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CERN COURIER

50 years 1959–2009

VOLUME 49 NUMBER 5 JUNE 2009

It's a kind of MAGIC!

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One eye on the T2K Daruma Doll p7

Pinning down neutrinos p13

A taste of Galileo's excitement p17

Cover: On 25 April the MAGIC Collaboration held the "first light" ceremony for a second 17 m Cherenkov telescope on the island of La Palma (p20). (Courtesy R Wagner/MAGIC.)

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

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ACCELERATORS

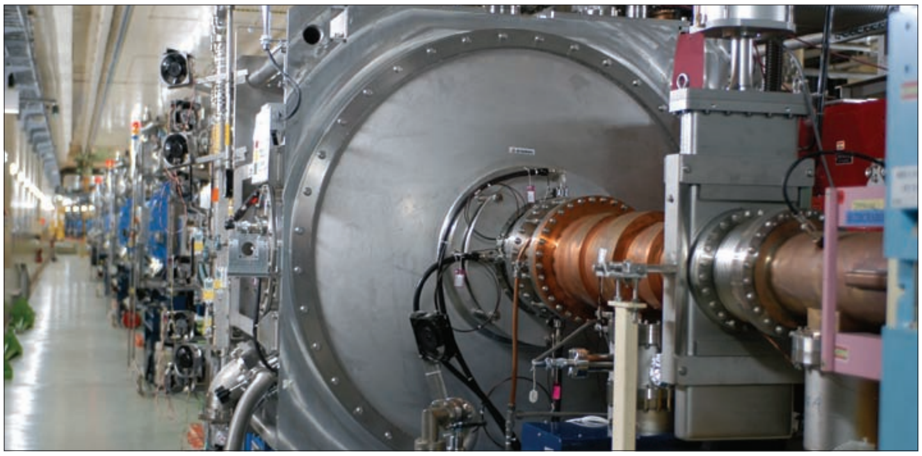
KEKB breaks luminosity record

A team working at the KEKB electron–positron collider at the KEK laboratory in Japan has broken the machine's existing world record for luminosity by using new accelerator components called "crab cavities". The new record is almost a factor of two higher than the original design luminosity of KEK's B-factory.

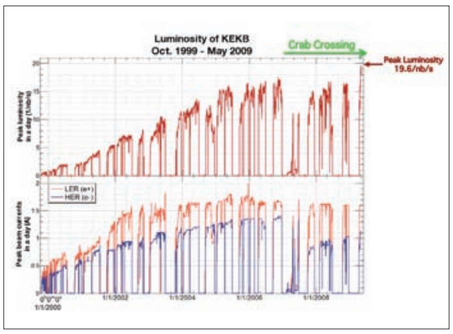
Until 2007 the electron and positron bunches in the KEKB accelerator beams crossed at an angle of 22 mrad. The crossing angle, a unique feature of the KEKB design, provided an effective separation of the beams after collision, avoiding a high background in the detectors. Its success was evident in the world-beating luminosities that the collider achieved previously. To boost the luminosity further, however, a scheme was required that would allow an effective head-on collision between the beams while still retaining the crossing angle. To accomplish this goal, the team at KEKB designed and built special superconducting RF cavities that kick each beam sideways in the horizontal plane so that the bunches collide head-on at the interaction point. These crab cavities for linear electron–positron colliders were first proposed almost 30 years ago by Robert Palmer and in 1989, K Oide and K Yokoya proposed using them in storage rings. This was followed in around 1992 by the development of designs and prototype models by K Akai as part of collaborative work between KEK and Cornell. Detailed engineering and prototyping by K Hosoyama's team then took place at KEKB to converge on the current design.

Full-sized cavities were developed after intense discussions and elaboration. The first pair were finally installed at KEKB in January 2007 and detailed commissioning began a month later (*CERN Courier* September 2007 p8). Recently the team achieved a breakthrough by controlling the behaviour of off-energy beam particles using special skew-sextupole magnets. On 6 May the machine broke the world record, reaching a luminosity of 1.96×10^{34} cm^2/s with the crab cavities. At the same time, the background remained at a good level and data continued to be recorded smoothly in the Belle experiment.

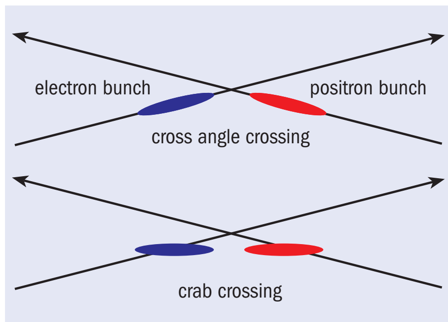
For the future, a B-factory upgrade called SuperKEKB is being planned and designed in Japan. This will build on the experience and hardware developed at KEKB and will increase the luminosity by a factor of 40. The recent breakthrough and the long history of world luminosity records at KEKB suggest that this future machine will achieve its goals. A large international collaboration has been formed to upgrade the Belle detector to observe the collisions at the new high-luminosity facility.



Crab cavities in the ring at the KEKB electron–positron collider. (Courtesy KEK.)



A decade of high luminosity at KEKB, including the latest record reached with the crab cavities.



Crab cavities tilt the electron and positron bunches so that they collide head-on.

Sommaire

LHC NEWS

Final magnet for sector 3-4 goes underground

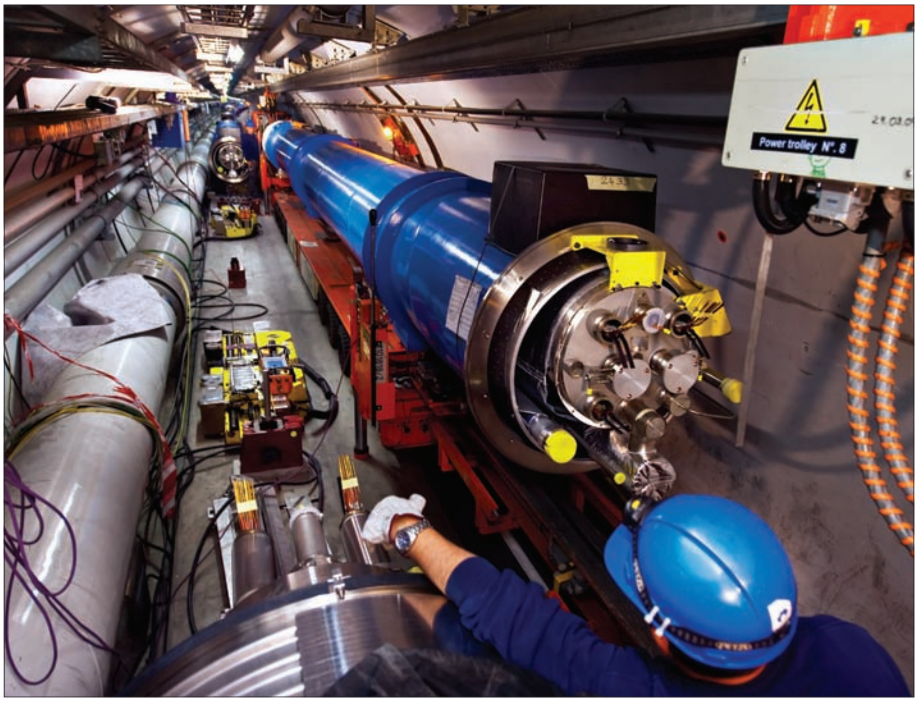
The final magnet – a quadrupole short straight section – to refit sector 3-4 of the LHC was lowered into the tunnel and transported to its location on 30 April, two weeks after the 39th and final, repaired dipole magnet was lowered and installed. This magnet system was the last of the spares to be prepared for use in the refurbished sector .

With all of the necessary magnets now underground, work in the tunnel will continue to connect them together. In total 53 magnets were removed from sector 3-4 following the incident on 19 September 2008 (*CERN Courier* January/February 2009 p6). Of these, 16 magnets had sustained minimal damage and so were refurbished and put back into the tunnel; the remaining 37 were replaced by spares, depleting the number of reserve magnets to nearly zero. Work will continue on the surface to repair the remaining damaged magnets to replenish the pool of spares.

Since the start of the repair work in sector 3-4, the Vacuum Group has been cleaning the beam pipes to remove metallic debris and soot created by the electrical arc at the root of the incident. All 4800 m of the beam pipes in sector 3-4 were first surveyed centimetre by centimetre to document the damage before the cleaning work began. The cleaning process itself involves passing a brush through the pipe to clean the surface mechanically, followed by vacuuming to remove any debris both inside and outside the beam pipe. This procedure is repeated ten times, followed by a final check with an endoscopic camera. By the end of April some 70% of the affected zone had been cleaned.

Work meanwhile continues on the installation of new pressure release ports to allow a greater rate of helium escape in the event of an incident similar to that of 19 September (*CERN Courier* April 2009 p6). This is now proceeding in the areas outside the arc sections – in particular on the inner triplets (the focusing magnets either side of the collision point). The ports have been slightly modified to fit the geometry of these magnets.

The root of the incident on 19 September was a splice failure interconnection between two magnets and since then CERN has developed highly sensitive methods to detect resistances of splices at the nano-ohm level (*CERN Courier* March 2009 p5). These have revealed a small number of splices with abnormally high resistance, which are being investigated, understood and dealt with. Now a new test has been developed to measure the electrical resistance of the connection joining the busbars of the superconducting magnets together. Each busbar consists of a superconducting cable surrounded by a larger copper block. Although the copper cannot carry the same level of current as the superconducting cable for sustained periods, it plays the essential role of providing a low resistance path to the current when a magnet or a busbar quenches: the copper gives time to the protection system to discharge the stored energy. The new test allows the electrical continuity of the copper part to be checked and so provides another important quality control safety check for the electrical connections.



Installation of a dipole magnet in the refurbished sector 3-4 of the LHC.

Careful tests have revealed that in some cases, the process of soldering the superconductor in the interconnecting high-current splice can melt the solder joining the superconducting cable to the copper of the busbar, and thereby impede its ability to do its job if a quench occurs. As a result, the teams at work on the consolidation process are improving the soldering process, and checking the whole of the LHC for similar faults. A test has been done for sectors at room temperature and studies are now going on to allow the same procedure at cryogenic, but non-superconducting temperatures. By mid-May, three sectors had been tested at room temperature, and five potentially faulty interconnections found. These are being repaired accordingly.


The short straight section en route to sector 3-4.

● For up-to-date news, see *The Bulletin* at http:/cdsweb.cern.ch/journal/.

CHARM

BEPCII/BESIII accumulates 100 million $\psi(2S)$ in Beijing

After five years of construction, the upgraded Beijing Electron–Positron Collider (BEPCII) and the new Beijing Spectrometer (BESIII) finished accumulating their first large data set of more than 100 million $\psi(2S)$ events on 14 April. This is the world's largest $\psi(2S)$ data set. Data taking started on 6 March, following a scan of the $\psi(2S)$ peak. During the following month, as machine commissioning continued, the peak luminosity of BEPCII increased steadily from 1.4 to 2.3×10^{32} $cm^{-1}s^{-2}$, with beam currents of 550 mA for both electrons and positrons.

The commissioning of the upgraded accelerator and the new detector began in summer 2008, with the first event observed on 18 July. Approximately 13 million $\psi(2S)$ events were obtained last autumn, providing data for studies of the new detector and for calibration. The results show that the detector performance is as expected: efficiency,

The BESIII detector. (Courtesy BESIII/IHEP.)

resolution and stability all meet specifications. The new data sample of 100 million $\psi(2S)$ events will allow more-detailed studies of detector performance, as well as many physics analyses, for example of h_c, ψ_c, and η_c charmonium states. After some accelerator studies, BEPCII and BESIII will now turn to running at the J/ψ peak, with the goal of collecting a high-statistics sample of J/ψ events.

BEPCII, the upgrade of BEPC at the Institute of High Energy Physics (IHEP) in Beijing, is a two-ring collider operating between 1 and 2.2 GeV beam energy in the charm energy region (*CERN Courier* March 2006 p23). It has a design luminosity of 1×10^{33} $cm^{-2}s^{-1}$ at 1.89 GeV, which is an improvement by two orders of magnitude on its predecessor. The BESIII detector features a beryllium beam pipe; a small-cell, helium-based drift chamber; a time-of-flight system; a CsI(Tl) electromagnetic calorimeter; a 1 T superconducting solenoid magnet; and a muon identifier using the magnet yoke interleaved with resistive plate chambers. The BESIII collaboration consists of groups from Germany, Italy, Japan, Russia, the US, as well as many Chinese Universities and IHEP.

NEUTRINOS

T2K beamline starts operation

On 23 April, the Tokai-to-Kamioka (T2K) long-baseline neutrino oscillation experiment confirmed the first production of the neutrino beam by observing the muons produced by the proton beam in the neutrino facility at the Japan Proton Accelerator Complex (J-PARC).

The T2K experiment uses a high-intensity proton beam at J-PARC at Tokai to generate neutrinos that will travel 295 km to the 50 kt water Cherenkov detector, Super-Kamiokande, which is located about 1000 m underground in the Kamioka mine (*CERN Courier* July/August 2008 p19). The experiment follows in the footsteps of KEK-to-Kamioka (K2K), which generated muon neutrinos at the12 GeV proton synchrotron at KEK.

With the beam generated at the J-PARC facility, T2K will have a muon-neutrino beam 100 times more intense than in K2K. This should allow the experimenters to measure θ_{13}, the smallest and least well known of the angles in the neutrino mixing matrix, which underlies the explanation of neutrino oscillations. Experiments with atmospheric neutrinos have found the mixing angle θ_{23} to be near to its maximal value of 45°, while the long-standing solar neutrino problem has been solved by neutrino oscillations with a large value for θ_{12} (p13).

Koichiro Nishikawa, director of IPNS/KEK and former spokesperson of T2K, paints an eye on a Daruma doll, wishing for a successful start up of the experiment. (Courtesy KEK.)

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.**

NUCLEAR PHYSICS

Precise mass measurements may help decode X-ray bursts

Researchers at the Michigan State University (MSU) National Superconducting Cyclotron Laboratory (NSCL) have made precise mass measurements of four proton-rich nuclei, ^{68}Se, ^{70}Se, ^{71}Br and an excited state of ^{70}Br. The results may make it easier to understand type I X-ray bursts, the most common stellar explosions in the galaxy.

