

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 46 NUMBER 4 MAY 2006



Watching neutrinos disappear

COSMOLOGY

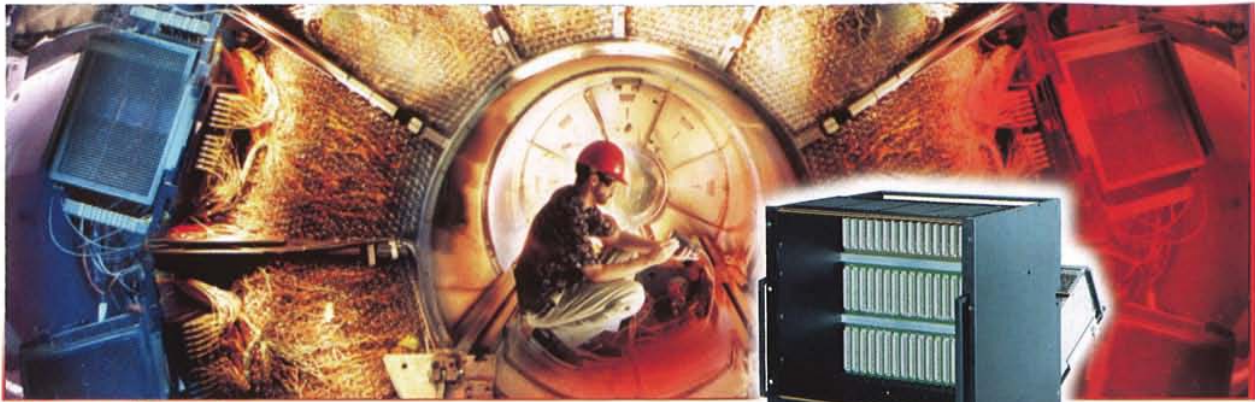
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Powered Crates

(Image courtesy Stanford Linear Accelerator Center)

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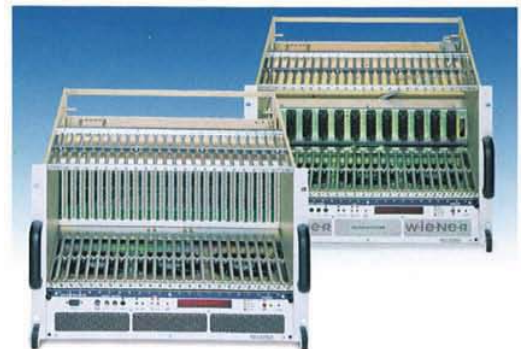
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Editor Christine Sutton
CERN, 1211 Geneva 23, Switzerland
E-mail: cern.courier@cern.ch
Fax: +41 (0) 22 785 0247
Web: cerncourier.com

Advisory board James Gillies, Rolf Landua and Maximilian Metzger

Laboratory correspondents:

Argonne National Laboratory (US): D Ayres
Brookhaven National Laboratory (US): P Yamin
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TRIUMF Laboratory (Canada): Marcello Pavan

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Institute of Physics Publishing Ltd, Dirac House, Temple Back,
Bristol BS1 6BE, UK
Tel: +44 (0)117 929 7481; E-mail: jo.nicholas@iop.org; Web: iop.org

Publishing director Richard Roe
Publisher Jo Nicholas
Art director Andrew Giaquinto
Production editor Jonathan Cailles
Technical illustrator Alison Tovey
Display advertisement manager Ed Jost
Display sales Europe Tom Houlden
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Recruitment and classified sales Adam Hylands, Jayne Orsborn and Kathryn Zerboni
Advertisement production Katie Graham
Product manager Claire Webber

Advertising
Tel: +44 (0)117 930 1026 (for UK/Europe display advertising),
+1 215 627 0880 (for North American display advertising), or
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E-mail: sales@cerncourier.com; Fax: +44 (0)117 930 1178

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Germany Veronika Werschner, DESY, Notkestr. 85, 22607
Hamburg, Germany. E-mail: desypr@desy.de

Italy Loredana Rum or Anna Pennacchietti, INFN, Casella Postale
56, 00044 Frascati, Rome, Italy. E-mail: loredana.rum@inf.infn.it

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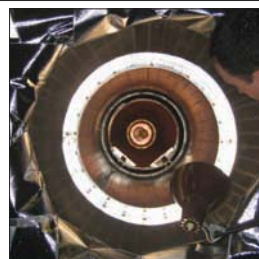


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Cover: One of the two "horns" in the neutrino beam line of the Neutrinos at the Main Injector facility at Fermilab. The facility produces an intense beam of neutrinos for the Main Injector Neutrino Oscillation Search (MINOS) experiment, which has announced new results on neutrino "disappearance" (p5). (Photo by Peter Ginter.)

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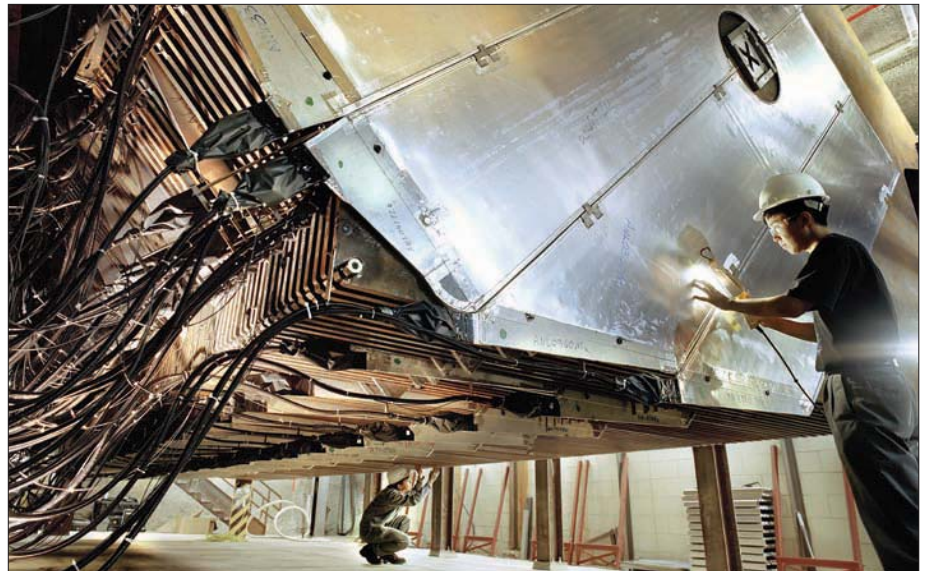
NEUTRINOS

Muon neutrinos vanish on way to Minnesota

Muon neutrinos definitely disappear *en route* from Fermilab in Illinois to Soudan in Minnesota. This is the conclusion from the first results of the Main Injector Neutrino Oscillation Search (MINOS), presented at a seminar at Fermilab on 30 March, which showed that MINOS has observed the disappearance of a significant fraction of these neutrinos. The observation is consistent with the phenomenon of neutrino oscillation, in which neutrinos change from one kind to another, and corroborates earlier observations of muon-neutrino disappearance, made by the Super-Kamiokande and KEK-to-Kamioka (K2K) experiments in Japan.

The Fermilab side of the MINOS experiment comprises a beam-line in a 1220 m long tunnel pointing towards Soudan. The tunnel holds the carbon target and beam-focusing elements that generate neutrinos from protons accelerated by Fermilab's Main Injector accelerator. A neutrino detector, the MINOS "near detector" located 100 m underground on the Fermilab site, measures the composition and intensity of the neutrino beam as it leaves the laboratory. The Soudan side of the experiment features the 6000 tonne "far" detector about 700 m underground, which measures the properties of the neutrinos after their 725 km trip to northern Minnesota.

If neutrinos did not change as they travel away from Fermilab, the MINOS detector in Soudan should have recorded 177 ± 11 muon neutrinos. Instead, the collaboration found only 92 muon-neutrino events – a clear observation of muon-neutrino disappearance. The deficit as a function of energy is consistent with the hypothesis of neutrino oscillations, which can occur only if different neutrino types have different masses. The MINOS observations yield a value of Δm^2 , the square of the mass difference between two



The near detector of the MINOS neutrino experiment at Fermilab. (Courtesy Peter Ginter.)

types of neutrinos, equal to 0.0031 ± 0.0006 (statistical uncertainty) ± 0.0001 (systematic uncertainty) eV^2 .

In the oscillation scenario, muon neutrinos can transform into electron neutrinos or tau neutrinos, but alternative models – such as neutrino decay and extra dimensions – are not yet excluded. The MINOS collaboration will need to record much more data to test more precisely the exact nature of the disappearance process. Over the next few years, the experiment should collect about fifteen times more data, yielding more results with higher precision.

The MINOS neutrino experiment follows on from the K2K long-baseline neutrino experiment in Japan. From 1999–2001 and 2003–2004, K2K sent neutrinos created at an accelerator at the KEK laboratory to a detector in Kamioka, a distance of about 240 km. Compared with K2K, the distance in the MINOS

experiment is three times longer, and both the intensity and the energy of the MINOS neutrino beam are higher. These advantages have enabled the MINOS experiment to observe in less than a year about three times as many neutrinos as K2K did in around four years. Later this year the CERN Neutrinos to Gran Sasso project will start delivering muon neutrinos to the Gran Sasso National Laboratory in Italy (*CERN Courier* March 2006 p6).

- The MINOS experiment includes about 150 scientists, engineers, technical specialists and students from 32 institutions in six countries, including Brazil, France, Greece, Russia, the UK and the US. The US Department of Energy provides the major share of the funding, with additional funding from the US National Science Foundation and the UK's Particle Physics and Astronomy Research Council. For more information on the experiment see www.numi.fnal.gov/.

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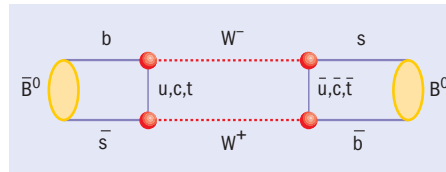
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B PHYSICS

D0 provides precise results on B_s^0 oscillations

The D0 collaboration at Fermilab has published the first direct two-sided bound on the oscillation frequency of the B_s^0 , the meson comprising a strange quark (s) and a bottom antiquark (\bar{b}). The result is consistent with what is expected from the Standard Model, within a 90% confidence level. The phenomenon in which a B_s^0 meson (with a down quark, d, instead of the strange quark) converts into its antiparticle \bar{B}_s^0 is well established, and its oscillation frequency Δm_d has been measured precisely (Heavy Flavour Averaging Group 2006). The value of the corresponding measure of the oscillation frequency of a B_s^0 meson into its antiparticle $\bar{B}_s^0 - \Delta m_s$ – was until now much more poorly known.

The D0 collaboration is an international team of 700 physicists from 90 institutions and 20 countries working at Fermilab's Tevatron, which provides high-energy



A B_s mixing “box diagram” through which the B_s^0 is able to oscillate to the \bar{B}_s^0 .

proton–antiproton collisions for two experiments, D0 and CDF. The data for the D0 result were taken from 1 fb^{-1} of total collision data, yielding more than a billion events (Abazov *et al.* 2006). The 90% confidence level means that the result does not qualify as a discovery, although it does provide a very strong indication. However, according to Rob Roser, co-spokesperson of CDF, within the next month or so the CDF collaboration should provide a result with

greater precision.

The D0 result already provides some interesting constraints on supersymmetry. “The D0 value of $17 < \Delta m_s < 21 \text{ ps}^{-1}$ limits the contributions to the oscillation process that could be made by supersymmetric particles,” explains D0 co-spokesperson Terry Wyatt, from the University of Manchester. “The basic idea is that supersymmetric particles may be exchanged in the box diagrams that are responsible for B_s^0 mixing.” Several theoretical models of supersymmetry predict a much faster oscillation of B_s^0 , and the D0 result now disfavors these models.

Further reading

V M Abazov *et al.* D0 Collaboration 2006
<http://arXiv.org/pdf/hep-ex/0603029>.
 Heavy Flavour Averaging Group 2006
<http://arXiv.org/pdf/hep-ex/0603003>.

FRASCATI

KLOE completes a successful run at the DAFNE collider

On 16 March, operation of the K Long Experiment (KLOE) detector ended after 23 months of continuous running at the DAFNE collider at Frascati. During this time the detector collected an integrated luminosity of 2.3 fb^{-1} , corresponding to the observation of some 6.2 billion ϕ decays. These data are in addition to the 450 pb^{-1} sample collected in shorter runs in 2000, 2001 and 2002.

DAFNE, the Frascati ϕ -factory, has been performing increasingly well, delivering 200 pb^{-1} a month by the end of 2005. The efforts by the DAFNE and KLOE teams to ensure good data-taking conditions have resulted in their collecting a large homogeneous data



Members of the KLOE team with the detector.

sample in terms of machine background, beam energy and detector performance. Smooth trigger and data-acquisition operations, and continuous running of detector calibration ensured high-quality data.

KLOE has many unique aspects, in particular detector performance, the special environment at the ϕ factory, the unique possibility of kaon species tagging, an open trigger and complete recording of all data. These allow the physics investigated to include

such varied topics as precision measurements of kaon properties, the study of scalar mesons and the measurement of the hadronic cross-section at less than 1 GeV, which is necessary for calculating the muon anomaly. The ϕ -meson decays are also a copious source of η and η' mesons.

With the analysis of 450 pb^{-1} of data, KLOE has reached accuracies of a fraction of 1% in the measurements of the kaon absolute branching ratios and lifetimes. The results have already removed a problem with the unitarity of the quark-mixing matrix that dates back more than 30 years. The new data set will lead to improvements of all published results, especially in the K_s sector, and to new measurements of the poorly known hadronic cross-section near threshold.

DAFNE will resume operation by the FINUDA collaboration in a few months to investigate hypernuclei. Plans to upgrade the collider to DAFNE2 and the detector to KLOE2 are being studied.

Les physiciens des particules du monde entier sont invités à apporter leurs contributions aux *CERN Courier*, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse cern.courier@cern.ch.

CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send your proposal to the editor at cern.courier@cern.ch.

LHC DETECTORS

CMS tracker sees first cosmic muons

The tracker for the CMS experiment at CERN passed an important milestone in March when the first cosmic-muon tracks were observed in one of the end caps. CMS is one of the two large multi-purpose detectors being constructed at the Large Hadron Collider. Its tracker system, comprising a barrel detector and two end caps, contains 25 000 silicon-microstrip sensors covering 210 m², with 9.6 million electronic readout channels. Its construction involves teams from the whole of Europe and the US, with the final assembly at CERN.

The two tracker end caps (TECs) feature silicon-strip modules mounted on wedge-



One of the muon events recorded in the first sector of the TEC+, under test in Aachen. The display shows the individual silicon-strip modules in the 18 “petals” that make up the sector.

shaped carbon-fibre support plates, or “petals”. Up to 28 modules are arranged in radial rings on both sides of these plates; one eighth of an end cap is populated with 18 petals and is called a “sector”.

One of the TECs, TEC+, is being constructed at the RWTH (Rheinisch-Westfälische Technische Hochschule) Aachen and testing began earlier this year. A total of 400 silicon-

strip modules are read out simultaneously, using close-to-final readout and power-supply components and data-acquisition software. The first sector has already been thoroughly tested, demonstrating a channel efficiency of less than 1% and common-mode noise of only 25% of the intrinsic noise.

To understand the behaviour of the TEC sector better, including the response to real particles, basic functionality testing was followed by a run with cosmic muons. Thousands of tracks have been recorded and will be used to study tracking performance and to exercise various track-alignment algorithms.

The next important step will be to test the first sector under CMS operating conditions, with the silicon modules working at a temperature of less than -10 °C. The remaining seven sectors will then be assembled and in autumn the TEC+ will be delivered to CERN.

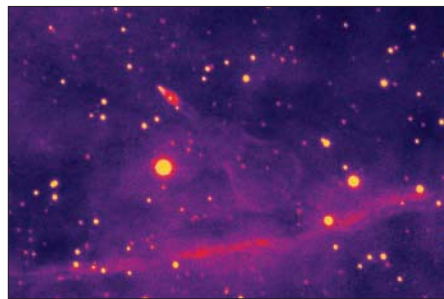
ASTROPARTICLES

Sterile neutrinos unravel astrophysics

Almost every current theoretical model of neutrino masses introduces sterile (“right-handed”) fields, which mix with the ordinary (“left-handed”) neutrinos. Ordinary neutrinos have no electrical charge and interact through the weak force, but there may also exist rogue sterile neutrinos that feel only gravity. Most models make these new particles very heavy, while also trying to explain the small masses of ordinary neutrinos. Now Peter Bierman of the Max Planck Institut for Radioastronomy, Bonn, and Alexander Kusenko of University of California, Los Angeles, have suggested that if some of the sterile neutrinos are relatively light, they could resolve several astrophysical puzzles. In particular, sterile neutrinos with kilo-electron-volt (keV) masses could account for dark matter, the origin of the rapid motion of observed pulsars and re-ionization of the universe (Bierman and Kusenko 2006).

These relatively light sterile neutrinos were the topic of a recent workshop, Sterile Neutrinos in Astrophysics and Cosmology, held in Crans Montana in March. The meeting looked not only at how keV sterile neutrinos can solve a variety of problems in astrophysics, but also at how their existence might be detected.

