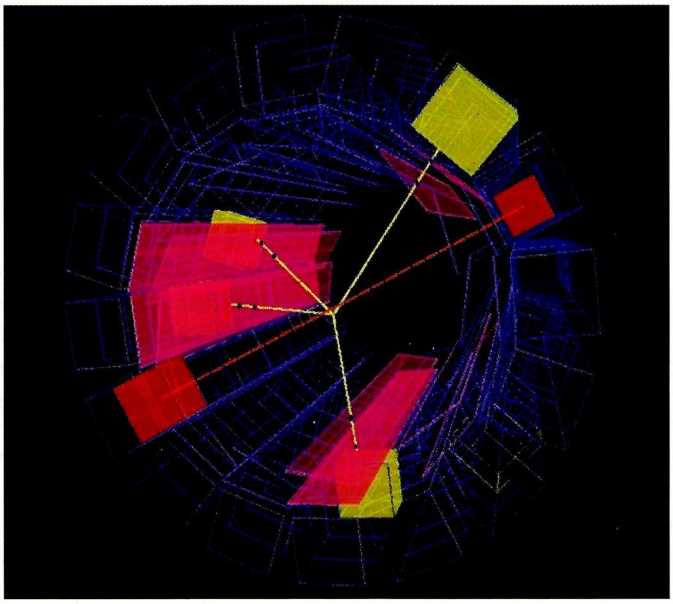
FUNDAMENTAL SYMMETRY

Cold antiatoms produced at CERN

Physicists working at CERN's Antiproton Decelerator (AD) have announced the first controlled production of large numbers of antihydrogen atoms at low energies. This is an important step on the way to testing the fundamental symmetry CPT through comparison of hydrogen with antihydrogen.

The hydrogen atom is the most completely understood atomic system, with its first excited state being pinned down to just 1.8 parts in 10^{14}. Antihydrogen, on the other hand, is almost completely unknown. A comparison of the two systems would give a very precise test of CPT symmetry, which is assumed to be conserved in the Standard Model of particle physics. CPT is the combination of charge conjugation, parity and time reversal. The violation of the CP combination is well established in kaon and B-meson decays, but so far, no experiments have shown evidence that CPT is not conserved in nature.



The ATHENA experiment has made the first observation of cold antihydrogen atoms. The red blocks measured in the experiment's caesium iodide calorimeter indicate photons from the positron annihilation. The yellow lines correspond to charged particles from the antiproton annihilation. These are detected by silicon detectors (pink) and the calorimeter (yellow blocks).

This latest development at CERN follows the production of small numbers of fast-moving antihydrogen atoms at CERN and Fermilab in the US in the mid-1990s. It is the result of several years of development work into the antiparticle trapping and mixing systems needed to produce slow (cold) antihydrogen atoms that can themselves be trapped for further study. ATHENA, one of two CERN experiments that plan to study antihydrogen, has been the first to produce cold antihydrogen atoms.

Says CERN director-general, Luciano Maiani: "The controlled production of antihydrogen observed in ATHENA is a great technological and scientific event. Even more so because ATHENA has produced antihydrogen in unexpectedly abundant quantities." Giving due credit to the ATRAP experiment (which also aims to study antihydrogen), he went on to say: "I'd like to recognize the contribution of ATRAP, which has pioneered the technology of trapping cold antiprotons and positrons, an essential step towards the present discovery." Last year the ATRAP experiment was the first to use cold positrons to cool antiprotons.

The ATHENA collaboration of 39 scientists from nine institutions worldwide has built on these techniques with the addition of a high-yield positron accumulator and powerful particle detector. The abundant numbers of positrons from the accumulator, coupled with good granularity and background rejection from the detector, allowed the collaboration to see its first clear signals for antihydrogen in August – appropriately, the 100th anniversary of the birth of theorist Paul Dirac, who predicted the existence of antimatter in the late 1920s.

