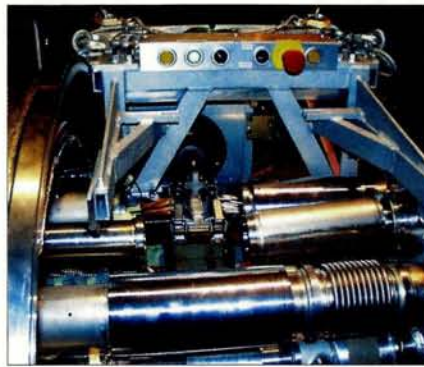


Fig. 5. Superconducting bus-bars are joined using an ultrasonic technique.

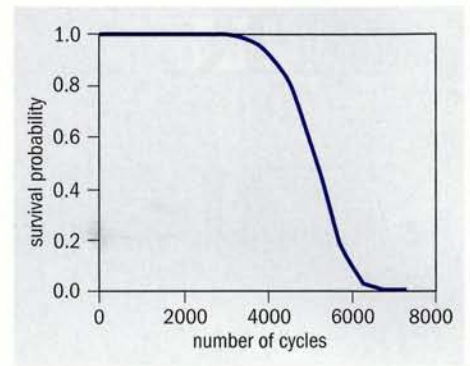


Fig. 6. The survival probability for the beam vacuum expansion bellows.

small superconducting bus-bars that power the corrector magnets (figure 5). Each joint contains two overlapping superconductors separated by a strip of $\text{Sn}_{96}\text{Ag}_4$ or a thin layer of copper (depending on the joining technology), so the dissipation of energy due to heating losses is localized in this non-superconducting layer. While typical resistances of the joints between Rutherford-type superconductors remain below $0.6 \text{ n}\Omega$ at 1.9 K , the joints located in the corrector circuits show some $3 \text{ n}\Omega$ of resistance. Given the total number of joints, the maximum dissipation of energy per interconnection zone (if all systems are simultaneously powered) amounts to around 670 mW at 1.9 K (in a dipole-quadrupole interconnection). Thus a large fraction of the total energy dissipated at low temperatures into the coolant (superfluid helium) is localized in the electrical interconnections between the main LHC magnets, and the amount of energy that can be "produced" in the interconnections in this way is severely limited by the thermodynamic budget of the LHC.

In view of the severity of the various criteria that the LHC interconnections must satisfy, a rigorous reliability analysis is a must. The target set for the availability of all the LHC interconnections (around 1700 zones) is based on the assumption of at most one short intervention (10.5 days) per 10 years of LHC operation. This ambitious goal implies that the availability of the LHC interconnections for the entire system must be equal to 99.5%. Generally, there are three groups of components subject to failure in the interconnections: the compensation system (expansion bellows), the connections of the superconductors (splices) and the RF contacts. Assuming that the expected availability is apportioned to each family of components on an equal basis, and given the number of interconnections in the LHC, the expected reliability level for one interconnect (per system) is 99.9999%.

The LHC interconnections will consist of a total of around 250 000 components of different size and some 123 000 connections will be needed to integrate all these components. The main objective of the Quality Assurance Programme for the LHC interconnections is to minimize the risk of frequent failures of the critical components and to reduce the number of interventions. Figure 6 shows a typical plot indicating the measured reliability of one of the expansion bellows for the beam vacuum interconnects. Since the theoretically expected number of thermal cycles (including quenches) in the LHC lifetime does not exceed 50, the corresponding reliability of this component, i.e. the probability of survival, is very high and close to 100%.

The Polish connection

In June 2003 a collaboration agreement was signed between CERN and the Cracow Institute of Nuclear Physics (HNINP), under which a Polish team will assist with the inspection of LHC assembly work (*CERN Courier* September 2003 p43). Under the terms of the agreement 22 physicists, engineers and technicians from HNINP will go to CERN to inspect the 1700 interconnections between the LHC magnets. These interconnections are complete systems as they have to ensure the continuity of the vacuum chamber, superconducting cable, cryogenic helium supply, main magnet and corrector magnet systems. All the interconnection components are inserted into a double-walled sleeve so that they can be kept at liquid-helium temperature.

The Polish "inspectors", many of whom have previously worked in the accelerator sector at DESY and Brookhaven, will start their inspection work in April 2004. Four teams of three will check that the components have been properly assembled, that there are no breaks in the systems and that the specifications have been complied with. A further team of nine will have special responsibility for testing the electrical systems.

The interconnections are one of the few systems for the LHC that will be almost entirely assembled in the tunnel (under the supervision of the LHC Interconnections Section) and not in laboratory conditions. Therefore, to achieve the target availability for the interconnection zones, a strict quality-control procedure has to be applied during the assembly process. This function will be fulfilled by a team of physicists and engineers (see "The Polish connection" box, above), who will check the interconnections one by one before the final closure of the accelerator. This "debugging" of interconnection zones aims to eliminate the errors in the connections that might jeopardize the electrical, cryogenic or mechanical functions of the machine. Given the total of around 123 000 connections – and a typical error rate during the assembly of complex systems of 0.3%, the number of possible errors to be eliminated reaches some 370. This alone is a sufficient reason to focus a great deal of attention on the complex interconnection systems located between the LHC superconducting magnets.

Blazej Skoczen, LHC Interconnections Section leader, CERN.

Hurricane Isabel gives accelerators a severe test

Swapan Chattopadhyay reports on the recovery of Jefferson Lab's superconducting linear accelerators in the wake of Hurricane Isabel last September.

Hurricane Isabel was at category five – the most violent on the Saffir–Simpson scale of hurricane strength – when it began threatening the central Atlantic seaboard of the US. Over the course of several days, precautions against the extreme weather conditions were taken across the Jefferson Lab site in south-east Virginia. On 18 September 2003, when Isabel struck North Carolina's Outer Banks and moved northward, directly across the region around the laboratory, the storm was still quite destructive, albeit considerably reduced in strength. The flood surge and trees felled by wind substantially damaged or even devastated buildings and homes, including many belonging to Jefferson Lab staff members.

For the laboratory itself, Isabel delivered an unplanned and severe challenge in another form: a power outage that lasted nearly three-and-a-half days, and which severely tested the robustness of Jefferson Lab's two superconducting machines, the Continuous Electron Beam Accelerator Facility (CEBAF) and the superconducting radiofrequency "driver" accelerator of the laboratory's free-electron laser. Robustness matters greatly for science at a time when microwave superconducting linear accelerators (linacs) are not only being considered, but in some cases already being built for projects such as neutron sources, rare-isotope accelerators, innovative light sources and TeV-scale electron–positron linear colliders.

Hurricane Isabel interrupted a several-week-long maintenance shutdown of CEBAF, which serves nuclear and particle physics and represents the world's pioneering large-scale implementation of superconducting radiofrequency (SRF) technology. The racetrack-shaped machine is actually a pair of 500–600 MeV SRF linacs interconnected by recirculation arc beamlines. CEBAF delivers simultaneous beams at up to 6 GeV to three experimental halls. An imminent upgrade will double the energy to 12 GeV and add an extra hall for "quark confinement" studies.

On a smaller scale, Jefferson Lab's original kilowatt-scale infrared free-electron laser (FEL) is "driven" by a high-current cousin of CEBAF, a 70 MeV SRF linac with a high-current injector. The FEL serves multi-disciplinary science and technology as the world's highest-average-power source of tunable coherent infrared light. An upgrade to 10 kW is in commissioning – as it was when Isabel began threatening.



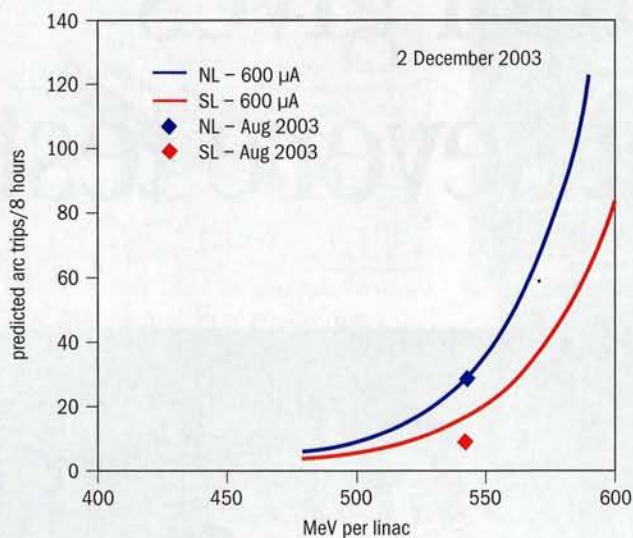
Hurricane Isabel on her relentless northward track toward Jefferson Lab in southeastern Virginia on the US Atlantic coast.



The Jefferson Lab cryogenic group at the critical point of reaching 2.09 K and holding it steady.

The power outage

The accelerator site lost electrical power at approximately 11 a.m. on 18 September during the hurricane, and was not restored until about 8:30 p.m. on 21 September. About an hour later, after the Central Helium Liquefier (CHL) control system was restored, it was >

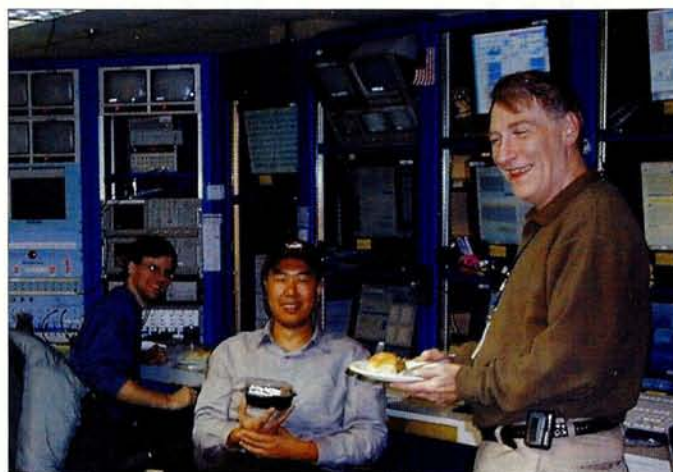


Minimum arc trips per shift with beam in CEBAF's north and south linacs (NL and SL) after Hurricane Isabel, as projected by a model created from prolonged observation of cavity behaviour without beam and compared with the actual situation pre-Isabel (August 2003). Each CEBAF cavity has a ceramic window 7.6 cm from the beamline at a temperature of 2 K. Field-emitted electrons charge up these windows until flash-overs occur, requiring the beam to be shut off. The frequency of these "RF faults" or "trips" is the prime determinant of CEBAF's energy capability and beam availability. The trip rates may improve with time as attention is given to refining some of the temperature interlock set points and as the benefits of additional helium processing of the RF windows are assessed.

found that all cryomodule temperatures were approaching ambient values. Without power, the CHL could not keep the CEBAF linacs or the FEL's driver linac cooled to the 2 K temperature required for superconducting operation. The liquid helium in both systems warmed up, boiled off, and was vented harmlessly but expensively to the atmosphere.

Some \$200 000 (~€160 000) in helium was lost – two-thirds of the overall inventory and an amount equivalent to a year's worth of losses from routine operation (comparable in mass to more than 70 000 litres of 4.22 K liquid helium). The episode was also costly to users' experiments and experimental schedules, to other aspects of CEBAF's status of operational readiness, and to the FEL upgrade commissioning. One consequence, in parallel with recovery activities, has been to revisit the construction-era determination that installing CHL backup power would not be cost-effective; now various options for reducing vulnerability to power outages are being considered.

For the six weeks following the incident, key activities included the procurement of replacement helium, pumping out of all the linac vacuum elements, cooling down the entire CEBAF accelerator complex, RF conditioning of the linacs and the commissioning of CEBAF's electron beam. The experimental nuclear/particle-physics programme was resumed on 2 December, a delay of six weeks, and commissioning the upgrade of the FEL was restarted.