Dark-matter sterile neutrinos could decay



The Guitar Nebula is formed by the wake of a neutron star moving through the interstellar medium at 1600 km/s. If keV sterile neutrinos exist, they could explain this extraordinarily rapid motion. (Courtesy S Chatterjee and JM Cordes, Cornell University/Palomar Observatory.)

into a lighter neutrino and an X-ray photon, and this seems to be the most promising path to discovery. The workshop brought together particle physicists and X-ray observers, who presented the current limits and discussed ways to search for dark-matter neutrino decays. One important feature of dark matter in the form of the sterile neutrinos is the smoothing of structures on small scales. This “warm” dark matter – in contrast with the “cold” and “hot” alternatives – would be indistinguishable from cold dark matter on large scales, but it would yield stellar structures with the smallest size relative to the dark-matter particle mass. Recent studies of dwarf spheroidal satellite galaxies have

reported seeing the minimal halo size, indicative of warm dark matter.

The same decays into X-ray photons happening in the early universe could have produced enough ionization to catalyse a rapid production of molecular hydrogen, which is the most important cooling agent for primordial gas. Enriched with molecular hydrogen, haloes of gas would cool and collapse, forming the first stars. These stars could have re-ionized the universe, in agreement with observations of the Wilkinson Microwave Anisotropy Probe (p12).

The role of sterile neutrinos in pulsars originates in supernova explosions, where sterile neutrinos with a mass of several keVs from the cooling nascent neutron star would be emitted preferentially in one direction, set by the star’s magnetic field. Although the neutrinos would not interact with the magnetic field, they would scatter off fermions polarized along the magnetic field in the neutron star. The anisotropy of sterile-neutrino emission would be sufficient to give the neutron star a recoil velocity of hundreds of kilometres a second. This agrees with observations of pulsars – magnetized rotating neutron stars – all of which have very large velocities. The origin of these velocities is a long-standing puzzle, which would have a simple explanation if sterile neutrinos exist.

Further reading

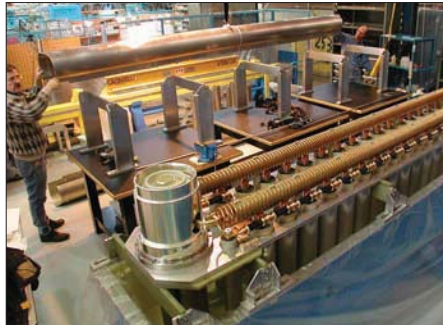
Peter L Bierman and Alexander Kusenko 2006 *Phys. Rev. Letts.* **96** 091301.

TRIUMF

Canadian modules take up position at LHC

As the many pieces of the Large Hadron Collider (LHC) and its experiments come together at CERN, Canada's contributions to the project are moving into their final positions. One of the hadronic end-cap calorimeters built at the Tri-University Meson Facility (TRIUMF) was recently installed in the ATLAS detector, and the first of the resistive twin-aperture quadrupoles for the "beam cleaning" regions in the LHC, designed at TRIUMF and built by Alstom Canada Inc, should be installed in the tunnel in June. However, the pulse-forming networks (PFNs) for the LHC injection kickers will soon become the first components from Canada to be completely installed.

The LHC will have fast-pulsed magnet systems – the kickers – to inject the two proton (or heavy-ion) beams into the main ring. Two pulsed systems are required, each comprising four magnets, four PFNs and four high-voltage thyatron-based switches. Each PFN consists of two 28 cell, 10 Ω lines connected in parallel at their ends. To kick the beam buckets from the Super Proton Synchrotron into the LHC ring,



Gary Wait (left) and Michael Barnes complete the assembly of a PFN module at TRIUMF.



One of the PFN modules installed in the LHC.

each system must produce a magnetic field pulse of 1.3 T.m strength, with a rise time of not more than 900 ns, an adjustable flattop duration up to 7.86 μ s, and a fall time of not more than 3 μ s. The total ripple in the field must be less than $\pm 0.5\%$.

The energy in a PFN is provided by a resonant-charging power supply (RCPS), which is used to reduce as much as possible the number of untriggered discharges of the thyratrons. The performance of the electrical circuit of the complete system, including a 66 kV RCPS and a 5 Ω PFN, was carefully simulated, and components were selected for the PFN on the basis of theoretical models in which a ripple of less than $\pm 0.1\%$ was attained.

As part of the Canadian contribution to the LHC, TRIUMF has built and tested in-house five RCPSs and nine PFNs. After shipment to CERN, the RCPSs and PFNs are thoroughly tested before insertion into the tunnel sections where injection into the LHC will occur. Installation began in May 2005, and the final systems should be installed this spring.

DESY

First results for the VUV-FEL radiation source

The first measuring period for external users at the vacuum ultraviolet free-electron laser (VUV-FEL), the new ultraviolet and X-ray radiation source at DESY, ended successfully on 27 February. Now the facility is gearing up for its second run in May.

The facility's centre-piece is the 300 m long FEL, which is the world's first – and until 2009, only – source of intense laser radiation at VUV and soft X-ray wavelengths. In January 2005, it generated its first laser pulses with a 32 nm wavelength, the shortest wavelength ever achieved with a FEL, and then started up for users in August. It is available for research groups from all over the world for experiments in areas such as cluster physics, solid-state physics, plasma research and biology. Four experimental stations are currently available, at which different instruments can be operated alternately.

Since the official start-up in August, a total



The beams of DESY's new radiation source, the VUV-FEL, serve a range of experiments.

of 14 research teams from 10 countries have carried out experiments ranging from generating and measuring plasmas to the first investigations of experimental methods for studying complex biomolecules, which will later be used at the European X-ray FEL (XFEL). As expected, the laser pulses of the

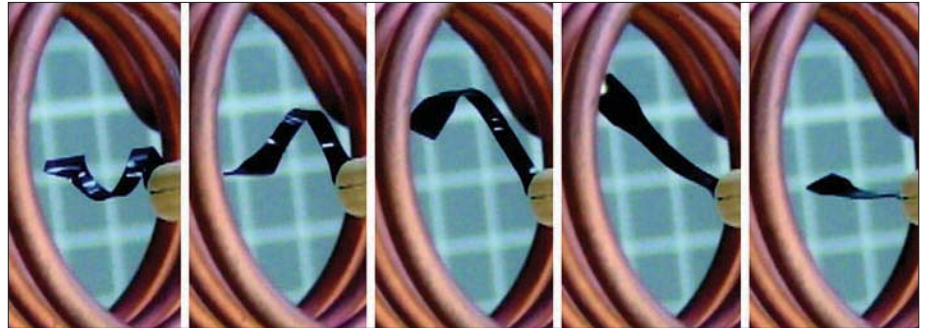
VUV-FEL are shorter than 50 fs. This allows researchers to trace various processes on extremely short time scales by taking time-resolved "snapshots" of the reaction process. Investigating such time-resolved processes with radiation of short wavelengths is one of the most important new applications of this kind of X-ray laser.

Before user experiments resume in May, the DESY team is carrying out machine studies to improve the stability of the facility, increase the energy of the laser pulses, and shorten the wavelength of the radiation to around 15 nm. At the same time, various studies are being done to prepare for the planned XFEL, which will be 3.4 km long and generate even shorter wavelengths, down to 0.085 nm, when it comes into operation in 2013. The VUV-FEL should produce its shortest wavelength of 6 nm in 2007, after an additional accelerator module is installed.

Nanoparticles create shape-shifting polymer

A novel material that changes its shape in response to a suitable magnetic field is the brainchild of Andreas Lendlein and colleagues at the Institute of Polymer Research at the GKSS Research Centre Geesthacht in Teltow and the German Institute of Polymers in Darmstadt. The material is a variant on shape-memory polymers, which change shape in response to temperature. The idea is to use inductive heating from a time-varying magnetic field to warm up magnetic nanoparticles in a thermoplastic polymer, so as to trigger a change in shape without having to alter the ambient temperature or making direct contact with the material.

The researchers used nanoparticles of iron oxide in a silica matrix, which they distributed homogeneously in polyetherurethane. They can set the temperature for the shape change



These photographs show the shape-memory effect in a polymer composite (Mohr et al. 2006).

by varying the proportion of nanoparticles in the polymer and the strength of the magnetic field. The team is particularly excited by the potential for applications in medical technology, such as remotely controlled instruments and “smart” implants, for

example for on-demand drug delivery triggered non-invasively by a magnetic field.

Further reading

R Mohr et al. 2006, *Proc. Nat. Acad. Sci.* **103** 3540.

Investigating parity violation in life...

The two most striking places in the universe where violation of parity is observed are in weak interactions, which are completely left-handed, and in biochemistry, where amino acids are left-handed and sugars are right-handed. While a precise link between the two phenomena has been elusive, new research has yielded a surprising clue in a spiral molecule called polyglutamic acid (PGA), which comes in left- and right-handed forms (L and R, respectively). Meir Shinitzky of the Weizmann Institute in Rehovot and colleagues have found that hydrochloric acid was dramatically more effective at unravelling the R form than the L.

Precisely what is going on is still unclear,

but there is a suggestion that weak interactions might make L amino acids of L-PGA slightly more magnetic and hence more likely to interact with the weakly magnetic forms of water (ortho-H₂O) that make up about 75% of normal water. This would then perhaps provide some degree of protection from the acid. There is no magnetic analogue of ortho-H₂O in deuterium oxide (heavy water), and as the effect is not seen if PGA is dissolved in heavy water, this lends some support to this idea.

Further reading

Yosef Scolnik et al. 2006 *Physical Chemistry Chemical Physics* **8** 333.

...and putting DNA through the wringer

DNA is a strange molecule, and not only because it can carry genetic information. If you try to twist it, it becomes longer, which is the opposite to what happens when wringing out a wet cloth. In an aptly titled paper, “Wringing out DNA”, Timothée Lionnet and colleagues of the Centre National de la Recherche Scientifique in Paris and Lyon found that a DNA molecule starts to extend

when it is anchored at one end and twisted via a magnetic bead attached to the other. As the twisting takes place, base pairs are brought closer together and are forced to tilt, which leads to a net extension.

Further reading

Timothée Lionnet et al. 2006 <http://xxx.lanl.gov/abs/q-bio.BM/0602008>.

CFC uses down-time

In counterfactual computation (CFC), quantum computing can use a computer without running it. Onur Hosten of the University of Illinois and colleagues demonstrated this in the first CFC proof-of-principle. A photon couples with a computational element that is both on and off to get partial data about what would have happened had it been on. The team made an optical realization of CFC with an interferometer using an optical implementation of Lov Grover’s algorithm for searching an unsorted database.

Further reading

Onur Hosten et al. 2006 *Nature* **439** 949.

Magnetic snails

Researchers have found a snail that grows magnetic iron-sulphide scales on its foot. Yohey Suzuki of the Japan Agency for Marine-Earth Science & Technology in Yokosuka and colleagues found the snail in a deep-sea hydrothermal field. It uses the scales against sulphides and to protect itself from predators.


Further reading

Yohey Suzuki et al. 2006 *Earth and Planetary Science Letters* **242** 39.

In May 2006, Outokumpu Copper Products will become Luvata

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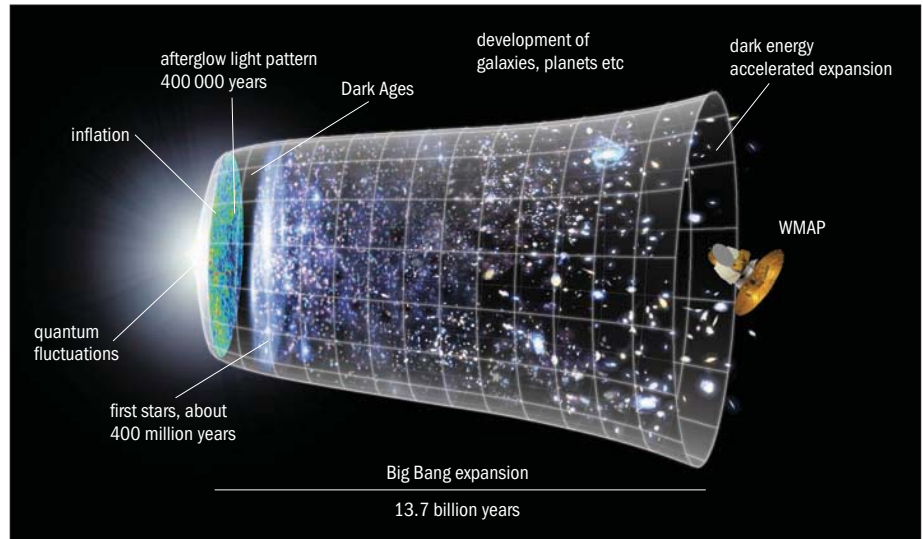
New WMAP results give support to inflation

NASA's Wilkinson Microwave Anisotropy Probe (WMAP) collaboration has finally released new observations of cosmic microwave background (CMB) radiation with updated results on the nature and origin of the universe. Three times more data and improved analyses give strong constraints on all cosmological parameters and provide evidence supporting the inflation scenario.

The long silence following the release of the first-year WMAP results in February 2003 (*CERN Courier* April 2003 p11) has been the subject of much speculation. Did the team find a problem affecting these results? Did they find something extraordinary? Are they in great trouble with instrumental effects or foreground emission for which they cannot properly account? In fact none of these was the case, the WMAP science team simply wanted to have the most reliable results to be published together. This eventually happened without much prior notice on 16 March at 1700h GMT. Within minutes, the press release, images and the four scientific papers were all available on the Web. In view of the amount of information in the 280 pages submitted to the *Astrophysical Journal*, it is easy to see that this could not have been prepared much faster.

The addition of two years of observations did not lead to a revolution in the field, but rather confirmed and refined the results of the first year. As well as the CMB's thermal fluctuations, the complementary polarization data have now been released. Combining the WMAP data with all kinds of other observational constraints from different missions and experiments, it seems that the main cosmological parameters are now well determined assuming cold dark matter (CDM) together with a cosmological constant (Λ_{CDM}).

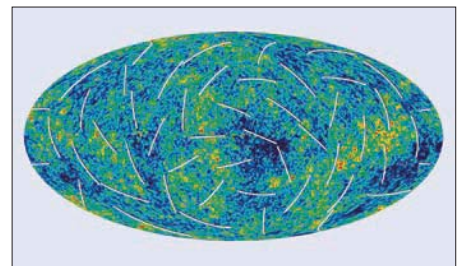
Specifically, the universe is 13.8 billion years old and its current expansion rate is characterized by a Hubble constant, $H_0 = 71 \pm 2$ km/s/Mpc. Baryonic matter (basically atoms) constitutes only $4.4 \pm 0.3\%$ of the matter-energy content of the universe, the rest being CDM of unknown nature ($22 \pm 2\%$) and dark energy ($74 \pm 2\%$). The combination of data from WMAP and the Supernova Legacy Survey gives a strong constraint on the equation of state of dark



Timeline of the universe from the Big Bang to now. Rapid inflation during the first second was first proposed 25 years ago and is now supported by the new results from WMAP.

energy, $w = -0.97 \pm 0.08$, which leaves not much freedom for something – like phantom energy if $w < -1$ or quintessence if $w > -1$ – other than a pure cosmological constant (*CERN Courier* May 2003 p13). This result does not rely much on the assumption of a spatially flat universe, which is well confirmed by the observations anyway. The epoch of reionization by the first stars is now found to be at a redshift of 7–12, which is later by a factor of two than suggested by the earlier data. Finally, the results yield an upper limit of 0.68 eV for the sum of the neutrino masses.

What is really new in these latest results is the ability to constrain inflation models based on the full-sky polarization map. According to the inflationary scenario, the origin of the CMB fluctuations are quantum fluctuations scaled up by a factor of 10^{30} during the first instants ($\sim 10^{-34}$ s) after the Big Bang. In the simplest inflationary models this would lead to a roughly scale-invariant spectrum of density fluctuations corresponding to a power-law index of $n = 1$ or slightly less. This is exactly what was found with the new WMAP data, which yield $n = 0.94 \pm 0.02$, showing a small but significant deviation from scale invariance in the sense that the largest-sized fluctuations are the strongest. The opposite behaviour was predicted by more complicated hybrid models, which now appear to be ruled



In this new, more detailed picture of the early universe from WMAP, colours indicate “warmer” (red) and “cooler” (blue) spots. The white bars show the polarization direction of the oldest light. (Images courtesy NASA/WMAP Science Team.)

out. This result also implies that primordial gravitational waves would have a relatively high amplitude not far below the current detection threshold. Detecting their signature in the CMB polarization map would be a stunning confirmation of inflation and is therefore an important goal for ESA's Planck mission to be launched in 2008.

Further reading

Papers of the three-year WMAP observations have been submitted to the *Astrophysical Journal* and are available at http://map.gsfc.nasa.gov/m_mm/pub_papers/threeyear.html.

CERN COURIER ARCHIVE: 1963

A look back to CERN Courier vol. 3, May 1963

NEUTRONS

A powerful source for solid-state physics

At CERN, our two accelerators [the SC and the PS] both produce high-energy protons for use as projectiles and probes in the search for increased knowledge of the constitution of matter. High-energy electrons are also used in some laboratories. Another possible tool, although it is of more interest to those studying the normal physical states of matter (notably solid and liquid) rather than its ultimate constitution, is the neutron.

