

CERN

Council appoints Rolf-Dieter Heuer as CERN's next director-general...

On 14 December, at its 145th meeting, CERN Council appointed Rolf-Dieter Heuer to succeed Robert Aymar as CERN's director-general. Heuer will take office on 1 January 2009 and serve a five-year term. His mandate will cover the early years of operation of the LHC and its first scientific results.

Heuer is currently research director for particle and astroparticle physics at the DESY laboratory in Hamburg, but is no stranger to CERN. From 1984 to 1998, he was a staff member at the laboratory, working for the OPAL collaboration at LEP. He was also OPAL's spokesperson from 1994 to 1998.



Rolf-Dieter Heuer. (Courtesy DESY.)

After obtaining a doctorate in 1977 from the University of Heidelberg, Heuer has spent much of his career involved with the construction and operation of large particle detector systems for studying electron-positron collisions. After leaving CERN in 1998 and joining the University of Hamburg he founded a group working on preparations for experiments at a possible future electron-positron collider. With his appointment at DESY in 2004, he became responsible for research at the HERA collider, DESY's participation in the LHC, and R&D for a future electron-positron collider.

...and looks to the LHC start-up and beyond

CERN director-general Robert Aymar, in his end-of-year status account to Council, reported on a year of progress at the LHC, which is due to start operation in the summer.

The machine components are now fully installed in the 27 km tunnel and commissioning is well underway. The successful commissioning of the second of the two transfer lines that will carry beams into the collider took place at the end of October, at the first attempt. Two of the LHC's eight sectors are currently cooling down to their operating temperature of 1.9 K and a further three sectors are being prepared for cool-down. More good news included a successful pressure test of sector 1-2 on 8 December. This was the final sector to undergo this test, which assesses the ability

of the mechanical design to withstand a pressure 25% above its design value.

Aymar told Council that CERN is on course for the LHC to start up in early summer 2008. However, it will not be possible to fix a definite date before the whole machine is cold and magnet electrical tests are positive. This should be in the spring, but any difficulties encountered during the commissioning that require a sector of the machine to be warmed up will lead to a delay of two to three months.

Installation of the LHC detectors is approaching its conclusion, and the collaborations are turning more attention towards physics analysis, including testing of the full data chains from the detectors through the Grid to data storage. All of the collaborations expect to have their initial

detectors ready for April. Some are already routinely taking data with cosmic rays, and baseline Grid services are in daily operation.

Council also approved a budget for CERN in 2008 that will allow consolidation of CERN's aging infrastructure to begin, together with provision for preparations for an intensity upgrade for the LHC. This paves the way for the renovation of the LHC's injector complex, including replacement of the venerable PS, which was first switched on in 1959. This process will allow the LHC's beam intensity to be increased by around 2016, thereby improving the sensitivity of the experiments to rare phenomena. The 2008 budget includes additional funds for this work, with special contributions being made by CERN's host states, France and Switzerland.

Sommaire

Le Conseil nomme Rolf-Dieter Heuer directeur général...	5	Des ions plomb au seuil du LHC	7
...dans la perspective du démarrage du LHC	5	Enregistrement optique de la désintégration à deux protons	8
Mauvaises surprises budgétaires pour les physiciens	6	ASACUSA: nouvelles expériences avec l'antihydrogène	9
Installation réussie du trajectographe de CMS	6	Quand la lumière ne va pas en ligne droite	10
Belle découverte un nouveau type de méson	7	Du plasma chaud dans la nébuleuse d'Orion	11

FUNDING

UK and US announce budget bombshells for particle physics

Within one week in December 2007, particle physicists in the UK and the US received unexpectedly bad budget news, which rocked the two communities. The funding decisions have together provided a large blow to work on a future International Linear Collider (ILC).

On 11 December the UK's Science and Technology Facilities Council (STFC) announced its Delivery Plan for 2008/9 to 2011/12. The plan sets out how the council intends to deliver world-class science, in part through providing access to international facilities, within the finances allocated in the 2007 Comprehensive Spending Review. Though this review gave the STFC an increase of some 13.5% over the period in question, the news for UK particle physicists – and their colleagues in astronomy – was far from good. The most serious aspect for particle physicists was summed up in a simple statement: “We will cease investment in the

International Linear Collider.” Astronomers received the news of withdrawal from “future investment in the twin 8-m Gemini telescopes”. The consequences of the overall UK budget announcement are still being assessed, but redundancies are likely.