The day-shift crew shared lunch in the Machine Control Center on 27 November, Thanksgiving Day, a holiday in any normal year.

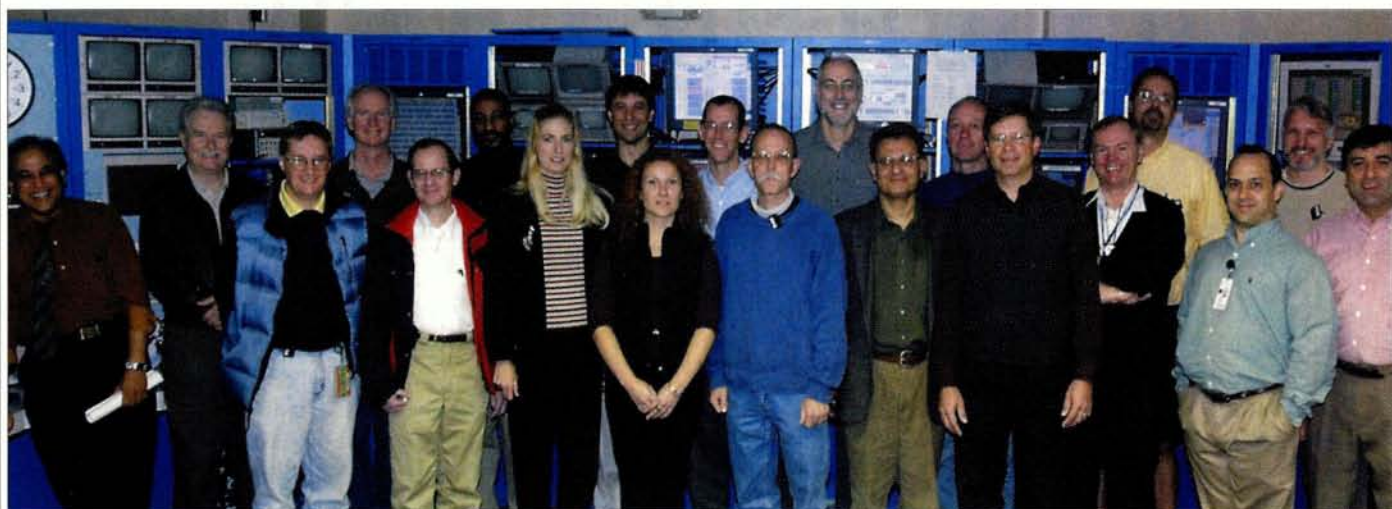
The recovery

In anticipation of the approaching storm, the laboratory had stored one-third of its liquid-helium inventory, thus enabling the "cooldown" of the CEBAF linacs to begin on 8 October. The plan was to cool eight or nine cryomodules per day, starting with the first three cryomodules. All cooldown rates were within the guidelines (150 K per hour) to avoid excessive thermal stresses and degradation of the cavity quality factor ("Q disease"). While no major mechanical-vacuum-related issues caused concern down to 4 K, cooldown to 2 K (the temperature at which liquid helium is superfluid) was approached gingerly indeed, being a further test of vacuum integrity.

Nearly 38 000 litres of 4 K liquid helium arrived at the laboratory early on 16 October, and the cryomodules were topped off at a rate of about 2400 litres per hour. The tasks to follow were cooldown to 2 K, further filling and stabilization, re-establishing a very low-gradient tune of all the cavities, operation of the cavities to determine their waveguide vacuum response, and RF conditioning of the cavities. Waveguide vacuum had been a challenge during CEBAF's early operational years in the 1990s, but it had cleared up with use.

On 20 October the cryogenic group, using manual control, pulled CEBAF's liquid-helium temperature down to below the lambda point, the transition to the superfluid state. Some 17 hours later, on 21 October, more than 99% of the CEBAF and FEL accelerator modules had been cooled to 2.09 K, the normal operating temperature. The End Station Refrigerator was then powered up to start delivering liquid helium for experiment preparation – the cooling of magnets and cryogenic target work.

As the liquid helium crossed the lambda point, one ailing cryomodule in north linac zone 5 was monitored carefully. The pressure in the waveguide feeds to the first and second of its four cavity pairs went up at a rapid rate; within hours the ion pump had saturated in the millitorr range and it tripped soon after. The four cavities in question were assessed as inoperable due to vacuum considerations; they were the only casualties of the storm. Out of CEBAF's total of 300, they represent at most 1% of the machine's



Jefferson Lab staff in the CEBAF Machine Control Center celebrate the delivery of beam to Halls B and C.

overall energy reach. RF conditioning has since revealed no other low-level leaks. After 36 hours of thermal stabilization at 2 K, the tasks at hand consisted of attaining low-gradient (2 MV/m) RF operation, followed by the assessment of vacuum stability with high-power RF operation.

The RF recovery of CEBAF and the FEL, following the complete cryogenic recovery, eliminated two major uncertainties: resonant frequencies were close enough to 1497 MHz that the cavities could be brought up without difficulty, and gradients in excess of 5 MV/m were sustained without extensive vacuum faults. By 7 November the CEBAF linacs had run in a stable fashion with RF but without electron beam for more than a week – an opportunity unlike any since CEBAF's commissioning a decade ago. The newly installed high-performance cryomodule in south linac zone 21 had operated in a quiet mode at an equivalent RF energy gain of 60 MeV, considerably higher than its operating voltage (approximately 40 MeV) before the Isabel shutdown.

The coming months

The observations and data processing on CEBAF's cavities to date give a more than 95% confidence level in the energy estimation of the linacs, promising a 5 GeV physics run for the next six months followed by possible runs at 5.5 GeV and above later in 2004. The linac RF appears at least comparable to its pre-Isabel capability, notwithstanding the four nonfunctional cavities in north linac zone 5.

A single global phase adjustment allowed the electron beam to go through the entire linac complex, indicating that the RF phases were reproducible after the temperature cycle. A detailed analysis of cavity and waveguide vacuum response during cool-down is being performed to gain an understanding of the actual vacuum conditions and the molecular species contributing to them. This will help us to understand better the vacuum trips and to set them properly in order to eliminate unnecessary trips due to lack of knowledge in the software. The warm window temperatures of the cavities are being monitored carefully and simultaneously with residual gas analyses to provide input for a knowledge-based control system for the RF vacuum trips, which should lead to

improved linac performance.

Thanks to the dedicated work of the physicists, engineers and operating crew (including throughout the traditional four-day Thanksgiving weekend), the implementation of all the above has brought CEBAF back to operational readiness. The machine is now rising to the significant challenge, never attempted before, of developing electron beams with very stringent characteristics for simultaneous use in all three halls.

A continuous-wave parity-quality beam of 40 microamperes is required in Hall C for the G0 experiment, with very small relative "helicity correlations" in beam properties (e.g. less than 20 nanometers of movement in the beam spot when the beam helicity is flipped, averaged over the entire experimental run time). In Hall A a 100 microampere beam is needed for the hypernuclear experiment, with the stringent requirement of a relative energy spread of less than 25 in one million. Finally, a low-current but high-quality beam is destined for Hall B. The first beam for the physics experiment in Hall C, the G0 engineering run, was delivered on schedule on 2 December. The experimental programme in Hall B has also begun, while Hall A is being prepared for the start of the hypernuclear experiment in January.

The recovery of the FEL followed on the heels of that of CEBAF, and as I write today the high-power commissioning has fully resumed, with lasing achieved at nearly the kilowatt level and the laser power level continuing to rise steadily.

Acknowledgments

The achievements reported here were made possible by the dedication and hard work of the Jefferson Lab staff.

Further reading

Further information and data on cryogenics, SRF and beam studies can be found at: www.jlab.org/accelphys.html, while there are details of the CEBAF scientific programme and individual experiments at: www.jlab.org/sciprog.html.

Swapan Chattopadhyay, associate director, Jefferson Lab.

The time projection chamber turns 25

A time projection chamber (TPC) provides a complete, 3D picture of the ionization deposited in a gas (or liquid) volume. It acts somewhat like a bubble chamber, albeit with a fast, all-electronic read-out. The TPC's 3D localization makes it extremely useful in tracking charged particles in a high-track-density environment, and for identifying particles through their ionization energy loss (dE/dx). To honour the 25th anniversary of the TPC, a symposium was organized at the Lawrence Berkeley National Laboratory on 17 October 2003, with workshops that included presentations on the past, present and future of the TPC.

The TPC was invented by Dave Nygren at the Lawrence Berkeley Laboratory (LBL) in the late 1970s. Its first major application was in the PEP-4 detector, which studied 29 GeV e^+e^- collisions at the PEP storage ring at SLAC. Since then TPCs have been used to study e^+e^- collisions at PEP, at the TRISTAN collider, at the KEK laboratory and at the Large Electron Positron (LEP) collider at CERN. A TPC could also be the central detector at future e^+e^- linear colliders.

The device has also figured in a number of experiments involving heavy-ion collisions at machines such as LBL's Bevalac and the Relativistic Heavy Ion Collider (RHIC) at Brookhaven; and now the ALICE collaboration is building a large TPC to study heavy-ion collisions at the Large Hadron Collider (LHC). TPCs have also been used in a whole host of non-accelerator experiments.

TPCs in particle physics

The PEP-4 TPC (figure 1) was built to combine charged-particle tracking with good particle identification by measuring the specific energy loss (dE/dx) of charged particles. This 2 m long cylindrical TPC had an inner diameter of 40 cm and an outer diameter of 2 m, and had most of the features of newer TPCs.

Charged particles from e^+e^- collisions in the centre of the TPC ionized molecules in a mixture of 80% argon and 20% methane gas at 8.5 atmosphere. A central membrane (the cathode) that was

Since its birth 25 years ago, the time projection chamber has developed into a mature technology that is used in many fields, as **Spencer Klein** describes.

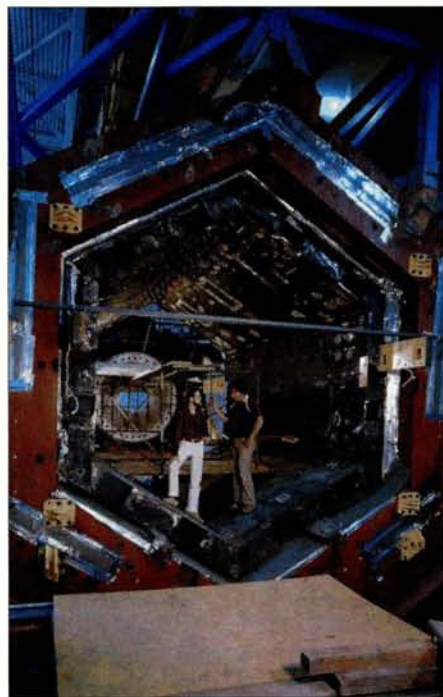


Fig. 1. Dave Nygren (left) and colleague stand in the PEP-4 experiment showing the TPC's eventual location. (Photo: LBNL.)

charged to -75 kV produced a strong electric field (figure 2, see p41). Under the influence of this field, ionization electrons drifted to one of the two end caps. A solenoidal magnetic field minimized the transverse diffusion and bent the charged particles to allow momentum measurement.

The end caps were divided into six sectors, each one containing a 183-anode multiwire proportional chamber (MWPC). Drifting electrons were accelerated in the strong electric fields around the wires and acquired enough kinetic energy to ionize the gas and produce an avalanche. A single drift electron produced about 1000 electrons in the wire.

The wire signals were sampled 10 million times per second to a 9-bit accuracy by an analogue storage unit based on a charge-coupled device (CCD). The signals were then digitized at a slower rate using inexpensive ADCs. The wire data were used to measure particle energy loss. Because of the high gas pressure, the ionization could be measured accurately and the dE/dx resolution achieved was an unprecedented 3%. This meant that pions, kaons and protons could be identified over most of the kinematic range.