These bursts occur in the hot and dense environment that arises when a neutron star accretes matter from a companion star in a binary system. In these circumstances, rapid burning of hydrogen and helium occurs through a series of proton captures and beta decays known as the rp process, releasing an energy of 10^{32}–10^{33} J in the form of X-rays in a burst 10–100 s long. Generally the capture-decay sequence happens in a matter of seconds or less, but "waiting points" occur at the proton dripline, where the protons become too weakly bound and the slower beta-decays intervene.

One of the major waiting points involves ^{68}Se, which has 34 neutrons and 34 protons, and closely related nuclei. The lifetimes of these nuclei influence the light curve of the X-ray burst as well as the final mix of elements created in the burst process. The lifetimes of the waiting points in turn depend critically on the masses of the nuclei involved, which also influence the possibility for double-proton capture that can bypass the beta-decay process and hence the waiting point.

The experiment at NSCL, conducted by Josh Savory and colleagues, used the Low Energy Beam and Ion Trap facility, LEBIT, for the mass measurements of the four nuclei. The nuclides themselves were produced by projectile fragmentation of a 150 MeV/u primary ^{78}Kr beam and separated in flight by the A1900 separator. LEBIT takes isotope beams travelling at roughly half the speed of light and then slows and stops the isotopes for highly accurate mass measurements via Penning-trap mass spectrometry.

The experiment was able to reach uncertainties as low as 0.5 keV for ^{68}Se to 0.15 keV for ^{70m}Br, with up to 100 times improvement in precision (for ^{71}Br) in comparison with previous measurements. The team then used the new measurements as input to calculations of the rp process and found an increase in the effective lifetime of ^{68}Se, together with more precise information on the luminosity of a type I X-ray burst and on the elements produced.

Further reading

J Savory *et al.* 2009 *Phys. Rev. Lett.* **102** 132501.

EDITOR'S NOTE

It is 400 years since Galileo Galilei looked at the heavens through a telescope and changed our view of the universe for ever. In celebration and to stimulate worldwide interest in astronomy and science, the International Astronomical Union (IAU) and UNESCO have initiated the International Year of Astronomy 2009 (IYA2009).

Particle and nuclear physics may deal with the smallest components of matter, but both have strong links with astronomy – the news story above is just one example. This issue of *CERN Courier* celebrates IYA2009 with this and several longer articles. Nobel laureate George Smoot considers the exciting times in modern cosmology (p17), while features on Borexino and MAGIC (p13 and p20) look at two of the many experiments in the new field of astroparticle physics. Lastly, Viewpoint (p38) considers a valuable message these "big" sciences offer to the public at large.

DESY

The new hall on PETRA III. (Courtesy DESY.)

PETRA III stores its first positron beam

DESY's new third-generation synchrotron radiation source, PETRA III, accelerated its first beam on 16 April. At 10.14 a.m. the positron bunches were injected and stored in the 2.3 km accelerator for the first time. The start of operation with the beam concludes a two-year upgrade that converted the storage ring PETRA into a world-class X-ray radiation source.

As the most powerful light source of its kind, PETRA III will offer excellent research possibilities to researchers who require tightly focused and very short-wavelength X-rays for their experiments. In particular, PETRA III will have the lowest emittance – 1 nm rad – of all high-energy (6 GeV) storage rings worldwide.

Following the stable storage of the particle beam achieved on 16 April, the accelerator is now being set up for the production of synchrotron radiation. The undulators – the magnets that ensure the machine's high brilliance in X-rays – will be positioned to force the beam to oscillate and emit the desired intense, short-wavelength radiation. At the same time, the mounting of the 14 beamlines to be used for experiments continues in the newly constructed experiment hall (*CERN Courier* September 2008 p19). A first test run with synchrotron radiation is planned for this summer; regular user operation of the new synchrotron radiation source will start in 2010.

The PETRA storage ring began life as a leading electron–positron collider in the 1980s and later became a pre-accelerator for the electron/positron–proton collider, HERA. The remodelling into PETRA III at a cost of €225 million was funded mainly by the Federal Ministry of Education and Research, the City of Hamburg and the Helmholtz Association.

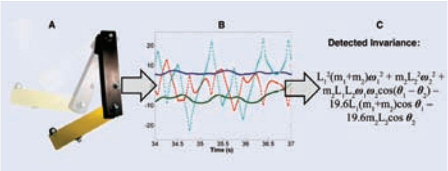
SCIENCEWATCH

Compiled by John Swain, Northeastern University

Computer algorithm reveals the complex laws of physics

A large part of science involves searching for the analytical expression of physical laws that govern various systems, which often depend on various symmetries and invariants. Attempts to automate the process have in the past proved unsuccessful, but now two researchers seem to have succeeded where others have failed.

Michael Schmidt and Hod Lipson of Cornell University have developed computer code that looks at data from physical systems ranging from simple harmonic oscillators to chaotic double pendula and proceeds to infer the appropriate Hamiltonians, Lagrangians and conservation laws – and all without any prior knowledge. "Might this process diminish the role of future scientists?" the researchers ask at the end of their paper. "Quite the contrary: scientists may use processes such as this to help focus on interesting phenomena more rapidly and to interpret their meaning." The software could provide valuable tools to help scientists work out the dynamics underlying all sorts of otherwise-confusing systems.



In this example, the researchers captured the velocities of a chaotic double-pendulum (A) using motion tracking (B), and automatically searched for equations that describe a single natural law relating these variables. The algorithm found the conservation law (C), which turns out to be the double pendulum's Hamiltonian.

Further reading

M Schmidt and H Lipson 2009 *Science* **324** 81.

Symmetry cuts face space

The computerized recognition of human faces has long been considered a difficult problem, largely because of the enormous dimension of the "space of distinct faces", or "face space", for short. Now Lawrence Sirovich and Marsha Meytlis of the Mount Sinai School of Medicine in New York City have shown that the dimension of this space is much smaller than had been previously thought.

The key insight is that perceptually, great use is made of the approximate symmetry between the left and right sides of the face. This means that the bulk of the relevant information lies in deviations from perfect symmetry or an artificially symmetrized facial image. This leads not only to a face recognition algorithm that is nearly 100% accurate, but also to a way of generating interesting and realistic synthetic faces.

Further reading

L Sirovich and M Meytlis 2009 *PNAS* **106** 6895.

Extending Faraday

According to Faraday's law, a changing magnetic field will produce an electric field, so a static magnetic field should produce no electric field. However, Phan Nam Hai and colleagues of the University of Tokyo have noticed that there is another subtlety when electron spins are considered. In this case, the motion of a spinning electron can cause a local change in the magnetization of material and an associated Faraday-law electric field.

In suitable tunnel junctions containing MnAs quantum nanomagnets, this effect can lead to huge magnetoresistances of up to 100 000 % – an effect that could lead to new magnetic sensors as well as new active devices including a "spin battery".

Further reading

Phan Nam Hai *et al.* 2009 *Nature* **458** 489.

Ultrasonic cavitation of water speeds up thorium decay

It is a common belief that radioactive decay rates are unchanged by external conditions, despite many examples of small shifts (particularly involving external pressure and K-capture decays) being well documented and understood. However, Fabio Cardone of the Institute per lo Studio dei Materiali Nanostrutturati in Rome and colleagues have shown a dramatic increase – by a factor of 10 000 – in the decay rate of thorium-228 in water as a result of ultrasonic cavitation. Exactly what the physics is and whether or not this sort of effect can be scaled up into a technology for nuclear waste treatment remain open issues.

Further reading

F Cardone, R Mignani and A Petrucci 2009 *Phys. Lett. A* **373** 1956.

Mixing nature with metals opens up an exciting new field

Two recent papers show how mixing a little bit of something from nature with a little metal from the lab can lead to interesting results. As a consequence, an exciting new field mixing natural products and standard lab techniques and chemicals seems to be emerging.

D Matthew Eby of Florida's Tyndall Air Force Base and colleagues showed that using the enzyme lysozyme from chicken eggs mixed with silver acetate in methanol, and exposing the mixture to light, is an inexpensive way to produce copious quantities of antibacterial silver nanoparticles. Meanwhile, Seung-Mo Lee of the Max Planck Institute of Microstructure Physics in Halle and colleagues have shown that zinc, titanium or aluminium can greatly enhance the toughness of spider silk.

Further reading

D Matthew Eby *et al.* 2009 *ACS Nano* **3** 984.

S-M Lee *et al.* 2009 *Science* **324** 488.

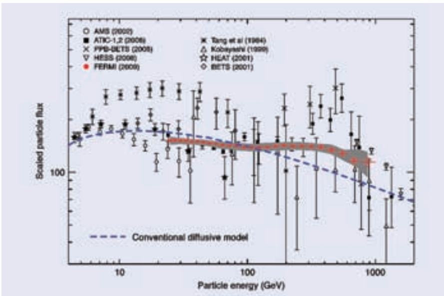
Compiled by Marc Türler, ISDC and Observatory of Geneva University

Fermi measures the spectrum of cosmic-ray electrons and positrons

The Fermi Gamma-Ray Telescope can find out about more than gamma rays. It has now provided the most accurate measurement of the spectrum of cosmic-ray electrons and positrons. These results are consistent with a single power-law, but visually they suggest an excess emission from about 100 GeV to 1 TeV. The additional source of electrons and positrons could come from nearby pulsars or dark-matter annihilation.

The characterization of cosmic rays is undergoing some profound investigation. In addition to the ground-based Pierre Auger and Milagro observatories, balloon- and space-borne experiments are measuring the spectrum of electrons and positrons. Before 2008 this spectrum was only determined to within a factor of two or three, by balloon-borne experiments and by the Space Shuttle flight of the Alpha Magnetic Spectrometer (AMS) in 1998 (*CERN Courier* June 1999 p6). Recently, however, results of the Advanced Thin Ionization Calorimeter (ATIC) have had a huge impact. This balloon experiment flown above Antarctica suggested a strong excess of electrons and positrons at energies of 300–800 GeV. The spectrum obtained has a peak that is consistent with the annihilation of dark-matter particles with an energy of about 600 GeV (Chang *et al.* 2008). Then, earlier this year, the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) space experiment found a clear excess of positrons over electrons at energies above 5 GeV (*CERN Courier* May 2009 p12).

The story continues to unfold with results from the Large Area Telescope (LAT) on board the Fermi mission (*CERN Courier* November 2008 p13). The LAT is sensitive to electromagnetic cascades generated inside the detector by either incoming gamma rays or by cosmic rays. Using only the first six months of data the Fermi collaboration obtained the most accurate measurement yet of the spectrum of electrons plus positrons in the 20 GeV to 1 TeV range (Abdo *et al.* 2009). The contamination of gamma rays in the electron/positron sample is estimated to be less than 2% and hadronic events could also be well discriminated against, such that the maximum systematic error remains below 20%, even at 1 TeV. The published spectrum is consistent with a simple power law when statistical and systematic errors are conservatively taken into account. The fitted power law falls with energy as $E^{-3.0}$, which is slightly harder than the expectation from a conventional model of diffusive electron propagation in the Milky Way.



The spectrum measured by the Fermi LAT (red circles with error bars with systematic errors represented by the grey band) compared with results from previous experiments and a conventional diffusive model.

Visually, however, the Fermi data suggest a deviation from a simple power law above about 100 GeV. There is evidence for a bump at these energies, suggesting an additional component of primary electrons. The bump resembles the excess found by ATIC, but is much less pronounced. It can be put in parallel with the increased positron fraction derived by PAMELA, but the latter is at energies that are 10 times lower. Although inconsistent with each other, all three experiments suggest that there is an additional component of electrons and positrons towards higher energies. The origin of the excess could be dark-matter annihilation, but there are also alternative explanations, in particular the contribution of nearby pulsars. These possibilities are not discussed in the published paper but the collaboration foresees that Fermi will significantly improve the understanding of the electron spectrum in the coming months, in particular by searching for anisotropies in the arrival direction of the electrons.

Further reading

A A Abdo *et al.* 2009 *Phys. Rev. Lett.* **102** 181101.
J Chang *et al.* 2008 *Nature* **456** 362.

Picture of the month

This brilliant image celebrates the 19th anniversary of the Hubble Space Telescope. Taken in January 2009, it is one of the last images by the Wide Field and Planetary Camera 2 (WFPC2). This successful instrument has taken some of the most famous pictures of space, such as the Eagle Nebula pillars (*CERN Courier* March 2007 p11) and the Hubble Deep Field. It was scheduled to be replaced by a new camera (WFPC3) installed by the crew of the Atlantis Space Shuttle that lifted off on 11 May. The image shows a group of interacting galaxies known as Arp 194 located 600 million light-years away in the constellation of Cepheus. The colliding galaxies are at the top of the image, while the bottom galaxy is in the background. The blue spiral arm that seems to connect them is a stream of star-forming gas ejected during the process of galaxy merging. (Courtesy NASA, ESA and the Hubble Heritage Team (STScI/AURA).)

A look back to *CERN Courier* vol. 6, June 1966, compiled by Peggie Rimmer

THE 32ND SESSION OF COUNCIL

Towards a 300 GeV laboratory

The European Committee for Future Accelerators ECFA has been reconvened, under the Chairmanship of Professor Amaldi (Italy), to consider the European high-energy physics situation as it has developed since the first ECFA presented its conclusions in 1963, the "Amaldi Report". Two full meetings of the new ECFA have been held this year and the Committee set up two Working Groups – the first to consider relations between national and international Laboratories; the second to look again at the proposed design of the 300 GeV accelerator recommended in the Amaldi Report and at the possibilities of its experimental exploitation.

Both Working Groups have made interim reports and, though the work of ECFA and the Groups still continues (the final report will be presented in a year's time), the Committee felt itself to be in the position already to present [some] conclusions.

The following extracts are from Professor Amaldi's presentation to Council.

– The conclusions of the Amaldi Report are still essentially valid, for both the "summit" and the "base of the pyramid" programmes. The summit programme concerns the intersecting storage rings ISR at CERN and a new proton accelerator of a very high energy. The base of pyramid programme concerns national or regional projects for meson factories, a high-energy electron machine, etc.

– The 300 GeV project remains the primary objective of the international high-energy programme in Europe. While some aspects of the project are still being studied, it appears that the main characteristics of this accelerator should correspond to the design by the Study Group of CERN based on the recommendations of ECFA in 1963. The Committee therefore urges the Member States to authorize this project at the earliest possible date.