The ATHENA collaboration estimates that some 50 000 antihydrogen atoms were created in its apparatus before announcing their result. Antiprotons decelerated by the AD to a leisurely pace – by CERN's standards – of a tenth of the speed of light were first trapped in an electromagnetic cage. From each AD pulse of 2×10^{7} antiprotons, some 10 000 were caught. The next stage was to mix them with about 75 million cold positrons collected from the decay of a radioactive isotope and caught within a second trap. Finally, the trap doors were opened, allowing the antiprotons and positrons to mix in a third trap. It is here that cold antihydrogen atoms formed.

ATHENA observes antihydrogen atoms when they annihilate with the walls of the mixing trap. Two photons from the positron annihilation are localized in space and time with charged particles coming from the antiproton annihilation. The next steps are to trap antihydrogen atoms and add a laser spectroscopy system. This will allow the CPT studies to begin.

NOBEL

2002 Nobel Prize for Physics is announced

The Royal Swedish Academy of Sciences has awarded this year's Nobel Prize for Physics to three astrophysics pioneers. Raymond Davis Jr and Masatoshi Koshiba share one half of the award "for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos". The second half goes to Riccardo Giacconi "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources".

Cosmic neutrinos

Neutrinos were postulated by Wolfgang Pauli in 1930 and first detected by Frederick Reines and Clyde Cowan in the mid-1950s using a detector placed close to a nuclear reactor. Soon after, Ray Davis proposed building an underground detector to look for neutrinos coming from the Sun. The majority of reactions in the Sun generate neutrinos with energies too low to be detected with the technology of the 1950s, but one relatively rare reaction – the decay of boron-8 – produces neutrinos of up to 15 MeV. This is high enough to be detected by the technique elaborated by Bruno Pontecorvo and Luis Alvarez, who had suggested in the 1940s that such neutrinos could interact with chlorine atoms to produce a radioactive isotope of argon with a half-life of around 35 days. By 1967, Davis had installed a tank filled with 615 tonnes of the common cleaning fluid tetrachloroethylene in the Homestake gold mine in South Dakota, US. His background in chemistry had allowed him to devise the techniques for extracting the argon atoms every few weeks and counting their number – a feat equivalent to finding a particular grain of sand in the Sahara desert.

What Davis discovered came as a surprise – he detected only about half the number of neutrinos expected from the standard solar model. This meant the experiment was wrong, the standard solar model was wrong, or something was happening to the neutrinos on their way from the Sun.

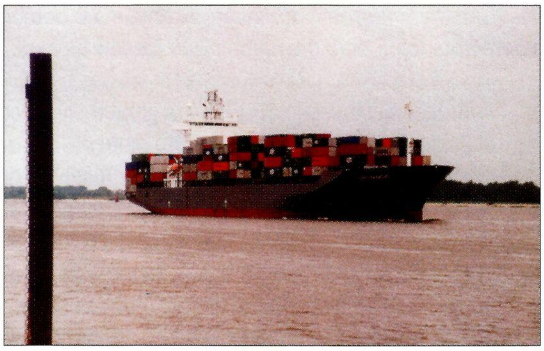
Davis's experiment ran continuously from 1967 to 1994, and was joined in 1987 by the huge Kamiokande water Cerenkov detector, built in Japan by a team led by Koshiba. This provided a confirmation that Davis's experiment was right, and focused attention on the hypothesis proposed by Pontecorvo and Vladimir Gribov in 1968 – one year after Davis's first results – that neutrinos oscillate, or change flavour on their way from the Sun. Both the Homestake and Kamiokande experiments are sensitive only to electron-type neutrinos. ▷

MIDDLE EAST

SESAME opens the door to Middle East co-operation

The SESAME (Synchrotron Radiation Light for Experimental Science and Applications in the Middle East) project to build a synchrotron light source in the Middle East took a step closer to reality in June, when it received unanimous approval from the UNESCO executive board. The board endorsed SESAME as "a model that should be made known to other regions", and described it as a quintessential UNESCO project.