This news immediately reverberated around the world, as the UK was a major contributor to the ILC, but bad news was also in store for their colleagues in the US. A week later on 18 December, the US budget for fiscal year 2008 was finally announced after several delays. In the rush to get the budget approved, several projects suffered big reductions, including “\$0 for the US contribution to ITER [the international fusion project]”, and no funds for the NOvA project at Fermilab's Tevatron. In addition the budget allowed for only 25% – \$15 million instead of \$60 million – of the amount requested for R&D on the ILC. This is much worse than it

appears, as the US system works in such a way that FY2008 began last October, so this allocation may already have been spent.

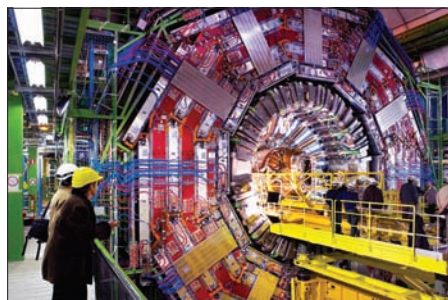
While these two adverse developments represent a major setback for the ILC, there are also immediate ramifications for personnel at Fermilab and SLAC. Pierre Oddone, Fermilab's director, had the unenviable task of announcing that some 200 layoffs from a workforce of about 2000 would probably be necessary, and that employees would now have two days enforced unpaid leave a month. Persis Drell, in her new role as director of SLAC (see p40), had to announce that work on the ILC had to stop on 1 January and that the B-factory would have to shut down prematurely. The laboratory would have to reduce its workforce by about 15%, implying 125 layoffs in addition to the nearly 100 announced previously as SLAC changes focus in its research.

LHC DETECTORS

CERN installs giant CMS tracking detector

The world's largest silicon tracking detector is now in its final location in the CMS detector at CERN. This completes the installation of sub-detectors inside CMS's huge solenoid magnet, which was lowered into the experiment's cavern on the LHC ring on 28 February last year.

With a total surface area of 205 m², the CMS Silicon Strip Tracking Detector is the largest detector of its kind ever constructed. Its sensors provide 10 million individual detection strips, each of which is read out by one of 80 000 custom-designed microelectronics chips. The silicon sensors are precisely assembled on 15 200 modules, which are in turn mounted on an extremely low-mass carbon fibre structure that maintains the position of the sensors to less than 100 µm. They will allow the charged



The Silicon Strip Tracking Detector has now reached its final resting place in the CMS experiment.

particles that are produced in the LHC's collisions at the heart of the detector to be tracked with a precision of better than 20 µm.

The overall assembly of the silicon tracking detector began in December 2006 and was completed in March 2007. All of the systems

were then fully commissioned, with 20% of the full detector operating over several months, during which it recorded 5 million cosmic-ray tracks. This commissioning demonstrated that the detector fully meets the experiment's requirements.

Finally, in the early hours of 13 December the detector began its journey from the main CERN site to the site of the CMS experiment near Cessy, France. Later that day it was lowered 90 m into the cavern. Installation began on 15 December and was concluded the following morning.

More than 500 scientists and engineers from 51 research institutions worldwide have contributed to the success of the project. These institutions are located in Austria, Belgium, CERN, Finland, France, Germany, Italy, Switzerland, the UK and the US.

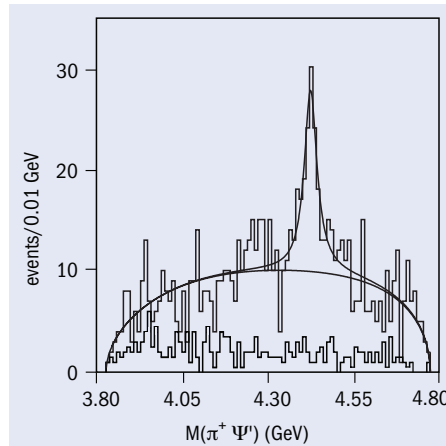
KEK

Belle Collaboration discovers new meson

The Belle collaboration at KEK has recently announced the discovery of an exotic new particle with non-zero electric charge. This particle, which the researchers have named the Z(4430), does not fit into the usual scheme of mesons.