Nuclear-physics research carried out with feeble sources of neutrons in the 1930s led to the discovery of fission and eventually to the construction of nuclear reactors in all their many forms, some with a fantastically great

production of neutrons. A great deal of work has been done on the gross effects of neutron irradiation on materials, but this is essentially applied research. For more fundamental research in this field and for studies in which the neutron is used more specifically as a probe, well-defined beams of neutrons of accurately known energy are required, as is the case when using protons. High intensity is also necessary. To achieve all this with neutrons emitted from a reactor, particularly while keeping to a minimum the heat produced at the same time, is no easy task. As yet, no such specialized "very high flux" reactor exists, though one approaching this description is now under construction at

Brookhaven National Laboratory in the US.

Following an initial recommendation from L Kowarski who, besides being leader of the Data Handling Division at CERN, is also scientific adviser to the European Nuclear Energy Agency, the agency has recently launched a study project for a reactor of this kind in Europe. If built, it could become the heart of another centre for fundamental research, like CERN. It is, however, more likely that the internationally built and owned reactor, together with its supporting laboratories, would form an annex to one of the existing reactor-research centres.

● Original article p70.

PARTICLES

The "particles" of sub-nuclear physics

From the early days of just the proton and the electron, the list of so-called "fundamental particles" grew until a year or two ago some 30 particles and antiparticles were known or

predicted. Then came the discovery of the first "resonances" or "excited states", and the list began rapidly to lengthen again. It now seems clear, however, that neither these new particles nor, perhaps, many of those in the earlier list are truly "fundamental" or "elementary". New ideas abound and a more rational classification will undoubtedly arise in time, but for the moment, for those not closely involved, a certain amount of confusion appears inevitable.

The known "particles" have been placed into two groups, arbitrarily defined to separate the older particles from the newer ones. It happens that these groups also correspond more or less to those of the "long-lived" and "short-lived" particles, by comparison with a "nuclear year", the time taken for a nucleon to revolve about the centre of a nucleus, about 10^{-22} s.

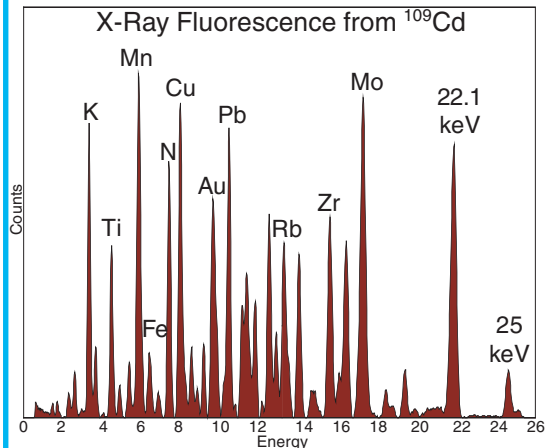
● Extracted from p66, where a second table also showed the "short-lived" particles.

The "elementary particles" – lifetime long compared with the nuclear year

		Particle name	Particle symbol and charge states	Mass (MeV)	Mean life (s)	Antiparticle symbol and charge states	Antiparticle name	
fermions (spin $\frac{1}{2}$)	leptons (light particles)	neutrino	ν_e	0	stable	$\bar{\nu}_e$	antineutrino	
		neutretto	ν_μ	< 3.5	stable	$\bar{\nu}_\mu$	antineutretto	
		electron	e^-	0.51	stable	e^+	positron	
		muon (mu minus)	μ^-	105.66	2.2×10^{-6}	μ^+	muon (mu plus)	
	baryons (heavy particles)	nucleons	proton	$p (=N^+)$	938.2	stable	$\bar{p} (-)$	antiproton
			neutron	$n (=N^0)$	939.5	1×10^{-3}	$\bar{n} (0)$	antineutron
		hyperons	lambda	$\Lambda (0)$	1115.4	2.5×10^{-10}	$\bar{\Lambda} (0)$	antilambda
			sigma plus	Σ^+	1189.4	8×10^{-11}	$\bar{\Sigma}^-$	antisigma
			sigma zero	Σ^0	1191.5	$\ll 1 \times 10^{-11}$	$\bar{\Sigma}^0$	
			sigma minus	Σ^-	1196.0	1.6×10^{-10}	$\bar{\Sigma}^+$	
xi zero	Ξ^0	1315	3.9×10^{-10}	$\bar{\Xi}^0$	antixi			
xi minus	Ξ^-	1321	1.7×10^{-10}	$\bar{\Xi}^+$				
bosons (spin 0 or 1)	mesons (intermediate particles)	photon	γ	0	stable	γ	photon	
		pion	pi zero	π^0	135.0	1.0×10^{-16}	π^0	pion
			plus or minus	π^+ or π^-	139.6	2.6×10^{-8}	π^- or π^+	
		kaon	K plus	K^+	493.9	1.2×10^{-8}	K^-	antikaon
			K zero	K^0 K_1^0 K_2^0	497.8	1.0×10^{-10} 6.0×10^{-8}	\bar{K}^0	

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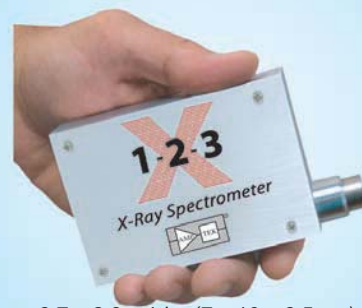


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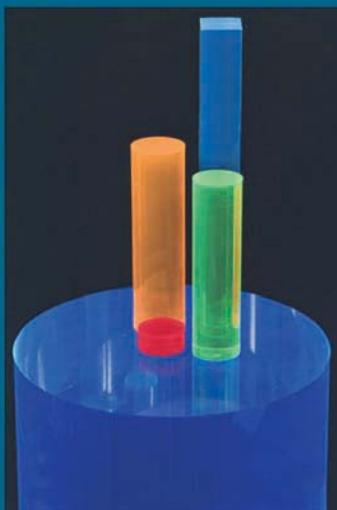
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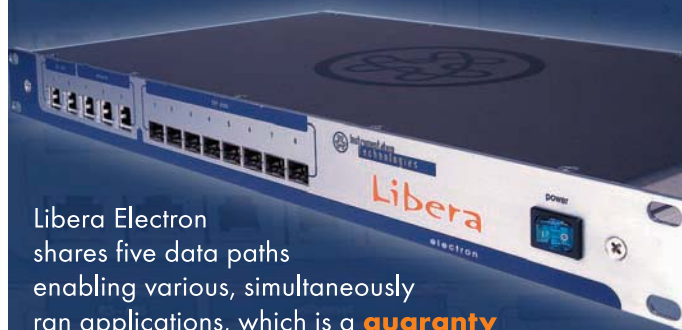


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PS and SPS accelerators are back in business

After a year of renovation and construction, CERN's accelerator complex is once again beginning to deliver different beams at a variety of energies.



A 35-tonne dipole from the PS is transferred by the 45-year-old locomotive that was brought back into service for the renovations.



Aging and ionizing radiation degrades the insulation on the PS dipoles' pole-face winding. This is one reason for the renovation.

Last year was a time for rejuvenation and building at CERN as a major part of the accelerator complex was shut down while preparations for the Large Hadron Collider (LHC) took place. During the shutdown, which started in November 2004 and continued throughout 2005, the Proton Synchrotron (PS) and the Super Proton Synchrotron (SPS) began an extensive renovation programme that will continue into the next decade. The LHC will depend on the injector complex that feeds it to deliver reliable and top-performance beams when it starts up in 2007. This comprises Linac2, Linac3, the PS Booster, the Low Energy Ion Ring (LEIR) and the PS and SPS.

The programme to renovate the main magnets of the PS, which has been operating since 1959, benefited from the long shutdown. The oldest accelerator of the injector complex had shown signs of its age, going offline for two weeks in 2003 when two magnets failed. The magnets were replaced, but to ensure it is in good condition when the LHC is turned on, the PS and CERN's other accelerators in the LHC injector chain started a consolidation programme. By renovating parts that are at the end of their useful life and updating obsolete components and systems, the consolidation programme intends to identify and resolve potential problems before operations are affected.

Wear and tear in the PS, which was still equipped with many of its original components, resulted from radiation degrading the materials and mechanical fatigue from pulsed magnetic forces. During 2005, 25 of the 100 main magnets were removed, renovated and re-installed in the PS tunnel. To move the 35-tonne magnets from the tunnel to the workshop in nearby building 180, the 45-year-old PS locomotive was restored. In the workshop, teams from the

Budker Institute of Nuclear Physics (BINP) in Novosibirsk, supervised by specialists from CERN, replaced the coils and pole-face windings and re-glued loose laminations. After testing, the renovated magnets were re-installed in the tunnel and re-aligned, ready for start-up in April 2006.

The SPS has also shown signs of age. In 2005, leaks appeared in the hydraulic circuits of some of the accelerator's dipoles, but after a thorough investigation, a way was found to make repairs. Those repairs and other upgrades will be completed during the 2006–07 shutdown.

New construction

The SPS is almost the last link in the chain that will supply beams to the LHC. The final connection will be made by two transfer lines, TI 2 and TI 8, that will take beams from the SPS (*CERN Courier* March 2005 p26). TI 8 was commissioned in 2004, and progress continued on TI 2 during 2005, with components installed and tested up to some 250 m before the shaft where the LHC magnets start the underground journey to their final locations (*CERN Courier* April 2005 p5). Upstream of TI 2, the beam extraction in the long straight section of the SPS has been converted into a fast extraction. Four upgraded kicker magnets have been installed to deflect the beam into the gap of existing septum magnets, which bend the beam horizontally out of the SPS ring. New extraction protection devices have also been installed to cope with the high-intensity beam for the LHC.

The recent shutdown also allowed time to work on Linac3 and LEIR. Together, they will provide heavy-ion beams to the LHC experiments in 2008. LEIR is the successor to the Low Energy Antiproton Ring and ▷

New magnet gives COMPASS wider view

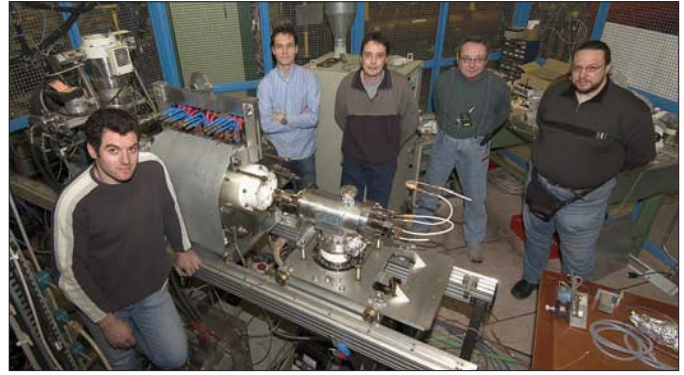


The COMPASS experiment's new superconducting solenoid.

When beams are delivered from the SPS to the North Area on 15 June, the team working on the Common Muon Proton Apparatus for Structure and Spectroscopy (COMPASS) experiment expect an unprecedented number of events, thanks to a new magnet. In December 2005, the experiment received the new magnet, which will make it easier to detect particles produced at large angles from collisions in the target. COMPASS is designed to study how quarks and gluons form hadrons and what exactly contributes to the spin of the nucleon. The experiment, which started to take data in 2002, currently uses a muon beam from the SPS together with the world's largest polarized target system in a 2.5 T field.

The new 5-tonne, 2.5-m-long superconducting magnet has a 63 cm diameter bore, much larger than the 27 cm opening of the previous magnet. To create the uniform field needed, a rather sophisticated magnet, much more complex than a simple solenoid, had to be designed and built. The number and variety of the different coils that form the magnet are the key to the high uniformity. There are two large compensator coils at either end of the magnet and sixteen correction coils throughout the volume. Finally, two "saddle" coils, one on top and one on the bottom, are used to change the orientation of the magnetic field rapidly to rotate the particles' spin into another direction. During testing at the Dapnia Laboratory of the Commissariat à l'Energie Atomique in Saclay, the team established a magnetic field homogeneity of $\pm 3 \times 10^{-5}$ over the target volume, three times better than required.

To take advantage of the magnet's larger aperture, the COMPASS collaboration is upgrading some detectors in the spectrometer. The tracker, which has 320 000 detection channels, will be enhanced to cover the new angular range. Moreover, to guarantee excellent performance in particle identification, the ring imaging Cherenkov detector is being upgraded with faster photon detectors based on multi-anode photomultipliers in the central region and with faster readout electronics for the existing photon detectors. The COMPASS experimental programme is scheduled to span the next five years.



Members of the team responsible for hadron sources and linacs with the new ECRIS mainly intended to supply ions to the LHC.

reuses much of the former machine's equipment. At the beginning of 2005, Linac3 was equipped with a new 14.5 GHz electron cyclotron resonance ion source (ECRIS) to increase the beam intensity. The configuration of the source was based on R&D done under a European Framework 5 project and the source itself was supplied by the Commissariat à l'Energie Atomique, Grenoble. In spring 2005 a beam was transported successfully from Linac3 to LEIR through the transfer line, which had been almost completely rebuilt.

LEIR itself was installed last summer and commissioning began when the first beam (of O^{4+} ions) was run in October. Preparation then began for the first studies of electron cooling, using collisions with an electron beam in a section of LEIR to reduce the dimensions of the ion beam. This focuses the beam and frees space to accumulate several pulses from Linac3 in LEIR. The cooling system, built by BINP, has been commissioned with electrons and the strong perturbations its magnetic system has on the ion beam have been corrected. The first cooling measurements took place at the end of the 2005 run, and the goal is to complete commissioning in 2006.

The new control centre

While various teams worked on improvements needed for different aspects of the LHC's operation, others were working to bring control of the future accelerator complex together in one room. The new CERN Control Centre (CCC) began operating on 1 February 2006 and was officially inaugurated on 16 March in a ceremony with members of the CERN Council.

The CCC, a sleek, futuristic room filled with a multitude of monitoring screens, combines the control rooms of all the laboratory's accelerators, as well as piloting cryogenics and technical infrastructures. The new centre has 39 control consoles laid out in four zones, one dedicated to each of the technical infrastructure, the PS complex, the SPS and the LHC. The cryogenics consoles are positioned between the LHC zone and the technical infrastructure zone. During peak operation periods there could be up to 13 operators working on any one shift, not counting the many experts responsible for assisting them. Built and installed in just 15 months, the centre is the first part of the LHC project to start up. The operators for accelerator testing are already on site, as the machines spring back into life.

By bringing together all of the operators and facets of the LHC injector chain, the CCC will guarantee a high-quality beam. It will also manage the beams to other experimental facilities at CERN. Similar to a rail network that uses the same infrastructure to send



The new CERN Control Centre unites all the control rooms.

passengers towards various destinations, the accelerators of CERN can transport several beams simultaneously and adapt each one to a given facility. The PS, for example, can prepare beams for the LHC while also feeding the Antiproton Decelerator (AD) and fixed-target experiments at the SPS. This multitasking is an important feature of accelerator and beam operations at CERN.

Now the machines are all coming back to life. The Isotope Separator On Line facility (ISOLDE) already started operation in April. Serviced by the PS Booster, ISOLDE had run during 2005, when it received record numbers of protons from the booster, as the PS and SPS were not operational. The PS service to the East Hall is scheduled to recommence on 22 May, and the AD should start up on 6 June. As of 15 June the SPS will provide the beam for the North Area, where several fixed-target experiments will be ready and waiting. On 29 May however, a major new project will come to life as commissioning begins for the CERN Neutrinos to Gran Sasso project (*CERN Courier* March 2006 p6). This facility will mark a new phase in the 30 years of the SPS when it delivers protons to generate a beam of neutrinos that will travel underground 730 km to the Gran Sasso Laboratory in Italy. It will continue the tradition of neutrino beams at CERN, which began with the PS and then moved to the SPS, and will test the recent improvements to the accelerator complex as the countdown continues towards the LHC start-up.

Résumé

Accélérateurs du PS et du SPS: le retour

L'année 2005 a été une période de rénovation et de construction au CERN. En effet, une grande partie du système d'accélérateurs a été arrêtée entre novembre 2004 et fin 2005 pour faciliter l'installation du Grand collisionneur de hadrons et permettre de grandes avancées dans le programme de rénovation complète du Synchrotron à protons (PS) et du Supersynchrotron à protons (SPS). Par ailleurs, on a construit le nouveau centre de contrôle du CERN, qui rassemble les salles de contrôle des huit accélérateurs du Laboratoire, ainsi que le pilotage de la cryogénie et des infrastructures techniques. Cette longue période de fermeture a permis de rénover les expériences à cible fixe telles que COMPASS.

Kendra Snyder, CERN, compiled from contributions to the CERN Bulletin and Annual Report.

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High schools focus on the extreme universe

James Pinfold reports on the large number of projects that are forging a connection between research in ultra-high-energy cosmic rays and practical scientific experience in schools.



Installing the first educational cosmic-ray array on the roof of Archbishop O'Leary High School in Edmonton, Alberta, on 23 February 1998. The array is part of the ALTA experiment.



Detectors from the Chicago Air Shower Array have become a garden feature at the Chaminade Middle School, where they form part of the California High School Cosmic Ray Observatory.