Charged particles were tracked using data from 15 rows of 7×7.5 mm² metallic pads located under the wires. When an electron produced an avalanche on an anode wire, a cloud of positively charged ions remained in the gas. The image charge that formed on the metallic pads was then measured using a charge-sensitive preamplifier. By measuring the relative

charge on several adjacent pads, the ionization could be localized to approximately 250 μ m. These pads were also read out by the CCD system.

Later TPCs used many of the techniques pioneered by PEP-4. Some notable examples were the ALEPH and DELPHI TPCs at LEP, the TOPAZ experiment at TRISTAN and the early vertex chambers for the CDF experiment at Fermilab. The ALEPH TPC at LEP was one of the larger examples, measuring 3.6 m in diameter and 4.4 m in

length, with twice as many dE/dx measurements as the PEP-4 TPC. Both of the LEP TPCs used flash ADC systems instead of CCDs.

TPCs have also been used in a number of smaller experiments, such as in studies of muon decay and capture. The MuCap experiment at the Paul Scherrer Institute, for example, is building a 10 atmosphere hydrogen-gas TPC to measure muon lifetime.

TPCs for heavy ions

With the growth of research with relativistic heavy-ion collisions in the early 1980s, TPCs found another home. The 3D picture of ionization is ideal for tracking particles in high-density environments – hundreds or thousands of particles from a single collision – in which other detectors are overwhelmed by the huge multiplicity. The first large-acceptance TPC was in the Equation-of-State experiment (EOS), which studied heavy-ion collisions at energies of a few GeV per nucleon at the Bevalac. The rectangular EOS TPC measured $150 \times 96 \times 75$ cm. Electrons drifted downwards in a uniform electric field and were amplified by 3000 times in a MWPC. Data were read out from 15 308 pads, which sensed the image charge from positive ions in the same way as in PEP-4.

One key development in using TPCs in heavy-ion collisions concerns the electronics. In the high-track-density environment many pads are required and each pad detects signals from such a large number of tracks that it must be read out by a waveform digitizer. The CCD analogue storage units used with earlier TPCs required considerable power and difficult calibrations. They were also expensive. So EOS used a new technique, the switched capacitor array (SCA), developed by Stuart Kleinfelder.

The EOS SCA consists of an array of 128 capacitors, each connected to an input by a switch. By rapidly opening and closing the switches, the capacitors can be connected to the input one by one, forming an analogue storage unit. The sampling rate is matched to the drift time of electrons across the TPC, and the capacitors are read out by an inexpensive (but slow) analogue-to-digital converter. This scheme reduced the cost and power consumption of waveform digitizers, making TPCs a practical tool for the study of heavy-ion collisions. Packaging was integral to the success of the electronics. The preamplifiers, SCAs, digitizers and multiplexers were mounted directly on the TPC, and a handful of optical fibres replaced 15 000 cables.

After completing its service at the Bevalac, the EOS TPC was moved to the Brookhaven Alternating Gradient Synchrotron (AGS), where it was used to study heavy-ion collisions in experiment E895 and proton-ion collisions in experiment E910, and then to Fermilab for experiment E907 probing higher energy proton-ion collisions. By the time E907 ends, EOS will have seen more than 15 years of service at three different laboratories.

EOS pioneered techniques that were used in many other experiments. At CERN the NA35, NA36 and NA49 experiments all used TPCs to study heavy-ion collisions. NA49 took the construction of the devices to new volumes with four huge TPCs – the largest pair measuring $3.8 \times 3.8 \times 1.3$ m. The complex was read out by 182 000 SCAs; these SCA chips had integral ADCs.

The next step up in heavy-ion collision energy was the RHIC at Brookhaven, and it was natural that TPCs would play a key role. Two original TPC-based proposals merged into the STAR detector, which

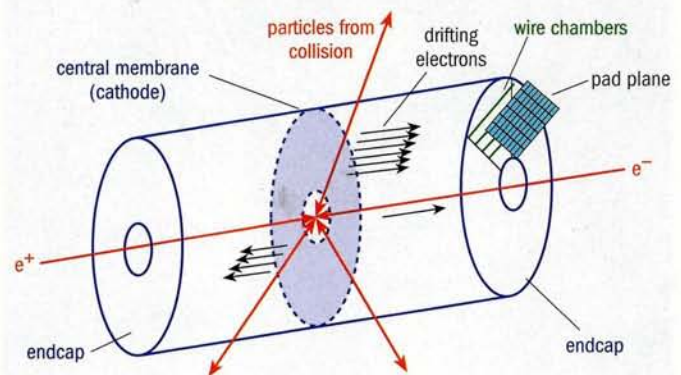


Fig. 2. A schematic view of the PEP-4 TPC showing the drift volume (dark blue), wire chambers (green) and pads (light blue).

has a 4 m diameter, 4 m long TPC at its centre. The TPC for STAR follows the geometry of the PEP-4 and ALEPH TPCs, but relies on 138 000 pads that are read out by SCA digitizers for both dE/dx and tracking information. The system is much faster than previous experiments: it can digitize an event containing 70 million volume elements to 10 bit precision and transmit it to the data-acquisition system in 10 microseconds. Figure 3 shows an event in the STAR TPC.

The ALICE heavy-ion experiment at the LHC is built around a mammoth TPC, 2.5×5.5 m with 750 000 pads. Analogue-to-digital-converter technology has matured and ALICE has replaced SCAs with custom integrated circuits, each containing 16×10 -bit ADCs with digital filters for tail suppression and zero-suppression circuitry. Data can be read out 1000 times per second.

Sometimes longitudinally drifting electrons may not be optimal. The collaborations for STAR and CERES (NA45 at CERN) have built cylindrical TPCs where the electrons drift outwards radially from a cylindrical central cathode towards anodes on a concentric outer cylinder. This geometry is advantageous when tracks are parallel to the cylinder's axis, but it introduces many complications. The electric and magnetic fields are no longer parallel, which leads to complex electron-drift trajectories. Curved pad-planes are then required, or the idealized cylindrical geometry must be complicated. For these reasons, radial-drift TPCs have a more complex structure and poorer resolution than linear-drift devices. However, sometimes these factors can provide a worthwhile trade-off.

Non-accelerator applications

TPCs are also used in many non-accelerator experiments such as double-beta decay and dark-matter searches. Often these experiments use dense media, such as liquids, where the active detector volume also serves as the experimental target (for neutrinos or dark matter) or a radioactive source (for double-beta decay, proton decay, etc.).

The first laboratory observation of double-beta decay, in 1987, by Steve Elliott, Alan Hahn and Michael Moe, used a thin layer of ^{82}Se deposited on the central cathode of a TPC. Though very successful, this technique was limited to relatively small sample volumes. Most current efforts use a single material, such as liquid ^{136}Xe , as both a source and drift medium. One particularly ambitious group, the Enriched Xenon Observatory collaboration, plans ▷

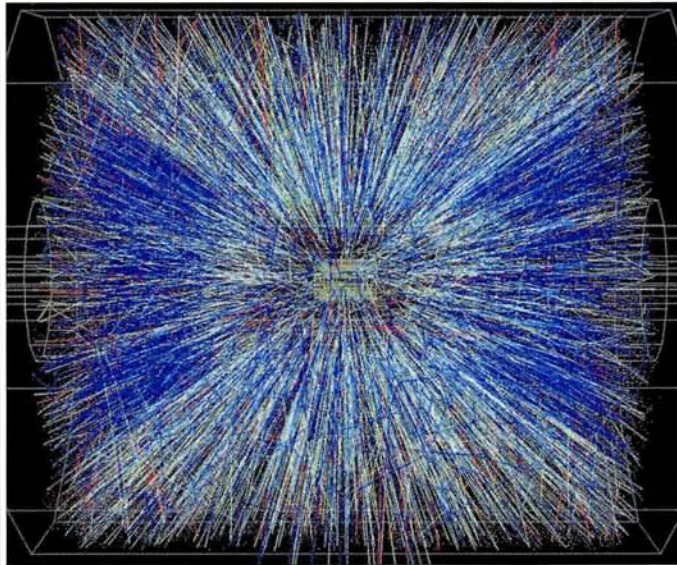


Fig. 3. A side view of the tracks from a 200 GeV per nucleon pair gold-on-gold collision at RHIC, as reconstructed in the TPC of the STAR experiment.

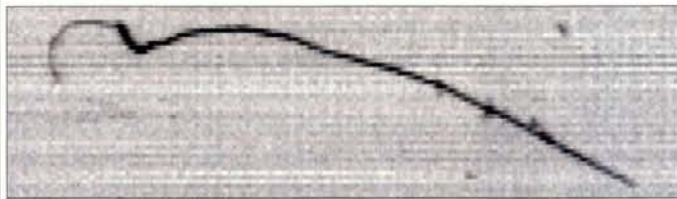


Fig. 4. This image shows a muon-to-electron decay recorded in the liquid-argon TPC that is used in the ICARUS project. The muon travels about 60 cm before decaying. The decay produces a pronounced kink.

to use a liquid-xenon TPC to localize double-beta decay events and then insert a probe into the xenon to extract the ^{136}Ba daughter product for detailed study.

Liquid-xenon TPCs are also being used as imaging detectors to track photons with energies of a few MeV. The photon directions are determined by reconstructing double-Compton interactions. A liquid-xenon imager has already been used to study the galactic centre. The technology might also be used to search for photons from smuggled nuclear material.

Liquid-argon TPCs have been studied for many years under the aegis of the ICARUS (Imaging Cosmic and Rare Underground Signals) project. The current T600 prototype, based on 476 tonnes of liquid argon in a volume of 275 m^3 , recently completed a 68 day engineering run. The collaboration's goal is a 3000 tonne detector in the Gran Sasso Laboratory in Italy, which will study solar and atmospheric neutrinos, terrestrial neutrinos from CERN's Super Proton Synchrotron (SPS), and also proton decay. The solar neutrino study may be quite challenging in terms of backgrounds.

One interesting idea being pursued by several groups is to use drifting ions rather than drifting electrons in a gas or liquid. Both positively and negatively charged ions have been considered; the latter can be formed when an ionization electron attaches itself to a

previously uncharged molecule. The advantage of ion drift is that the diffusion can be much smaller. One big drawback is that positively charged ions cannot induce avalanches, greatly complicating the detection of the signal. The much slower drift velocity seems to offer both advantages and disadvantages. Ion-drift TPCs have been considered for a variety of applications, including double-beta decay and dark-matter and axion searches.

Future directions

The most exciting technological developments in gaseous TPCs concern electron amplification, where two new technologies are replacing wire chambers. Gas Electron Multipliers (GEMs) are plastic foils that are metal coated on both sides, with 50–100 μm diameter holes punched in them.

The metal coatings are charged to a potential difference of a few hundred volts, creating strong electric fields in the holes. Electrons drifting into the holes ionize the gas, creating an avalanche much like that formed around anode wires in conventional chambers. GEMs have several advantages over wire chambers. They are easily supported, eliminating wire sag and instability, and can be placed very near to read-out pads, reducing diffusion after amplification. The high hole density provides an even amplification over a large area. Positive ions generated in the wire avalanche drift naturally away from the amplification region, eliminating the build-up of space charge in the amplification region.

Micromesh gaseous structure chambers (Micromegas) use a thin metal mesh instead of anode wires. The mesh can be supported a small distance above the pads. A simple wire grid above the Micromegas produces a potential difference with the mesh, so electron avalanches form in the strong electric fields around the mesh elements. Like GEMs, Micromegas can be placed very close to read-out pads, greatly reducing diffusion. They also have the same advantage as GEMs for positive-ion elimination.

Both GEMs and Micromegas have a somewhat lower gain than wire chambers. However, two or three layers of GEMs or Micromegas can be cascaded by placing the foils or meshes on top of each other, thereby multiplying the gains. GEMs and Micromegas are beginning to replace wire chambers in some experiments, most notably in the COMPASS experiment at the SPS at CERN. They are also prominent in R&D for future linear colliders and for upgrades of the detectors at RHIC.