The idea for SESAME dates back to 1997 when, at a seminar on Middle East Scientific Co-operation (initiated by CERN's Sergio Fubini), Herman Winick of SLAC and Gustav-Adolf Voss from DESY suggested using components of Berlin's BESSY 1 machine, scheduled to be closed down in 1999, as the core facility for a new laboratory in the Middle East (*CERN Courier* March 2000 p17). Soon after, an interim council was established along identical lines to CERN under the auspices of UNESCO. Like CERN before it, SESAME is a project designed not only to advance science and technology, but equally importantly to help bring peace and stability to a troubled region through scientific collaboration. Former CERN director-general, Herwig Schopper, chairs its interim council.



The BESSY 1 synchrotron sets sail from Germany, bound for a new life as the core of the third-generation SESAME light source in Jordan.

In 2000, Jordan was chosen to host the new facility (*CERN Courier* June 2000 p6); 13 interim council member states undertook to provide $50 000 (€50 000) per year each for three years from 1 January 2001 for preparatory work, and the US State Department and Department of Energy contributed $200 000.

The endorsement of the SESAME project by UNESCO's executive board is an important step towards establishing SESAME as an independent international scientific organization. As soon as six potential member states have deposited their agreement of the new laboratory's statutes with UNESCO, SESAME will gain its independence and the interim council will give way to a governing council, again based on the CERN model.

So far Bahrain, Iran, Jordan, the Palestinian Authority and Turkey have formally decided to join SESAME. Other member states of the interim council are Egypt, Greece, Israel, Morocco, Oman, Pakistan and the United Arab Emirates.

Armenia and Cyprus, originally members of the interim council, have changed their status to observer. For Armenia, the change of status came when the country took the decision to build its own light source (*CERN Courier* October p7). Other observers are France, Germany, Italy, Japan, Kuwait, the Russian Federation, Sudan, Sweden, the UK and the US. Kuwait has indicated that it intends to become a full member of SESAME.

Originally conceived as a 1 GeV machine, the interim council has already approved plans presented by technical director Dieter ▷

Kamiokande was also able to trace the direction of incoming neutrinos, confirming that they came from the Sun.

Koshiba went on to build the larger Superkamiokande experiment, which saw evidence for neutrino oscillation in neutrinos produced in the atmosphere by cosmic rays. Solar neutrino oscillation has since been confirmed by the Sudbury Neutrino Observatory in Canada (*CERN Courier* June p5).

X-ray sources

It was not until 1949 that X-ray astronomy got off the ground. X-rays from cosmic sources are almost entirely absorbed by the Earth's atmosphere, and it was only in the 1940s that rocket technology had advanced sufficiently to allow Herbert Friedman and colleagues to launch detectors to a sufficiently high altitude to make significant measurements. These experiments showed that X-ray radiation comes from areas on the surface of the Sun with sunspots and eruptions, and from the surrounding corona. Their observations were, however, confined to the solar system.

When in June 1962, Giacconi's group launched an instrument consisting of three Geiger counters equipped with windows of varying thickness aboard a rocket, they became the first to record a source of X-rays beyond the solar system. Designed to see whether the Moon could emit X-rays under the influence of the Sun, the experiment instead located a source at a far greater distance, and observed an evenly distributed X-ray background. These discoveries gave an impetus to the development of X-ray astronomy.

The first source to be identified with a visible object was Scorpio X-1; other important sources were the stars Cygnus X-1, X-2 and X-3. Most proved to be binary systems in which a visible star orbits around a dense compact object such as a neutron star or a black hole. Detailed studies using short flights on rockets were, however, difficult, so Giacconi initiated construction of the UHURU satellite, which was launched in 1970. This was 10 times more sensitive than the rocket experiments, and was itself succeeded by the Einstein X-ray observatory – the first X-ray telescope capable of generating sharp images at X-ray wavelengths. Giacconi's most recent accomplishment is the Chandra observatory, named for astrophysicist Subrahmanyan Chandrasekhar. Initiated by Giacconi in 1976, Chandra was launched in 1999 and has provided remarkable images of the X-ray universe.

Giacconi's pioneering efforts in X-ray astronomy have changed our view of the universe. Some 50 years ago, the universe appeared largely to be a system in equilibrium. Today, we know that it is also the scene of extremely rapid developments in which enormous amounts of energy are released in processes lasting less than a second, in connection with objects not much larger than the Earth. Studies of these processes, and of the central parts of active galaxy cores, are largely based on data from X-ray astronomy.