On 15 October 1991 the highest-energy cosmic-ray particle ever measured struck Earth's atmosphere tens of kilometres above the Utah Desert. Colliding with a nucleus, it lit up the night for an instant and then was gone. The Fly's Eye detector at the Dugway Proving Grounds in Utah captured the trail of light emitted as the cascade of secondary particles created in the collision made the atmosphere fluoresce. The Fly's Eye researchers measured the energy of the unusual ultra-high-energy cosmic-ray event – dubbed the “Oh-My-God (OMG) event” – at 320 exa-electron-volts (EeV), or 320×10^{18} eV. In SI units, the particle, probably a proton, hit the atmosphere with a total kinetic energy of about 5 J. For a microscopic particle this is a truly macroscopic energy – enough to lift a mass of 1 kg half a metre against gravity. On 3 December 1993, on the opposite side of the world, the Akeno Giant Air Shower Array (AGASA) in Japan recorded another OMG event with an energy of 200 EeV. In this case the cosmic ray was recorded using a large array of detectors on the ground to measure the extended air shower (EAS) resulting from the primary cosmic ray interacting with the atmosphere.

Since these first observations at least a dozen OMG events have been recorded, confirming the phenomenon and mystifying cosmic-ray physicists. It seemed that particles with energies more than about 50 EeV should not reach Earth from any plausible source in the universe more than around 100 million parsecs distant, as they should

rapidly lose their energy in collisions with the 2.7 K cosmic-microwave background radiation from the Big Bang – the Greisen–Zatsepin–Kuzmin limit. While many explanations have been proposed, experiments have so far failed to decipher a clear message from these highly energetic messengers, and the existence of the OMG events has become a profound puzzle. Now a new eye on these ultra-high-energy events has come into focus, based on the great plain of the Pampa Amarilla in western Argentina. The Pierre Auger Observatory (PAO), with its unprecedented collecting power, has begun to study cosmic rays at the highest energies (*CERN Courier* March 2002 p6 and January/February 2006 p8).

However signs of the extreme-energy universe may also come in a different guise – not as a single OMG event but rather as bursts of events of more-modest energy. On 20 January 1981, near Winnipeg, a cluster of 32 EASs – with an estimated mean energy of 3000 tera-electron-volts – was observed within 5 min (Smith *et al.* 1983). Only one such event would have been expected. This observation was the only one of its kind during an experiment that recorded 150 000 showers in 18 months. In the same year an Irish group reported an unusual simultaneous increase in the cosmic-ray shower rate at two recording stations 250 km apart (Fegan *et al.* 1983). The event, recorded in 1975, lasted 20 s and was the only one of its kind detected in three years of observation. ▷



School students construct a scintillator detector for one of the five regional clusters for the HISPARC cosmic-ray detector array.



Boxes containing cosmic-ray detectors on a school rooftop as part of the HISPARC project. (Photos courtesy Ilka Tánčzos.)

There have since been a few hints of such “correlated” cosmic-ray phenomena seen by some small cosmic-ray experiments dotted around the world, such as a Swiss experiment that deployed four detector systems in Basel, Bern, Geneva and Le Locle, with a total enclosed area of around 5000 km². In addition, the Baksan air-shower-array group has presented evidence from data from 1992 to 1996 for short bursts of super-high-energy gamma rays from the direction of the active galactic nucleus Markarian 501. The AGASA collaboration has also reported small-scale clustering in arrival directions, and possibly in the arrival times of these clustering events.

One mechanism that could generate correlated showers over hundreds of kilometres is the photodisintegration of high-energy cosmic-ray nuclei passing through the vicinity of the Sun, first proposed by N M Gerasimova and Georgy Zatsepin back in the 1950s. Other more recent and more exotic examples of phenomena that could give rise to large-area non-random cosmic-ray correlations include relativistic dust grains, antineutrino bursts from collapsing stellar systems, primordial black-hole evaporation and even mechanisms arising from the presence of extra dimensions.

Working together

Whichever way the high-energy universe is incarnated on Earth, the signs should be exceedingly rare, requiring large numbers of detectors deployed over vast areas to provide a reasonable signal. The detection of a single OMG particle requires dense EAS arrays and/or atmospheric fluorescence detectors, with detector spacings of the order of a kilometre, as in the PAO. Detection of cosmic-ray phenomena correlated over very large areas requires even bigger detection areas, which at present are economically feasible only with more sparse EAS arrays (on average much fewer than one detector per km²). In fact, global positioning system (GPS) technology makes it possible to perform precision timing over ultra-large areas, enabling a number of detector networks to be deployed as essentially one huge array. An example is the Large Area Air Shower array, which started taking data in the mid-1990s. It comprises around 10 compact EAS arrays spread across Japan, forming a sparse detector network with an unprecedented enclosed area of the order of 30 000 km².

Now, however a new dimension to cosmic-ray research has opened up. In 1998 in Alberta, building on a proposal first presented in 1995, the first node of a new kind of sparse very-large-area network of cosmic-ray detectors began to take data. The innovative

aspect of the Alberta Large-area Time-coincidence Array (ALTA) is that it is deployed in high schools. By the end of 1999 three high-school sites were operating, each communicating with the central site at the University of Alberta. In 2000 the Cosmic Ray Observatory Project (CROP), centred at the University of Nebraska, set up five schools with detectors from the decommissioned Chicago Air Shower Array. Around the same time the Washington Large-area Time-coincidence Array (WALTA) installed its first detectors.

The ALTA, CROP and WALTA projects have a distinct purpose – to forge a connection between two seemingly unrelated but equally important aims. The first is to study the extreme-energy universe by searching for large-area cosmic-ray coincidences and their sources; the second is to involve high-school students and teachers in the excitement of fundamental research. These “educational arrays”, with their serious research purpose, provide a unique educational experience, and the paradigm has spread to many other sites in North America. The detector systems are simple but effective. Following the ALTA/CROP model they use a small local array of plastic scintillators, which are read by custom-made electronics and which use GPS for precise coincidence timing with other nodes in a network of local arrays over a large area. Most of the local systems forming an array use three or more detectors, which, with a separation of the order of 10 m and a hard-wired coincidence, allow accurate pointing at each local site. Today the ALTA/CROP/WALTA arrays involve more than 60 high schools and there are three further North American educational arrays in operation: the California High School Cosmic Ray Observatory (CHICOS) and the Snowmass Area Large-scale Time-coincidence Array (SALTA) in the US, and the Victoria Time-coincidence Array (VICTA) in Canada. At least seven more North American projects are planned.

The CHICOS array is the largest ground-based array in the Northern Hemisphere. Its detectors, donated by the CYGNUS collaboration, are deployed on more than 70 high-school rooftops across 400 km² in the Los Angeles area. Each site has two 1 m² plastic scintillator detectors separated by a few metres. Local pointing at each site is not possible, nor is it required as CHICOS uses GPS pointing across multiple sites to concentrate on the search for single ultra-high-energy cosmic-ray air showers. Recently the collaboration reported their results at the 29th International Cosmic Ray Conference in Pune, India (McKeown *et al.* 2005).

Innovative detection techniques have also been employed in this



Two high-school students who are part of the Italian EEE project build an MRPC muon chamber in CERN's Building 29.

burgeoning collaboration between researchers and high-school students and teachers in North America. A prime example is the project for Mixed Apparatus for Radar Investigation of Cosmic Rays of High Ionization (MARIACHI), based at Brookhaven National Laboratory, New York. The plan is for the experiment to detect ultra-high-energy cosmic rays using the passive bistatic radar technique, where stations continuously listen to a radio frequency that illuminates the sky above it. The ionization trails of ultra-high-energy cosmic-ray showers – as well as meteors, micro-meteors and even aeroplanes – in the field of the radio beam will reflect radio waves into the high-school-based detectors. These schools will also be equipped with conventional cosmic-ray air-shower detectors. The technique, if successful, will speed the construction of ultra-large-area cosmic-ray detectors.

The European endeavour

Across the Atlantic, schools in many European countries are also getting involved in studying the extreme-energy universe (see figure 1, p22). In 2001 physicists from the University of Wuppertal proposed SkyView – the first European project to suggest using high-school-based cosmic-ray detectors. This ambitious project proposed an immense 5000 km² array, the size of the PAO, using thousands of universities, colleges, schools and other public buildings in the North Rhine-Westphalia area. Roughly a year later CERN entered the field with a collaborative effort to distribute cosmic-ray detectors from the terminated High Energy Gamma Ray Astronomy project in schools around Dusseldorf. A test array of 20 counters was set up at Point 4 on the tunnel for the Large Electron-Positron (LEP) collider, with the aim of studying coincidences with counters installed about 5 km away at Point 3 as part of cosmic-ray studies by the L3 experiment on the LEP.

Also in 2002 the High School Project on Astrophysics Research with Cosmics (HiSPARC), initiated by physicists from the University of Nijmegen in the Netherlands, joined the European effort (*CERN Courier* July/August 2004 p35). HiSPARC now has five regional clusters of detectors being developed in the areas of Amsterdam, Groningen, Leiden, Nijmegen and Utrecht. Around 40 high schools are participating so far and more are joining. In March 2005 the HiSPARC array registered an event of energy 8×10^{19} eV, in the ultra-high-energy “ankle” region of the cosmic-ray energy spectrum, which was also reported at the international conference in Pune (Timmermans 2005).

The HiSPARC collaboration is also planning to use a recent and

exciting development of the Low Frequency Array (LOFAR) Prototype Station (LOPES) experiment in Karlsruhe. Using a relatively simple radio antenna, LOPES detects the coherent low-frequency radio signal that accompanies the showers of secondary particles from ultra-high-energy cosmic rays. A large array of these low-frequency radio antennas, the LOFAR observatory, is already being constructed in the Netherlands. Such technology can also be exploited by high-school-based observatories around the world to expand their capability rapidly to become effective partners in the search for point sources of ultra-high-energy particles.

Elsewhere, the School Physics Project was initiated in Finland and is now under development. Also in 2002 the Stockholm Educational Air Shower Array (SEASA) was proposed to the Royal Institute of Technology in Stockholm. SEASA has two stations of cosmic-ray detectors running at the AlbaNova University Centre and the first cluster of stations for schools in the Stockholm area is now in the production stage. Meanwhile, in the Czech Republic the Technical University in Prague and the University of Opava in the province of Silesia – working closely with the ALTA collaboration – each have a detector system taking data, with a third to be deployed this summer.

A number of other European efforts are gearing up, including two that have links to the discovery of cosmic-ray air showers in 1938 by Pierre Auger, Roland Maze and Thérèse Grivet-Meyer working at the Paris Observatory. The Réseau de Lycées pour Cosmiques (RELYC) project, centred on the Collège de France/Laboratoire Astroparticule et Cosmologie in Paris, is preparing to install detectors in high schools close to where Auger and colleagues performed their ground-breaking experiments. The Roland Maze project is centred on the Cosmic Ray Laboratory of the Andrzej Soltan Institute for Nuclear Studies in Lodz, Poland, where it continues a long tradition in studies of cosmic-ray air showers initiated in partnership with Maze some 50 years ago. The plans are to deploy detectors in more than 30 local high schools. In the UK, physicists from King's College London in collaboration with the Canadian ALTA group will place detector systems in the London area during 2006. In northern England, Preston College is continuing to work on a pilot project, initiated in 2001, to develop an affordable cosmic-ray detection system as part of the Cosmic Schools Group Proposal, involving the University of Liverpool and John Moores University in Liverpool. Finally, a project to set up cosmic-ray telescopes with GPS in 10 Portuguese high schools is underway, spearheaded by the Laboratório de Instrumentação e Física Experimental de Partículas and the engineering faculty of the Technical University in Lisbon.

While the majority of the European projects are based on plastic scintillators, the Italian Extreme Energy Events (EEE) project has opted instead for multigap resistive plate chambers (MRPCs) as their basic detector element. These allow a precise measurement of the direction and time of arrival of a cosmic ray. The aim of this project, the roots of which date back to 1996, is to have a system of MRPC telescopes distributed over a surface of 106 km², for precise detection of extreme-energy events (Zichichi 1996). These chambers are similar to those that will be used in the time-of-flight detector for the ALICE experiment at CERN's Large Hadron Collider. Three MRPC chambers form a detector “telescope” that can reconstruct the trajectories of cosmic muons in a shower. At present 23 schools from across Italy are involved in the pilot project, with around 100 others on a waiting list from the length and breadth of the Italian peninsula. More than ▷



Fig. 1. The main school-based cosmic-ray arrays in Europe. The next step could be to join forces with North American projects.



Fig. 2. The geographical distribution of the North American cosmic-ray projects that together make up the NALTA network.

60 MRPCs have been built at CERN by teams of high-school students and teachers under the guidance of experts from Italian universities and the INFN.

A worldwide network

Most of the major groups in Canada and the US have formed a loose collaboration – the North American Large-area Time Coincidence Arrays (NALTA) – with more than 100 detector stations spread across North America (figure 2). The aim is to share educational resources and information. However, it is also planned to have one central access point where students and researchers can use data from all of the NALTA sites, creating in effect a single giant array. Such a combined network across North America could eventually consist of thousands of cosmic-ray detectors, with the primary research aim of studying ultra-high-energy cosmic-ray showers and correlated cosmic-ray phenomena over a very large area. Until the PAO collaboration constructs its second array in Colorado, US, the NALTA arrays, along with their European counterparts, will dominate the ground-based investigation of the extreme-energy universe in the Northern Hemisphere.

The European groups are also developing a similar collaboration, called Eurocosmics. It is clear that a natural next step is to combine the North American and European networks into a worldwide network that could contribute significantly to elucidating the extreme-energy universe. Such a network could aid and encompass other efforts throughout the world, including in developing countries where it could provide a natural bridgehead into the global scientific culture (see p46).

Further reading

Further information about many of the projects in North America can be found at <http://csr.phys.ualberta.ca/nalta/>, and for Europe at www.nikhef.nl/extern/eurocosmics/.
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Resumé

Les lycéens explorent l'univers des énergies extrêmes

En Europe comme en Amérique du Nord, la recherche sur le rayonnement cosmique prend depuis quelques années de nouvelles formes, avec des réseaux de détecteurs disséminés sur de très grandes surfaces. Ce qui est nouveau, c'est que les détecteurs sont installés dans des établissements scolaires. Il s'agit d'atteindre deux objectifs distincts mais également importants: le premier est d'étudier l'univers à des énergies extrêmement élevées en recherchant sur de grandes surfaces des rayons cosmique arrivant en coïncidence pour en découvrir l'origine; le deuxième est d'initier les lycéens et leurs professeurs aux joies de la recherche fondamentale.

James Pinfold, University of Alberta.

Relativity on a mountain

Alan Walker describes how a schoolgirl from Scotland used steel and scintillator to test Einstein's special theory of relativity.

Studying cosmic rays from mountain tops has a grand tradition with famous observatories in dramatic surroundings, such as the Jungfrauoch in Switzerland, the Pic du Midi in France and Mount Chacaltaya in Bolivia. Last year one of Scotland's highest mountains, Cairn Gorm, temporarily joined the elite club when Ingrid Burt from Beeslack High School in Penicuik, near Edinburgh, set up a high-school cosmic-ray project. Rather than measuring cosmic-ray showers, as many schools projects are now doing (see p19), Burt set out during World Year of Physics to test Albert Einstein's special theory of relativity.

Burt spent six weeks funded by a Nuffield Bursary looking at the feasibility of doing such an experiment with a small muon detector, using a UK mountain. Peter Reid from the Scottish Science and Technology Road Show and myself of the Particle Physics Group at the University of Edinburgh guided her studies. The study and the subsequent experiment were undertaken in conjunction with the Particle Physics for Scottish Schools outreach project, which also provided the detector. The aim was to verify time dilation by comparing the number of cosmic-ray muons detected near the top of the mountain at 1097 m with the number arriving in the university 76 m above sea level.

The amount of dilation depends on the particle's velocity, so a key part of the experiment was to ensure that the muons detected in the physics department at close to sea-level had the same speed when they passed the altitude of Cairn Gorm as the muons actually detected on the mountain. To do this we used steel sheets to slow the muons until they stopped in a thick scintillator detector and subsequently decayed. The "signal" was thus a pulse in a thin counter from a muon entering the apparatus followed within 20 μ s by a delayed pulse from the exiting electron created in the muon's decay.

For a student in Edinburgh, Cairn Gorm was a clear choice for an experiment at altitude. It is only 227 km from Edinburgh and, like the Jungfrauoch, has a mountain railway – an important criterion where heavy equipment is involved. To this end, Burt asked Cairn Gorm Mountain Ltd, the company that operates the funicular railway, for help in transporting the 400 kg of steel and other apparatus.

We took the first measurements at the Ptarmigan Top Station of the Cairn Gorm funicular railway, where we needed 49.3 cm of steel to slow the muons so that they would stop and decay in the scintillator. Given that we can calculate the energy losses in both materials, this accurately measures the velocity of the muons as they enter the top of the steel at this altitude before they stop and decay in the scintillator.