Over the past 25 years, TPCs have grown into a proven, mature and flexible technology. With these new developments the next quarter century looks equally bright.

Further reading

J A MacDonald (ed) 1984 *The Time Projection Chamber AIP Conf. Proc.* **108** (AIP, New York).

Jay N Marx and Dave Nygren 1978 *Physics Today* October 46.

For more about the Time Projection Chamber symposium, see www-tpc.lbl.gov/symposium/.

For more about the use of TPCs at future linear colliders, see www-lc.lbl.gov/tpc/meeting/.

Spencer Klein, Lawrence Berkeley National Laboratory.

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PRIZES

Dyson and Rubakov share the Pomeranchuk Prize for 2003

Freeman Dyson, from the Institute for Advanced Study in Princeton, and Valery Rubakov, from the Institute for Nuclear Research (INR) in Moscow, have been awarded the Pomeranchuk Prize for 2003, which is administered by Moscow's Institute for Theoretical and Experimental Physics (ITEP).

Dyson, who is one of the founders of modern quantum electrodynamics (QED), receives the prize for outstanding contributions to quantum field theory. With the publication in 1949 of his papers on QED, there was at last a general and systematic formalism physicists could easily learn to use, and which provided a common language for the subsequent applications of quantum field theory to problems in physics. The famous Schwinger–Dyson equations are still used to solve many problems in quantum



Freeman Dyson (left) and Valery Rubakov.

field theory, not only in QED. Nowadays, Dyson is working on ecological problems, in particular the issue of global warming.

Rubakov, who receives the prize for the theoretical analysis of the baryonic asymmetry of the universe at the electroweak scale, is one of the best known Russian theorists. His popular papers include those on monopole catalysis and, together with Vladimir Kuzmin and Mikhael Shaposhnikov, on the effect of electroweak non-conservation of baryon and lepton numbers at high temperatures, currently a cornerstone of modern astroparticle physics. Recently, Rubakov has been working on the brane world; indeed, he and Shaposhnikov suggested the possibility that we are living on a brane as early as 1983. These ideas have been greatly boosted by recent developments.

Indian awards for the physics of plasmas

The Indian Physics Association has named the recipients of its prestigious R D Birla Memorial Award for 2002; they are Preshman Kaw of the Institute of Plasma Research, Ahmedabad, and Bikash Sinha of the Saha Institute of Nuclear Physics and Variable Energy Cyclotron Centre, Kolkata. The R D Birla Award is given biennially for excellence in pure physics, and previous winners have included Nobel laureates Abdus Salam and

Subrahmanyan Chandrasekhar.

Sinha receives the award for his sustained and outstanding contribution to the field of quark–gluon plasma (QGP) physics, proposing signals for QGP that are now used as an essential part of the experimental set up for the nucleus–nucleus programme at the Relativistic Heavy Ion Collider at Brookhaven and for the future Large Hadron Collider at CERN. He has also contributed significantly to the consequences of the density inhomogeneity created in the early universe due to a possible first-order phase transition from QGP to hadrons. In addition, Sinha has been responsible for establishing an

internationally recognized school of QGP physicists in India, which carries out experiments in relativistic heavy-ion collisions at CERN and Brookhaven.

Kaw, an internationally acclaimed plasma physicist, has made several pioneering contributions to the physics of nonlinear collective phenomena in plasmas and magnetically confined fusion plasmas. These contributions include the laser–plasma interaction, thermonuclear fusion and astrophysical dusty plasmas. He has also been mainly responsible for starting a major programme in plasma research and thermonuclear fusion at the Institute for Plasma Research in India.

Young physicist wins Gustav Hertz Prize

Klaus Blaum, of GSI Darmstadt and the project leader of the ISOLTRAP experiment at CERN, has been awarded the Gustav Hertz Prize for 2004 for his outstanding work on the mass determination of unstable atomic nuclei. This is the highest award given by the German Physical Society to a young physicist without a professorship. Blaum extended the measuring capability of the ISOLTRAP experi-

ment at CERN's ISOLDE facility by installing a source of carbon clusters. These provide the reference of choice for precision mass spectrometry, since the atomic mass standard is based on the mass of ^{12}C . Using carbon clusters as mass references in this way allows ISOLTRAP to make higher precision and absolute atomic mass measurements on short-lived isotopes.



AWARDS

New Year knighthood for Tim Berners-Lee

Tim Berners-Lee has been awarded his country's highest honour – a knighthood – in the UK's New Year's Honours List for his work, while at CERN, on the "World Wide Web". The idea for the Web goes back to March 1989 when Berners-Lee wrote a proposal for a "Distributed Information Management System" for the high-energy physics community. By Christmas 1990 this had become the World Wide Web, with its first servers and browsers running at CERN. On 30 April 1993 CERN issued a statement declaring that the software was in the public domain, thus

opening the floodgates to Web development around the world.

In the same honours list Roger Cashmore has been made a Companion of the Order of St Michael and St George (CMG) "for his services to international co-operation in particle physics". Cashmore was CERN's director for collider programmes between 1999 and 2003, and is now principal of Brasenose College, Oxford. Chris Damerell of the Rutherford Appleton Laboratory has also received the Order of the British Empire (OBE) for services to particle physics.



CELEBRATIONS

DESY holds colloquium for Schmidt-Parzefall

On 27 November 2003 the Faculty of Physics at Hamburg University and the DESY laboratory held a special colloquium – a "Festkolloquium" – in honour of Walter Schmidt-Parzefall, who retired on 31 March. After studying in Göttingen and Karlsruhe, Schmidt-Parzefall joined the group of Klaus Winter at CERN in 1970, where he was involved in experiments at the Intersecting Storage Rings and in the preparation of the CHARM neutrino experiment. He then went to DESY in 1977 to work at the DORIS electron-positron collider, where as spokesperson of DASP (between 1977 and



Walter Schmidt-Parzefall (right) and Michael Danilov at the Festkolloquium in November.

1980) and ARGUS (between 1978 and 1990) he played a decisive role in both experiments, contributing to the outstanding scientific results of the ARGUS collaboration. He became professor at the University of Hamburg in 1990, and was elected director of the 2nd Institute of Experimental Physics one year later. Schmidt-Parzefall is seen in the picture with Michael Danilov of the Moscow Institute for Theoretical and Experimental Physics. Danilov reviewed "20 Years with ARGUS" for the approximately 300 participants at the Festkolloquium.

J C Sens celebrates his 75th birthday

One of the pioneers of the first muon $g-2$ experiments at CERN, "Hans" (J C) Sens, celebrated his 75th birthday on 30 November 2003. Sens, who gained his PhD working on muons with Valentin Telegdi at the University of Chicago, came to CERN in 1958 at the same time as Leon Lederman, and together they initiated a study of the methods for

measuring the muon $g-2$. In 1966, after working on various experiments with muons, Sens left CERN to join the Foundation for Fundamental Research on Matter in the Netherlands and the University of Utrecht. With the advent of the Intersecting Storage Rings (ISR) at CERN, he became spokesman of the CERN-Holland-Lancaster-Manchester collaboration at the ISR.

In 1976, while on leave of absence in the US, Sens joined Lederman's experiment that discovered the upsilon particle and hence the fifth quark, "bottom" or "beauty". He later

spent seven years at SLAC (between 1979 and 1986) working with fellow Dutch collaborators on electron-positron and photon-photon collisions at the PEP collider. Sens then returned to particle physics at CERN, and worked on the development of the analysis programs for the L3 experiment at the Large Electron Positron collider. He retired in 1993, but has since spent time as a visiting scientist at the Academia Sinica and the National Central University of Taiwan, and is now at the Institut Non-Linéaire de Nice.

LABORATORIES

NIKHEF appoints Karel Gaemers as new director

Karel Gaemers has been appointed director *ad interim* of NIKHEF, the Dutch national institute for subatomic physics, as of 1 January 2004. Gaemers has been full professor in theoretical physics at the University of Amsterdam since 1980, and served as scientific director of the high-energy physics section of NIKHEF between 1989 and 1995. He was

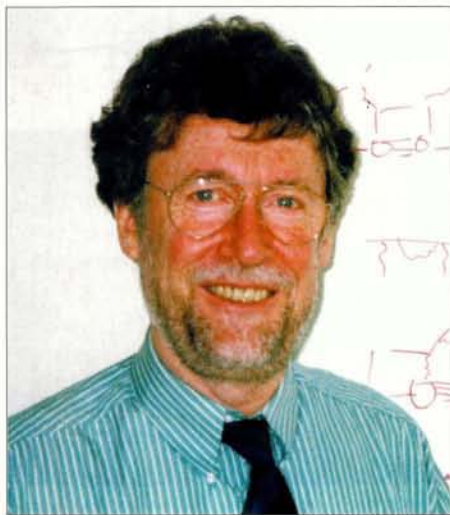
a member of CERN's scientific policy committee between 1996 and 2002, and has also been a member of the extended scientific councils of DESY and RECFA (Restricted ECFA), and of the executive committee of the European Physical Society. Former NIKHEF director Jos Engelen has moved on to CERN to become chief scientific officer (see p5).



DESY director-general stays in office for another five years...

Albrecht Wagner, the chairman of the board of directors of the DESY research centre, will officiate for a further five years after the completion of his first term of office in July 2004. This decision was made by the Administrative Council of the research centre at its meeting on 4 December 2003, and was on the basis of a recommendation by the DESY Scientific Council.

Wagner has worked on experiments at DESY's DORIS and PETRA storage rings, and at CERN. In 1991 he took up a post as professor of experimental physics at the University of Hamburg and became the research director of DESY. Wagner took over as the chair of the DESY board of directors in July 1999.



...while Henning continues at GSI...

The governmental supervisory board of the German heavy-ion research centre, GSI (Gesellschaft für Schwerionenforschung mbH) Darmstadt, has extended the term of office of Walter Henning as scientific director until 31 March 2007. Henning has held this position since 1 October 1999, during which time the GSI Future Project was proposed and approved. In this project a double-ring facility of 1100 m circumference will be built by 2012, followed by a system of cooler-storage rings and various experimental halls. The project is expected to cost €675 million and will be funded by the German federal government and the state of Hesse. Promoting the Future Project while minimizing interference with existing experiments and commissioning the therapy accelerator at the University Hospital, Heidelberg, are Henning's main goals for the coming term.

...and Jefferson Lab announces Thomas as the new head of its Theory Group

Anthony (Tony) Thomas has accepted the position of chief scientist and head of the Theory Group at Jefferson Lab. Thomas brings 30 years of experience in nuclear and particle physics to Jefferson Lab, where he will lead an internationally recognized theory group. His interests include chiral symmetry, lattice QCD, quark models, structure functions, nuclear forces, symmetries and symmetry breaking.

Thomas comes to Jefferson Lab from a position as Elder Professor of Physics – the chair first held by William Henry Bragg – in the Department of Physics and Mathematical Physics at the University of Adelaide in South Australia. He is also director of the Special Research Centre for the Subatomic Structure of Matter and the National Institute for Theoretical Physics.



SUMMER STUDENTS

New initiative benefits Greek students

The National Technical University of Athens (NTUA) is Greece's oldest and most prestigious educational institution in the field of technology, and has a long tradition in nuclear and high-energy physics research and in the development of detectors and electronics instrumentation. Nicholas Christofilos, whose pioneering work contributed to the development of induction acceleration at the Lawrence Livermore National Laboratory in the US, was an NTUA graduate, and Theodore Kouyoumzellis, professor at NTUA, was the Greek scientific delegate at CERN for many years and put his personal stamp on the development of high-energy physics both at NTUA and in Greece. Now this tradition is continuing with a new initiative, through which physics and engineering students from NTUA can benefit from time at CERN.