This cover photo shows the Director General, Professor Gregory (right) in conversation with Professor Amaldi, Italy, Chairman of the European Committee for Future Accelerators, during a break at the 32nd CERN Council Meeting in June.

Professor Puppi, speaking as Chairman of the Scientific Policy Committee, endorsed the ECFA conclusions. He said that the project has a sound technical basis, a large measure of support from the European physicists and that a number of suitable sites for the machine had been found. He urged the Council to undertake practical steps to implement the project.

COMPILER'S NOTE

CERN's Intersecting Storage Rings (ISR), the world's first proton–proton collider, was approved in 1965. With a circumference of 1 km, it was too big for the original CERN/Meyrin site in Switzerland but could be built on French soil by the simple expedient of extending the boundary fence – with permission of course!

The initial proposal for the 300 GeV Super Proton Synchrotron SPS, with a circumference of 7 km, had been to find an entirely new site elsewhere in Europe. However, choosing between the dozen sites on offer proved tendentious until John Adams wisely emphasized the advantages of building the machine close to the CERN/Meyrin site, using the Proton Synchrotron as the injector. And so, in 1971, as the ISR was producing its first collisions, the Member States finally approved a new laboratory, Lab II, to be built in Prévessin, France, some 3 km from the original Lab I in Switzerland. The CERN Labs in the two host states remained administratively separate until 1976, when they united following the start-up of the SPS.

By 1981 the SPS had been converted into the collider that produced the world's first proton–antiproton collisions and in that same year the member states approved CERN's next collider, the 27 km Large Electron Positron ring, LEP.

The next steps

Discussion has been going on in the Committee of Council concerning the Convention for the proposed laboratory. There are two possibilities – that the present CERN Laboratory and the 300 GeV Laboratory, while being executively autonomous, be brought under the same umbrella by making a minimum of changes to the present CERN Convention, or that a completely new Convention be drawn up for the new Laboratory.

The first alternative avoids duplication of Councils and Committees and provides for simpler coordination of European policy. It is hoped that at the Council Meeting in December 1966, Governments will express a preference, or even give a decision, as to which of these courses should be followed.

On the burning question of the site for the proposed accelerator, a large, detailed, preliminary report (CERN/644) has been prepared, entitled "Proposals by the CERN Member States for a site for a European 300 GeV proton synchrotron". The introduction to the report emphasizes that the 300 GeV project, involving a ten-fold scaling up of the largest existing accelerator, is near the limit of what is technically feasible. Every component of the machine needs to be chosen to give maximum reliability and one of the most important components is the site.

Since 1962, over 140 places have been considered in an informal way but most were found unsuitable. In response to the request for official offers from Member States, made by the Council in June 1964, 22 proposals were received. [At present] 12 sites in 9 States are under active study.

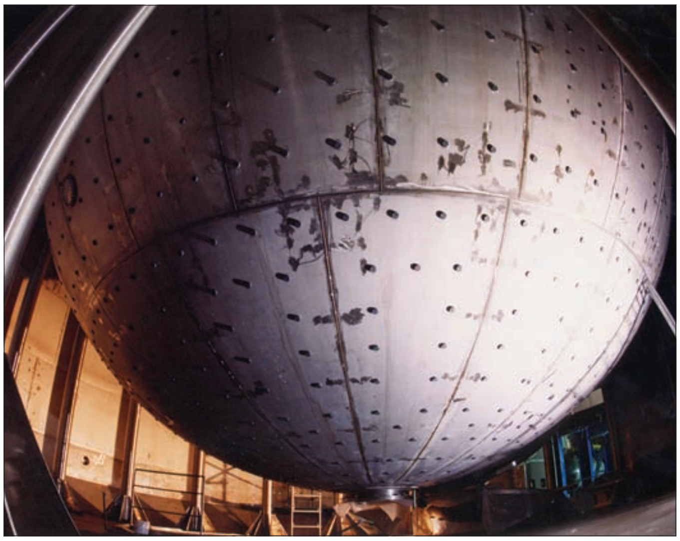
● Compiled from the report on the 32nd session of Council pp105–108.

Borexino homes in on neutrino oscillations

By detecting solar neutrinos in real time at both low and high energies, the Borexino Experiment has found experimental evidence for the transition between vacuum and matter-enhanced neutrino oscillations – a key element of the mechanism invoked to explain the problem of the "missing" solar neutrinos. **Gianpaolo Bellini** and **Aldo Ianni** report.

The mystery of the "missing" solar neutrinos arose in the 1970s when the pioneering experiment by Raymond Davis and colleagues in the Homestake Mine in South Dakota detected only one-third or so of the number of electron-neutrinos from the Sun that they expected. It was 30 years before this puzzle was solved, when the Sudbury Neutrino Observatory (SNO) confirmed the proposal that the neutrinos change type on their way from the centre of the Sun, reducing the number of electron-neutrinos arriving at the Earth (*CERN Courier* May 2007 p26). Such oscillations from one type to another can only occur if the neutrinos detected are mixtures of states with some difference in mass, in turn implying that neutrinos must have mass – a finding that lies beyond the Standard Model of particle physics.

Solar neutrinos have for the past 40 years been detected either by exploiting radiochemical techniques or by the detection of Cherenkov radiation. The Homestake detector exemplified the radiochemical method, with electron-neutrinos interacting with ^{37}Cl to produce ^{37}Ar, which was then extracted and detected through its radioactive decay. SNO, on the other hand, used heavy water to detect Cherenkov radiation from charged particles that were produced by neutrino interactions in the liquid. The results from all of the various experiments are best described by the theoretical description of neutrino oscillation developed by Stanislav Mikheyev, Alexei Smirnov and Lincoln Wolfenstein (MSW), and in particular the solution with a large mixing angle (LMA) between the mass states.



The Borexino stainless-steel sphere. It serves both as a support structure for the 2200 photomultipliers that detect the scintillation light and as a container for the inner part of the detector, which consists of a nylon balloon with 278 t of scintillator surrounded by a buffer liquid (950 t). (Courtesy INFN–Gran Sasso National Laboratories.)

Towards the MSW-LMA scenario

To explain the flux of electron-neutrinos relative to the total flux of solar neutrinos observed in SNO, as well as the results from Homestake and other experiments, the MSW-LMA mechanism requires two different regimes for neutrino oscillation: resonant, matter-enhanced oscillations in the dense core of the Sun for energies above 5 MeV (as in SNO); and vacuum-driven oscillations for low energies, below 2 MeV (as in the gallium radiochemical experiments, GALLEX, its successor the Gallium Neutrino Observatory and SAGE). Now, for the first time, the Borexino Experiment at the Gran Sasso National Laboratories has found experimental evidence for the transition between these two oscillation regimes by detecting in real time both low-energy (0.862 MeV) and high-energy (3–16 MeV) solar neutrinos, from ^{7}Be and ^{8}B, respectively. These nuclei are both formed in certain branches of the principal chain of reactions that converts hydrogen to helium at the Sun's core – the so-called proton–proton (pp) chain, which starts with the pp process, $p+p \rightarrow d+e^{+}+\nu_e$. While the ^{7}Be neutrinos form 7% of the neutrinos that emanate from the Sun, the ^{8}B neutrinos above 5 MeV correspond to only 0.006% of the total flux.

Borexino consists of an unsegmented liquid-scintillator detector with a target mass of 278 t of pseudocumene (C_9H_{12}) doped with ▷

1.5 g/l of PPO (2,5 diphenyloxazole). The scintillator is contained inside a thin (125 μm) nylon vessel that is shielded against external background by a second nylon vessel and about 1 kt of buffer, which consists of pseudocumene mixed with 5 g/l of light quencher (dimethylphthalate). A total of 2212 8-inch photomultipliers mounted on a 13.7 m diameter stainless-steel sphere (SSS) detect the scintillator light. The SSS works as a containment vessel for both the scintillator and the buffer. It is installed inside a tank containing 2100 t of high-purity water.

The ^{7}Be measurement

One of the main research goals for Borexino is the detection of the solar neutrinos emanating from the electron-capture reactions of ^{7}Be, which occurs in 15% of the conversions through the proton–proton chain. The ^{7}Be neutrinos are monoenergetic (0.862 MeV, with a 90% branching ratio) and in Borexino they are detected via elastic scattering between neutrinos and electrons. The ^{7}Be solar neutrinos offer a unique way to tag events: the kinematic Compton-like edge at 0.665 MeV. This is an important feature because solar-neutrino interactions cannot be disentangled from the residual beta-decay radioactivity arising from natural contaminants that are present in the scintillator. Figure 1 shows the expected solar-neutrino spectrum in Borexino, emphasizing the signal from the ^{7}Be neutrinos.

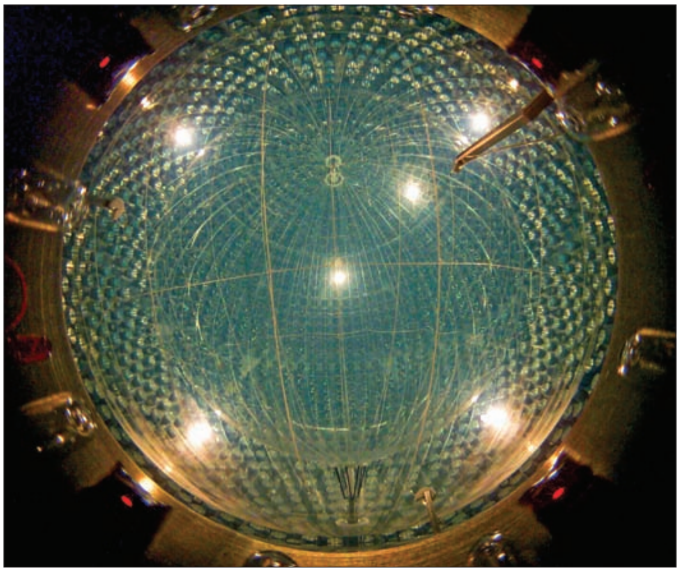
The intrinsic radiopurity level of the scintillator is the main experimental challenge for such a detector. In Borexino, after five years of R&D, we developed purification methods that allowed us to achieve excellent purity, with intrinsic ^{238}U and ^{232}Th contamination levels of less than 1 in 10^{17}. This level of radiopurity – a record in the field – allows us to study neutrino interactions in real time at, and below, 1 MeV. It also opens up new research windows such as:

- the possibility of detecting, in real time, neutrinos from the pep reaction and the CNO chain
- measuring low-energy ^{8}B neutrinos through the reaction $^{13}C(\nu_e,e^-)^{13}N$
- searching for rare processes with very high sensitivity, such as probing the Pauli-exclusion principle at the level of $>10^{30}$ y^{-1} by searching for non-Paulian transitions in ^{12}C nuclei (Derbin 2008).

Borexino has been taking data since May 2007. After a few months a clear signal in the energy spectrum of events detected in the fiducial mass of about 80 t revealed the first detection of ^{7}Be solar neutrinos (Borexino Collaboration, Arpesella *et al.* 2008). This observation allowed the first direct determination of the electron-neutrino survival probability, P_{ee}, below 1 MeV. The MSW-LMA model predicts two regimes for P_{ee}: namely, below 1 MeV, with P_{ee} ~0.6; and above 2 MeV, with P_{ee} ~0.3. Prior to Borexino only radiochemical experiments could probe the energy region below 1 MeV and they all measured an integrated solar-neutrino flux above a certain threshold – the threshold for the electron-neutrino capture interaction. The observation of ^{7}Be neutrinos by Borexino provides a result of $P_{ee}=0.56\pm0.10$ at 0.862 MeV, which is in good agreement with the MSW-LMA prediction (Borexino Collaboration, Alimonti *et al.* 2008).

This measurement casts light on another unresolved aspect of the physics of the solar core: the ratio of helium production via the pp chain and a cycle that involves carbon, nitrogen and oxygen (the CNO cycle). When taken all together, the integrated rates measured by Homestake and the gallium experiments are a function of the fluxes of solar neutrinos from pp, ^{7}Be, the CNO cycle and the decay of ^{8}B. Therefore, using the Borexino result on ^{7}Be neutrinos, it is possible to study the correlation between the pp and CNO fluxes. Figure 2 shows contours at the 68%, 90% and 99% confidence levels for the combined estimate of the pp and CNO fluxes, normalized to the predictions of the Solar Standard Model (SMM). The ^{8}B flux is fixed by the Cherenkov experiments (Super-Kamiokande and SNO).

As figure 2 shows, the measurement of ^{7}Be neutrinos is important for the study of a fundamental parameter, the flux of pp neutrinos, which are the most abundant solar neutrinos produced in the core of the Sun. The theory for beta-decay, with some extension, allows



A view inside the Borexino detector after filling with scintillator was completed on 15 May 2007. The phototubes on the inner surface of the SSS are clearly visible, as is the inner nylon balloon that contains the scintillator. (Courtesy Borexino Collaboration.)

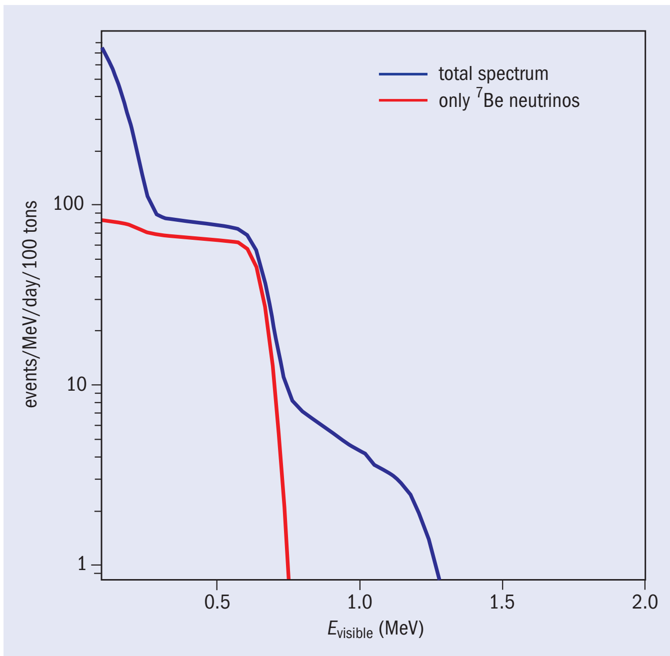


Fig. 1. The expected solar-neutrino spectrum in Borexino.