The energy lost as a muon of this velocity passes through the atmosphere can also be accurately calculated, so we compensated for this loss between the Cairn Gorm and university sites by removing 21 cm of steel – the equivalent to the slowing power of the intervening 1021 m of atmosphere – and ran the experiment at the



Ingrid Burt (right), with Fiona Milligan of Cairn Gorm Mountain Ltd and Alan Walker, with the experiment's kit. (Courtesy Peter Reid.)

university with 28.3 cm of steel. This meant that the muons detected at both experimental sites had the same energies and speeds. As muons travel down from Cairn Gorm to the university, they change velocity and their numbers reduce according to the exponential decay law. The number of muons detected each minute decreases as they travel downwards, and the reduction depends solely on the time elapsed. Without the effect of time dilation, the reduction in this experiment would be a factor of about 4; taking time dilation into account gives a reduction factor of 1.3.

For 10 days in October 2005, visitors arriving at the top of the Cairn Gorm funicular had the chance to see the experiment in action as it counted stopping muons there – at a rate of 1.3 a minute. This meant that if Einstein was right, we should detect 1 a minute at the university, and it was no surprise to do so.

Burt is now refining these calculations to estimate the errors in the predictions, but we do not expect these to render the results invalid. It would be interesting to repeat the experiment with a greater height difference, for example at CERN and at the top of Jungfrauoch railway.

- Ingrid Burt was a gold finalist at the British Association 2006 Crest Science Fair, and won a week at the London International Science Fair in August.

Résumé

Relativité dans les Highlands

Pendant 10 jours, en octobre 2005, les visiteurs arrivant au sommet du funiculaire de Cairn Gorm ont pu découvrir une expérience sur les rayons cosmiques, réalisée par une lycéenne. Ingrid Burt, élève d'un lycée écossais, a voulu, à l'occasion de l'Année mondiale de la physique, vérifier expérimentalement la théorie de la relativité restreinte d'Albert Einstein. Au moyen de tôles d'acier et d'un détecteur à scintillation, elle a étudié le phénomène de dilatation du temps en comparant le nombre de muons issus du rayonnement cosmique arrêtés par l'appareil au sommet de la montagne avec le nombre mesuré au niveau de la mer.

Alan Walker, University of Edinburgh.

The world's biggest neutrino

After a successful construction season over the Austral summer at the South Pole, the

The second season of construction for the IceCube detector in Antarctica has recently ended as summer in the Southern Hemisphere has drawn to a close. Now with nine strings of sensors, IceCube is the largest neutrino detector in the world, and is well on the way to its goal of detecting extraterrestrial neutrinos with energies of more than 100 GeV (*CERN Courier* May 2005 p17).

By early February, eight strings, each comprising 60 optical sensors had been deployed, bringing the total number of in-ice sensors to 540. Each sensor includes a 25 cm photomultiplier tube in a pressure vessel. The associated electronics provides integrated trigger, readout, control, data-formatting and calibration functions, essentially forming a “mini-satellite”.

The strings form a triangular grid with 125 m sides, with the sensors installed 1450–2450 m below the surface, encompassing a volume of more than 3000 million tonnes of ice. A laser “standard candle” and a “dust-logger” to measure ice properties were also deployed. In addition, 24 IceTop tanks were installed, expanding the surface air-shower array to 32 tanks. The schedule was helped by generally good weather, with temperatures remaining above $-30\text{ }^{\circ}\text{C}$ until the end of January.

The season also saw the start of rapid production drilling, in which the heating system supplied hot water to one drill tower while a second tower was moved to the next hole. Although drilling got off to a late start, by the end of January holes were being drilled every four days, with string deployment smoothly following drilling. By the end of the season, it only took about 12 hours to connect the optical modules to the cable and lower the string into place. Strings were commissioned soon after deployment. About 99% of the detectors appear fully functional; the half-dozen or so failures stem from a variety of causes.

In addition to preparing for this season, IceCube has been collecting data from the single string and eight tanks that were deployed in 2004/05. Several different types of events have been studied: downward-going cosmic-ray muons, air showers and “flasher” events designed to mimic showers from the interactions of electron neutrinos. Flasher events are produced by the 12 LEDs contained in each sensor module. Events have also been studied that contain coincidences between the new strings and tanks, as well as between the new strings and the Antarctic Muon and Neutrino Detector Array (IceCube’s predecessor) and the South Pole Air Shower Array.

The initial data analyses included a search for neutrino events. Two clear muon neutrinos were observed, appearing as near-vertical, upward-going muons. One event was seen by 50 detectors, which tracked the muon over an 850 m trajectory. The other muon was observed by 35 sensors over about 650 m. These tracks correspond to minimum muon energies of about 420 and 330 GeV, respectively. The ratio of upward-going to downward-going muons is about 500 000:1; being able to separate clean neutrino events with a single string shows the power of the detector. Several additional possible candidates were observed with shorter tracks, with 8–11 hits.



The IceCube construction crew, in front of the reel holding the 2500 m of dri



Members of the IceCube team prepare to close one of the IceTop tanks for. The ice is first covered with insulation to reduce the rate of temperature ch

However, with a single string, these lower-multiplicity events could not be conclusively identified as neutrinos.

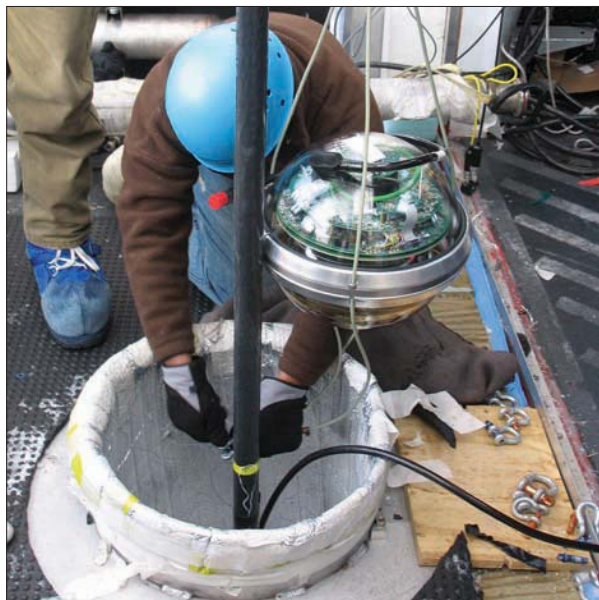
These data have been closely scrutinized to measure detector performance. Both the muon and light-flasher data demonstrate that the timing across the entire array (including the surface detectors) is consistent to better than 3 ns. The sensors are highly efficient for single photoelectrons, but also have adequate dynamic range to measure light pulses of up to 10 000 photoelectrons. Directional comparisons between air showers reconstructed with IceTop, and coincident muons seen in the deep ice were used to verify the point-

Detector gets ready for physics

IceCube detector array is now preparing to tackle real physics. **Spencer Klein** reports.



hose needed.



Researchers prepare to deploy a string of optical sensors.



the winter.
ange.



The freighter Tern, carrying key IceCube hardware needed for construction next season, being escorted into McMurdo Sound by the Russian icebreaker Krasin.

ing accuracy and angular resolutions. For muons, the angular resolution is better than 10° for events with 8 sensors hit, improving to 1.5° for events with more than 30 hits; the muon and neutrino directions are nearly co-linear.

The detector's dark-noise rates are particularly important for supernova searches; a pulse of low-energy neutrinos from a supernova will manifest itself as an increase in the noise rates in the phototubes. Shortly after the phototubes were deployed, their noise rates rose dramatically owing to triboluminescence – light produced by friction as the ice freezes. However, after the freeze-in was com-

plete, the phototube rates dropped to an average of 650 Hz. With $51 \mu\text{s}$ of deadtime after each pulse to remove correlated light, the rate drops to 350 Hz. This rate is even less than anticipated, increasing IceCube's sensitivity to supernovae.

These successes bode well for the future of IceCube and physics analyses are now beginning. Working groups are forming to search for point sources of neutrinos, such as active galactic nuclei and gamma-ray bursters, to search for diffuse extra-terrestrial neutrinos and to study the composition of cosmic rays. IceCube will also shed light on many areas of nuclear and particle physics through searches for signs of supersymmetry, annihilation of weakly interacting massive particles in the Sun and Earth, and for exotica such as magnetic monopoles. It will also probe quantum chromodynamics, through a measurement of neutrino cross-sections at high energies (via absorption in Earth) and thereby explore saturation in nuclear-parton distributions at low parton energy fraction, i.e. low x . With a full programme of physics to explore, detailed plans for deployment are being made for the coming seasons, with at least 75 strings expected to be complete by 2011.

- IceCube is a collaboration of about 250 scientists and engineers from 30 institutions in the US, Europe, Japan and New Zealand. The \$270 m project is funded largely by the US National Science Foundation, with smaller contributions from the US Department of Energy, the University of Wisconsin and several European countries.

Further reading

For more information about IceCube see www.icecube.wisc.edu or <http://icecube.lbl.gov>.

A Achterberg *et al.* 2005 astro-ph/0509330, papers presented at the 29th International Cosmic Ray Conference.

Résumé

IceCube: le plus grand détecteur de neutrinos du monde

Alors que l'été austral touchait à sa fin, la deuxième saison de construction au Pôle Sud du détecteur IceCube arrivait également à son terme. Huit lignes de 60 capteurs optiques ont été immergées, portant à 540 au total le nombre de détecteurs dans la glace. Avec ses neuf lignes de photomultiplicateurs, IceCube est maintenant le plus grand détecteur de neutrinos du monde et il est à pied d'œuvre pour découvrir des neutrinos extraterrestres d'énergie supérieure à 100 GeV. De plus, l'analyse des données produites par l'unique ligne et les huit cuves (IceTop) installées en 2004–2005 laisse penser que le détecteur donnera de bons résultats. Ces succès augurent bien pour l'avenir; dès à présent, les analyses de physique commencent.

Spencer Klein, Lawrence Berkeley National Laboratory.



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Closed-loop technology speeds up beam control

Brookhaven National Laboratory, Fermilab and CERN have together developed a feedback-control system that is already speeding up operations at RHIC and should prove invaluable in commissioning the LHC.

Peter Cameron explains.

Successful beam acceleration in the Large Hadron Collider (LHC) at CERN will require accurate and robust control of a variety of machine parameters. With a sufficiently accurate model, it might be possible to control these parameters by the “set it and forget it” method, more often referred to by control specialists as open-loop control. However, in complex systems such as the LHC it becomes advantageous to measure continuously the value of the parameters to be controlled and to adjust the strength of correction elements to maintain the desired values. This method is called closed-loop, or feedback, control.

In addition to correction of absolute position, beam control in the transverse (horizontal and vertical) directions in a synchrotron must regulate two parameters in each plane: betatron tune and chromaticity. The beam in a synchrotron is focused by quadrupole magnets, the equivalent of focusing lenses in optics. The beam particles oscillate transversely in these confining fields, similar to a mass on a spring. This is known as betatron motion and the frequency of oscillation is the betatron tune. In addition, the momentum spread of the beam causes particles with different momenta to experience different focusing, a property of the accelerator known as chromaticity, which is corrected with sextupole magnets.

Equally important is that inevitable magnetic-field errors cause the betatron motions in horizontal and vertical planes to become coupled to each other, and this coupling must be carefully controlled. In the “mass on a spring” model, the horizontal and vertical motions are equivalent to two independent masses vibrating on separate springs, and coupling is a third spring that joins the two masses. This coupling may be corrected with skew quadrupole magnets. Coupling control is often one of the more difficult problems in accelerator control. Inadequate coupling control makes it impossible to control betatron tune properly and also reduces the area of the stable transverse space available to the beam.

Historically, control of tune, chromaticity and coupling has been open loop. However, the LHC pushes design frontiers to the limit, and successful beam acceleration will require closed-loop feedback con-

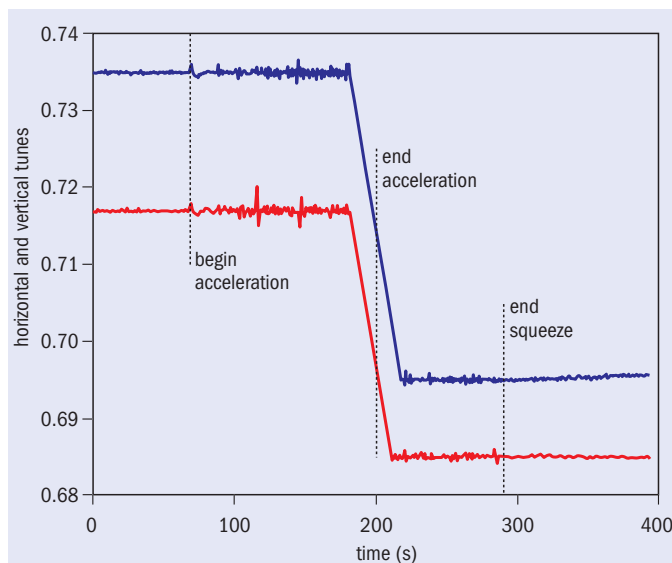


Fig. 1. Data from a typical development ramp early in RHIC Run 6 in February 2006, with tune and coupling feedback enabled. The red and blue traces (left scale) are the betatron tunes.

trol of these transverse parameters. In 2002 a collaboration was established between CERN and the Collider–Accelerator Department at the Brookhaven National Laboratory. The purpose was to benefit the LHC from the tune-feedback programme at Brookhaven, and to benefit Brookhaven from CERN expertise. This collaboration is now sponsored by the US LHC Accelerator Research Program (LARP), funded by the US Department of Energy, and has been expanded to include Fermilab. The collaborative effort paid off spectacularly at the beginning of the 2006 run of the Relativistic Heavy Ion Collider (RHIC), with robust control of tune and coupling up the acceleration ramps.

Figure 1 shows data on betatron tunes from a typical development ramp early in RHIC Run 6, with tune and coupling feedback enabled. The drop in tune near the end of the acceleration ramp follows from the fact that RHIC is currently running with polarized protons. The working point used during the acceleration ramp is chosen to minimize growth in the emittance of the beam; once the machine is at full energy the working point is shifted to minimize the effect on the protons of depolarizing resonances. The feedbacks were turned off at the end of the beta squeeze. With the feedbacks on, the largest departures from the desired tunes were around 10^{-3} , while the rms variation of tune was a few 10^{-4} .

The accomplishment of successful ramps with feedback control of tune and coupling was the result of an effort that evolved over ▷



RHIC's tune and coupling feedback could be used at the LHC.

several years. Early efforts at RHIC were persistently confounded by two obstacles. The first was a problem of dynamic range. To avoid blowing up the transverse size of the beam, and thereby reducing the beam brightness available to the physics experiments, the beam excitations needed to measure and control tune must be very small. The power in the resulting betatron signal is of the order of femto-watts (10^{-15} W), while the power delivered to the pickup by the beam unrelated to the betatron tune is in the range of tens of watts. We therefore devoted our attention to this dynamic-range problem, attempting many solutions, all with only partial success. Ultimately, CERN provided the solution by way of an analogue front-end using direct diode detection, or "3D" (Gasior and Jones 2005).

The second obstacle to tune feedback at RHIC was linear coupling, which rotates the planes of the betatron oscillations away from the horizontal and vertical in which the magnet portion of a tune-feedback loop applies corrections. When this rotation approaches 45° the magnet loop then applies tune corrections in the wrong plane relative to the tune measurement, and the tune-feedback loop is driven unstable. RHIC (like the LHC) requires strong sextupoles to compensate for natural chromaticity; unfortunately, vertical offset in the sextupoles introduces coupling, and vertical-orbit fluctuations from ramp to ramp in RHIC were often sufficient to cause the tunes to become fully coupled.

In 2004 we fully understood the coupling problem, so efforts to implement tune feedback ceased, and we began to implement coupling feedback. We reconfigured the tune-measurement system to measure both projections of the tunes in both planes during tune tracking. Due to hardware limitations, this could be done in only one ring at a time. However, the excellent quality of the resulting data made it clear that we could implement coupling feedback. Over the course of the next two years this was studied in some detail and a decoupling algorithm was formulated (Cameron *et al.* 2005 and Luo *et al.* 2005).

For the 2006 run at RHIC a new system for measuring baseband tune – or baseband Q (BBQ) – was developed. This incorporates measurement of both tunes in both planes in both rings, as well as the 3D analogue front ends. The system was extensively commissioned on analogue test resonators before working with a real beam, both for tune and coupling measurement. Within minutes of the first circulating bunched beam in RHIC, the BBQ was measuring tune and coupling "out of the box". During the period of machine set-up and tuning in preparation for developing acceleration ramps, the control-system interface to the magnets was completed, together with measurements of overall system loop gains and the design of the loop filters.

Ramping began on the evening of 15 February. The beam was lost

early in the first ramp, which was done without tune and coupling feedback to establish a baseline. For the second ramp the feedback loops were closed and the beam was delivered to full energy, with tune control of around 0.001 or better, with the machine well decoupled throughout the ramp. This successful ramp was the world's first attempt to implement simultaneous tune and coupling feedback during beam acceleration – good news for the LHC. There is now a reasonable expectation, given sufficient attention to integration with the controls and magnet systems, that an operational tune- and coupling-feedback system will be available early in the LHC commissioning.

As the tune- and coupling-feedback system for RHIC moves towards full operational integration as a "non-expert" system, the focus for instrumentation has shifted to chromaticity control and feedback. As valuable as robust tune and coupling feedback will be for LHC commissioning, the most urgent need will be for chromaticity measurement and control, to combat the chromatic effect of "snapback" transients at the beginning of the acceleration ramp.