In 2002 NTUA set up, through former rector Themistoklis Xanthopoulos and his colleagues Simos Simopoulos (former vice-rector) and Evangelos Gazis, an agreement for a CERN-NTUA educational protocol, under which students from NTUA can participate in CERN's educational activities (as summer, technical and doctoral students and as fellows). This protocol provides a special arrangement for the acceptance of NTUA students, with financial support from NTUA complementing support from CERN.

The summer of 2003 saw the first results of the agreement when four NTUA students from the faculty of Applied Mathematical and Physical Sciences received sponsorship to



In 2003 the CERN summer students from the National Technical University of Athens (NTUA) included four sponsored through the newly established CERN-NTUA educational agreement, as well as two who participated under the standard CERN summer student scheme. Here Magda Lola of the CERN Recruitment Service (third from left), Evangelos Gazis of NTUA (centre) and Claude Détraz, director for fixed target and future programmes at CERN (fourth from right), pose with all six students, from left to right, Dimitris Skipis, Dimitris Kouzis-Loukas, Ilias Holis, Dimitris Perrakis, Iro Koletsos and Nassia Assiki.

attend the CERN summer student programme. In addition, two more NTUA students from the Faculty of Electrical and Computer Engineering received normal CERN summer studentships, and so a small NTUA student community made its appearance at CERN.

The excellent results of the students and their enthusiastic feedback have confirmed that NTUA should continue this effort. The stay in the unique learning environment of CERN is seen as providing the students with a big

push in their careers. Not only is the laboratory a major source of new scientific and technological knowledge, but the vitality of more than 7000 researchers using CERN's facilities creates a continuous exchange of ideas and people from all over the world. The current NTUA rector Andreas Andreopoulos and vice-rectors Panagiotis Kottis and Manolis Dris are therefore planning to continue with and improve this successful educational agreement.

VISITS

Italian president tours CERN

The president of the Italian republic, Carlo Azeglio Ciampi, visited CERN on 2 December, where he met some of the Italians working at CERN. Italians are the second-largest nationality at CERN, numbering around 1500, which is about one-sixth of the total number of visitors and staff working at the laboratory. The president visited the CMS assembly hall and the LHC superconducting magnet test hall before meeting the CERN community, in

particular Italian personnel, in the main auditorium. There he emphasized the role of CERN as a transnational model for research that has not only achieved great results in science but is also a powerful vehicle for progress in other fields. "CERN stands as the demonstration of the great results that science can achieve [...] when it succeeds in getting all the main players in international scientific co-operation involved," he said.



President Ciampi (right) listens intently to Fabiola Gianotti of the ATLAS collaboration during his visit to CERN in December.

VISITS



CERN's new director-general **Robert Aymar** (second left) was present when the 2003 edition of the "France at CERN" exhibition was opened on 23 September by **Bernard Frois** (second right), director of the Department for Energy, Transport and Environment of the French Ministry for Research and New Technologies. Here they are seen together with, from left to right, **Jean-Claude Brisson**, ILO, **Françoise Le Moign**, assistant general consul at Geneva, **Alain Guillouët**, head of the economic mission in Switzerland, French Embassy, **Thierry Boquien**, Ubifrance, French agency for international development of companies and **Claude Détraz**, director for fixed targets and future programmes at CERN.



Petr Mares, deputy prime minister for research and development, human rights and human resources of the Czech Republic, visited CERN on 9 December 2003. While at the laboratory, he toured the assembly halls and underground cavern for the ATLAS experiment, the test facility for the LHC superconducting magnets, the main computer centre and the underground cavern for the ALICE experiment. Here, he is seen, on the left, in an ALICE cleanroom together with **Frantisek Kozel**, deputy minister of vice prime minister, and **Wolfgang Klempt** from CERN/ALICE (right).

MEETINGS

The 7th DESY Workshop on Elementary Particle Theory "Loops and Legs in Quantum Field Theory" will take place on 25–30 April 2004 in Zinnowitz (Usedom Island), Germany. For further information see www.zeuthen.desy.de/theory/LL2004.

The International Symposium "40 years of colliding beams" (COLLID04), a joint SLAC–Novosibirsk meeting, will be held at the Budker Institute of Nuclear Physics in Novosibirsk, Russia, on 17–18 May. The symposium will be dedicated to the anniversary of the first electron–electron beam collisions. Its programme will review the history of the colliding beam experiments, discuss the status of the current programmes and focus on the future prospects for high-energy physics at e^+e^- colliding beam machines. For more information e-mail collid04@inp.nsk.su or see www.inp.nsk.su/events/conf/collid04.

The 9th Topical Seminar on "Innovative particle and radiation detectors" will take place at the University of Siena, Italy, from 23–26 May. Attendance will be by invitation. Interested physicists should write to the organizing committee, indicating name, address,

affiliation and, if applicable, the title of a contribution. The deadline for submitting an abstract is 15 March. For further information see www.bo.infn.it/sminiato/siena04.html.

Neutrino 2004 – The 21st International Conference on Neutrino Physics and Astrophysics, will be held in Collège de France, Paris, on 14–19 June. The scientific programme will cover the latest developments in neutrino physics, astrophysics and related topics through a set of invited talks and a poster session. Participation is by invitation. For more details see <http://neutrino2004.in2p3.fr>.

QCD 04, the 11th Montpellier International Conference, will be held on 5–9 July. As in previous years, different theoretical and experimental aspects of quantum chromodynamics will be discussed, and contributions from young post-docs will be encouraged. For further information see www.lpm.univ-montp2.fr:6714/~qcd/qcd.html.

HEP-MAD 04, the 2nd Madagascar International Conference in High-Energy Physics, will be held from 26 September to 2 October. The conference, which is part specialized meeting and part introductory school, will discuss different aspects of high-energy and

astroparticle physics. For more details see www.lpm.univ-montp2.fr:6714/~qcd/hep.html.

CHEP '04, the next in the series of computing in high-energy physics conferences, will take place in Interlaken, Switzerland, from 27 September to 1 October. The CHEP conferences provide an international forum to exchange information on computing experience and the needs of the community, and to review recent, ongoing and future activities. CHEP '04 is organized by CERN, on the occasion of its 50th anniversary. Registration should open early in 2004. For further details see www.chep2004.org.

The IEEE 2004 Nuclear Science Symposium, Medical Imaging Conference, Symposium on Nuclear Power Systems and 14th International Workshop on Room Temperature Semiconductor X- and Gamma-Ray Detectors will be held in Rome on 16–22 October. This conference represents a unique occasion for scientists and engineers to participate and present their work in a variety of subjects related to nuclear science and medical imaging. The deadline for the submission of abstracts is 15 May. For further information see <http://nss-mic-rtsd-2004.df.unipi.it/nsshome2004.html>.

OBITUARY

Jan Kwieciński 1938–2003

Jan Kwieciński, head of the Department of Theoretical Physics at the Henryk Niewodniczański Institute of Nuclear Physics in Cracow, Poland, died unexpectedly on 29 August 2003.

Jan graduated from the Jagiellonian University in Cracow in 1960 with a degree in theoretical physics. He then devoted his entire scientific career to the Institute of Nuclear Physics, which was created in 1955 by Henryk Niewodniczański. There he joined the theory group formed by Wiesław Czyż. The group later transformed into a department, which was headed by Jan from 1988 until his death.

From the beginning Jan was a very independent researcher with a strong mathematical background. As Czyż recalls: "At first I made an attempt to introduce him to some simple problems in nuclear physics, but I quickly realized that he was 'a cat who walks his own path'." The theory of strong interactions was the major focus of Jan's research. His early work concentrated on the analytical properties of amplitudes for high-energy hadron collisions. He successfully applied Reggeon calculus to the dual theory of the scattering matrix and high-energy nuclear collisions. Soon after the formulation of quantum chromodynamics (QCD), he studied the Regge limit of QCD, which he successfully applied to the description of semi-hard processes. In 1980 he wrote a seminal paper on a three-gluon exchange with odd charge parity, where he derived the odderon equation now widely known as the BKP (Bartels–Kwieciński–Praszalowicz) equation.

The last 15 years of Jan's scientific activity were dominated by the physics of deep-inelastic scattering at small values of the

Bjorken variable x . His papers with Alan Martin were vital for the experimental programme at HERA in DESY. Jan was one of the first to understand the implications of the increase of gluon density at small x on the behaviour of the total cross-sections such as in the structure function F_2 or the minijet cross-section. He also pioneered studies of nonlinear parton shadowing effects. Recently, with his Cracow collaborators, he discovered a new type of scaling in deep-inelastic scattering at small x .

Jan's scientific work was strongly valued by experimentalists, who were always eager to enter into discussions and collaborate with him. Together with experimentalist Barbara Badelek he wrote important papers on nucleon structure functions at low Q^2 , spin structure functions and nuclear shadowing. In the last few years he mostly worked on projects oriented towards the future, such as cosmic-neutrino interactions at the highest energies and the application of unintegrated parton distributions to Higgs production at the LHC.

Jan formed collaborations with physicists in many physics institutes around the world, and made lengthy visits to several of them. In particular he had a long and fruitful collaboration with the University of Durham in the UK, where he was a visiting professor. In all these places he made many friends, who were impressed by the depth of his theoretical insight into current experimental results.

In recognition of his scientific achievements Jan was elected a member of the Polish Academy of Arts and Sciences and the Polish Academy of Science. Grey College of the University of Durham also awarded him an honorary fellowship. In addition, he was a



Photo by Teresa Kwiecińska.

member of the editorial boards of *Acta Physica Polonica B* and the *European Physical Journal C*.

Jan was also an inspirational teacher. His enthusiasm and competence attracted many research students, both in Cracow and the other places he visited. He was always generous to people, full of trust and respect, and ignited others with his enthusiasm. His gentleness in treating people led one of his English friends to say about him: "absolutely the kindest man I have ever met in my whole life."

Jan had three great passions in life: physics, music and mountains. He was a keen pianist and members of Grey College can fondly recall his performances, which were sometimes played in a duet. Jan was also a fervent mountain hiker and skier. His long-lasting love of mountains ended on a mountain trail. He is sorely missed. *Krzysztof Golec-Biernat and Leonard Leśniak, Institute of Nuclear Physics in Cracow.*

NEW PRODUCTS

COMSOL has announced the release of FEMLAB 3, the latest version of FEMLAB, which uses the finite-element analysis method to solve models of physical phenomena. Compared with its predecessor, this new product can compute some models as much as 20 times faster while using up to 20 times less memory. The new software also has access to a library of more than 200 completely solved and fully documented models of commonly

encountered systems in fields such as waveguides, antennas and micro-electromechanical systems. For further details call +44 1865 338 036 or see www.uk.comsol.com.

Thales Computers now offers support for the Linux operating system for its low-cost, low-power VCE405 "connectivity engine", a rugged single board computer for I/O operations. The company has also announced support for 2eSST transfers on VME systems running LynxOS. For further information call

+1 800 848 2330 or see the website at www.thalescomputers.com.

X-tronix has released a new vacuum components catalogue, which lists more than 1500 items with an emphasis on flanges, viewports, feedthroughs, gauges and many supplies for vacuum and thin-film applications. Some 300 engineering drawings, pictures and graphs support the product descriptions. For further details contact Xavier Gorra or Mirjam Tissot, tel +41 21 802 5490, or see www.x-tronix.com.

LETTERS

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

That third pion

In his recent book *Facts and Mysteries in Elementary Particle Physics* (*CERN Courier* October 2003 p52) Tini Veltman states that some people believe Marietta Blau should have shared the 1950 Nobel prize with Cecil Powell for the development of the nuclear emulsion technique. He also credits me, much too generously, with the discovery of the pion. Since the discovery of the pion and of strange particles in 1947 really kick-started the 50 year history of high-energy physics at accelerators, perhaps I may pass a few comments as one of the last survivors of that era.