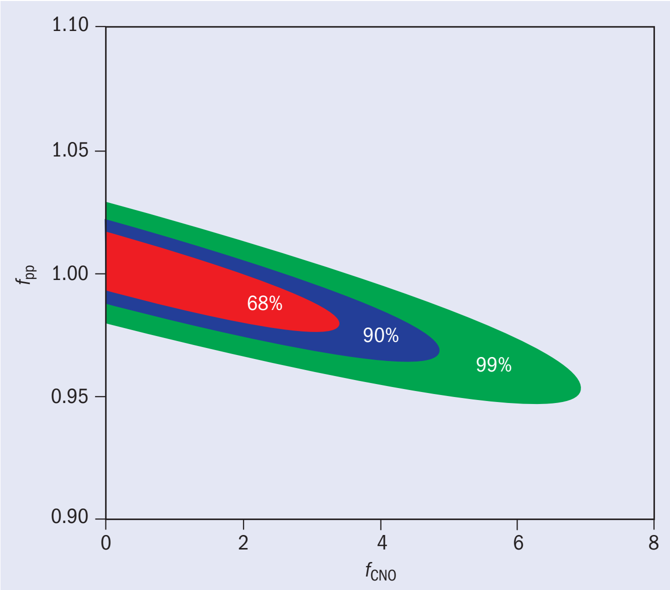


Fig. 2. Contours at different confidence levels showing the correlation between the pp and CNO fluxes using the measurement by the Borexino experiment together with the luminosity constraint.

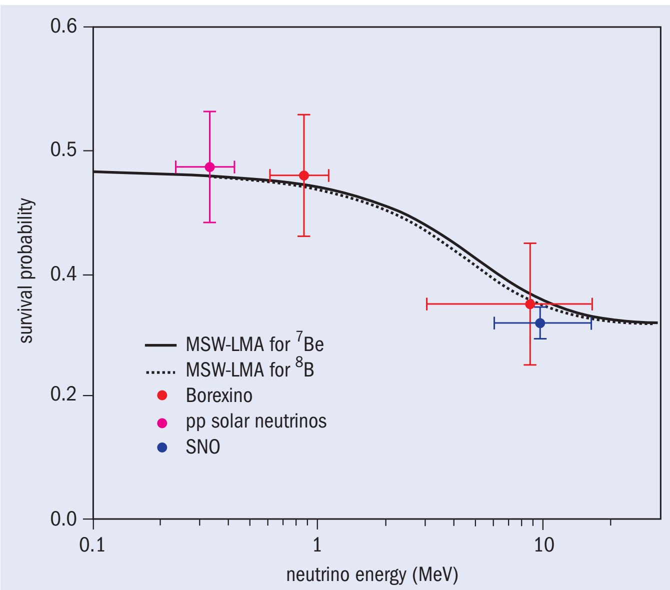


Fig. 3. Survival probability at Earth for electron solar neutrinos as a function of energy. The two Borexino measurements are shown together with the SNO result and the value predicted for pp neutrinos.

the calculation of the basic pp$\rightarrow$d+e+ν_e cross-section, which at 1 MeV is around 10^{-47} cm^2. Measuring such a small value is beyond the reach of current technology, so the cross-section for this important process – which drives the evolution of the Sun – can only be determined theoretically. A check of the flux predicted by the SMM for pp neutrinos is therefore important.

Figure 2 makes use of the luminosity constraint – a specific linear combination of solar-neutrino fluxes that corresponds to the measured photon-solar luminosity, assuming that nuclear-fusion reactions are responsible for generating energy inside the Sun. It leads to a value of $f_{pp}=1.04^{+0.13}_{-0.19}$ with the luminosity constraint; without the constraint $f_{pp}=1.005^{+0.008}_{-0.020}$. These are the best measurements of the pp solar-neutrino flux. The result on f_{CNO} translates into a CNO contribution to the solar luminosity of <5.4% (90% CL); the current SMM predicts a contribution of order 1%.

Borexino has also recently performed a measurement of the ^{8}B solar-neutrino flux above 3 MeV, which was possible because of the high radiopurity achieved. Prior to Borexino, ^{8}B neutrinos were measured above 5 MeV using Cherenkov detectors. The results from these experiments agree well with Borexino's measurement.

The measurement of the ^{8}B flux allows a determination of the corresponding value of P_{ee} at an effective energy (taking into account the spectrum of ^{8}B neutrinos) of 8.6 MeV. So by detecting ^{8}B neutrinos Borexino has measured P_{ee} simultaneously at 0.862 MeV and at 8.6 MeV (figure 3). Disregarding systematic effects, which are the same for the measurement of P_{ee} at low and high energies, the result determines a difference at about 2σ for P_{ee} for ^{7}Be and ^{8}B neutrinos. The measured ratio of the survival probability for ^{7}Be and ^{8}B neutrinos is currently 1.60±0.33 (Borexino collaboration, Bellini *et al.* 2008). Using other solar-neutrino observations it is also possible to determine P_{ee} for pp neutrinos, which figure 3 also shows. Combined, these results confirm for the first time the vacuum-matter transition predicted by the MSW-LMA scenario at today's accuracy.

● Borexino at the Gran Sasso Laboratory is an international collaboration funded by INFN (Italy); NSF (US) for Princeton University, Virginia Tech, University of Massachusetts Amherst; BMBF and DFG (Germany) for MPI für Kernphysik Heidelberg, TU München; Rosnauka (Russia) for RRC Kurchatov Institute and JINR; MNiSW (Poland) for Institute of Physics Jagellonian University; and Laboratoire APC Paris.

Further reading

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Borexino Collaboration, C Arpesella *et al.* 2008a *Phys. Lett. B* **658** 101.
Borexino Collaboration, C Arpesella *et al.* 2008b *Phys. Rev. Lett.* **101** 091302.
Borexino Collaboration, G Bellini *et al.* 2008, arXiv:0808.2868v1.
A Derbin 2008 *SpinStat Proceedings*, www.ts.infn.it/eventi/spinstat2008/.

Résumé

Borexino se penche sur les oscillations de neutrinos

La meilleure explication du nombre de neutrinos solaires détectés sur Terre est la théorie Mikheyev-Smirnov-Wolfenstein (MSW)sur les oscillations de neutrinos à grand angle de mélange (LMA). Cette théorie prévoit des oscillations dans la matière dans le cœur du Soleil pour des énergies supérieures à 5 MeV et des oscillations entraînées par le vide pour des énergies inférieures à 2 MeV. L'expérience Borexino au laboratoire national du Gran Sasso a trouvé la première preuve expérimentale de la transition entre ces deux régimes d'oscillation, en détectant à la fois des neutrinos solaires basse énergie (0.862 MeV) et des neutrinos solaires haute énergie (3–16 MeV), issus de ^{7}Be et ^{8}B, respectivement. Les résultats confirment la transition prévue par le scénario MSW-LMA.

Gianpaolo Bellini *and* **Aldo Ianni**, *for the Borexino Collaboration.*

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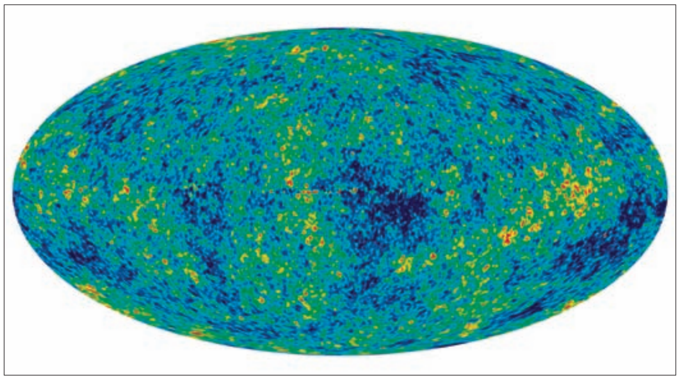
Cosmology's golden age

Four centuries after Galileo Galilei turned his telescope to the heavens, **George Smoot** considers the unprecedented and exciting times that cosmologists are now experiencing.

"La verità è il destino per il quale siamo stati fatti (Truth is the destiny for which we were made)". This article gives an example of how "truth" is achieved through "discovery" – the method used in science. By revealing nature, discovery is the way in which we can achieve truth, or at least glimpse it. But how can we know or have confidence that we have made a correct discovery? Here we can look to the major architect of the scientific method, Galileo Galilei: *"La matematica è l'afabeto nel quale Dio ha scritto l'Universo"* (Mathematics is the language with which God has written the universe). A discovery will be described best – and most economically and poetically – mathematically.



The cosmic microwave temperature fluctuations from the 5-year Wilkinson Microwave Anisotropy Probe data seen over the full sky. The average temperature is 2.725 K and the colours represent the temperature fluctuations. Red regions are warmer and blue regions are colder by about 0.0002 degrees. (Courtesy NASA/WMAP Science Team.)

Virtual space flight

There has never been a more exciting time for cosmologists than now. Through advanced techniques and ingenious, and often heroic observational efforts, we have obtained a direct and extraordinarily detailed picture of the universe – from very early times to the present. I recently had the pleasure of using a specially outfitted planetarium at the Chabot Observatory Space and Science Center in Oakland, California, and taking a virtual flight through the universe on a realistic (though often faster-than-light) journey based on real astronomical data.

We took off from the surface of the Earth and zoomed up to see the International Space Station at its correct location in orbit. When we first arrived we could only see a dark region moving above the Earth but soon the space station's orbit brought it out of the Earth's shadow into direct Sun light. We circled round, looking at it from all sides and then swiftly moved on to see the solar system with all the planets in their correct current locations. After a brief visit to the spectacular sight of Saturn we continued out to see the stars in our neighbourhood before moving on, impatient to see the whole galaxy with all the stars in the positions determined by the Hipparchos Satellite mission. After that we travelled farther out to see our local group of galaxies dominated by our own Milky Way and the Andromeda galaxy.

Moving more and more quickly we zoomed out and saw many clusters of galaxies. I was having trouble deciding quickly enough which supercluster was Coma, Perseus-Pisces or Hydra-Centaurus when viewed from an arbitrary location and moving through the universe so fast. Then, using the latest galaxy survey data, we went out farther to where we were seeing half-way to the edge of the observable universe. All the galaxies were displayed in their observed colours and locations – millions of them, admittedly only a fraction of the estimated 100 billion in the visible universe, but still incredibly impressive in number and scope, revealing the web of the cosmos.

We were actually moving through time as well as space. As we went farther away from the Earth we were at distances where light takes a long time to reach our own planet, so we were looking at objects with a very much younger age (earlier in time). It was fun flying round through the universe at hyperfaster-than-light speed and seeing all of the known galaxies. Soon I asked to see to the edge (and beyond). The operator brought up the data for the cosmic microwave background (CMB) – at the time, the 3-year maps from the Wilkinson Microwave Anisotropy Probe – and it appeared behind the distance galaxies. I asked to move right to the edge, and in the process of zooming out we went past the CMB map surface and were looking back at the sphere containing the full observable universe. Where were we? Out in the part from which light has not had time to reach Earth and – if our current understanding is correct – will never reach us. But still we wonder about what is out there, and we have some hope of understanding.

The second reason why this is such an incredibly exciting time in cosmology is that these observations, combined with careful reasoning and an occasional brilliant insight, have allowed us to formulate an elegant and precisely quantitative model for the origin and evolution of the universe. This model reproduces to high accuracy everything that we observe over the history of the universe, images of which are displayed in the planetarium.

We now have precise observations of a very early epoch in the universe through the images made using the CMB radiation and we hope to start a newer and even more precise and illuminating ▷

effort with the launch of the Planck Mission on 14 May. However, we also have many impressive galaxy surveys and plans for even more extensive surveys using new ideas to see the relics of the acoustic oscillations in the very, very early universe, as well as the gravitational lensing caused by the more recently formed large-scale structures, such as clusters of galaxies that slightly warp the fabric of space–time by their presence. Each will give us new images and thus new information about the overall history of the universe.

However, the model invokes new physics; some explicitly and some by omission. First, we put in inflation, the physical mechanism that takes a small homogeneous piece of space–time and turns it into something probably much larger than our currently observable universe but with all its features, including the very-small-amplitude fluctuations discovered with the Differential Microwave Radiometers on the Cosmic Background Explorer, which are the seeds of modern galaxies and clusters. Second, we put in dark matter, which plays the key role in the formation of structure in the universe and holds the clusters and galaxies together. This is a completely new kind of matter – unlike any other with which we have experience. It does not interact electromagnetically with light but apparently does interact gravitationally, precisely the property needed for it to form structure. A third additional ingredient is dark energy, which is used to balance the energy budget of the universe and explain the accelerating rate of expansion observed in the more recent history of the universe. Last, we need baryogenesis, the physical mechanism that explains the dominance of matter over antimatter. We have good reason to believe that there were equal amounts of matter and antimatter at the very beginning, but now matter prevails.

If we add these four extra ingredients in the simplest possible form we can reproduce the observable universe in our simulations or analytic calculations to an accuracy that is equal to (and probably better than) the current observational accuracy – at roughly the per cent level.

There are other things that we don't put in so explicitly but have reason to suspect might be there. For example, we work with a universe constrained by three large dimensions of space and one of time, even though we know that more dimensions are possible and may be necessary. We do not deal with our confinement to 4D. We also stick with the four known basic forces even though there is plenty of opportunity for new forces; and likewise for additional relics from earlier epochs.

Universal ingredients

The success of the standard cosmological model has many consequences that puzzle us and also raises several key questions, which are far from answered. The observation of dark energy demonstrates that our well established theories of particles and gravity are at least incomplete – or not fully correct. What makes up the dark side of the universe? What process, in detail, created the primordial fluctuations? Is gravity purely geometry as Albert Einstein envisaged, or is there more to it (such as scalar partners and extra dimensions)? An unprecedented experimental effort is currently being devoted to address these grand-challenge questions in cosmology. This is an intrinsically interdisciplinary issue that will inevitably be at the forefront of research in astrophysics and fundamental physics in the coming decades. Cosmology is offering us a new laboratory where standard and exotic fundamental theories can be tested on scales not otherwise accessible.

George Smoot at CERN in July 2007 at the site of the CMS detector, which will search at the LHC for particles that could explain dark matter.

The situation in cosmology is rife with opportunities. There are well defined but fundamental questions to be answered and new observations arriving to guide us in this quest. We should learn much more about inflation from the observations that we can anticipate over the next few years. Likewise we can hope to learn about the true nature of dark matter from laboratory and new accelerator experiments that are underway or soon to be operating, as at the LHC. We hope to learn more about possible extra dimensions through observations.