Many approaches to the problem of fast and accurate chromaticity measurement during ramping are being investigated. The most promising approach implemented so far tracks tune while simultaneously modulating the beam momentum very slightly. Measurement of the resulting tune modulations has permitted determination of chromaticity during ramping with an accuracy of around a unit, and a bandwidth of about 1 Hz. This method has been operational in RHIC for the past two years as a non-expert measurement under sequencer control (Cameron *et al.* 2005). During the coming weeks and months both this and other methods will be further evaluated at RHIC, in close collaboration with Fermilab and CERN, and we look forward to reporting here on successful results from these efforts.

- For more about US-LARP see www.agshrhome.bnl.gov/LARP/.

Further reading

- P Cameron *et al.* 2005 "Advances Towards the Measurement and Control of LHC Tune and Chromaticity", DIPAC 2005, Lyon.
 M Gasior and R Jones 2005 "High Sensitivity Tune Measurement by Direct Diode Detection", DIPAC 2005, Lyon.
 Y Luo *et al.* 2005 "Possible Phase Loop for the Global Decoupling", PAC 2005, Knoxville.

Résumé

Contrôle de faisceaux amélioré

Pour accélérer des faisceaux dans le Grand collisionneur de hadrons (LHC) du CERN, il faudra disposer de systèmes de contrôle-commande précis et fiables pour différents paramètres – en particulier, la fréquence de l'oscillation bêta-tron ("l'accord bêta-tron") et le couplage des oscillations sur différents plans. Une collaboration entre Brookhaven, Fermilab, et le CERN a mis au point un système de contrôle avec rétroaction, dans le cadre du programme américain LARP de recherche sur les accélérateurs. Il s'agit du premier système au monde assurant simultanément une rétroaction sur l'accord et sur le couplage pendant l'accélération du faisceau. Ce système permet déjà un réglage plus rapide du Collisionneur d'ions lourds relativistes (RHIC). Il devrait être extrêmement précieux lors de la mise en service du LHC.

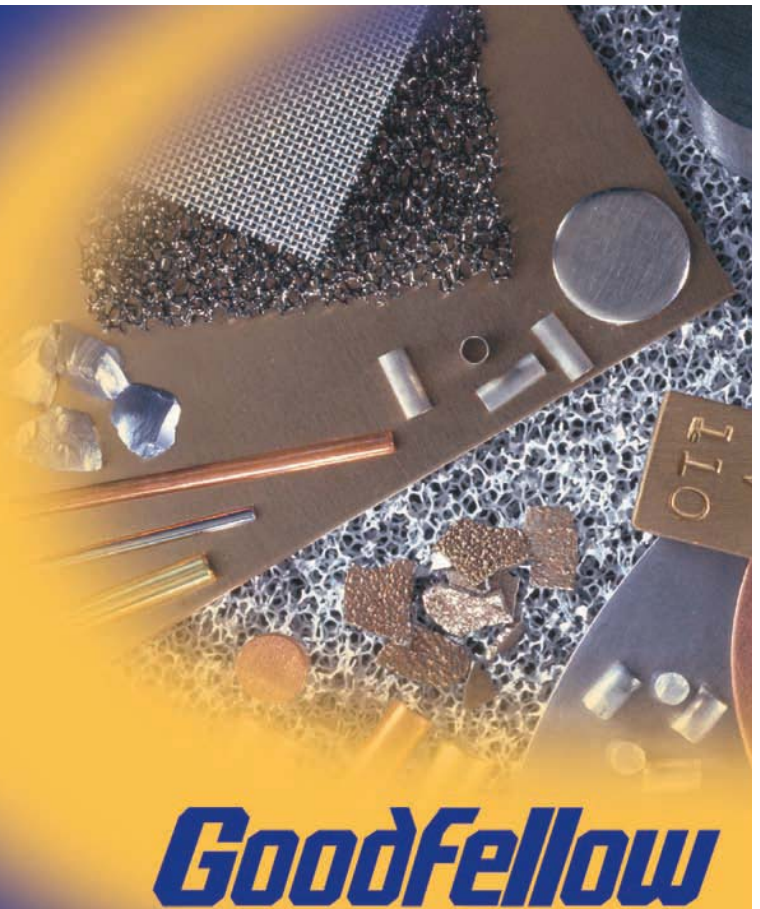
Peter Cameron, Brookhaven National Laboratory.

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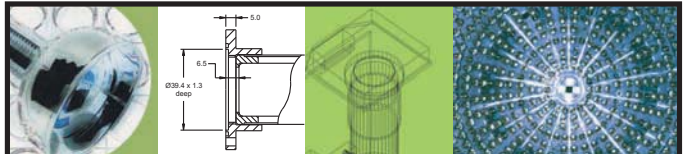


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FACES AND PLACES

AWARDS

CMS honours international industry with both crystal and gold awards

The seventh annual CMS Awards ceremony was held on 13 March to recognize industries that have made substantial contributions to the construction of the collaboration's detector.

General Tecnica of Italy received the prestigious crystal award for developing and producing the resistive plate chambers (RPCs) for the barrel muon detector and prototyping for the endcap RPC detector. The company began working with CERN on the project in the early 1980s, making major improvements to certain assembly procedures. General Tecnica has already built 300 of the 480 RPCs needed for the experiment.

Other companies making excellent contributions to the CMS project were recognized with gold awards. AICON 3D Systems GmbH received their award for developing and constructing components for the optical camera-based 3D systems that are used to measure large parts of CMS.

Firms from three countries were rewarded for work connected with the CMS superconducting solenoid magnet. KONCAR Electrical Industries of Croatia won gold for manufacturing the magnet's 20 kA power



Representatives of the firms that received the CMS crystal and gold awards for 2006.

lines and installing them in the pillar wall between the service and experiment caverns. The French company SDMS was honoured for designing and constructing the proximity cryogenics system for the coil, while ZEC Services of Poland was rewarded for producing and assembling cooling and gas circuits on the magnet yoke.

Three Swiss firms received gold for work related to electronics. ASCOM was honoured for producing and assembling electronic

boards for the electromagnetic calorimeter barrel; Cicorel was rewarded for producing and laminating the tracker front-end hybrid circuits, and Hybrid SA received its award for component assembly and for testing the tracker front-end hybrids.

eXception EMS of the UK received gold for manufacturing drivers for the tracker front-end, and TM Engineers, also of the UK, was rewarded for manufacturing the electromagnetic calorimeter endcap support structures.

DESY director-general receives Cross of Merit

Albrecht Wagner, chair of the DESY board of directors, received the Cross of Merit, First Class, of the Order of Merit of the Federal Republic of Germany on 16 March. He was honoured for his contributions "to the present and future of one of the most important research centres in Europe, and to high-energy physics in general". According to the Order, Wagner's numerous contacts in many countries rendered outstanding services to Germany's international reputation. Frieder Meyer-Krahmer, state secretary of the German Federal Ministry of Education and Research, presented the award at a ceremony at DESY in Hamburg.

Wagner has been chair of the DESY board



Frieder Meyer-Krahmer (left) presents the Federal Republic of Germany's Order of Merit to Albrecht Wagner. (Courtesy DESY.)

of directors since 1999. He is also the spokesman of the TeV-Energy Superconducting Linear Accelerator (TESLA) Technology Collaboration. This international collaboration has made decisive contributions to developing the superconducting TESLA technology, which has been chosen as the basis for both the planned European X-ray Free-Electron Laser and the International Linear Collider. As the declaration states, "thanks to his expertise, his untiring commitment, his acknowledged authority and his exemplary circumspection, [Wagner] was able to maintain and enhance the excellent international reputation of DESY".

COLLABORATION

HPLUS meets WASA: Chinese and German physicists join forces in studies of strong QCD

On 13–18 January, the Joint Sino-German symposium on Hadron Physics at COSY and CSR (HPC²) took place in Lanzhou, located in central China on the banks of the Yellow River. The symposium was jointly organized by the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences, and the Institute for Nuclear Physics (IKP) of the Research Centre Jülich, and financed by the Sino-German Center for Research Promotion in Beijing. Around 80 participants, mostly from China and Germany, attended the workshop.

The IKP has been operating the Cooler Synchrotron, COSY, for more than 10 years, providing proton and deuteron beams with momenta up to 3.7 GeV/c. A similar facility – with the CSRm and CSRc rings – has been built at the IMP and is now in the commissioning phase.

At COSY several detection systems – such as the ANKE dipole spectrometer and the non-magnetic COSY-TOF experiment – are used for experiments on hadron physics. A disadvantage of these detectors is that they



HPC² participants in front of the IMP building.

are “photon blind”. This will change with the start of operation of the Wide Angle Shower Apparatus (WASA) in 2007 (*CERN Courier* April 2005, p8). WASA is a fixed-target 4 π detector and is designed to detect neutral and charged particles.

On the Chinese side, a novel detector, HPLUS, is being prepared for hadron physics experiments. This device is designed to study baryon resonances, scalar mesons and/or isospin-violating effects. The R&D for the project has started at the IMP with participation from other Chinese universities.

Once operating, the WASA and HPLUS detectors will allow researchers to investigate

basic questions of non-perturbative quantum chromodynamics (strong QCD), for example through a precise study of symmetry breaking and through specific investigations of hadron structure. Decays of η and η' that vanish in the limit of equal light-quark masses reveal the explicit isospin symmetry breaking in QCD. Precision measurements of rare η and η' decays can be used to obtain new limits on the breaking of charge, parity and time symmetries or their combinations. Last but not least, through precise measurements of decay chains and couplings to other hadrons, WASA and HPLUS can both contribute to testing the various models offered to explain exotic and crypto-exotic hadrons.

These and other hot topics of strong QCD were discussed in about 40 talks during the symposium, with the aim of coordinating the physics programmes of the two experiments and of sharing technological expertise. Further common projects, focused on measurements with WASA and the preparation of HPLUS, are now being launched.

VISITS

CERN welcomes King and Queen of Norway

King Harald V and Queen Sonja of Norway visited CERN on 4 April, taking a tour of part of the Large Hadron Collider (LHC) tunnel and the ATLAS cavern, and also greeting Norwegian students, scientists and industrialists at the laboratory.

The tour was part of the royal couple’s state visit to Switzerland, which also included a stop in Bern. Robert Aymar, CERN’s director-general, welcomed the royal party and provided an overview of CERN’s history and research. Steinar Stapnes, the deputy spokesman of ATLAS, explained the concept and inner workings of the LHC and ATLAS, which is one of the main experiments at CERN to receive Norwegian contributions.

Norway was one of the founding 12 countries when the laboratory was established in 1954.



King Harald V of Norway watches while Queen Sonja signs CERN’s visitor’s book.



King Harald (left) and Queen Sonja with CERN’s director-general, Robert Aymar, during their tour of the ATLAS cavern.

There are currently 17 Norwegian staff members, a user community from Norwegian universities of more than 100 and about 10 technical students at CERN. Norwegian

contributions are focused on the ATLAS and ALICE experiments, particularly the silicon detector systems, calorimeter modules and trigger and read-out electronics.

PUBLISHING

New European journal brings science research to schools

EIROforum, the partnership between Europe's seven largest intergovernmental research organizations, has launched *Science in School*, a new European journal to help teachers to make their science lessons exciting and inspiring. The aim is to provide a platform for communication between science teachers, practising scientists and others involved in science education, so bridging the gap between the worlds of research and schools.

Science in School will address science teaching not only across Europe, but also across disciplines. It will highlight the best in teaching and cutting-edge research, drawing on the overlap between subjects and the potential for interdisciplinary work. Furthermore, the discussion forum on the website will enable readers to pose questions, offer solutions and discuss current topics – communicating directly across national and subject boundaries.

Science in School will appear quarterly online and in print and will feature news about the latest scientific discoveries, teaching materials, interviews with inspiring teachers and scientists, reviews of books, films and websites, suggestions for class trips, training opportunities and many other resources for science teachers. Contributors to the first issue include the world-renowned neurologist and author Oliver Sacks and scientists and teachers from nine countries.

- *Science in School* is supported by the



Science in School will bring news of cutting-edge research into Europe's classrooms.

European Commission's Science and Society programme in the framework of the Nucleus project (see www.xplora.org/ww/en/pub/xplora/nucleus_home.htm).

Further reading

For the online edition of *Science in School* see www.scienceinschool.org/.

Max Planck Society provides funding for the open-access *New Journal of Physics*

In a move to open up access to scientific research, a new initiative will let German scientists publish their research for free in the *New Journal of Physics* (NJP), the online open-access journal jointly owned by the UK Institute of Physics and the Deutsche Physikalische Gesellschaft. The Max Planck Society will centrally pay the publication charge for NJP articles for all of its scientists who submit work to the journal before the end of 2008.

NJP was one of the first open-access, electronic-only journals, publishing original research articles across the whole of physics. Free to read, it is funded solely by article publication charges. The journal has grown by more than 900% since 2001 and more than 40 000 of its articles are now downloaded each month. Its official impact factor has risen from 2.480 in 2003 to a current value of 3.095.

MEETINGS

Duke University in Durham, North Carolina, will host the **Hadron Collider Physics Symposium 2006** from 22–26 May. This has been a major forum for presenting Tevatron Collider measurements and has recently merged with the LHC Symposium. This meeting will mark the transition to the LHC era. Tevatron results based upon about 1 fb^{-1} of data will be presented, along with recent measurements made at RHIC. The status and plans for all LHC experiments will also be presented, together with theoretical reviews relevant to the full range of hadron-collider research. For further details see <http://hcp2006.phy.duke.edu/>.

The **2006 CERN School of Computing**, organized by CERN and the Helsinki Institute of Physics, will be held on 21 August – 1 September in Helsinki. It is aimed at postgraduate students and research workers with a few years' experience in particle physics, computing or related fields. Special themes this year are GRID and software technologies and physics computing. Grants from the European Union Framework Programme 6 are available to participants to cover part or all of their costs. For further details see www.cern.ch/CSC/. To register, which should be before 15 May, click on "How to apply".

Diffraction 2006, the International Workshop on Diffraction in High-Energy Physics, will be held in Adamantas, Milos, Greece, on 5–10 September. This is the fourth biennial workshop on theoretical and experimental progress in diffractive hadronic collisions at high energies. Topics to be covered fall into three main categories: experimental results and prospects, phenomenological approaches to diffraction and progress in the theoretical description of diffraction. For further information see www.cs.infn.it/diff2006/.

Beauty 2006, the 11th International Conference on B-physics at Hadron Machines, will be held on 25–29 September at Keble College, Oxford. The conference will review results in B-physics and charge–parity violation and will explore the potential and experimental reach of current and future generations of B-physics experiments at hadron machines. For further details see www.physics.ox.ac.uk/Beauty2006/, or e-mail Neville Harnew at n.harnew1@physics.ox.ac.uk.

OBITUARIES

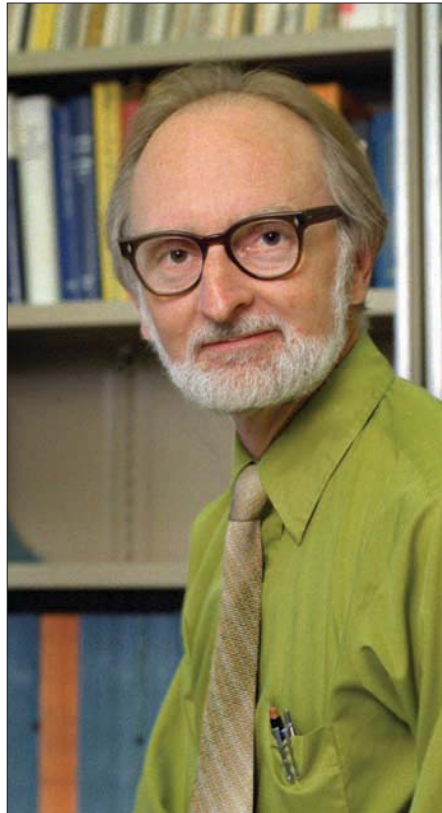
Owen Chamberlain 1920–2006

Owen Chamberlain, who shared the 1959 Nobel Prize for the discovery of the antiproton, passed away quietly in his home in Berkeley, on 28 February 2006, following a long struggle with Parkinson's disease. He was 85. Chamberlain, an emeritus professor of physics at the University of California, Berkeley, had an almost 60 year association with Lawrence Berkeley National Laboratory (LBNL).

Chamberlain, working with Emilio Segrè, Clyde Wiegand and Thomas Ypsilantis, discovered the antiproton in 1955 at the Rad Lab (now LBNL). The accelerated protons to an energy of 6 GeV, just enough to produce proton–antiproton pairs (*CERN Courier* November 2005 p27). Chamberlain and his collaborators used a magnetic spectrometer to select fixed-momentum particles from proton–copper collisions. Two scintillation counters were used to measure the time of flight over a 10 m flight path. The time-of-flight system was supplemented with two Cherenkov counters, also to measure velocity. The combined Cherenkov identification and time-of-flight velocity measurement provided the 40 000 to 1 rejection factor needed to separate single candidate antiprotons from background particles, mostly negative pions and kaons. An expanded collaboration later used a stack of emulsion to confirm the discovery.