The development of the nuclear emulsion method for recording high-energy charged particles involved several physicists worldwide during the 1930s. The work of the Viennese ladies Marietta Blau and Hertha Wambacher (an unlikely pair – one a Jewess and the other an active Nazi party member) is well known (see pXX). They exposed Agfa emulsions sensitized with pinakryptol yellow on the Zugspitze and Hafelekar and recorded a few nuclear disintegrations. Comparable contributions were made at that time by Zhdanov in Russia, Powell in England, and Wilkins, Rumbaugh and Locher in the US. However, the real breakthrough was made in 1946, when at the behest of a panel set up by Blackett and chaired by Rotblat, an industrial chemist, C Waller of Ilford Ltd in Essex, produced the first “concentrated” emulsions, with four times the normal halide/gelatine ratio, sensitive enough to make the tracks of

mesons visible for the first time.

With regard to the discovery of the pion, it is true that when at Imperial College I published the first example of nuclear capture of a negative pion in January 1947. Occhialini and Powell at Bristol published six more examples two weeks later. The first two examples of decay at rest of a positive pion to a muon (and neutrino) were published by Lattes, Occhialini, Muirhead and Powell in May 1947. In the following July, I observed a third example, but although it appeared in my thesis, I never published it. Valerie Gibson of Cambridge once asked me: “Why not?” My reply was that the two Bristol events gave the same range for the muon, convincing me that it was a simple two-body decay. Confirmation from a third event was not really necessary and I didn’t want to clog the literature! However, confirmation for the world at large really had to wait until October 1947, when the Bristol group published 10 more complete pi–mu decays from emulsions exposed on Mount Chacaltaya.

Tini Veltman has kind words for Guiseppe (Beppo) Occhialini, who indeed missed out on sharing a Nobel prize with either Blackett or Powell. Occhialini spent the Second World War in Brazil, and became a mountain guide. I am told that even now if you get lost in the Andes and shout “Beppo” loudly enough, people will come to your rescue. He is also famous through the BeppoSax satellite named after him, which made a major breakthrough in pinning down the origin of gamma-ray bursts. So Occhialini’s name lives on.

Don Perkins, Oxford.

Why Weep for ISABELLE?

I would like to thank the *CERN Courier* and Gordon Fraser for putting out a fair review of

my rather unusual book *Weep for ISABELLE*. (*CERN Courier* November 2003 p48). Just seeing the review in print gave me delight, and I really have no bones to pick with it. On the other hand, Gordon chose to take a stab at the question of what drove me to write the book. This is precisely the territory, that of what makes people do what they do, that I explore in great depth in my 600-page tome. It is a tough place to manoeuvre in, filled with dark alleys, dead-ends and unseen obstacles. Gordon concludes that I was embittered by a perceived injustice done to me, the obvious implication being that I wrote the book to try to get back at those who hurt me. It was a catharsis, he says, presumably to purge me of the demons of the night.

Actually, his interpretation sounds quite logical, quite right. But only from a distance! If you move closer in order to see the reality in detail, you’ll find that there is another very different picture. True, I was devilishly impatient with those who wouldn’t heed my advice. But my reaction was not disgruntlement. In fact I naively fought back, becoming a thorny provocateur. The truth is that I was having fun with the whole dirty business.

Ironically, in the end, ISABELLE’s continued downhill slide came to liberate me. I got on with my life and built a highly varied career, not only in science but also in government management, education, science community work, writing and now university teaching. In short, I happen to be a happy man. As for my book, wanting to try my hand at generating one, I opted to write about a major part of my professional life. In doing so, and sticking to the principles I was brought up with, my story tells it like it was.

Mel Month.

CORRECTIONS

In the November issue, in the article “International interactions at Fermilab”, on p17 we see Youhei Morita, deputy head of the Public Relations Office from the KEK

laboratory, making changes to a poster at the Lepton Photon 2003 conference at Fermilab. As the picture clearly shows, the poster is from the K2K experiment, not the BELLE experiment as erroneously stated in the caption.

Also in the November issue, the article “French industry shows its wares” in the People section (p37) was accompanied by a photo from a previous exhibition, in 2001. For this year’s exhibition, see p48 of this issue.



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FACULTY POSITION IN EXPERIMENTAL HIGH ENERGY PHYSICS

The Department of Physics at the University of California, Riverside, is seeking an outstanding individual for a faculty appointment in experimental high energy physics. The appointment will be at the tenure track assistant professor level. The position is intended to strengthen our program of electron-positron collision physics with the BABAR experiment at SLAC. UCR has a well established program in the area of electron-positron collisions. In addition to BABAR, we participate in the OPAL and L3 experiments at LEP. The Department also has strong efforts in the DO and CMS hadron collider programs, theoretical high energy physics, heavy ion physics, condensed matter physics, and astrophysics.

The successful candidate is expected to initiate and maintain a vigorous research program with international prominence, and to demonstrate excellence in teaching at both the undergraduate and graduate levels. A Ph.D. in physics and postdoctoral experience in experimental high energy physics are required.

Salary will be competitive and commensurate with qualifications and level of appointment.

Candidates should submit a letter of application, curriculum vitae, statement of research interests, and list of publications to:

Chair, Experimental High Energy Physics Search Committee
Department of Physics
University of California, Riverside
Riverside, CA, 92521-0412
USA

Full review of applications will begin January 12, 2004.
The position will remain open until filled.



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UNIVERSITY OF TORONTO

Department of Physics

TENURE TRACK FACULTY POSITION in EXPERIMENTAL PARTICLE PHYSICS



The Department of Physics at the University of Toronto plans to make a tenure track appointment in experimental particle physics at the rank of Assistant Professor, with starting date of July 1, 2004.

The University has a strong experimental particle physics program, consisting of seven faculty members playing leading roles in the ATLAS experiment at CERN, the CDF-II experiment at Fermilab and the ZEUS experiment at DESY. This is reinforced by a strong group in theoretical particle physics and in astrophysics. This appointment will allow the candidate to focus on developing a successful research program.

For this position, we seek candidates with a Ph.D. in physics and proven or potential excellence in both research and teaching. We invite prospective candidates to visit our home page at www.physics.utoronto.ca. The salary will be commensurate with qualifications and experience.

Applicants should submit hard copies only of a curriculum vitae, list of publications, and research plan, and must arrange for at least three letters of reference, to be sent to:

Professor Henry M. van Driel, Chair,
Department of Physics, University of Toronto,
Toronto, Ontario, Canada M5S 1A7

Applications will be reviewed beginning March 15, 2004 until the position is filled.

The University of Toronto offers the opportunity to teach, conduct research and live in one of the most diverse cities in the world. The University is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, persons with disabilities, members of sexual minority groups and others who may contribute to further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.



Research Associate Experimental Particle Physics

A Research Associate position is available with the particle physics group at TRIUMF and the University of British Columbia working on rare kaon decay experiments E949 and KOPIO at Brookhaven National Laboratory. These challenging discovery-oriented experiments offer unique potential for probing quark mixing and CP violation that is competitive with and complementary to future B physics measurements. Participation in other projects associated with the new Laboratory for Advanced Detector Development (LADD), such as liquid xenon detectors, is also possible. In addition to a recent PhD in experimental particle physics, applicants should have strong interest and experience in detector technologies, electronics, simulation, and data analysis.

The position will be based at TRIUMF, in Vancouver, British Columbia. Applications from qualified candidates should include a detailed CV and at least three reference letters sent to the following address, or fax, prior to March 31, 2004. TRIUMF Human Resources, Competition No. 924, 4004 Wesbrook Mall, Vancouver, B.C. V6T 2A3 Canada. Fax: (604) 222-1074. For further information contact Douglas Bryman (doug@triumf.ca).

Postdoctoral Research Associate in Particle Physics Institute of Physics, Academia Sinica, Taiwan



The Particle Physics Group at the Academia Sinica invites applications for several Postdoctoral Research Associate positions to support its experimental and theory programs. Visiting Scientist positions are available for more senior candidates.

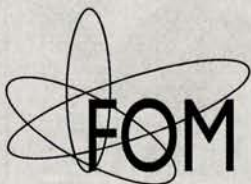
Academia Sinica is the leading basic research institution in Taiwan. The experimental group has active participation in the CDF, ATLAS, AMS, LEPs experiments and the GRID project. It also heads the TEXONO neutrino program and a sonoluminescence project. The theory group covers all major areas of particle physics and cosmology, particularly the studies of B/CP physics, cosmic microwave background and quantum computation. Positions can be made available in all these fields to match the candidates' research interest. For details, see <http://hepmail.phys.sinica.edu.tw/~recruit>.

Applications (including curriculum vitae and three reference letters) and inquiries can be forwarded to: **Dr. Henry Wong, Institute of Physics, Academia Sinica, Taipei 11529, Taiwan RoC** (htwong@phys.sinica.edu.tw). Applications are accepted until the positions are filled. We particularly welcome candidates with international experience to apply.

PhysicsJobs @physicsweb.org

Foundation FOM

The Foundation for Fundamental Research of Matter (FOM) stimulates and coordinates fundamental physics research in the Netherlands. For that, she is enabled by grants from the Dutch government through the Dutch Organisation for Scientific Research (NWO). FOM receives funds from NWO, Euratom, EU and several companies. The 1000 employees approximately, mainly scientists (including Ph.D. students) and technicians, are divided over five laboratories and approximately 100 departments at general and technical universities. FOM - founded in 1946 - is a foundation recognized by NWO.



Director of the National Institute NIKHEF

NIKHEF is a joint venture of FOM with 4 Dutch universities.

It co-ordinates experimental high energy and astro particle physics in the Netherlands. The director of the FOM institute for subatomic physics NIKHEF is also director of the NIKHEF collaboration between FOM and these 4 universities.

FOM is seeking applications/ nominations for this important post.

The FOM institute is one of the three scientific institutes of FOM.

The director of this institute plays a dual role, on the one hand guiding and directing the scientific, technical and administrative functions of the laboratory, and on the other hand co-ordinating the national programme in subatomic physics and the Dutch input in the international programmes in these areas. As such it is viewed as a challenging and crucial appointment in the Dutch physics community.

The director's main task will be to develop and guide the scientific policy for high energy and astro particle physics in the Netherlands. The director will have considerable responsibility for obtaining funding for the institute and for technology transfer and outreach.

Candidates should be established physicists of high international repute with both scientific vision and managerial skills. Ideally they should

have experience in both the Dutch and international arenas with the ability to inspire and lead a world class laboratory.

The director will promote the position of the institute in the broader context of society.

The successful candidate will be offered a permanent appointment by FOM. However, the initial appointment as director of the FOM institute will be for a period of 5 years with the possibility of re-appointment for a further period of 5 years. The appointment is at full professorial level.

The terms of employment of the foundation (FOM) are subject to the collective terms of employment (CAO). The employee will become a member of the Foundation State Employees Pension Scheme (ABP).

Further information may be obtained from either mr. B.J. Geerts, (e-mail: ben.geerts@fom.nl) or the chairman of the selection committee, prof. B. de Wit (e-mail: bdewit@phys.uu.nl).

Nominations and applications, which should include a c.v. and list of publications should be sent to mr. B.J. Geerts, head of the Human Resources Department, PO Box 3021, 3502 Utrecht, The Netherlands.

The closing date is 20 February 2004.



The CCLRC is a government-funded science research organisation. We provide world leading research facilities across a broad spectrum of science, engineering and technology. The expertise of our staff, and the research carried out at our three laboratories, are internationally-renowned.

RESEARCH POSITIONS IN EXPERIMENTAL PARTICLE PHYSICS (ATLAS) (VN2491/CC)

The Particle Physics Department has two vacancies to work on the ATLAS silicon tracker system (SCT) and on the development of a real-time system for the ATLAS Level-2 trigger. There will be opportunities to take a significant role in the integration and final commissioning work at CERN, and in the preparation for LHC physics analysis.

Applicants must have a PhD in experimental particle physics, or equivalent experience.