We continue to seek and encourage new ideas and concepts for understanding the universe. These concepts and ideas must pass muster – like a camel going through the eye of a needle – in agreeing with the multitude of precise observations and thereby yield an effective version of our now-working cosmological model. This is the key point of modern cosmology, which is fully flowering and truly exciting. It is the natural consequence and culmination of the path that Galileo started us on four centuries ago.

Résumé

L'âge d'or de la cosmologie

Quatre siècles après Galilée et son télescope, George Smoot, prix Nobel, se penche sur l'époque exceptionnelle que vivent les cosmologistes. Grâce à des observations détaillées, associées à un raisonnement rigoureux et, de temps en temps, à des intuitions brillantes, on a pu produire un modèle élégant et précis du point de vue quantitatif, qui reproduit très précisément tout ce que nous avons observé, depuis des temps très reculés jusqu'à nos jours. La nouvelle cosmologie propose un nouveau laboratoire où des théories fondamentales classiques ou révolutionnaires peuvent être mises à l'épreuve à des échelles qui seraient inaccessibles autrement. Nous nous trouvons ainsi à une époque critique de la cosmologie moderne, en suivant toujours la voie tracée par Galilée.

George F Smoot, *Lawrence Berkeley National Laboratory.*

A MAGIC touch brings

The “first light” ceremony for a second MAGIC telescope provided the opportunity to look at the bac

In a simple ceremony on a mountaintop under blue skies and bright sunlight on 25 April, a small group of colleagues, family and friends paused in silence in memory of a young physicist who died there last September. Florian Goebel suffered a fatal accident while putting the finishing touches to the MAGIC-II telescope at the Roque de Los Muchachos Observatory on the Canary Island of La Palma (*CERN Courier* November 2008 p39). He had been the project manager and it is fitting that the two MAGIC telescopes were named the Florian Goebel Telescopes at the ceremony. Shortly afterwards, Florian’s brother helped to cut the white, blue and yellow ribbons that symbolically held the telescope, releasing it for its “first light”.

MAGIC-II thus joined its older sibling, MAGIC-I, in exploring the gamma-ray sky, each with a larger segmented mirror than any other reflecting telescope. While MAGIC-I has already made major discoveries, together the two telescopes will make simultaneous observations and achieve a sensitivity three times greater than when working independently.

The Major Atmospheric Gamma-Ray Imaging Cherenkov (MAGIC) project is one of four around the world that use reflecting telescopes to detect the short bursts of Cherenkov light emitted by the showers of charged particles produced when a high-energy gamma ray interacts in the Earth’s upper atmosphere. The High Energy Stereoscopic System (HESS) has been operating in the highlands of Namibia since September 2004 (*CERN Courier* January/February 2005 p30); the Very Energetic Radiation Imaging Telescope Array System (VERITAS) in Arizona began it first observations in 2003 (*CERN Courier* July/August 2007 p19); and the CANGAROO collaboration between Australia and Japan, which has been observing gamma-ray sources since 1992, began full operation of its most recent telescopes in 2004.

A textbook example

Gamma-rays reveal the highest-energy phenomena in the universe, but a major goal for MAGIC is to extend observations to lower gamma-ray energies, which will allow it to see deeper into the universe and farther back in time. At lower energies, the gamma rays are less likely to interact with other light on their long journey through space.

The story of the MAGIC project is a textbook example of the merging of particle physics and astronomy into the modern field of astroparticle physics. For many years, Eckart Lorenz from MPI Munich was a familiar face at CERN and other particle physics laboratories, working in a number of well known collaborations involving the Munich group. By the 1990s he began to apply his expertise in particle-detection techniques to the study of high-energy cosmic gamma rays, in particular by using imaging atmospheric Cherenkov telescopes.

The MAGIC-II telescope on the inauguration day. Its segmented mirror reflects an image of its “twin”, MAGIC-I. (Inauguration photos courtesy T Pritchard.)

Eckart Lorenz, Alexander Goebel and Elena Perez from Garafia municipality each cut the yellow, blue and white ribbons, which freed MAGIC-II to observe its “first light”.

Detecting the Cherenkov light emitted as charged particles pass through a medium faster than light does is a well known technique in particle physics. The method is used to identify charged particles according to their velocities, as implemented for example in the LHCb experiment at CERN (*CERN Courier* July/August 2007 p30). The radiation forms a cone about the particle’s path; the angle of the cone depends on the refractive index of the medium, n, and the particle’s velocity, v. The higher the velocity, the larger the angle, θ, with $\cos\theta = c/nv$, where c is the speed of light in free space. For Cherenkov telescopes the medium used is the Earth’s atmosphere, and in gamma-ray showers the particles are primarily electrons and

astronomical delights

ackground to a project that uses particle-physics techniques to observe the depths of the universe.

The MAGIC site at the Roque de Los Muchachos Observatory on La Palma. The two telescopes stand 85 m apart. The control house between them was designed by J Porta from the Canary Islands, the winner of a competition for architecture students at the Polytechnic University of Catalonia. The shape of the roof resembles the hat of the "midget", who is a character in local folklore. (Courtesy R Wagner/MAGIC.)

The memorial to Florian Goebel, unveiled just prior to the inauguration.

positrons travelling close to the limiting velocity, *c*.

The showers develop to contain a maximum number of particles around 10 km above sea level; the Cherenkov light that they emit forms a "disc" typically a metre or so thick, with a diameter of about 250 m when it arrives at the Earth's surface. This disc of light is like an image of the shower. It contains essential information about the direction and the energy of the original gamma-ray and – because gamma-rays are uninfluenced by magnetic fields in space – in effect points back to the gamma-ray source.

An imaging atmospheric Cherenkov telescope with its axis pointing in the direction of the source will intercept a small part of the disc of Cherenkov light and form an image of it at the focal point. The main challenge lies in detecting very low intensity light at the level of single photons, because the Cherenkov radiation from the shower is spread across the whole disc. Moreover, the showers from charged primary cosmic rays (hadrons, mainly protons) produce a substantial background with a rate some 10 000 times greater than that of gamma-ray-induced showers. Fortunately, the shape and structure of the two types of shower differ sufficiently for the image in the telescope to have different characteristics. Appropriate image-analysis techniques can ultimately reject the unwanted hadronic showers.

Bridging the energy gap

The Cherenkov radiation from cosmic-ray showers constitutes only about 0.01% of the light in the night sky – but it is detectable, as Bill Galbraith and John Jelley first showed at Harwell in the UK in 1953 with not much more than a dustbin with a 60 cm diameter mirror and a photomultiplier tube (PMT) at its focus. Using the same principle each MAGIC telescope, with its diameter of 17 m, has an array of hundreds of PMTs at the focus – 576 in the case of MAGIC-I and 1039 for MAGIC-II.

The potential of using Cherenkov detectors for gamma-ray astronomy was suggested by Giuseppe Cocconi in 1959, who also proposed that the Crab nebula should be a strong source of high-energy gamma rays. This inspired Aleksandr Chudakov to build a pioneering gamma-ray telescope in Crimea in the early 1960s. It took 30 years before Trevor Weekes and colleagues could finally claim observation of the Crab with the Whipple imaging air Cherenkov telescope in 1989. With its 10 m segmented mirror viewed by an array of PMTs, Whipple pioneered the use of this technique in studies of the gamma-ray sky at energies from around 100 GeV to 10 TeV. It discovered the first source of gamma rays beyond our galaxy, with the detection of very high-energy emission from the active galaxy Markarian 421 (Mkn 421).

Around the same time the High-Energy Gamma-Ray Astronomy (HEGRA) project was also observing air showers with a range of detectors at the Roque de Los Muchachos Observatory. These included five 8.5 m diameter atmospheric Cherenkov telescopes that operated in coincidence to achieve better angular resolution and a much improved rejection of background, in particular from hadron showers. The system successfully detected gamma rays up to more than 10 TeV in energy, emitted by the active galactic nuclei Mkn 421 and Mkn 501, which are prime examples of the variable and intense gamma-ray sources known as "blazars".

While Whipple and HEGRA searched for sources of very high-energy gamma rays, the Energetic Gamma Ray Emission Telescope (EGRET) on board NASA's Compton Gamma Ray Observatory was collecting a wealth of data on the gamma-ray sky at lower ▷

energies, from 20 MeV to 10 GeV. Being above the Earth's atmosphere it could detect gamma-rays directly. However, with a small detection area and because the number of gamma rays per unit area falls steeply with energy, a small detector becomes inefficient at higher energies, with a practical limit of about 10 GeV.

It was around this time that Lorenz, who was a member of the HEGRA project, began to dream of bridging the gap in energy accessed by the ground-based and space-based instruments. This would require a larger-area mirror to collect more light, making it more sensitive to showers from the gamma rays below 100 GeV; the minimum detectable energy varies more or less inversely with the area of the mirror. At first the idea did not seem too promising because a large telescope looked likely to cost as much as a satellite. However, Lorenz and colleagues discovered that the German solar-power research programme had built a 17 m reflector dish using a relatively simple construction – and the first ideas for the MAGIC telescope were soon sketched out in a Munich beer garden.

Making MAGIC

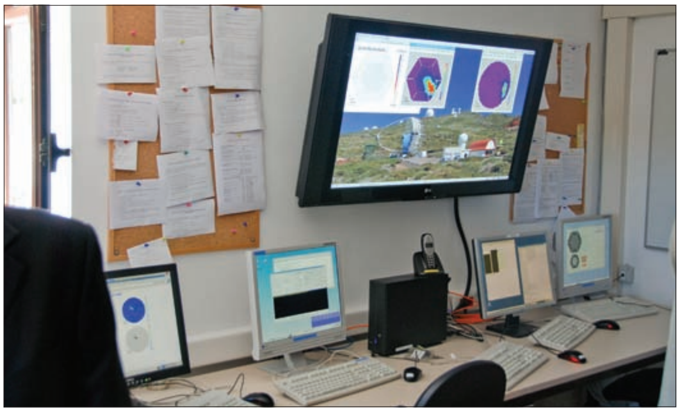
The main features of the 17 m telescope for MAGIC were clear from the outset. It had to be lightweight to react and move quickly in searches for gamma-ray bursts (GRBs) – the puzzling, powerful phenomena discovered some 30 years ago. At the same time the structure had to be rigid enough to avoid deformations. The chosen solution was to build a framework of carbon-fibre tubes and the reflector was constructed of light-weight aluminium mirrors, with diamond-machined surfaces and an active control system to adjust each mirror to counteract any small deformations arising in the frame. In addition, the aim was to use the telescope to collect as much data as possible; on moonlit nights and at large zenith angles, close to the horizon, where the Cherenkov radiation reddens, like sunlight, as it travels farther through the atmosphere to the detector. This would require novel phototubes with high quantum efficiency to improve on the light collection and to increase sensitivity

Lorenz first presented MAGIC publicly at the International Cosmic Ray Conference in Rome in 1995. The project had many new ideas – possibly too many. It initially met with resistance: critics said that the construction was too light and it would blow over; the carbon fibre would be too expensive and so on. However, there were supporters such as the Italian National Institute for High Energy Physics (INFN) and the Spanish Institute for High Energy Physics (IFAE), which joined the project in 1997, took part in the R&D and participated in the technical design report published in 1998. By this time the collaboration counted nearly 50 members mainly from Germany, Italy and Spain.

The eventual site for MAGIC was undecided at the time of the technical proposal but it was evident that, like other Cherenkov telescopes, it should be at high altitude in a location with skies clear enough to "see" the faint Cherenkov light. The site at 2200 m on La Palma, already used for HEGRA, had the added advantage of offering relatively stable temperatures, which is important for minimizing thermal stress on the telescope structure.

Funding for construction on La Palma was approved towards the end of 2000, although MAGIC had already benefited from a misfortune that had befallen HEGRA. In 1997 a forest fire had destroyed one third of the detectors; they were insured, and the insurance company stipulated that the money had to be used for ongoing research.

The "staggered" image in MAGIC-II demonstrates the action of the active mirror control. This normally operates on the individual mirrors to ensure the correct parabolic shape for the overall reflecting surface. The mirrors are mounted on three points, two controlled by actuators.



A screen in the control room displays recorded images from MAGIC-I and MAGIC-II against a background showing the site. (Courtesy T Pritchard.)

Construction of MAGIC-I began in August 2001 and its inauguration took place on 10 October 2003 (*CERN Courier* December 2003 p7). The telescope has since observed dozens of high-energy gamma-ray sources: mainly active galactic nuclei like Mkn 421 and Mkn 501 and nebulae around pulsars, but also supernova remnants and binary systems.

The observations include impressive "firsts" and exciting discoveries. On 13 July 2005, for example, the telescope demonstrated its ability to respond rapidly to a GRB alert from NASA's Swift satellite, locating GRB050713A only 40 s after its explosion (*CERN Courier* October 2005 p5). This allowed the first simultaneous observation of a GRB in both high-energy gamma rays and X-rays. In June 2006 the collaboration reported the detection of variable high-energy gamma-ray emission from the microquasar LSI+61 303, a gravitationally bound binary-star system consisting of a massive ordinary star and a compact object of a few solar masses (*CERN Courier* July/August 2006 p6). More recently, in June 2008, MAGIC discovered gamma-ray emission from 3C 279, a quasar more than 5000 million light-years from Earth – making it the most distant source of very high-energy gamma rays yet known. Detecting the gamma radiation from so far away poses interesting questions because, over such great distances, even gamma rays should interact with the background light from stars and galaxies. The universe, it seems, is darker than current theories suggest.

MAGIC-I was always viewed as the project's first telescope, which would focus resources on an advanced design aiming at as low a detection energy as possible, while maximizing the potential for discoveries. Its success laid the foundations for MAGIC-II – a "twin" to allow studies of greater sensitivity and precision. The design began in 2005 and the construction was finally completed in 2008.

In designing MAGIC-II, the collaboration has benefited both from the experience with MAGIC-I and from technological developments. While the mounts of the two telescopes are essentially the same, the differences lie in the reflecting surface and in particular in the PMTs for the "camera". MAGIC-II has the same overall surface as MAGIC-I, but is made of fewer, larger plates: 140 1m^2 diamond-milled aluminium plates, with 100 additional coated glass mirrors at the outer edges. While the aluminium mirrors have some excellent properties, their technology is not easy to extend to mass production. For MAGIC-II the collaboration turned to glass mirrors and formed a partnership with industry to trial the production of a total of 100 m^2.