The Z(4430) particle has appeared in the decay products of B mesons (containing a bottom quark), which are produced in large numbers at KEKB, the B-factory at the KEK laboratory in Japan. While investigating various decays of B mesons in a data sample containing nearly 660 million pairs of B and anti-B mesons, the Belle team observed 120 B mesons that decay into a Z(4430) and a K meson. The Z(4430) then instantly decays into a Ψ' and a π meson. The team found that the new particle has negative charge and a mass about 4.7 times that of the proton.

Both Belle and the BaBar experiment at SLAC have found a number of peculiar new particles during the past few years, such as the X(3872), Y(4260), X(3940) and Y(3940). These all have masses in the region of 4–4.5 times the proton's mass, and decay



This diagram shows the distributions of the measured mass for combinations of a detected π meson and a Ψ' meson. The newly discovered Z(4430) is visible as the peak at 4430 MeV.

into J/Ψ or Ψ' particles and π mesons. A simple explanation for these particles would be that they are examples of charmonium, the family of bound states of a charm quark (c) and antiquark (\bar{c}) that includes the

J/Ψ and Ψ' . However, their masses and decay properties do not match theoretical expectations for charmonium, so theorists have proposed other explanations.

One possibility is that some of the new particles are multi-quark states containing a c and (\bar{c}) together with another lighter quark and antiquark, for example, an up quark (u) and antiquark (\bar{u}) or down quark (d) and antiquark (\bar{d}). However, because the particles previously discovered are electrically neutral, it has not been possible experimentally to rule out entirely that they are unusual charmonium states.

The newly discovered Z(4430), on the other hand, has non-zero electric charge, a characteristic that clearly distinguishes it from charmonium. This raises the possibility that it could be indeed be a multi-quark state, containing a c and \bar{c} together with a quark and different antiquark, for example $cu\bar{c}\bar{d}$.

Further reading

K Abe et al. 2007 <http://arxiv.org/pdf/0708.1790>.

LHC NEWS

Lead ions knock at the LHC's door

There was jubilation in the CERN Control Centre late in the afternoon on 12 November. Only a few hours before the annual winter shutdown of the accelerators, monitoring screens showed that a beam of lead ions dispatched from the SPS had reached the threshold of the LHC. For the first time the beam had been extracted close to the LHC along the TT60 transfer line. It marked another milestone towards the final target of circulating lead ions in the LHC to produce collisions.

Since the installation of the Low Energy Ion Ring (LEIR) in 2005, the team working on I-LHC, the project to deliver heavy ions to the LHC, has focused on the injector chain in order to supply ion beams to the LHC in optimal conditions. A year previously, ions that had been accumulated in LEIR and sent to the PS were ejected at the threshold of the SPS for the first time.

In 2007, ions were successfully injected into the SPS from the beginning of September. After many adjustments and studies, the beam had been accelerated with a view to its extraction into one of the two transfer lines linking the SPS and the LHC. But technical problems had arisen,

including a vacuum leak detected in the PS at the beginning of November. By increasing ion losses, this leak had resulted in a reduction in the intensity of the ion beam, placing the success of the operation in jeopardy. However, at approximately 5.00 p.m. on 12 November, thanks to an increase in beam intensity to 20 million ions per bunch, the long-awaited beam finally made its appearance on the screens in the control room.

The next stage will be to refine and optimize the beam to reach the nominal intensity for the LHC of 100 million ions per bunch – this will be five times higher than that recently obtained.