One appointment will be fixed-term for three years, and will suit applicants seeking to develop their interests and expertise in either of the above major areas. The other appointment will be an established post, and the successful candidate will have expertise in one of the areas of work outlined above as well as the potential for leadership and project management. Applicants should indicate whether they are applying for the fixed-term post, the established post, or both.

Further information about the SCT post can be obtained from Dr Mike Tyndel (Tel +44 (0)1235 445246, email: m.tyndel@rl.ac.uk) and at <http://www.cclrc.ac.uk/activity/section=5210> For the Level-2 post further information can be obtained from Dr Fred Wickens (Tel +44 (0)1235 445737, email: f.wickens@rl.ac.uk) and at <http://www.cclrc.ac.uk/activity/section=5209>

The starting salary for the fixed-term post is in the range £20,630 to £25,790, and for the established post is in the range £26,190 to £32,740, (pay award pending).

All applications must be returned by 20th February 2004. Interviews will be held in mid-March 2004.

RF PHYSICIST (VN2488/CC)

ISIS is the world's most powerful source of pulsed neutrons and muons. It currently operates 25 neutron and muon instruments, which provide scientists and engineers with unique tools for studying the structure and dynamics of materials on the atomic/molecular scale. ISIS is based at the Council for the Central Laboratory of the Research Councils (CCLRC) in Oxfordshire.

The source is driven by an 800 MeV proton synchrotron, and a versatile physicist with substantial experience of RF is required to work on the synchrotron RF system consisting of swept frequency ferrite loaded beam accelerating cavities and their thermionic vacuum tube drivers.

The successful applicant will be expected to:

- work with existing RF experts on the six RF systems already installed on the synchrotron, and to propose strategies for ensuring effectiveness and reliability of the system over the next two decades.
- work on commissioning four new RF systems providing a second harmonic addition to the RF waveforms already present in the synchrotron.
- participate in experimental accelerator physics work with a view to enhancing the performance of the synchrotron RF system as a whole.

In the interest of keeping ISIS fully operational, willingness to resolve faults and problems in the RF systems during silent hours would be an advantage.

The candidate would be expected to have a degree in physics and proven experience of particle acceleration in RF fields. Experience of large-scale facility operational environments would be an advantage.

The salary range is between £26,190 and £32,740 (pay award pending).

Further information on this post is available from Adrian Morris, Leader, Synchrotron and Electrical Engineering Group, e-mail a.morris@rl.ac.uk or David Findlay, Acting Head, ISIS Accelerator Division, e-mail d.j.s.findlay@rl.ac.uk

All applications must be returned by 9th February 2004.

Salaries on appointment are awarded according to relevant experience. An excellent index linked pension scheme and a generous leave allowance are also offered.

More information about CCLRC and these posts is available from CCLRC's World Wide Web pages at <http://www.cclrc.ac.uk>.

Application forms can be obtained from: Operations Group, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or email recruit@rl.ac.uk quoting the appropriate reference number.

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Due to the impending retirement of one of the two General Managers, we are seeking an individual to take responsibility for the running of DANTE overseeing its technical direction, contractual relationships with the European Commission, and contact with partners. The General Manager will share joint responsibility for all management and staff issues and also for public relations and communications.

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The Candidate:

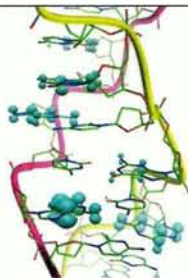
- A knowledge of technology, networking and the internet and how they can be used to support the strategic objectives of research and education.
- Previous experience in a partner/stakeholder liaison role preferably in a European context.
- A knowledge of the European NREN community through previous work in or with the education or research sectors is desirable.

Please reply in confidence, with full career and current salary details, quoting reference JG/5967C

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Further information about Diamond Light Source and these particular posts is available from our website www.diamond.ac.uk or contact our recruitment team on 01235 445435 (answerphone), 01235 445943 (fax number) for an application form quoting the appropriate reference number. Electronic applications are preferred and should be sent to recruitment@diamond.ac.uk



Closing date for applications: 30th January 2004
 Interviews will take place towards the end of February 2004.

Diamond Light Source Ltd, Rutherford Appleton Laboratory,
 Chilton, Didcot, Oxfordshire OX11 0QX



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.

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Postdoc (m/f)

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Contact to project group: Dr. F. Stephan, phone +49-(0)33762-77338, e-mail frank.stephan@desy.de

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UNIVERSITY OF
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Departmental Lecturer and Research Assistant in R&D for the next Linear Collider

The Subdepartment of Particle Physics, University of Oxford, is seeking two outstanding physicists to play major roles in the use of advanced laser systems to meet the challenging requirements for metrology and beam characterisation for a future linear electron positron collider (LC). The activities involve hardware and software development; one position will be on the LiCAS project, whose aim is to provide a survey and alignment system for the LC; the other will be on the Laser-Wire project, which aims to provide a beam-profile measurement system. The successful candidates will be working in the framework of a concerted UK effort to develop a beam-delivery system for a future LC.

A highly qualified successful candidate will be employed by the University of Oxford as a Departmental Lecturer for a fixed term of up to 6 years. A Research Assistant appointment is for an initial fixed term of 3 years with some possibility of renewal for one more year.

The application deadline is 20th February 2004. Further particulars about the post and information on how to apply are available at <http://www.physics.ox.ac.uk/pnp/jobs/LC-DL-RA-fp.htm> or from Mrs Sue Geddes, +44 (0)1865 273353. Informal enquiries about the projects and these posts may be made to Dr Armin Reichold (a.reichold@physics.ox.ac.uk).

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SCIENTIFIC STAFF POSITIONS

Strong Interaction Theory

The RIKEN BNL Research Center (RBRC) at Brookhaven National Laboratory (BNL) carries out a theoretical research program focused on the physics of the Relativistic Heavy Ion Collider (RHIC), heavy ion reactions, hard QCD/spin physics, and lattice QCD. Members of the center work closely with the existing nuclear and high energy physics groups at BNL as well as with the lattice group at Columbia University. The lattice QCD effort makes use of the local one teraflop QCDSF (QCD is a signal processor) and the soon to be completed ten teraflop QCDOC (QCD on a chip) super-computers. Applications will be considered for Research Associates (two-year appointments) and RIKEN BNL Fellows (up to five-year appointments) for the fall of 2004.

Scientists with appropriate backgrounds who are interested in applying for these theory positions should send a curriculum vitae and have three letters of reference sent to Prof. T.D. Lee, RIKEN BNL Research Center, Building 510A, Brookhaven National Laboratory, Upton, NY 11973. Applications should be received by January 30, 2004. BNL is an equal opportunity employer committed to workforce diversity.

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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 a 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 March 1, 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, Phone: +41 31 631-4403, Fax: +41 31 631-4405, e-mail: wbenz@phim.unibe.ch

Marietta Blau – Sterne der Zertrümmerung by Robert Rosner and Birgitte Strohmaier (eds), Böhlau Verlag. ISBN 3205770889, €29.90.

Marietta Blau – Sterne der Zertrümmerung (stars of fragmentation) is the third in a new series devoted to scientists from Austrian history, following on from those about Hans Thirring and Ludwig Boltzmann.

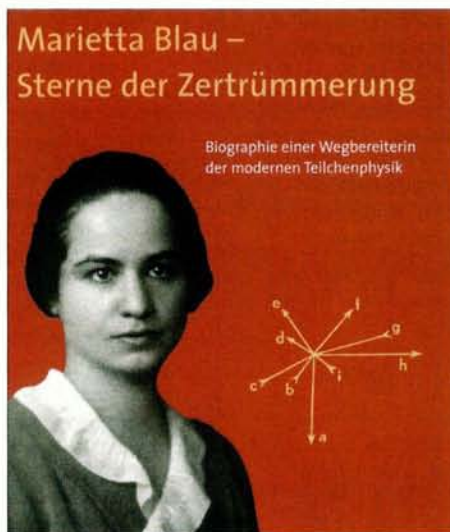
In brief, Marietta Blau was born in Vienna in 1894 to a moderately well-to-do Jewish family, and was among the first women to study physics at the University of Vienna. In 1923 she joined the Radium Institute in Vienna, but was forced into exile in 1938. After five years in Mexico and 16 years in the US she returned to her native Austria in 1960, aged 66 and badly in need of medical treatment. She died of cancer in Vienna in 1970.

The book begins with a long and well-documented biographic chapter written by the editors. Here the history of the Radium Institute is described so vividly that I had the feeling I was actually moving around the building and meeting the people working there. The reader is presented with some interesting and at times surprising details.

For example, more than one-third of the researchers at the Radium Institute were women and the majority of Blau's PhD students were female. However, this was not a general phenomenon during the 1930s. After leaving Austria, aided by Albert Einstein, Blau found refuge in Mexico as a staff member at the Polytechnic Institute in Mexico City between 1939 and 1944. One of the pictures in the book shows the teaching staff at the institute in 1940, and out of 58 people in the photo, Blau is the only woman. (It is interesting to compare this with our own time. A recent picture in *CERN Courier* (September 2003 p27) shows the participants at a conference on supergravity, and three out of the 52 are women.)

Another surprising fact is that the majority of the researchers at the Radium Institute, both male and female and including Blau, were unpaid. Perhaps they were working there simply to have a meaningful life? The book quotes the famous Austrian physicist Lise Meitner to have said in 1963: "I believe that all young people think about how they would like their lives to develop. When I did so, I always arrived at the conclusion that life need not be easy; what is important is that it not be empty. And this wish I have been granted."

The book also describes how Blau turned



down academic job offers during her most productive years to take care of her sick mother, and her close collaboration with Hertha Wambacher (1903–1950), who having originally studied chemistry had turned to physics and chosen Blau as her supervisor. After Wambacher had finished her doctorate, the two women had an extensive and fruitful collaboration for the next six years, in particular in trying to improve the emulsion technique for detecting particles. However, much of their relationship remains a great mystery. Wambacher was a member of the Nazi party, but obituaries for her shed no light on this matter as they deal exclusively with her work.

Other topics covered in detail include Blau's work before and after the Second World War, and there are reminiscences from those who had contact with Blau in the latter stages of her career when she was in her sixties. Blau's last PhD student worked from 1960 to 1964 analysing an experiment done at CERN in which emulsions were exposed to a beam of protons. This was one of a large number of experiments at CERN at this time that used emulsions. At the end of the book there is a reprint of three of Blau's papers, two of which were with Wambacher, and a list of all her publications.

Blau was an expert on nuclear emulsions, a detection technique with old roots. In 1937 she and Wambacher observed 31 "stars" in emulsions exposed to cosmic rays. The stars were made by collisions in the emulsions, which produced several particle tracks emanating from the collision point; one of the stars had no less than 12 tracks! The observation of these stars drew the attention of the

scientific community to emulsions, which were considered by some as being rather out of date. However, to claim that the work by Blau and Wambacher was a prerequisite for the discovery of the pion is a gross exaggeration. Emulsions had to be enormously improved to achieve the required sensitivity. One of the authors in the book also claims that Blau must have been frustrated that Cecil Powell was awarded the Nobel prize for a discovery using her method, so much so that she erroneously attributed the first observation of the negative pion to Don Perkins. However, this speculation is unfounded; Blau was in fact giving a correct account of what had happened (see Letters, p50). Another point made concerns the nomination of Blau and Wambacher for the Nobel Prize in Physics. By itself this is not a measure of the highest excellence as every year there are a large number of such nominations.