The camera for MAGIC-II has more smaller-size PMTs of a new design with 10% higher quantum efficiency. MAGIC-I has 396 1″ PMTs to cover the inner area, surrounded by 180 1.5″ PMTs for the outer region. With 1039 1″ PMTs, the MAGIC-II camera covers the same area with more pixels and hence has higher resolution.

Working alone in a special low-energy mode, MAGIC-I has already observed gamma rays down to 25 GeV. Operating in unison, the two telescopes will provide better coverage of such low energies and see deeper into the Universe. The pioneering space-borne EGRET now has a more powerful successor in the Large Area Telescope (LAT) on the recently launched Fermi Gamma-Ray Space Telescope, which has an energy range from 20 MeV up to 300 GeV (*CERN Courier* November 2008 p13). With the MAGIC twins and the Fermi-LAT, Lorenz's dream of closing the energy gap is coming close to realization.

● The MAGIC collaboration currently consists of some 150 researchers from 24 institutes in Croatia, Bulgaria, Finland, Germany, Italy, Poland, Spain, Switzerland and the US.

Further reading

For more information about MAGIC and its results, see http://magic.mppmu.mpg.de.

Résumé

Le télescope MAGIC-II inauguré

La cérémonie d'inauguration du deuxième télescope MAGIC a eu lieu le 25 avril à l'Observatoire du Roque de Los Muchachos, à La Palma (Îles Canaries). MAGIC-II a ainsi rejoint son grand frère MAGIC-I pour l'exploration du ciel de rayons gamma. Chacun dispose d'un miroir segmenté d'une dimension exceptionnelle pour un télescope à réflecteur. Si MAGIC-I a déjà réalisé des découvertes importantes, les deux télescopes seront en mesure de faire des observations simultanées, avec une sensibilité trois fois supérieure à leur sensibilité en solo. L'article donne une vue d'ensemble de ce projet innovant, qui utilise les techniques de la physique des particules pour observer les profondeurs de l'Univers.

Christine Sutton, *CERN*.

Spin and snakes come to the land of Jefferson

As host of the international symposium, SPIN 2008, the University of Virginia welcomed physicists from high-energy and nuclear physics with a common interest in recent developments in spin studies.

Anatoly Kondratenko, one of the inventors of the Siberian snake, outside the symposium's building on the beautiful Virginia campus, which was originally designed by Thomas Jefferson. (Courtesy M Leonova.)

The International Spin Physics Symposia series started at the Argonne National Laboratory in 1974, just after its 12 GeV Zero Gradient Synchrotron (ZGS) had accelerated the world's first polarized proton beam. Paul Dirac gave the keynote lecture in which he reviewed the history of spin, starting with the first ideas in the 1920s. The 18th Symposium, SPIN 2008, was held in October 2008 at the University of Virginia, which was founded by Thomas Jefferson in 1821. Jefferson became third president of the US and is best known as the main author of the US Declaration of Independence. He had a keen interest in science and was president of the American Philosophical Society. As a fitting tribute, an appropriately-dressed person – who claimed to be Jefferson – gave the after-dinner talk at SPIN 2008. Speaking with a polite 1800s Virginian accent, he gave wise scientific advice that is as relevant now as it was in the early 19th century.

Maria Leonova of Michigan beside a statue of Thomas Jefferson. She discussed recent data from SPIN@COSY and the proper equations for the deuteron spin-depolarizing resonance strengths from RF dipole and RF solenoid magnets. (Courtesy Vasily Morozov.)

Symposia highlights

SPIN 2008 was attended by 282 high-energy and nuclear spin physicists from around the world. There were 195 parallel talks and 37 plenary talks, so this report mentions only a few of the exciting highlights. After the welcoming talks, the ever-enthusiastic Elliot Leader of Imperial College, London, opened the symposium with a rousing lecture on "The power of spin: a scalpel-like probe of theoretical ideas". He was followed by Klaus Rith of Erlangen, who gave a detailed experimental overview in his talk that addressed selected highlights of spin experiments and their technological challenges.

The main highlight of the symposium was the success of Brookhaven's RHIC in its operations as a polarized-proton collider. The machine has produced a great deal of high-quality data in 100 GeV-on-100 GeV collisions and had a brief but successful test of stored 250 GeV polarized protons. For this impressive achievement, Thomas Roser, Mei Bai and their team of polarized-beam experts used two Siberian snakes in each RHIC ring together with two partial Siberian snakes in the venerable Alternating Gradient Synchrotron, which serves as the injector for RHIC. These operations were possible thanks to some vital external contributions. James Simons, mathematics professor at Stony Brook, a Brookhaven trustee and now a "renaissance-technologies" billionaire, provided $13 million to allow a 6 month polarized run of RHIC. Moreover, the long-term support of Akito Arima – a nuclear theorist who became a member of the Japanese Diet and science minister – resulted in more than $20 million for RHIC's four superconducting Siberian snakes and other essential hardware. The funds were transferred from Japan to Brookhaven via the RIKEN research institute.

One interesting result was the measurement by the BRAHMS ▷

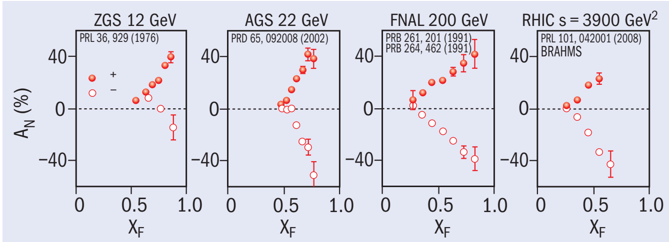


Fig. 1. Measurements at RHIC by BRAHMS of the left–right spin asymmetry, A_n, in the inclusive production of π^+ and π^- mesons, show no change compared with results at lower energies – contrary to PQCD predictions.

Mei Bai talks about the Siberian snakes at RHIC. (Courtesy M Leonova.)

experiment at RHIC of the left–right spin asymmetry, A_n, in the inclusive production of π^+ and π^- mesons, which was presented by Christine Aidala of the University of Massachusetts at Amherst. The data show that, despite the prediction of perturbative QCD (PQCD) that spin would be unimportant at high energy, the inclusive A_n at large Feynman-x reached the same value of about 40% at 3900 GeV^2 ($P_{Lab} \approx 2$ TeV/c) as at Argonne's ZGS, Brookhaven's AGS and Fermilab at momentum values of 12, 22, and 200 GeV/c, respectively (figure 1). This result might encourage PQCD theorists to define more clearly what is meant by "high" energy.

In an overview of the transverse spin structure of the nucleon, Mario Anselmino of Turin reported on the very large observed transverse spin effects, which are still not fully understood. Karl Slifer of the University of Virginia gave a talk on what polarized electron scattering has revealed about the spin content of the nucleon. He discussed the theoretical implications of recent polarized-electron experiments, many of which were done at the 6 GeV polarized-electron ring at the Thomas Jefferson National Accelerator Facility (Jefferson Lab). The use of polarized radioactive beams was the subject of an interesting talk by Koichiro Asahi of Tokyo Institute of Technology.

Speakers also covered the more experimental aspects of spin studies, namely the production of polarized beams and polarized targets. Richard Milner of the Massachusetts Institute of Technology gave an excellent review of the progress towards a future polarized-electron ring, which would allow collisions with either polarized protons or polarized nuclear ions stored in a much larger ring – possibly one of the rings at RHIC. Erhard Steffens of Erlangen, the new chair-elect of the International Spin Physics Committee, summarized the discussions at the second workshop on 'How to Polarize Antiprotons', held in August 2007 at the Cockcroft Institute at the Daresbury Laboratory in the UK. There has been significant progress on this challenging topic during the 22 years since Owen Chamberlain and Alan Krisch organized the first Polarized Antiproton Workshop in 1985 at Bodega Bay near Berkeley, but there is still no clearly defined solution to this difficult problem.

Werner Meyer of Bochum reviewed the continuing progress, since SPIN 2006 in Kyoto, on cryogenic polarized proton and deuteron targets. Brookhaven's Anatoly Zelenski then described the recent progress on polarized-ion sources – the subject of a joint paper with Alexander Belov of the Institute for Nuclear Research, Troitsk. This progress is important because these polarized sources feed RHIC. Indeed, Brookhaven and the Spin Physics Committee sponsored a recent workshop on this topic at Brookhaven. Matt Poelker of Jefferson Lab reviewed progress on polarized-electron sources and polarimeters, which was the subject of another recent spin workshop at the laboratory. These sources and polarimeters are vital to progress in polarized-electron experiments.

Anatoly Kondratenko of Novosibirsk, who along with Yaroslav Derbenev invented Siberian snakes in the 1970s, gave an interesting talk on his more recent idea, now named Kondratenko Crossing (KC). This uses a symmetric spin-resonance crossing pattern that forces the resonance's depolarizing effects to cancel themselves. Richard Raymond of Michigan reported on new data from the SPIN@COSY team at the Cooler Synchrotron (COSY) at the Forschungszentrum in Jülich. The results show that KC works, at least for RF-solenoid-induced resonances with deuterons. In the same parallel session accelerator pioneer Ernest Courant, of Brookhaven, still going strong at 89, discussed his new theoretical work on the behaviour of stored polarized beams.

There was also a special evening plenary session where the director (or proxy) of each of the major laboratories involved in spin-physics studies reported on their plans at GSI-Darmstadt, Brookhaven, Jefferson Lab, IHEP-Protvino, JINR-Dubna, J-PARC, and COSY-Jülich. On the last day, Thomas Roser, the new past-chair of the Spin Physics Committee, gave an excellent lecture on the future of high-energy polarized beams. The symposium ended with closing remarks from committee chair, Kenichi Imai of Kyoto. He announced that SPIN 2010 would be hosted by Forschungszentrum Jülich, while a high priority would be given to SPIN 2012 being hosted somewhere in Russia.

● For more information about SPIN 2008, see http://www.faculty.virginia.edu/spin2008/.

Résumé

Spin et serpent au pays de Jefferson

Le 18^e colloque SPIN2008 a eu lieu en octobre 2008 à l'Université de Virginie, fondée en 1821 par Thomas Jefferson. Il y a été beaucoup question du succès du RHIC de Brookhaven comme collisionneur de protons polarisés. Les intervenants ont également évoqué plusieurs aspects expérimentaux des études de spin, tels que la production de faisceaux polarisés et de cibles polarisées. Il a été question des possibilités de faisceaux radioactifs polarisés, de sources d'électrons polarisés et des difficultés liées à la production d'antiprotons polarisés. Une session plénière spéciale a permis aux grands laboratoires travaillant dans le domaine de la physique du spin de présenter leurs derniers projets.

Don Crabb, *University of Virginia, and colleagues, on behalf of the organizing committee.*

CELEBRATION

CERN honours Carlo Rubbia as he turns 75

On 7 April CERN hosted a celebration to mark Carlo Rubbia's 75th birthday and the 25th anniversary of the award to him of the Nobel Prize in Physics. "Today we will celebrate 100 years of Carlo Rubbia," quipped CERN's director-general Rolf Heuer in opening the symposium held in Rubbia's honour.

Rubbia received the 1984 Nobel Prize in Physics together with Simon van der Meer for their contributions to the discovery of the W and Z bosons, the carriers of the weak interaction. During the symposium colleagues recalled the accelerator and detector developments that made possible this discovery – and with it the first Nobel prize for research at CERN. Speakers also looked at other areas of science to which Rubbia has made decisive contributions and in which he retains a passionate interest.

CERN honours Carlo Rubbia. From left to right: Sergio Bertolucci, Robert Klapisch, Sven Kullander, Rolf Heuer, Hans Joachim Schellnhuber, Herwig Schopper, Giovanni Bignami, Carlo Rubbia, Michel Spiro, Lyn Evans and Alan Astbury.

Michel Spiro, director of the French National Institute of Nuclear and Particle Physics of the CNRS, began with an overview of neutrinos in particle physics and astrophysics. He reminded the audience of Rubbia's experiments from the 1960s and 1970s that had involved neutrinos, as well as his important contributions to innovative technologies in use now, and in the future, for neutrino physics and neutrino astronomy. These include the large-scale water Cherenkov detectors and the liquid-argon time-projection chamber.

CERN's Lyn Evans was closely involved with the accelerator work that made possible the conversion of the SPS into the world's first proton–antiproton collider, the machine that enabled the discovery of the W and Z particles. As early as 1968, van der Meer had the idea of "stochastic cooling", in which beam fluctuations are damped down by feedback from the fluctuations themselves. He initially thought his idea "too far-fetched", but the technique was demonstrated at the Intersecting Storage Rings in 1974. It formed a key part of Rubbia's proposal to convert the SPS into a proton–antiproton collider to reach a higher energy regime. Authorization for the modifications to the SPS came in 1978 and their implementation began in 1980, followed by the first proton–antiproton collisions on 10 July 1981. The experience gained by the accelerator teams was later to bear fruit with the successful start up of the LHC in September 2008.

Rubbia's experiment to search for the W and Z, named UA1 after its location on the ring, was put together by a collaboration of some 130 physicists and engineers (CERN Courier May 2003 p26). Alan Astbury, now with the University of Victoria and one-time co-spokesperson of UA1, looked at the task the experiment and its sibling, UA2, had to fulfil to find the predicted W and Z particles. UA1 was very much a general-purpose detector, the first ancestor of detectors such as ATLAS and CMS at the LHC, while UA2 was more specialized. The path to the W and Z was not without obstacles, as Astbury recalled, but by 1983 both experiments had clear evidence for the W and Z events.

The results from UA1 and UA2 emerged just as collaborations were putting together technical proposals for the experiments at LEP, the 27 km electron–positron collider that was to be built at CERN in the 1980s. Former CERN director-general Herwig Schopper talked about the background to the LEP proposal and its subsequent success. It later gave way to the LHC, the existence of which owes a great deal to Rubbia, who pushed for it strongly, in particular during his own mandate as director-general.

Moving beyond CERN and terrestrial particle physics, Giovanni Bignami, former president of the Italian Space Agency and professor at the IUSS School for Advanced Studies in Pavia, took a delightful journey into space. He described the current frontiers of astronomy, 400 years after Galileo Galilei began to use a telescope to study the heavens, showing how important "particle astronomy" is now becoming.