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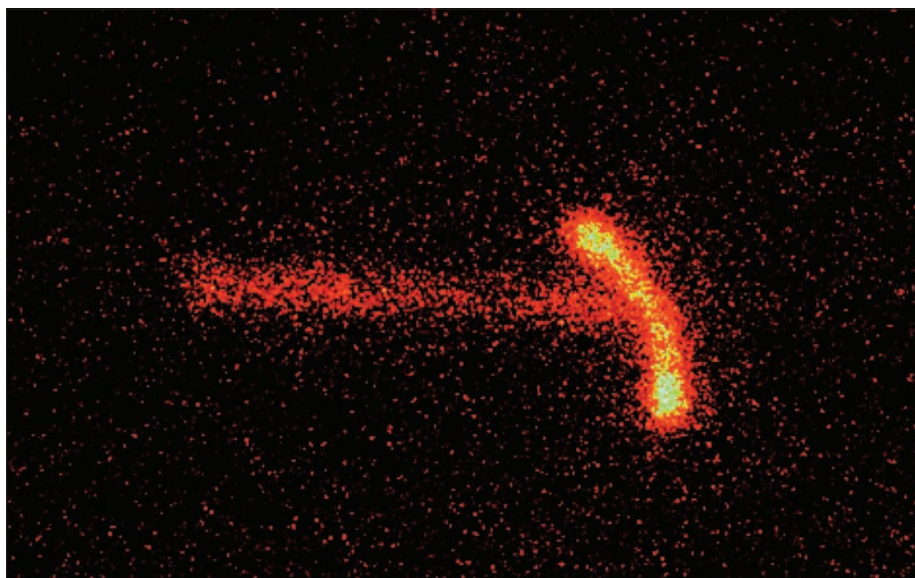
NUCLEAR PHYSICS

Camera captures image of two-proton decay

In work that harks back to the early days of nuclear physics, an international team of researchers at Michigan State University's National Superconducting Cyclotron Laboratory (NSCL) has used a novel detector incorporating a CCD camera to record optically the tracks of charged particles emitted in the two-proton decay of iron-45 (^{45}Fe). The technique has allowed the first measurement of correlations between the two protons, demonstrating that the process is indeed a three-body decay. Besides shedding light on a novel form of radioactive decay, the technique could lead to additional discoveries about short-lived rare isotopes, which may hold the key to understanding processes inside neutron stars and determining the limits of nuclear existence.

Although it is more than 100 years since Henri Becquerel opened the door to nuclear physics with his discovery of radioactivity, there are still open questions that continue to nag experimentalists. One such example is the mechanism underlying the two-proton emission of neutron-deficient nuclei, first observed in the 1980s (*CERN Courier* December 2002 p27).

Now Krzysztof Miernik and colleagues from Poland, Russia and the US have taken several steps towards an answer, by peering closely at the radioactive decay of a rare iron isotope at the edge of the known nuclear map (Miernik *et al.* 2007). The researchers set out to obtain a better understanding of two-proton emission from ^{45}Fe , which has a nucleus of 26 protons and 19 neutrons; in comparison, the stable form of iron most abundant on Earth has 30 neutrons. One possibility was that the neutron-deficient ^{45}Fe might occasionally release a diproton – an energetically correlated pair of protons. It was also possible that the two protons, whether emitted in quick succession or simultaneously, were unlinked.



A two-proton decay recorded by Optical Time Projection Chamber. A ^{45}Fe ion enters the chamber from the left. The two bright, short tracks are protons of approximately 0.6 MeV. (K Miernik *et al.* 2007.)

The experiment's key device was the novel imaging detector built by Marek Pfitzner and colleagues from Warsaw University – the Optical Time Projection Chamber (OPTC). This consists of a front-end gas chamber that accepts and slows down rare isotopes in a beam from the NSCL Coupled Cyclotron Facility. Electrons from the ionized tracks drift in a uniform electric field to a double amplification structure, where UV emission occurs. A luminescent foil converts these photons to optical wavelengths, for detection by a CCD camera. In this way, the camera records the projection of the particle tracks on the luminescent foil. A photomultiplier tube also detects the photons from the foil to provide information on the drift time of the electrons, and hence the third dimension, normal to the plane of the CCD.

Analysis of these images ruled out the proposed diproton emission and indicated that the correlations between emitted protons

are best described by a three-body decay. A theory of this process has been described by Leonid Grigorenko, a physicist at JINR, and a co-author of the paper.