The literature on emulsion techniques is vast and it is very difficult to do justice to all those who have contributed to this field. Nonetheless, I was deeply touched by the portrait of this exceptional woman, described as shy, gentle and highly dedicated to her métier, but who had the misfortune to live in a hostile environment, a victim of a sick society. *Cecilia Jarlskog, CERN.*

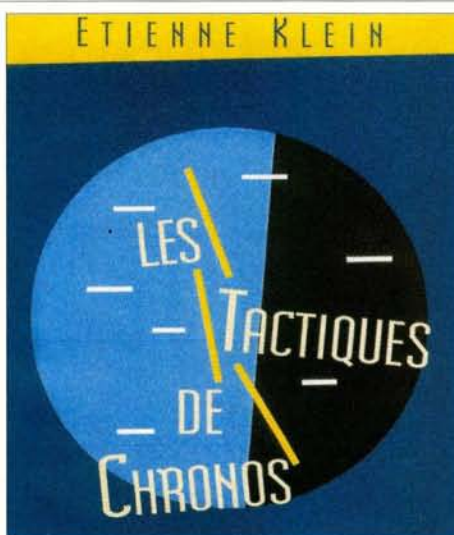
Les tactiques de Chronos by Etienne Klein, Editions Flammarion. ISBN 208210091X, €18.00.

Time is an elusive concept and presents itself in manifold and disparate guises. As a result, dictionaries mention it in relation to fields as varied as choreography, economics, horse-riding, linguistics, liturgy, seafaring, sports, forestry, hunting and, obviously, physics. In his book *Les tactiques de Chronos* (Chronos's tactics), Etienne Klein sheds some light on the ideas each of us have of the disconcerting parameter that is time.

With his considerable store of philosophical and scientific knowledge, the author sets out to help the reader understand the concept of time. However, the meaning of time remains ambiguous and the book warns of the difficulties in providing a definition. The reader is reminded of the words of Saint Augustine: "What, then, is time? If no one asks me, I know what it is. If I wish to explain it to him who asks, I do not know."

Klein attempts to assist Saint Augustine. He begins with a summary of the various philo- ▷

sophies put forward over the ages, before introducing the concept of physical time with Galileo, who included time as a variable in dynamic equations. The concept of time was revolutionized by relativity theory and lost its absolute quality. Quantum mechanics suggests that going back in time is like crossing over into the world of antimatter. Klein goes on to discuss the "arrow" of time, which stipulates the irreversibility of macroscopic phenomena, and is illustrated by effects such as entropy and the evolution towards more probable states. This brings him to a discussion of CP violation, which implies T violation, in microscopic phenomena. The author does not shy away even from the most speculative of concepts, such as discontinuous time or time with several dimensions as a possible consequence of superstring theory. On the anecdotal side, the reader learns who wrote the article on time in Diderot and d'Alembert's encyclopaedia. It was J J Rousseau. We also find out to whom the phrase "eternity is long, especially towards the end" can be attributed – a list that over the years has



included Franz Kafka, French humorist Pierre Dac and Woody Allen – and about S B Preuss, the physicist who put his name to just one article, albeit alongside Albert Einstein's.

While reading the book, which is a pleasure, it becomes clear that physics has made an

important contribution to our understanding of time. It also becomes evident that a subjective time exists that is distinct from physical time, or if you prefer an individual time that is superimposed on universal time. Is not subjective time evidence of our relationship to physical time? This question is addressed in the final chapter of the book, entitled "Has physics forgotten about death?". Life still transcends the laws of physics, and it may be that man's concept of time is defined by his awareness of his own mortality. This hypothesis remains unanswered and the book is rounded off with a comprehensive bibliography of the sources used by the author.

Having finished the book, the physicist is left with the feeling of being closer to the philosopher, and maybe the philosopher will be better able to understand the need to take into account the major advances in physics in order to provide a more complete picture of the human experience.

François Vannucci, Université de Paris 7 and IN2P3.

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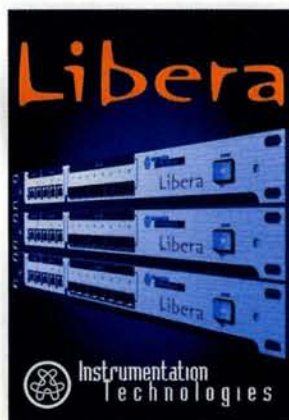
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Science in the information society

In hosting the recent RSIS conference, CERN took a bold step into the global policy arena.

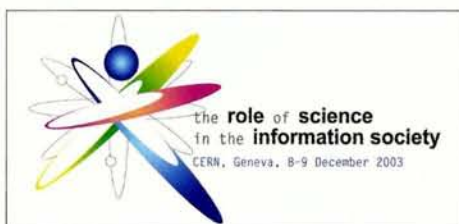
Manjit Dosanjh, John Ellis and Hans Hoffmann explain why.

On 8 and 9 December 2003, CERN hosted a conference on The Role of Science in the Information Society (RSIS, see p14), immediately prior to the World Summit on the Information Society (WSIS). Our efforts to organize this conference were stimulated by a challenge that the UN secretary-general Kofi Annan made to the world scientific community. Last March in the magazine *Science*, he wrote that "recent advances in information technology, genetics and biotechnology hold extraordinary prospects for individual well-being and humankind as a whole," but noted that "the way in which scientific endeavours are pursued around the world is marked by clear inequalities." Annan called on the world's scientists to work with the UN to extend the benefits of modern science to developing countries.

The open exchange of information, made possible by the World Wide Web and other information technologies, has revolutionized everything from global commerce to how we communicate with friends and family. We live in the age of the "information society", but without science there would be no such thing; it was basic science that made the underlying technologies possible. Moreover, continuing scientific research is necessary to underpin the future development of the information society – through the sharing of distributed computing resources via the Grid, for example.

The information society has the potential to empower scientists from regions of the world that have not been prominent in recent scientific research, but have valuable human resources and original perspectives on many of the problems we all face. This could create, in the words of Adolf Ogi, special advisor to the Swiss Federal Council on WSIS, "science sans frontières", making use of what Adama Samassékou, president of WSIS PrepCom, described as "indigenous knowledge".

Prior to the conference CERN conducted an online forum where scientists, policy makers and stakeholders from around the world



reviewed the prospects that developments in science and technology offer for the future of the information society, especially in education, health, environment, economic development and enabling technologies. These issues formed the basis for discussions in five parallel sessions at RSIS, which complemented the plenary sessions. The result is a vision for how information and communication technologies can be applied for the greater benefit of all.

Education is a key element for development. Information and communication technologies (ICTs) are vital for learning at all stages of life. Here, south-south co-operation is as important as north-south co-operation. In the area of health, ICTs can help in priority public-health areas by promoting the dissemination of health information, enhancing capacity-building and permitting telemedicine. In the case of environmental issues, planners and decision-makers need accurate, local and timely information – global collaboration is vital to ensure access to appropriate environmental data. To accelerate economic development, education and the dissemination of scientific knowledge and technological know-how through ICTs is a critical component of local and national development. It is important for scientists in all countries to unite to define their local needs in terms of ICT infrastructure and content.

Through these examples in particular, RSIS was able to formulate a vision of how ICTs can be applied to benefit all. The following themes emerged as guidelines and received clear support at RSIS: that fundamental scientific information be made

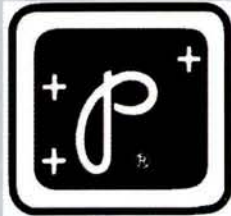
freely available; that the software tools for disseminating this information be also made freely available; that networking infrastructure for distributing this information be established worldwide; that the training of people and equipment to use this information be provided in the host nations; that general education underpins all these goals and is an indispensable basis for the information society.

Several of the objectives defined at RSIS are already making headway. In particular, the WSIS draft Declaration of Principles recognizes that "science has a central role in the development of the information society." Moreover, the WSIS draft Action Plan aims to promote high-speed Internet connections for all universities and research institutions; the dissemination of knowledge through electronic publishing and peer-to-peer technology; and the efficient collection and preservation of essential scientific data.

In hosting the RSIS conference, CERN took a bold step forward into the policy arena. Since scientific research underpins the past and future development of ICTs and thereby the information society, we scientists have a particular moral responsibility to prevent the "digital divide" from further increasing the gap between rich and poor. Moreover, the information society offers scientists from all parts of the world the opportunity to contribute to the global scientific adventure of which CERN's Large Hadron Collider is just one example.

It is vital that the global scientific community engages fully in the policy arena, through the development of new and affordable technologies to overcome the digital divide. The scientific community should commit its best efforts to implementing the WSIS Action Plan and to demonstrating real progress by the time of the next WSIS meeting in Tunis in 2005.

Manjit Dosanjh, John Ellis and Hans Hoffmann were members of CERN's RSIS organizing committee.



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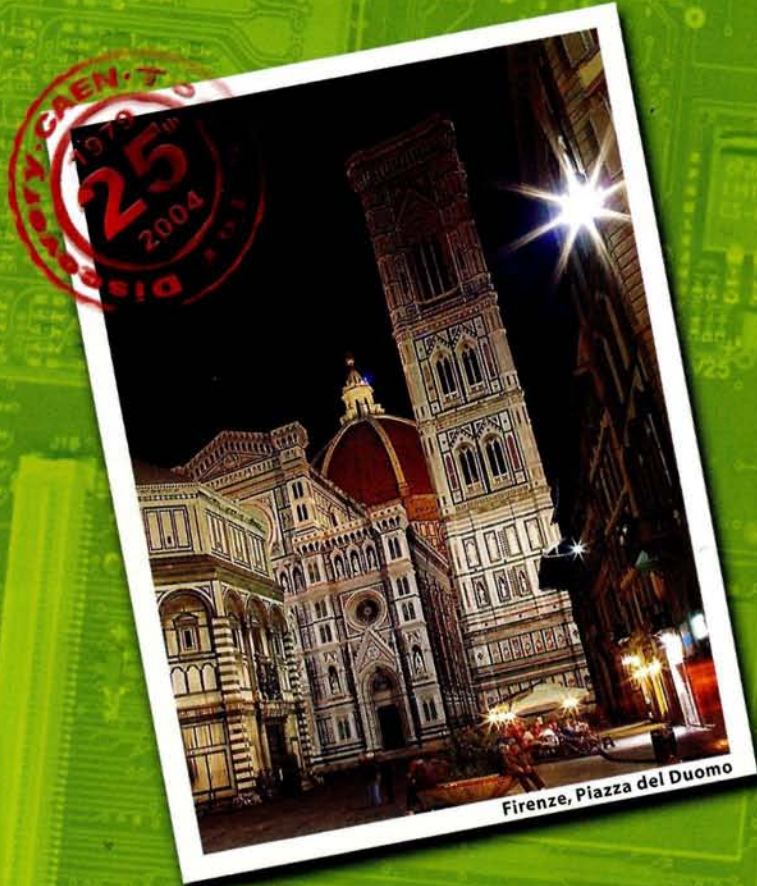
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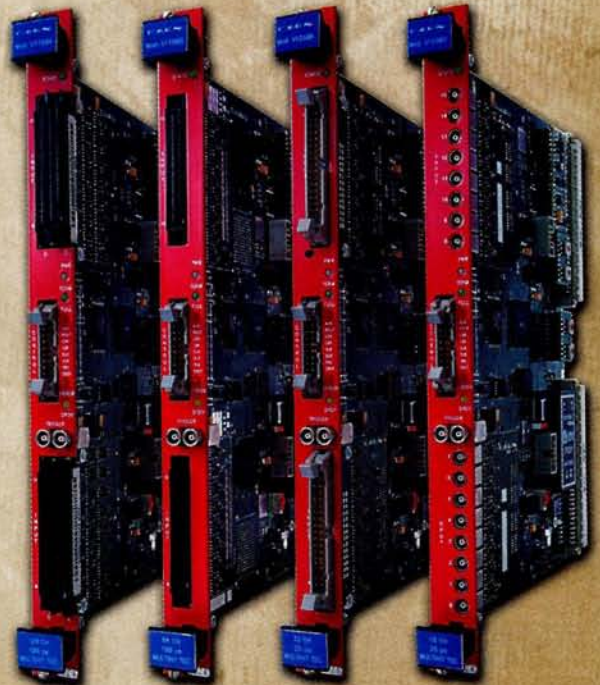
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