Hans Joachim Schellnhuber of the Potsdam Institute for Climate Research and Sven Kullander of the Royal Swedish Academy of Science both spoke about an issue to which Rubbia has dedicated himself in recent years – renewable energy. While president of the Italian alternative-energy agency ENEA (between 1999 and 2005) Rubbia developed a novel method for concentrating solar power at high temperatures for energy production, known as the Archimedes Project, which is currently being developed by industry for commercial use.

● The presentations and a recording of the symposium are available at http://indico.cern.ch/conferenceDisplay.py?confId=54479.

LABORATORIES

Groundbreaking ceremonies take place for Jefferson Lab 12 GeV upgrade…

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia, marked the beginning of construction of its $310 million (€9.5 million) 12 GeV upgrade project with a groundbreaking ceremony on 14 April. The event was attended by more than 400 people, including local, state and national political leaders.

Mayor of Newport News, Joe Frank, addresses attendees at a groundbreaking event for Jefferson Lab's 12 GeV upgrade. (Courtesy JLab photos.)

The 12 GeV upgrade at Jefferson Lab, which will be completed in 2015, will double the energy of the laboratory's electron-beam accelerator, from the current value of 6 GeV (*CERN Courier* April 2009 p15). The upgrade project, which also includes the construction of a fourth experimental hall, a 250 ft extension to the underground accelerator tunnel, and new roads and utilities, recently received $65 million in stimulus funds to accelerate the work.

The 12 GeV project guarantees Jefferson Lab's future well beyond the next decade. It will also allow the laboratory to pursue broader, more effective collaborations, while training the next generation of scientists and engineers.

…and for the latest long-baseline neutrino experiment in Minnesota

On 1 May congressmen James Oberstar of Minnesota and Bill Foster of Illinois joined officials from the US Department of Energy (DOE), Fermilab and the University of Minnesota to break ground for the NuMI Off-Axis Neutrino Appearance (NOvA) project. The experiment is to study neutrino oscillation using a new detector 60 km southeast of International Falls, Minnesota, near the US–Canada border.

Ground-breaking gives the NOvA project an official start. (Courtesy Fermilab Visual Media Services.)

The NOvA experiment is designed to search for oscillations of muon–neutrinos to electron–neutrinos by comparing the electron–neutrino event rate measured at Fermilab with the electron–neutrino event rate at the new site, 810 km away. It will use the Neutrinos at the Main Injector (NuMI) beam at Fermilab, which is producing neutrinos for the MINOS experiment. Unlike the MINOS far detector, which is located on the centreline of the neutrino beam, the NOvA detector will be slightly off the centreline. This off-axis location produces a large neutrino flux that peaks at 2 GeV, the energy where oscillation to electron–neutrinos is expected to be at a maximum.

The new far detector, which will contain 15 kt of liquid scintillator, will measure 15.7 × 15.7 × 78 m. A smaller copy of the far detector will be constructed in the NuMI beam on the Fermilab site to measure the neutrino event rates prior to oscillation.

The NOvA Detector Facility will reside in a laboratory at the University of Minnesota, which currently runs the Soudan Underground Laboratory where the MINOS far detector is located. The DOE Office of Science has provided $40.1 million (€29 million) in Recovery Act funding for the construction project. It will also provide $9.9 million in Recovery Act funding to Fermilab, which manages the project.

MEETINGS

EDS '09, the **13th International Conference on Elastic & Diffractive Scattering** (13th "Blois Workshop") will be held on 29 June – 3 July at CERN. The conference will discuss the physics of high-energy hadronic interactions with a focus on: elastic and total hadron–hadron cross-sections, soft/hard diffractive collisions, central-exclusive processes, photon-induced collisions, low-x QCD and heavy-ions, and ultrahigh-energy cosmic rays. Talks will include the status of the LHC and a discussion on experimental techniques in forward physics. See http://eds09.web.cern.ch/eds09/.

The international summer course, **Digital Libraries à la Carte**, will be held on 28 July – 5 August at Tilburg University, the Netherlands. The programme consists of a "menu" of seven one-day modules: Strategic Developments and Library Management; Change – Making it Happen in Your Library; Tomorrow's Library Leaders; Integrated Search Solutions Toward Catalogue 2.0; Institutional Repositories – Preservation and Advocacy; Libraries and Research Data – Embracing New Content; Libraries and Collaborative Research Communities. See www.tilburguniversity.nl/ticer/09carte/.

The **9th Ion Beam Analysis (IBA) Conference** will be held on 7–11 September. This is a biennial series that brings together physicists, materials scientists, biologists and other scientists using ion beams for analysis. In the centenary year of the first Rutherford backscattering spectrometry experiment the 2009 meeting is being held at the University of Cambridge, where Rutherford was Cavendish Professor of Physics. It is being organized in collaboration with the Institute of Physics. For more details, see www.iba2009.org.

Sponsored by the Institute of Nuclear Materials Management, the **International Conference on Advanced Methods of Laser Applications in Nuclear Science and Neutron Scattering** will take place on 2–7 December in Alexandria. Abstracts should be submitted to Prof. Ashraf Elsayed Mohamed Mohamed at ashraf.mohamed@physics.org or ashrafmohamed83@gmail.com. For more details, see www.iaea.org/cgi-bin/maeps.page.pl/search.htm and then select Egypt.

DESY

Lab says its farewells to Albrecht Wagner…

On 3 April, DESY celebrated its own Wagner Fest – a farewell colloquium to mark the retirement of its long-time chair of the board of directors, Albrecht Wagner.

Wagner was a member of the DESY directorate for 18 years – first as research director, then as its chairman from 1999 until he handed over the baton to his successor, Helmut Dosch, on 2 March. "Wagner made crucial contributions towards the building of several new top-class facilities for basic research at DESY," emphasized Frieder Meyer-Krahmer, state secretary of the German Federal Ministry of Education and Research, in his welcome address. He congratulated the long-time DESY director for his merits. He said: "You rendered outstanding and lasting services to DESY and basic research in Germany and to the Federal Republic of Germany."

During the colloquium, which was attended by around 500 guests from all over the world, several eminent speakers gave their personal recollections of Wagner and honoured his decisive achievements as a key player in science and research policy. Among the speakers were Atsuto Suzuki, director-general of KEK and chair of the International Committee for Future Accelerators (ICFA), who said he was "very impressed by Wagner's outstanding, strong leadership and deep enthusiasm for science", and CERN's director-general, Rolf Heuer, who honoured him as "a friend and colleague who is always a step ahead".

Albrecht Wagner, right, talks with Rolf Heuer, CERN's director-general, left, and Ralph Eichler, president of ETH Zurich. (Courtesy DESY Hamburg.)

Other laboratory directors included William G Stirling, former director-general of the ESRF, who highlighted Wagner's contributions to the development of photon science at DESY and around the world. Maury Tigner, director of the Cornell Laboratory for Accelerator-based Sciences and Education, emphasized his achievements as a key leader in the planning and development of lepton colliders, especially through his former position as chair of ICFA and the International Linear Collider (ILC) Steering Committee. Ralph Eichler, president of ETH Zurich, praised Wagner's management skills in "convincing partners, public and politics" even in difficult times, and Jonathan Dorfan, former director of SLAC, honoured him as a "leader whose influence has been truly global and who will be greatly missed".

Under Wagner's leadership, decisions were made at DESY to build the X-ray free-electron laser (European XFEL) and upgrade the PETRA storage ring to be the most brilliant synchrotron radiation source in the world – PETRA III (p8). The ILC and the European XFEL are both to be realized using superconducting RF technology that was developed by the international TESLA Technology Collaboration under DESY's leadership. Wagner played a decisive role in this success, which is appreciated all over the world.

Wagner has been connected with DESY since 1974. After his studies at the universities of Munich, Göttingen and Heidelberg, he worked on experiments at Lawrence Berkeley Laboratory, CERN and at the DESY storage rings DORIS and PETRA. From 1984 to 1991, he was a professor at the University of Heidelberg; in 1991 he was appointed professor at the University of Hamburg and Research Director of DESY.

…while Hamburg honours Volker Soergel

Volker Soergel, who was chair of the DESY Board of Directors from 1981 to 1993, has received an honorary doctorate from the University of Hamburg.

Soergel was honoured for his merits in the close and successful collaboration of DESY and the University of Hamburg and for his contributions to the national and international visibility of Hamburg as a centre of science and research. Under his aegis, the electron–proton storage ring HERA was built in Hamburg. HERA offered unique research possibilities to students and scientists from Hamburg and significantly strengthened Hamburg as a research location.

Volker Soergel, right, with Heinrich Graener, Dean of the Faculty of Mathematics, Informatics and Natural Sciences at the University of Hamburg. (Courtesy DESY.)

VISITS

Google vice-president, **Vint Cerf** (left) visited CERN on 26 February. He toured the ATLAS experimental cavern with ATLAS spokesperson, **Peter Jenni** (right) and visited the CERN Computer Centre, where he attended a presentation on the LCG project, before giving a colloquium in the main auditorium.

Just as the block-buster with a CERN theme, *Angels & Demons*, was about to be released, another film director came to CERN in search of locations for a forthcoming film. **Cédric Klapisch**, seen here with **Corinne Pralavorio** of the Communication Group, is probably best known for *L'auberge Espagnol*, about a French student who spends a year in Spain under the Erasmus European exchange programme. He is the son of Robert Klapisch, a physicist and former director of research at CERN.

Mariastella Gelmini, the Italian minister of education, university and research (left) visited CERN on 11 March. She toured the CMS experiment accompanied by **Guido Tonelli**, CMS deputy spokesperson (right) and also visited the ATLAS experiment and the LHC tunnel. After returning to the surface she met with Italian scientists and signed the CERN guest book.

On 16 March HRH princess **Maha Chakri Sirindhorn** of Thailand (centre right) came to CERN for the third time. She toured the CMS experiment and LHC tunnel with **Emmanuel Tsesmelis** (far left) from the CERN directorate office; **Jim Virdee** (centre left) CMS spokesperson; and **Felicitas Pauss**, CERN coordinator for external relations. She also had discussions with the Education Group and visited the CERN Computing Centre.

AWARDS

Italy honours new ATLAS spokesperson

On 7 March, on the occasion of International Woman's Day, Fabiola Gianotti – ATLAS spokesperson – was one of eight women to be honoured for their achievements by Italian president, Giorgio Napolitan.

Gianotti was awarded *Commendatore della Repubblica Italiana* for her "scientific knowledge and her excellent management skills demonstrated in guiding the ATLAS project" as well as "her contribution to the prestige of the Italian scientific community in the field of nuclear physics".

Gianotti took over from Peter Jenni as spokesperson for the nearly 3000-strong ATLAS collaboration in March this year (*CERN Courier* May p31).

President of the Italian Republic, Giorgio Napolitano, presenting CERN's Fabiola Gianotti with her award on 7 March. (Courtesy F Gianotti.).

EXHIBITIONS

CERN sets particle physics on the road

CERN's new travelling exhibition, Accelerating Science, was inaugurated on 1 April at the University of Geneva as part of celebrations to mark the university's 450th anniversary. Developed by CERN's communication group working with physicists at the laboratory and in partnership with the University of Geneva, the exhibition has been financed by the H Dudley Wright Foundation, which aims to promote public awareness of the sciences.

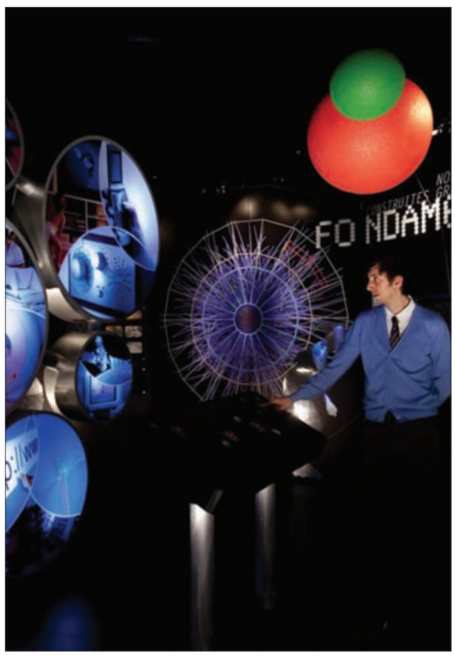
Accelerating Science takes the form of a discovery trail along which visitors learn about particle physics, its fundamental questions and aims, and the tools used in its investigations. There are five interconnecting zones, each of which is designed to take visitors into a world of mystery and suspense.

After passing through the entrance tunnel, visitors encounter the first zone where a film and a mural recount the history of the Universe. The second zone is filled with interactive exhibits revealing the world of elementary particles. The giant mushrooms in the third zone explain through sound and images the main issues of contemporary particle physics, while in the fourth zone, visitors come face to face with the LHC machine and experiments.

The last zone comes back to the reality of day-to-day life, showing how fundamental physics serves the technological advances on which modern life depends.

Covering more than 400 square metres, Accelerating Science has been designed to travel through the CERN member states. With this in mind, it has a modular design and is thus able to adapt to different venues. It will stay at the university in Geneva until 28 June before moving to CERN's Globe of Science and Innovation for three months. Then it will be off to whichever member state requests it.

Left to right: CERN's director-general, Rolf Heuer, the rector of Geneva University, Jean-Dominique Vassalli, and Jean Patry, president of the H Dudley Wright Foundation, inaugurated the exhibition on 1 April.



A display worthy of a science fiction film transports the visitor into the world of fundamental research.

Polish mobile exhibition gets down to basics

Poland has developed its own successful travelling exhibition, The Large Hadron Collider – How does it work? Organized by a group of Polish institutions taking part in the LHC research programme, its aim is to explain what hadrons are and why we want to make them collide together, plus much more.

The original exhibition, shown for the first time in November 2008 in the physics department of Warsaw University of Technology as part of the Warsaw Festival of Science, consisted of three main parts.

The first of them contained seven separate stations – each manned by experts – devoted to the LHC accelerator, the four experiments, LHC physics and the constituents of matter. The machine stations included 3D models of detectors at 1:30 scale; exhibits from CERN and from Polish institutes involved in constructing parts of the detectors; and large photos and graphics. A special attraction was an interactive animation prepared by Polish students, which visualizes collisions in ALICE and the work of elements of the detector.