The experiment itself recalls the early days of experimental nuclear physics in which visual information served as the raw data, with tracks recorded in photographic emulsion. Indeed, this was the process that lay behind Becquerel's discovery of radioactivity. The new result may represent the first time in modern nuclear physics that fundamental information about radioactive decays has been captured in a camera image and in a digital format. Usually, nuclear physics experiments provide digitized data and numerical information of various types, but not images.

Further reading

K Miernik *et al.* 2007 *Phys. Rev. Lett.* **99** 192501.

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.

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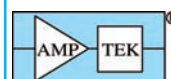
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ANTIMATTER

ASACUSA moves towards new antihydrogen experiments

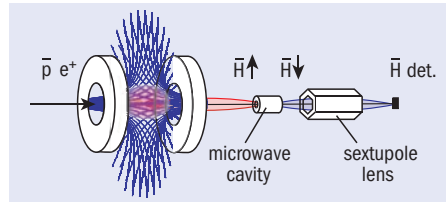
Antihydrogen experiments under way at CERN's Antiproton Decelerator have so far aimed at making high-precision measurements of the frequency of optical transitions, such as that between antihydrogen's 1S ground state and its first excited, 2S state, near 2466THz. Comparing this with the same frequency for ordinary hydrogen constitutes a highly sensitive test of CPT symmetry, which involves simultaneous inversions of charge (C), parity (P) and time (T) (see p23).

Recently, the Japanese-European ASACUSA group made the first steps towards producing a low-velocity antihydrogen beam, which may be used to measure the hyperfine transition frequency between the two spin substates of antihydrogen's ground state. Its value for ordinary hydrogen is near 1420 MHz.

Before this can be done antiprotons must be confined and cooled in an evacuated container in which magnetic and/or electric fields produce restoring forces that stop the antiprotons drifting to the container walls, where they would annihilate. To do this, the MUSASHI group of the ASACUSA collaboration has introduced a novel variant of the familiar Helmholtz coils. The MUSASHI coils differ from the usual configuration by having antiparallel rather than parallel excitation currents. This produces a magnetic quadrupole field rather than the normal constant one, and is symmetric about the coil axis. If a suitable electrostatic multipole field is added to this so-called "magnetic cusp" field, all of the restoring forces needed to confine both positive and negative charges are present within the container.

This "cusp trap" can thus also hold positrons, with which the antiprotons recombine to create the antihydrogen, as well as electrons. The latter can be used to cool the antiprotons to the extremely low temperature at which recombination occurs. In the recent tests, some 3 million antiprotons were stored in the trap and cooled with electrons.

A well known obstacle to CPT tests with antihydrogen is that both the hyperfine



Oppositely wound Helmholtz coils produce an axially symmetric quadrupole field to which an electric multipole field is added. These produce trapping potentials for positive and negative particles, as well as for low-field seeking antihydrogen atoms. After de-excitation to the ground state, a beam of spin-polarized antihydrogen atoms emerges.

and the 1S–2S frequency measurements must be performed on ground-state atoms, while it appears that positron–antiproton recombination produces them in very highly excited states. One great advantage of the cusp trap is that if these neutral atoms are cold enough its quadrupole field pulls on their large magnetic moment, causing them to seek the field minimum at the trap centre. They remain confined there until they reach the ground state. However, since their magnetic moment falls as they de-excite, the pull weakens. This means that in the ground state, only antihydrogen atoms in one of the two possible spin states are pulled to the centre, while those in the other state are expelled along the trap axis, emerging as a spin-polarized, ground-state antihydrogen beam.

This is ideal for the classical type of slow atomic beam experiment in which a microwave cavity induces spin flips when tuned to the correct hyperfine frequency (see figure). The resonant frequency can then be detected using a sextupole magnet which focuses flipped atoms onto a detector but defocuses unflipped ones. Comparison with the well measured hydrogen frequency then gives a stringent test of CPT symmetry.

Although much of this remains to be done, the recent successes are so encouraging that further steps along the road to a slow antihydrogen beam are now planned.