Einfeld to upgrade SESAME from the 0.8 GeV BESSY 1 machine to 2 GeV, resulting in a third-generation light source with 13 positions for insertion devices. Advisory committees have been appointed, and tangible progress was made in June, when the BESSY 1 machine set sail from Germany bound for the Jordanian port of Al-Aqabe. A request has been made to the European Union (EU) for €8 million for the installation and upgrade of the machine. An evaluation panel has submitted a report to the EU, but its contents have not yet been made public.

A seminar organized and financed by the Japanese Society for the Promotion of Science to discuss the scientific programme, including the first beamlines, was held in the Jordanian capital Amman in October. Several laboratories have offered beamline equipment, and financial support for beamlines is being sought from the International Atomic Energy Authority in Vienna and from US agencies. Meanwhile, the Jordanian government has agreed to finance the building that will house the centre at a campus of the Al-Balqa' Applied University in Allan, 30 km from Amman.
A ground-breaking ceremony in the presence of the Jordanian king, HM Abdullah II, and the director-general of UNESCO, Koïchiro Matsuura, is planned for 6 January 2003.

ASTROPHYSICS

Gamma-ray facility inaugurated in Namibia

The first telescope of the high-energy stereoscopic system (HESS), named in honour of Victor Hess, the discoverer of cosmic radiation, was officially inaugurated in Namibia in September. HESS is a system of large Cerenkov telescopes intended for high-energy gamma-ray astrophysics.

The HESS collaboration identified the Gamsberg area of Namibia as an ideal location for a high-energy gamma-ray observatory in January 1998. With the support of the Namibian government and local landowners, construction began in 1999. HESS was originally conceived as a two-phase project, with four telescopes being installed in the initial phase and a further 12 identical telescopes being added later. The first telescope began operation this summer, with phase one scheduled for completion by 2004. Options for phase two are currently being studied.

The physics motivation behind HESS is to pinpoint the origins of high-energy cosmic rays through the study of cosmic gamma rays from around 100 GeV to several TeV. Although Hess began the work that led to the discovery of cosmic rays in 1911, there is still very little known about their origins. The majority of primary cosmic rays are atomic nuclei, whose trajectories through space are influenced by interstellar and intergalactic magnetic fields. Such fields, however, do not affect gamma rays, and so their detection will point right back to the source.

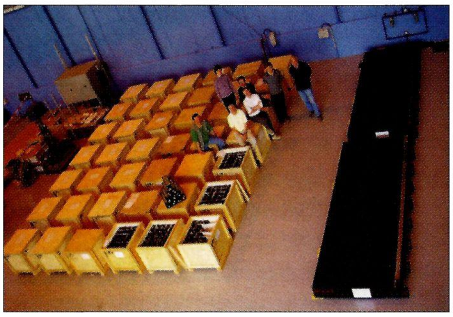
Werner Hofmann of the HESS collaboration (right) discusses telescope technology with Namibian Minister of Higher Education, Training and Employment Creation, Nahas Angula, at the inauguration of the first HESS telescope. (HESS collaboration.)

CERN

LHCb receives delivery from Russia

The LHCb collaboration, dedicated to studying CP violation in B-meson decays at CERN's Large Hadron Collider (LHC), has received the first components of its calorimeter system from Russia. The first 1200 of 3300 electromagnetic calorimeter (ECAL) modules and the first two of 52 hadron calorimeter (HCAL) modules were delivered to CERN in September. The so-called shashlik-type (lead-scintillator sandwich) ECAL modules are being produced by Russia's Institute for Theoretical and Experimental Physics in collaboration with CERN. The HCAL tile calorimeter is the responsibility of the Institute of High Energy Physics in Protvino, with contributions from the Horia Hulubei National Institute for Physics and Nuclear Engineering in Bucharest, Romania; the Institute of Physics and Technologies in Kharkiv, Ukraine; and CERN. Series production of a Preshower detector is under preparation at the Institute for Nuclear Research in Moscow. The fast 40 MHz calorimeter detector readout electronics are the responsibility of French (Annecy, LAL-Orsay and Clermont-Ferrand) and Spanish (Barcelona) LHCb groups.