The second part of the exhibition is the main interactive part. About 20 different experiments present the laws of nature used in the construction of LHC and its detectors, starting at a very basic level (the aim is that the exhibition is accessible even to very young children). The quark model was illustrated with the help of coloured balloons: three small ones encased in a larger, transparent one, all filled with helium and "constructed" by the visitor. Electric acceleration, the Lorentz force, electromagnets, Ohm's law – "almost all" that is needed to understand how the LHC works – are explained in a set of experiments that everyone can repeat at home. More sophisticated experiments show how particle detectors work and demonstrate superconductors.

The exhibition draws a crowd in Toruń, the birthplace of Nicolas Copernicus. (Courtesy Karol Karnowski.)

The third part shows what the LHC should bring. While it is not possible to predict the applications of LHC results, this section covers the benefits we have had from the past 50 years of research at CERN and other high-energy physics institutes, such as the World Wide Web and the Grid.

The exhibition is financed by the Polish Ministry of Science and Higher Education, Polish research institutes (primarily Warsaw University of Technology, Soltan Institute for Nuclear Studies, University of Warsaw and Henryk Niewodniczanski Institute for Nuclear Physics), by sponsors and local institutions. Support in the form of printed materials, exhibits, and the documentation needed to construct models was provided by CERN.

The exhibition is proving very successful. By the end of April it had visited Warsaw, Krakow, Tarnów, Poznań, Gliwice and Toruń, attracting an estimated 30 000 visitors. It was scheduled next to visit Lublin, Białystok and Gdansk. The contract with the ministry was for a total of 11 venues, but with a longer waiting list the organizers are looking for sponsors to keep the show on the road.

LETTER

A plasma-wakefield collider at the LHC?

Earlier this year Mourou *et al*. made futuristic proposals on studies that could be made of the vacuum using high-intensity lasers to drive compact plasma-wakefield accelerators (*CERN Courier* March p21). I would like to point out further possibilities that could be pursued at the LHC using plasma-wakefields.

Caldwell *et al.* showed recently (2009 *Nat. Phys.* in press; arXiv:0807.4599) that electrons could be accelerated to tera-electronvolt (TeV) energies in plasma-wakefields driven by TeV protons. The LHC could therefore be converted to an electron–electron collider, and thence to a $\gamma\gamma$ collider, via the process $e^-e^- \rightarrow e^-e^-\gamma^*\gamma^* \rightarrow e^-e^-X$. A similar strategy was followed at LEP for $e^-e^+ \rightarrow e^-e^+\gamma^*\gamma^* \rightarrow e^-e^+X$, but the e^-e^- channel is preferable for generating $\gamma\gamma$ collisions, as it suffers from less background interference.

A $\gamma\gamma$ collider at the LHC could be used to follow up unexpected results that were obtained with LEP in $\gamma\gamma$ collisions. Events similar to the multi-muon events that were reported recently at Fermilab were seen beforehand at LEP in $\gamma\gamma$ collisions. Also the cross-section for hadron production was found at LEP to exceed the prediction of QCD by 10 times at the highest transverse momenta, and still to be growing (P Yock 2009 *Int. J. Mod. Phys. A* in press; arXiv:0903.0434). The cross-section for the latter puzzle provides a strong constraint on the charges of quarks (E Witten 1977 *Nucl. Phys. B* **120** 189).

These legacies from LEP are important. The first questions the particle classification of the quark model and the second questions the charges of quarks, both pillars of the Standard Model. Such questions would assume more importance if the Higgs fails to materialize at Fermilab and the LHC.

Philip Yock, University of Auckland.

OBITUARIES

Kazuhiko Nishijima 1926–2009

The eminent physicist and former director of the Yukawa Institute for Theoretical Physics, Kazuhiko Nishijima, passed away on 15 February. He had been ill for the past year.

Nishijima is well known for his contributions to particle physics. His study of the physics of strange particles and introduction of the quantum number "strangeness" was a decisive step in the development of particle physics. His work played a crucial role in subsequent developments of the quark model and flavour symmetry in particle physics.

He is also well known for his work on the two-component theory of neutrinos, and the axiomatic formulation of bound states in quantum field theory. His interpretation of renormalization in field theory from the point of view of dispersion relations has also been highly influential.

Kazuhiko Nishijima. (Courtesy YITP.)

Nishijima had positions at the University of Illinois (1961–6) and the University of Tokyo (1966–86) before becoming director of the Yukawa Institute of Theoretical Physics at Kyoto University in 1986–70. During his directorship at the Yukawa Institute he arranged its unification with the Institute of Theoretical Physics of Hiroshima University. He became a member of the Japan Academy in 1989 and received the order of culture, the highest honour of cultural achievements in Japan, in 2003. We offer our sincere condolences to his family.

Tohru Eguchi, director, Yukawa Institute for Theoretical Physics, Kyoto University.

Earle Fowler 1921–2008

Earle Cabell Fowler died on 1 March 2008 in Chapel Hill, North Carolina. In a long career in high-energy physics he led research groups, a university department, and a team at the US Department of Energy (DOE).

Born on 10 June 1921 in Kentucky, Earle studied chemistry at the University of Kentucky and served as a meteorologist in the Army Air Force during the Second World War. He then studied physics at Harvard, using a cloud chamber to investigate cosmic rays.

After completing his PhD in 1949, Earle became a member of Ralph Shutt's group at the Brookhaven National Laboratory, later joined by his brother Bill. The group built a cloud chamber for the Cosmotron; this early tracking chamber led to a very productive bubble chamber programme at both the Cosmotron and the Alternating Gradient Synchrotron (AGS).

Earle moved to Yale in 1952 and used the Brookhaven accelerators in collaboration with the Shutt group. The Yale approach was a model for university–laboratory collaborations in physics. With colleagues Horace Taft and Jack Sandweiss, Earle encouraged students to work on detectors as well as analysis; he also wrote a book on strange particles with Bob Adair.

Earle Fowler. (Courtesy Marjorie Fowler.)

In 1962 Earle moved to Duke University, continuing his research programme at the AGS. He hosted several conferences on hadron resonances and helped to establish a university computer centre. From 1967 to 1969 he was a charter member of the High-Energy Physics Advisory Panel appointed by the Atomic Energy Commission. He was elected a fellow of the American Physical Society and secretary-treasurer of its Division of Particles and Fields.

Earle became head of the physics department at Purdue University in 1972. He found time to continue his research, by now at SLAC and Fermilab, and hosted a major conference, Neutrino-78. He spent a year with Bill Willis's group at CERN, helping them to commission their detector at the Intersecting Storage Rings.

In 1980 Earle joined the DOE and led its Facility Operations Team for High Energy Physics. His substantial experience was a key resource for DOE. He managed the US–China Agreement on High Energy Physics and worked on site selection for the Superconducting Super Collider. He retired in 1997 and went home to Chapel Hill.

Earle's judgement and wisdom were assets to high-energy physics. He was a lively, engaging person who provided inspiration and guidance to graduate students and senior physicists alike. We miss him.

Neil Baggett, Bill Fowler, James Sanford and Bill Willis.

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Der/die Stelleninhaber/in ist zuständig für die Planung, Berechnung und Entwicklung von digitalen und analogen Steuer-, Überwachungs-, Mess- und Datenerfassungssystemen sowie von Geräten der Leistungselektronik für den Betrieb der Beschleunigeranlagen und den Experimentiereinrichtungen. Diese Aufgaben beinhalten die Erstellung von Gesamtkonzeptionen der elektronischen Instrumentierung, die Festlegung der einzusetzenden Technologien und die Definition der Schnittstellen der Teilprojekte. Zum Aufgabengebiet gehört ferner die Formulierung der Teilprobleme für die Entwickler (Ingenieure und Techniker der Technischen Betriebsgruppe Elektronik), das Aufzeigen der Realisierungsmöglichkeiten sowie die Beratung, Unterstützung und Motivation der Entwickler bei der Durchführung ihrer Aufgaben. Die Mitarbeit im Bereich der akademischen Lehre wie z.B. die Durchführung von Vorlesungen auf dem Gebiet der Elektronik und Signalverarbeitung sowie die Mitarbeit an den entsprechenden Praktika wird ausdrücklich gewünscht.

Einstellungsvoraussetzung ist ein abgeschlossenes, wissenschaftliches Hochschulstudium als Dipl.-Physiker / Dipl.-Physikerin oder vergleichbare Kenntnisse und Fähigkeiten. Weiterhin ist der Nachweis der Fähigkeit zu selbständiger wissenschaftlicher Arbeit Voraussetzung (Promotion).

Der Stelleninhaber / die Stelleninhaberin muss neben erstklassigen Kenntnissen der allgemeinen Elektronik und Datenerfassung auch ein weit überdurchschnittliches Wissen im Bereich der kernphysikalischen Sonderelektronik, der Detektortechnik, der Datenverarbeitung und verwandter Gebiete besitzen. Die Abwicklung der verschiedenen Projekte erfordern vom Leiter dieses Bereiches Führungsqualitäten, Managementvermögen und ausgezeichnete organisatorische Fähigkeiten.

Die Johannes Gutenberg-Universität Mainz ist bestrebt, den Anteil der Frauen im wissenschaftlichen Bereich zu erhöhen, und bittet daher Wissenschaftlerinnen, sich zu bewerben.

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Big Science, bigger outreach

Miguel-Angel Sanchis-Lozano argues that today's "Big Science" has valuable messages for society, beyond the dissemination of results and technologies.

In 1609 Galileo Galilei made the first recorded telescope observations of the night sky – an event that is being celebrated all through 2009 in the International Year of Astronomy. He soon ran into trouble with the ecclesiastical authorities, partly because he used Italian instead of Latin in many of his letters and books, which gave people access to his new scientific interpretation of the world. Fortunately things have changed since then and today the scientific community and the relevant authorities on scientific policies share a general consensus on the importance of conveying to society the main results and general consequences of research.

Take high-energy physics as an example: over the past few years, dedicated working groups and projects have been set up to develop outreach activities. A good example of an annual activity of this kind, aimed at young students in physics and high-school teachers, is the EPPOG Masterclasses, which involves the participation of some 80 research institutes and universities across Europe (see www.physicsmasterclasses.org/mc.htm). Recently several African and American institutes joined the project.

Permanent or travelling exhibitions are another interesting means for the "large-scale" dissemination of high-energy physics information, showing the public the still-unresolved mysteries of the universe and the gigantic equipment needed in particle accelerators (such as the LHC), detectors and computing systems (such as the Grid).

These valuable initiatives have been unquestionably successful but their real reach to society is limited because of the relatively reduced number of participants and the competition from other fields (scientific or not) already on the market, such as websites, video games and so on. We can think of taking advantage of these more loosely related activities such as the film adaptation of Dan Brown's bestselling novel, *Angels & Demons*, currently in cinemas around the world. While artists should be allowed creative

freedom and their view on science should not be rejected, they sometimes risk being somewhat misleading. I am not particularly enthusiastic about spreading the idea that a bomb made of antimatter stolen from CERN could destroy the Vatican (or any other city). Nonetheless, the association of physics (and more generally, science) with other social and cultural manifestations should be mutually beneficial and deserves closer attention.

Despite the universality of its principles, methodology and objectivity of results, the advancement of scientific knowledge has proved to be socially dependent, from the golden age of Pericles and the "invention" of democracy to the Renaissance and the rise of humanism together with the birth of modern science. Society itself may fuel scientific advancement in a particular direction: thermodynamics was driven by the need for building more efficient heat engines at the beginning of Industrial Revolution, thereby decisively contributing to the foundations of classical physics in the 19th century.

As an example from particle physics, CERN was created as a free forum for nuclear science in a Europe devastated by the Second World War "to encourage the formation of research laboratories in order to increase international scientific collaboration..." (as stated at the Fifth UNESCO Conference in Florence, 1950). The CERN convention was gradually ratified during 1953–54 by the 12 founding member states, while the Treaty of Rome that founded the European Union was signed in 1957. Science often goes ahead of society.

In this regard the Web – born at CERN – has represented a dramatic democratization of knowledge, teaching and information. Virtually free for everybody on the planet (wherever electricity is available), it was an almost direct consequence of the free circulation of scientific data among researchers. More generally, big scientific collaborations are genuine examples of worldwide co-operation between different scientists and technicians regardless of their age, gender, religious beliefs or nationality.

Social needs, in turn, continuously demand technological achievements that ultimately stem from fundamental research. Nuclear and particle physics, for instance, have provided crucial tools for medical diagnosis, from the discovery of X rays to modern medical-imaging techniques.

Undoubtedly outreach must convey to society the excitement of scientific discovery and the importance of technological returns. However, in my opinion, the message from science should not stop there. Galileo's *Sidereus Nuncius* (Sidereal Messenger) was heralding in 1610 not only the existence of mountains on the Moon or satellites around Jupiter, but also the dawn of a new epoch. Indeed, the social impact and controversy turned out to be much greater than with *De revolutionibus* by Nicolaus Copernicus (1543) or Johannes Kepler's *Astronomia nova* (1609) – because it was easier to read.

We are currently witnessing crucial developments of society globally, from a more just economy to extended human rights, environmental protection and nature conservation. While keeping the possible misuse of scientific and technological applications in mind as a warning, we should ensure that the virtues that are traditionally associated with "Big Science", historically entangled in the social progress of humanity, are praised as an example to counteract ignorance, obscurantism and fanaticism.

Miguel-Angel Sanchis-Lozano, IFIC (University of Valencia-CSIC), and Spanish representative on the European Particle Physics Outreach Group (EPPOG).

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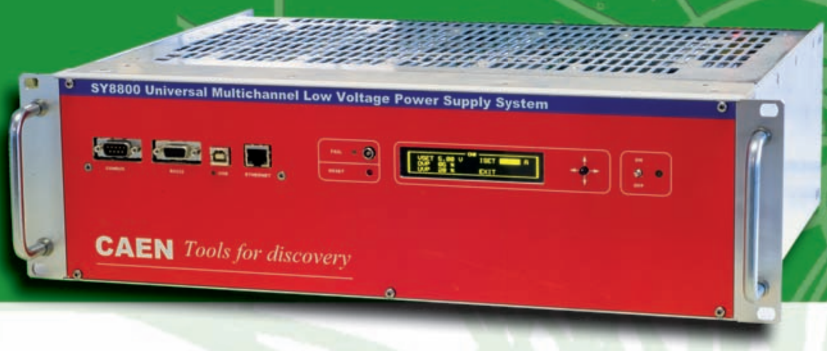

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