Chamberlain was born in San Francisco on 10 July 1920, the son of W Edward Chamberlain, a prominent radiologist who had a strong interest in particle physics, and Genevieve Lucinda Owen. His family moved to Philadelphia in 1930. After obtaining a bachelor's degree from Dartmouth College in 1941, Chamberlain entered graduate school at UC Berkeley.

In early 1942, at the prompting of Ernest Lawrence, Chamberlain joined the Manhattan Project, the effort to build an atomic bomb. In



Owen Chamberlain, emeritus professor at UC Berkeley, who died in February aged 85.

Berkeley, and later in Los Alamos he investigated nuclear cross-sections for intermediate-energy neutrons and the spontaneous fission of heavy elements. After the war, he returned to graduate work at the University of Chicago to study under Enrico Fermi. Chamberlain's doctoral project was a study of the diffraction of slow neutrons in liquids. After receiving his PhD in 1948, he returned to UC Berkeley and began his research at the Rad Lab, initially studying proton scattering on various targets. This included some of the first experiments with

polarized-proton beams.

Chamberlain's later research covered a variety of fields. After the antiproton discovery, he went on to study antiproton interactions in hydrogen, deuterium and other elements, and then observed antineutron production from antiproton interactions.

In the early 1960s, Chamberlain pioneered the application of polarized targets to high-energy physics. He spent much of the next 20 years using polarized targets to study spin physics and other topics. This included notable early experiments on the parity of the Σ baryon, and tests of time reversal. He did this work at a variety of accelerators, including the LBNL 184 inch cyclotron, the Bevalac, accelerators at SLAC and Fermilab and others.

Even later in life, he continued his hands-on work. In the late 1970s and early 1980s, he worked on the high-voltage field cage for the SLAC/PEP-9 Time Projection Chamber; this required considerable study of material properties. Despite ill health, after retirement, he maintained his interest in physics, often appearing at seminars and colloquia.

In his later years Chamberlain became an outspoken activist for nuclear-arms control and other issues of social concern. In the 1960s he supported the Free Speech Movement at UC Berkeley, and strongly advocated increased minority recruitment and enrolment there. He spoke out against the repression of scientists in the former Soviet Union, demonstrated against the Vietnam War and was a founder of the nuclear-freeze movement of the early 1980s.

"As a Nobelist, I'd been made prominent and well known," he once said in an interview. "My advice was sought in a number of areas and I felt a responsibility to speak up on important issues."

Spencer Klein and Lynn Yarris, Lawrence Berkeley National Laboratory.

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Albert Romana 1948–2005

Albert Romana passed away on 14 December 2005, on the eve of his 58th birthday. He made his entire career at the Laboratoire Leprince-Ringuet at Ecole Polytechnique, where he was deputy-director from July 1990 to June 1998, then interim-director up to November of the same year.

Most of Albert Romana's scientific activity is closely linked to experiments done at CERN, where he used to spend long periods every year and where he met many colleagues and collaborators who also soon became friends. More recently, his physics interests led him to Brookhaven where he became involved in an experiment at the Relativistic Heavy Ion Collider at Brookhaven.

As a student, Albert started by participating in an experiment with a hyperon beam at the CERN Proton Synchrotron, looking for leptonic hyperon decays in a streamer chamber. He wrote his "thèse de 3ème cycle" on the subject. After his military service, he moved to an experiment on the Omega Spectrometer at the Super Proton Synchrotron (SPS) – the so-called beam-dump experiment – to study the hadroproduction of the newly discovered charmed particles, J/ψ and charmed mesons, with incident protons, antiprotons, pions and kaons; this was the subject of his "thèse d'Etat". He then made significant contributions in the new NA10 experiment, studying prompt muon-pair production with a high-intensity pion beam and testing, in particular, Drell–Yan scale invariance.

By the end of the 1980s, the acceleration



of ions in the SPS opened the field to quark–gluon-plasma observation. Albert contributed greatly to modifying and adapting the NA10 muon spectrometer for the new difficult environment of the high-intensity incident heavy-ion beams. He then played a key role in the NA38 experiment and later in NA50, the latter leading to widely publicized evidence for the quark–gluon plasma. Some years before, Albert had made a significant personal contribution to the first measurement of the asymmetry of the sea-quarks of the nucleon, analysing the data collected specifically for this purpose in the NA51 experiment, once again based on the NA10 muon spectrometer.

After being at the CMS experiment for some time, Albert soon came back to heavy ions

and became deeply involved in the PHENIX experiment at Brookhaven, which was emerging as a proper continuation of NA50. For several years he led the PHENIX group of Ecole Polytechnique.

Albert played a fundamental role in all the experiments mentioned here, often volunteering for tasks of general interest for the collaboration, such as designing, tuning and providing basic tools and also managing and organizing the data to enable a coordinated and coherent data analysis. This led him to interact continuously with most of his colleagues, both with the data-taking and hardware experts on one side and with the teams analysing the data on the other.

Because of his extensive skills as an experimentalist, of his personal modesty and his always optimistic and smiling approach to any problem, he was the ideal introducer and guide for newcomers, such as new groups or young students joining the experiment. For everybody, it was always a real pleasure to work and collaborate with him.

We will remember Albert as a kind and dedicated friend and colleague, always ready to listen, to discuss and to help with an open mind, at both the professional and personal level. We will miss him.

● Published in English at the request of the authors for the benefit of Albert Romana's colleagues world-wide.

Louis Kluberg, Roberto Salmeron and Henri Videau, Laboratoire Leprince-Ringuet, Ecole Polytechnique.

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Resolve Optics Ltd has released a new series of technical datasheets describing its range of high-performance lens adapters. Used typically to change the field of view or image format of the lens, they can produce high-resolution images with minimal distortion. For further information tel: +44 1494 777100, or e-mail sales@resolveoptics.com. Copies of the new datasheets can be downloaded from www.resolveoptics.com/adapters.htm.

LETTERS

From form factors to heavy leptons

Regarding the report of the Frascati three-day meeting on nucleon form factors (*CERN Courier* April 2006, p33), I would like to add a contribution related to the value of the experiments performed at CERN in the early 1960s when I was a student of Professor Zichichi at the University of Bologna. I was very enthusiastic when it was discovered in 1963 that the proton has indeed a time-like electromagnetic structure; the cross-section measured was in fact found by Zichichi and collaborators to be 500 times below the predicted point-like value. This discovery by Zichichi and his group opened the field of time-like electromagnetic form factors.

At the time when this series of experiments was performed at CERN using the Proton-Antiproton into LEpton Pairs (PAPLEP) set-up, there were no e^+e^- colliders.

Nevertheless it was at CERN that the first dedicated search for the third lepton, called

the heavy lepton, was started, looking for $e\mu$ acoplanar pairs. Also the study of vector-meson mixing and of pseudoscalar-meson mixing based on the strong production of these mesons and their electromagnetic decay-rates was carried out at CERN.

In the following years, the Bologna-CERN-Frascati (BCF) group moved to Frascati and played an important role at the ADONE e^+e^- collider. This group established the first limit on the mass of the heavy lepton by searching for acoplanar ($e\mu$) final states, the same channel that brought the SLAC group later on to the actual discovery of the third lepton with a very high background due to the low rejection power of the SLAC experimental apparatus. The experimental apparatus used in Frascati was especially designed to keep the background level extremely low. With such a powerful instrument the BCF group was also able to prove that the π and K pseudoscalar mesons have time-like structures.

In his historical introduction at the N'05 Workshop on Nuclear Form Factors, Zichichi did

not want to emphasize his own achievements and generously underlined the role played by Frascati in pursuing this extremely interesting field of research. However, as reported in a celebrated review paper by Professor Claudio Villi, INFN president of the time, it is thanks to Zichichi's work at CERN in the 1960s that neither the ideas nor the technologies were then missing in Frascati for the discovery of the J/ψ and of the third lepton. The only missing parameter was the energy.


More information and all references can be found in two volumes: one edited by N Cabibbo [*Lepton Physics at CERN and Frascati, 20th Century Physics Series, Vol. 8, World Scientific (1994)*] and the other by C S Wu [*The Origin of the Third Family, in honour of A. Zichichi on the XXX Anniversary of the Proposal to Search for the Third Lepton at ADONE, Rome (1997) and World Scientific (1998)*].

Professor Enzo Boschi, president of the Italian National Institute of Geophysics and Vulcanology and former student of Professor Zichichi during the 1960s.

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DIRECTOR OF TRIUMF



TRIUMF is Canada's national research facility for particle and nuclear physics. We are located on the campus of the University of British Columbia, and are operated by a national consortium of universities, and funded by a contribution from the National Research Council of Canada. TRIUMF is a leader in particle and nuclear physics and accelerator development in Canada and abroad, through international partnerships. At TRIUMF, a 520 MeV H⁻ cyclotron provides beam to a large number of experimental facilities including an advanced new radioactive beam facility, ISAC. Our facility provides key infrastructure support for the Canadian Particle Physics program as well as for leading research programs in molecular and materials science and life sciences. TRIUMF employs 375 scientists, engineers, technicians, and general staff and some 400 scientists visit from institutions worldwide to conduct experiments.

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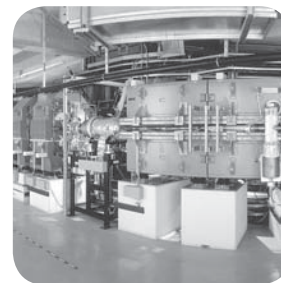
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**Prof. R. Eichler, Inst. of Particle Physics,
5232 Villigen-PSI, Switzerland**

**For further information, please contact Prof. R. A. Eichler
(email: Ralph.Eichler@psi.ch).**

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The Max-Planck-Institute of Physics invites applications for a

Postdoctoral position

for the GERDA project, a new experiment to be located at the Gran Sasso National Laboratory.

The GERDA experiment is designed to investigate the nature of the neutrino and its absolute mass-scale by searching for the neutrinoless double-beta decay of ^{76}Ge . The goal is to either establish the Majorana nature of the neutrino or push the relevant exclusion limits to the mass-scale indicated by neutrino oscillations. The experiment uses the novel approach of shielding crystals with a cryogenic liquid.

The Max-Planck-Institute is one of the leading institutes in the project. The institute is responsible for the design and construction of new germanium detectors, the detector suspension and insertion system and the corresponding infrastructure. It is also involved in the software to support simulation and analysis. The successful candidate is expected to contribute in both sectors.

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Interested applicants should submit an application letter, a statement of research interests, a curriculum vitae, a list of publications, and arrange for three letters of support to be sent to

Max-Planck-Institut für Physik

Prof. Allen Caldwell
Föhringer Ring 6, D-80805 München

Further information can be obtained from Prof. Allen Caldwell (EMail: caldwell@mppmu.mpg.de) or Dr. Iris Abt (EMail: isa@mppmu.mpg.de).

Toohig Fellowships Accelerator Science & Engineering

The U.S. LHC Accelerator Research Program, LARP, is pleased to announce postdoctoral research positions in accelerator science for recent Ph.D.s in physics or engineering. These positions are explicitly for studies and activities concerning CERN's Large Hadron Collider. The term of the Fellowship is two years, extendable to three. Approximately half of the fellowship time is expected to be spent at CERN and the remainder at a U.S. Department of Energy (DOE) laboratory involved in the LARP collaboration.

LARP is a collaborative initiative of the U.S. DOE Office of High Energy Physics in the Office of Science and the U.S. DOE laboratories. LARP's mission is to study and improve the operation of the LHC by helping with commissioning activities, by participating in accelerator research on the collider, and by pursuing R&D on instruments, magnets, and other equipment that could facilitate LHC operations and increase its luminosity.

The laboratories presently involved in LARP are Brookhaven National Laboratory, Fermilab, Lawrence Berkeley National Laboratory, and the Stanford Linear Accelerator Center. The choice of resident laboratory for each Fellow will be negotiated, and will depend on the individual's research interests. The present activities of LARP include accelerator instrumentation and diagnostics, advanced superconducting magnet R&D, and beam-physics calculations and simulations. LARP scientists, engineers and postdocs, including Toohig Fellows, will participate in the commissioning of the equipment and beams of the LHC, and other activities that might become part of the LARP mission, as needs and resources clarify.

The Toohig Fellowships are established in honor of the late Dr. Timothy Toohig, a physicist and Jesuit priest, who devoted his life to promoting accelerator science and to increasing understanding, communication and collaboration among scientists of all nations and religions.

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**Dr. Peter Limon
Toohig Fellowship Committee
Fermilab
P.O. Box 500, MS-316
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Director

Brookhaven Science Associates LLC (BSA) announces the search for Director of the Brookhaven National Laboratory (BNL). The BSA Board comprises representatives from the partners Stony Brook University and Battelle Memorial Institute as well as from the six collaborating universities that are core participants in the missions of the Lab: Columbia, Cornell, Harvard, MIT, Princeton, and Yale.

Founded in 1947, Brookhaven National Laboratory is located on Long Island in Upton, New York, and is one of five multipurpose laboratories operated by the Office of Science of the U.S. Department of Energy. The Laboratory's primary mission is scientific research in fields frequently requiring the design, construction and operation of complex facilities for external users as well as for its own scientists. BNL scientific programs are organized in five directorates: Basic Energy Sciences, Energy/Environment/National Security, High-Energy and Nuclear Physics, Life Sciences, and Light Sources. Major facilities include the Relativistic Heavy Ion Collider (RHIC), the National Synchrotron Light Source (NSLS), and the Center for Functional Nanomaterials (CFN). The Laboratory has over 2,600 employees, an annual budget of approximately \$500 million, and more than 4,500 scientific users of its facilities per year.

The Director of Brookhaven National Lab also serves as President of BSA. The new director must have strong scientific credentials, experience in developing and operating a complex scientific organization, and demonstrated success in engaging all the stakeholders associated with the functioning of such an organization.

Nominations and expressions of interest should be submitted, in total confidence, to:

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E-mail may be addressed to BNL@es.atkearney.com

For best consideration, please submit applications or nominations no later than May 15, 2006. Electronic submissions are particularly encouraged.

Further information about BNL can be found on the website: www.bnl.gov



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In addition to this project, the department is also concerned with the operation and further development of the COSY Jülich **cooler synchrotron** for the provision of unpolarized and polarized proton and deuteron beams with high phase space density by electron cooling and stochastic phase space cooling in order to implement internal and external experiments for medium-energy and hadron physics.

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Qualified and interested candidates must submit a current resume with a list of three references to the Oak Ridge National Laboratory Employment Opportunities web site (www.ornl.gov and select jobs) to ensure consideration. For more information visit our web site at www.sns.gov.

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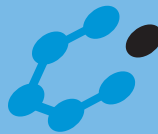
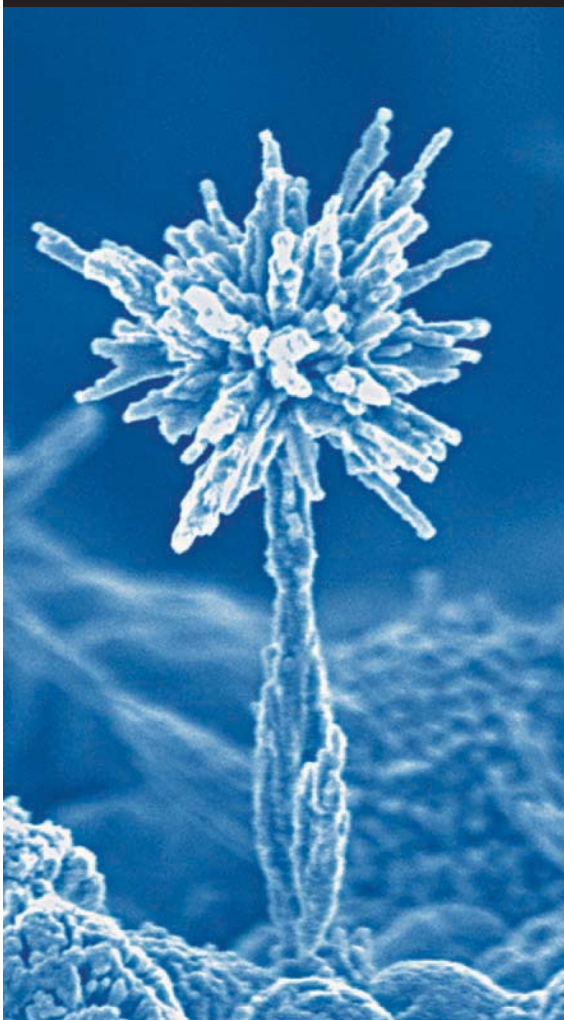
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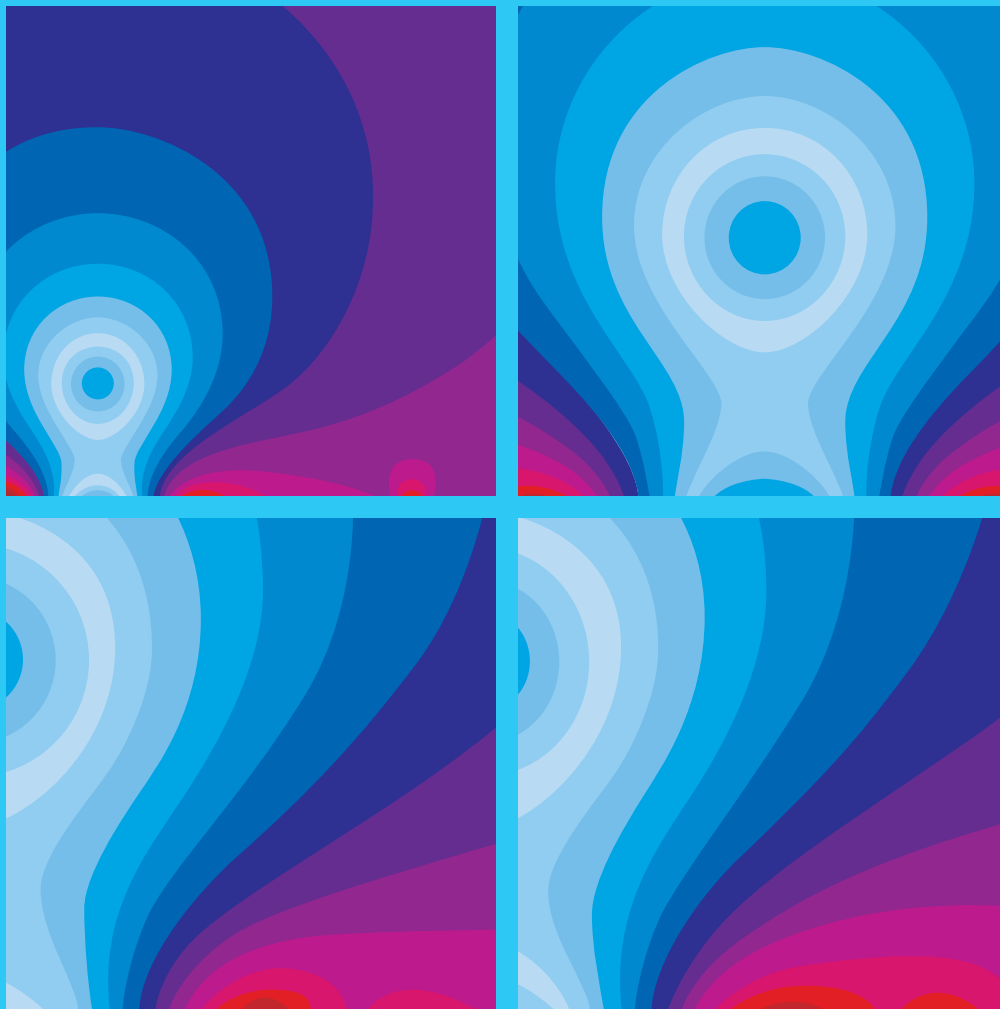
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BOOKSHELF