LHCb's calorimeter has been designed for speed, since it will be used for triggering on collisions arising from the LHC's 40 MHz bunch crossing rate. All three sub-detectors (Preshower, ECAL and HCAL) are based on fast scintillators with wavelength-shifting fibre readout. The HCAL (which will be used exclusively for triggering) uses iron as its passive medium, while the ECAL uses lead. While also participating in the trigger, another important function of the ECAL will be to reconstruct neutral pions and photons from B-meson decays. Production is set to continue at a rate of 10 ECAL modules per day and one HCAL module every two weeks.



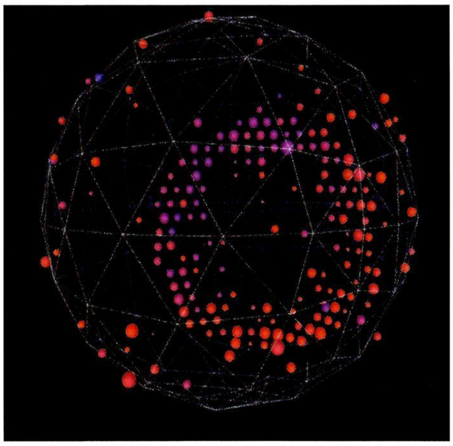
Members of the LHCb collaboration begin to unpack the first 1200 modules of their ECAL in September. To the right are the first two of 52 HCAL modules to arrive at CERN.

NEUTRINOS

MiniBOONE goes live at Fermilab

The MiniBOONE experiment at Fermilab in the US saw its first neutrinos in September. Designed to test the controversial neutrino oscillation result from the Los Alamos LSND experiment, which is so far the only accelerator-based signal for oscillation, the experiment will take data for two years. That will allow the MiniBOONE collaboration to study the entire LSND allowed region with high sensitivity.

The LSND result remains controversial, since it is difficult to reconcile with oscillation results from Superkamiokande in Japan and the Sudbury Neutrino Observatory in Canada without invoking an extra type of neutrino. Confirmation would therefore require a major rethink of current particle theory. If the LSND result is correct, MiniBOONE expects to see around 1000 electron neutrinos in the pure muon-neutrino beam over the next two years.



This ring of lit-up phototubes inside the MiniBOONE detector indicates the collision of a muon-neutrino with an atomic nucleus in the mineral oil that fills the detector. (Fermilab Visual Media Services.)

COMPUTING

Grid technology developed by ALICE

The ALICE experiment, which is being prepared for CERN's Large Hadron Collider, has developed the ALICE production environment (AliEn), which implements many components of the Grid computing technologies that will be needed to analyse ALICE data. Through AliEn, the computer centres that participate in ALICE can be seen and used as a single entity – any available node executes jobs and file access is transparent to the user, wherever in the world a file might be.

For AliEn, the ALICE collaboration has adopted the latest Internet standards for information exchange (known as Web Services), along with strong certificate-based security and authentication protocols. The system is built around open-source components and provides an implementation of a Grid system applicable to cases where handling many distributed read-only files is required.

AliEn aims to offer a stable interface for ALICE researchers over the lifetime of the experiment (more than 20 years). As progress is made in the definition of Grid standards and interoperability, AliEn will be progressively interfaced to emerging products from both Europe and the US. Moreover, it is not specific to ALICE, and has already been adopted by the MammoGrid project (supported by the European Union), which aims to create a pan-European database of mammograms.

ALICE is currently using the system for distributed production of Monte Carlo data at more than 30 sites on four continents. During the last year more than 15 000 jobs have been run under AliEn control worldwide, totalling 25 CPU years and producing 20 Tbyte of data. Information about AliEn is available at http://alien.cern.ch.

HEP email news wire

Fermilab and SLAC announced the launch of an email news wire for high-energy physics and related fields in September. Available at http://www.interactions.org/, the news wire is the first element of a service that aims to group information from the world's particle physics laboratories on a single website.