Quand le Ciel nous bombarde: Qu'est-ce que les rayons cosmiques? de Michel Crozon, Editions Vuibert. Broché ISBN 2711771539, €28.

Sous un titre évocateur des grandes offensives aériennes des années quarante, voici un nouveau compendium du rayonnement cosmique. Ces corpuscules naturellement accélérés depuis le fin fond de l'univers jusqu'à des énergies susceptibles de faire pâlir d'envie le physicien moderne, ont été mis en évidence voici bientôt un siècle grâce aux pacifiques ballons de l'Autrichien Viktor Hess.

Plus tard une foule d'autres pionniers tels que Robert Millikan et Carl Anderson traquèrent le mystérieux rayonnement. Ils furent suivis en Europe par Pierre Auger et Louis Leprince-Ringuet avec son école du Pic du Midi de Bigorre, lesquels ne tardèrent pas à se tourner vers l'exploitation des appareillages d'un CERN pas encore adulte. Aujourd'hui la chasse aux rayons cosmiques dispose de vastes installations de détection comparables de par leur ampleur à celles ceinturant le futur accélérateur européen LHC. Implantés dans les entrailles du globe, sous les glaces du Pole Sud, en Méditerranée, voire en de profondes mines, ces instruments tentent d'expliquer l'origine de corpuscules extra-galactiques dont l'énergie peut frôler les 10^{20} électronvolts.

L'ouvrage survole l'essentiel des expériences réalisées avant et depuis la

guerre afin de mieux connaître ces messagers célestes. Au fil de 240 pages bien illustrées, l'auteur situe cette expérimentation dans le contexte des développements de la physique corpusculaire. Son approche n'en demeure cependant pas liée aux seuls développements théoriques. Elle décrit aussi l'outillage de plus en plus perfectionné mis en œuvre: émulsions, compteurs Geiger-Müller, ballons, chambres à brouillard ou à bulles, détecteurs souterrains ou sondes embarquées sur satellites.

L'auteur qualifie son travail d'ouvrage de vulgarisation. Toutefois, à destination du lecteur plus féru de détails technico-scientifiques, l'usage de caractères d'imprimerie différents permet occasionnellement de passer à un registre plus avancé. Le livre ne manque d'ailleurs pas d'autres atouts, à commencer par une table des matières commodément située en début de volume, et un lexique bien charpenté. En contrepartie il faut se satisfaire de quelques inconvénients tels que la sempiternelle orthographe d'électronvolt en deux mots ou, moins mineure, l'absence d'index.

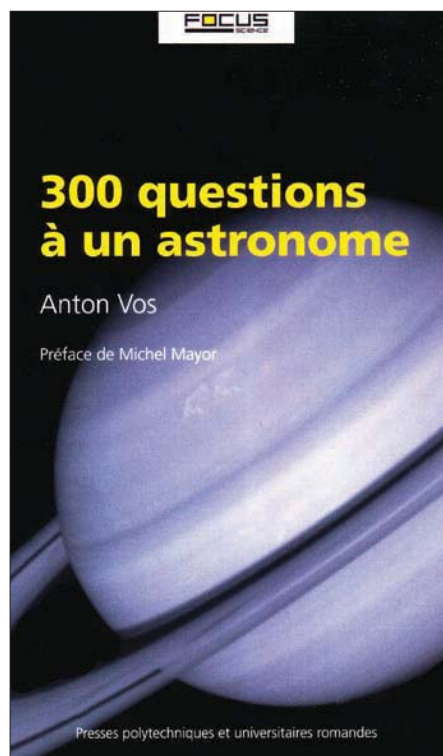
En bref, le lecteur avide de science et désireux de mieux cerner la physique des corpuscules de hautes énergies pourra assouvir sa curiosité grâce à cette incursion dans le royaume de la plus gigantesque des machines accélératrices de particules: l'univers lui-même.

Roger Anthoine, Péron.

300 questions à un astronome de Anton Vos, Presses Polytechniques et Universitaires Romandes. Broché ISBN 2880746566, €26.

Comment l'eau est-elle apparue sur Terre? Peut-on voyager dans le temps? Est-il possible de créer un trou noir en laboratoire? Voici quelques-unes des 300 questions qui apparaissent dans ce livre.

Comme on peut le lire dans l'avant-propos, le livre est né sur l'Internet, sur le site de l'Observatoire astronomique de l'Université de Genève. Un espace y avait été ouvert pour que les internautes posent directement leurs questions aux astronomes. A partir de ces questions/réponses, Anton Vos, journaliste scientifique a réalisé cet ouvrage. Ces deux aspects apparaissent très clairement dans le livre. Les questions sont très directes et pratiques, une caractéristique typique des sites où le public est invité à intervenir. D'autre part, un énorme travail de journaliste



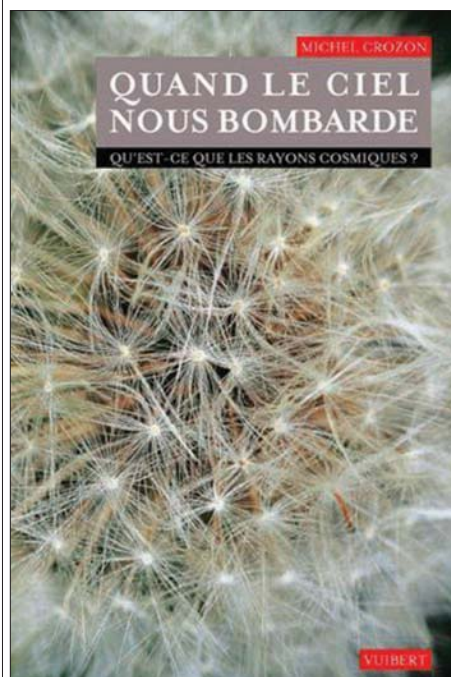
a été réalisé pour simplifier le contenu, ce qui rend la lecture très agréable.

Avant de lire le livre, j'ai formulé une question dans ma tête pour vérifier que l'ouvrage contenait vraiment "tout ce que vous avez toujours voulu savoir sur l'astronomie", comme la quatrième de couverture l'annonçait. J'ai trouvé ma question ainsi qu'une réponse pertinente.

Pour conclure, la structure du livre se prête à des approches de lecture différentes: on peut le picorer ou le lire de bout en bout, sans que la compréhension s'en ressente. De quelque manière que vous le lisiez, vous aurez appris beaucoup de choses sur l'astronomie et sans trop de difficultés. Antonella del Rosso, CERN.

Books received
Chern-Simons Theory, Matrix Models, and Topological Strings by Marcos Mariño J Rothe, Oxford University Press. Hardback ISBN 0198568495 £49.50.

One of the most important examples of string theory/gauge theory correspondence relates Chern-Simons theory – a topological gauge theory in three dimensions that describes knot and three-manifold invariants – to topological string theory. This book gives the first coherent presentation of this and



other related topics. After an introduction to matrix models and Chern–Simons theory, it describes the topological string theories that correspond to these gauge theories and develops the mathematical implications of this duality for the enumerative geometry of Calabi–Yau manifolds and knot theory. It will be useful reading for graduate students and researchers in both mathematics and physics.

Theoretical Nuclear and Subnuclear Physics, 2nd edition by John Dirk Walecka, World Scientific. Hardback ISBN 9812387951 £60 (\$98). Paperback ISBN 9812388982 £29 (\$48).

This second edition is a revised and updated version of the original comprehensive text on nuclear and subnuclear physics, first published in 1995. It maintains the original goal of providing for graduate students a clear, logical, in-depth and unifying treatment of modern nuclear theory, ranging from the non-relativistic many-body problem to the Standard Model of the strong, electromagnetic and weak interactions. Researchers will also benefit from the updates on developments and the bibliography. This edition incorporates new chapters on the theoretical and experimental advances made in nuclear and subnuclear physics in the past decade.


Lattice Gauge Theories: An Introduction, 3rd edition by Heinz J Rothe, World Scientific. Hardback ISBN 9812560629 £51 (\$84). Paperback ISBN 9812561684 £29 (\$48).

This broad introduction to lattice gauge field theories, in particular quantum chromodynamics, serves as a textbook for advanced graduate students, and also provides the reader with the necessary analytical and numerical techniques to carry out research. Although the analytic calculations can be demanding, they are discussed in sufficient detail that the reader can fill in the missing steps. The book also introduces problems currently under investigation and emphasizes numerical results from pioneering work.

Field Theory, the Renormalization Group and Critical Phenomena: Graphs to Computers, 3rd edition by Daniel J Amit and Victor Martín-Mayor, World Scientific. Hardback ISBN 9812561099 £52 (\$86). Paperback ISBN 9812561196 £27 (\$44).

Linking field-theory methods and concepts from particle physics with those in critical phenomena and statistical mechanics, this book starts from the latter point of view. In this way, it introduces quantum field theory to those already grounded in the concepts of statistical mechanics and advanced quantum

theory. Non-perturbative methods and numerical simulations are introduced in this third edition, with new chapters on real-space methods, finite size scaling, Monte Carlo methods and numerical field theory. There are sufficient exercises in each chapter for use as a textbook in a one-semester graduate course.



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A cosmic vision for world science

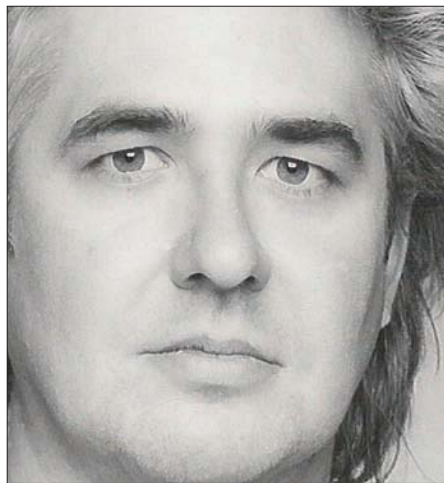
James Pinfold considers how relatively low-cost experiments to study ultra-high-energy cosmic rays could bring developing countries into frontier research

Many developed countries face the challenge of encouraging more young people to take up science to ensure future innovation to benefit society. However, there is a related and equally important challenge – to promote a scientific infrastructure to aid the academic and career ambitions of members of under-represented and economically disadvantaged groups, as well as scientists from developing countries, to increase their participation in scientific and technical fields worldwide.

Severe constraints on resources, which are a common feature in developing countries, mean that research there does not usually consist of designing and making equipment for a new experiment at the forefront of the field. In many schools, colleges and universities laboratories either do not exist or are poorly equipped. Consequently, the brain drain of bright young scientists from developing to developed countries seems to be the norm, and further intellectually impoverishes the developing world. Collaborative programmes between scientists from developed and developing countries are urgently needed.

The Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste has set an international example by providing both a forum and practical support for collaboration in theoretical physics between developing and developed countries. It has also supported indigenous physics programmes in developing countries. Importantly, the director of ICTP, Katapalli Sreenivasan, plans to include experimental physics in the programme. CERN has also taken a significant step to foster a relationship with physicists from developing countries that does not require large cash contributions to CERN, but instead encourages the production of detector components at the home laboratories (*CERN Courier* July/August 2003, p26). This lets physicists from developing countries participate in frontier research.

The Pierre Auger Collaboration is involved in Vietnam in developing experimental work to



understand the universe at the highest energies. The Vietnam Auger Training Laboratory (VATLY) at the Institute for Nuclear Science and Techniques in Hanoi was inaugurated as a training ground for future experimentalists in astroparticle physics and related areas, and an exact replica of the water Cherenkov detector used in the Pierre Auger Observatory has been installed at VATLY. More recently, the atmospheric muon spectrum was measured in Vietnam for the first time. The phenomenology of neutrino oscillation is also being studied at this laboratory. Indeed, a Vietnamese community for experimental particle physics is developing well – in 2001 a group from the Institute of Physics in Ho Chi Minh City joined the DO collaboration at Fermilab.

In many areas of research, leading-edge science is expensive and there are few support networks for disadvantaged groups. However, cost-effective projects to investigate the nature of ultra-high-energy cosmic rays (UHECR) are already being developed for high schools and could provide an ideal vehicle for such an effort (p19). These projects demonstrate the basic elements of research and technology, with modern detectors, fast electronics, GPS timing, computerized data acquisition and

data analysis. Perhaps just as importantly, they also teach social skills such as collaborative effort, organization, long-term planning and teamwork.

Efforts to bring the developing world into such projects have already begun. For example, the collaboration behind the Mixed Apparatus for Radar Investigation of Cosmic-rays of High Ionization project has established contact with the Maseno University in Kisumu, Kenya, the University of Zambia in Lusaka and the University of Rio de Janeiro in Brazil, to investigate the hypothesis that some forms of lightning are induced by cosmic rays. The collaboration is also working with Rio de Janeiro to deploy detectors that register UHECR showers and meteors in high-school-based receivers.

These are just two examples of the diverse topics related to the “cosmic connection” between research and education in both the developed and developing world. These include not only the astrophysics and particle physics of cosmic rays, but also topics in biology (e.g. the effects of natural radiation), mathematics, computer science and programming, chemistry, and environmental and Earth sciences (e.g. studying the chemistry of ozone and how that could affect the transmission of cosmic rays).

The educational paradigm created by the networks of cosmic-ray arrays in high schools is one that can be employed in many areas. In geophysics, for example, one could use distributed arrays of seismometers to study geological activity over a large area. A specific example is the project BAMBI, which promotes the construction of an amateur array of radio telescopes distributed over a large area to study the radio sky at 4 GHz and search for signs of extraterrestrial intelligence. Such large-area, national and international school-based detector networks could aid and encompass other efforts throughout the world including developing countries, where it could provide entry to the global scientific community.
James Pinfold, University of Alberta.

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**Overview**

The V1495 is a fully programmable General Purpose VME board, suited to a variety of different applications. The heart of the board is a large FPGA (ALTERA® Cyclone), whose firmware can be directly customized by the user for his specific application.

The V1495 has a modular architecture: a mother-board with 98 I/O channels (64 inputs LVDS/ECL/PECL, 32 outputs LVDS, 2 I/O NIM/TTL) can be either used alone or expanded with 1, 2 or 3 additional piggy-back, choosing any combinations of the 4 available types:

- A395A: 32 LVDS/ECL/PECL input channels
- A395B: 32 LVDS output channels
- A395C: 32 ECL output channels
- A395D: 8 NIM/TTL input/output channels

V1495 General Purpose VME board**Highlights**

- User programmable FPGA
- Up to 194 I/O channels
- LVDS / ECL / PECL / TTL / NIM signals
- 200 MHz min. bandwidth
- I/O delay < 15 ns
- 4 asynchronous independent timers

Applications

- Logic / Coincidence / Trigger
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- Translator
- Fan in / Fan out
- I/O Register
- Test Pattern Generator