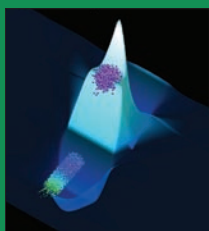


CERN COURIER

VOLUME 51 NUMBER 2 MARCH 2011

Antihydrogen gets caught in the act



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A new facility for plasma wakefield acceleration
p23

ICECUBE

Neutrino physics straight outta Antarctica
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The 100th anniversary of International Women's Day p33

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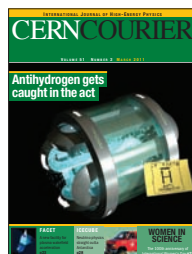
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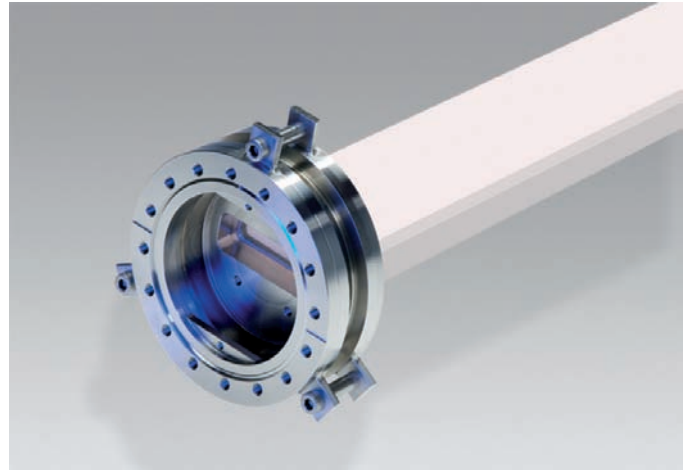
On the cover: Last November, the ALPHA collaboration achieved one of the long-stated goals of the physics programme at CERN's Antiproton Decelerator, with the first successful magnetic trapping of antihydrogen atoms (p13). A month later, the ASACUSA collaboration reported their own breakthrough towards extracting a beam of antihydrogen (p17). (Image credit: Chukman So / ALPHA.)

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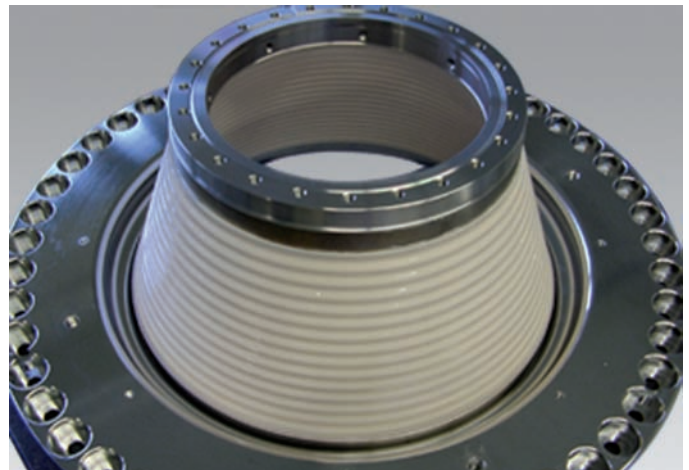
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News

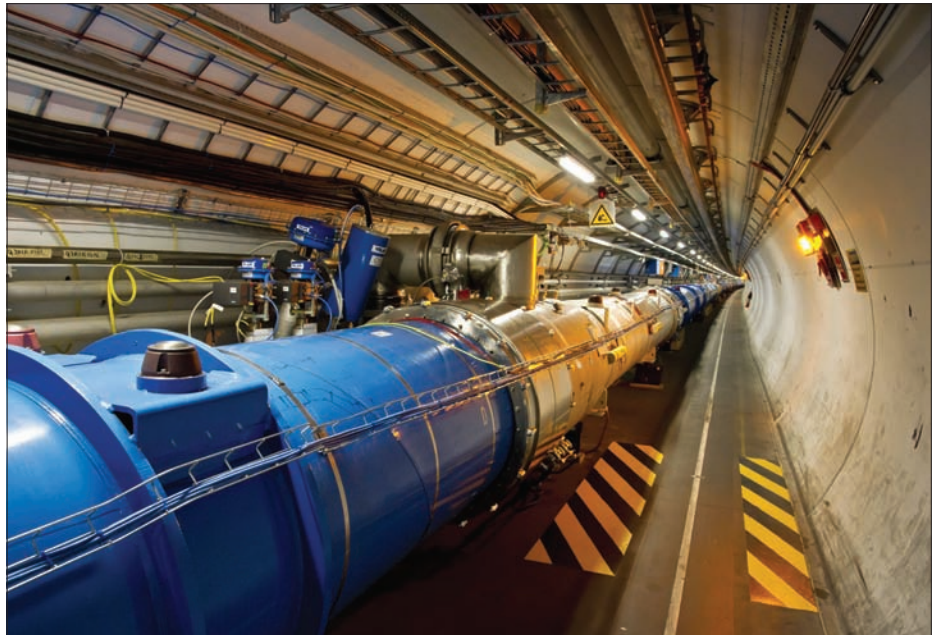
CERN

The LHC is to run in 2012

CERN has announced that the LHC will run through to the end of 2012, with a short technical stop at the end of 2011. The beam energy for 2011 will be 3.5 TeV. This decision, taken by CERN management following the annual planning workshop held in Chamonix last week and a report delivered by the laboratory's machine advisory committee, gives the LHC experiments a good chance of finding new physics in the next two years, before the machine goes into a long shutdown to prepare for higher-energy running starting in 2014.

"If the LHC continues to improve in 2011 as it did in 2010, we've got a very exciting year ahead of us," says Steve Myers, CERN's director for accelerators and technology. "The signs are that we should be able to increase the data-collection rate by at least a factor of three over the course of this year."

The LHC was previously scheduled to run to the end of 2011 before going into a long technical stop to prepare it for running at the full design energy of 7 TeV per beam. However, the machine's excellent performance in its first full year of operation forced a rethink. Improvements in 2011 should increase the rate at which the experiments can collect data by at least a factor of three compared with 2010. That would lead to enough data being collected in 2011 to bring tantalizing hints of any new physics that might be within reach of the LHC operating at its current energy. However, to turn those hints into a discovery would require more data than can be delivered in one year, hence the decision



The LHC lies in wait to start up again in February and run until the end of 2012.

to postpone the long shutdown. Running through 2012 will give the LHC experiments the data needed to explore this energy range fully before moving up to higher energy.

"With the LHC running so well in 2010, and further improvements in performance expected, there's a real chance that exciting new physics may be within our sights by the end of the year," says Sergio Bertolucci, CERN's director for research and computing. "For example, if nature is kind to us and the lightest supersymmetric particle, or the Higgs boson, is within reach of the

LHC's current energy, the data we expect to collect by the end of 2012 will put it within our grasp."

The schedule foresees beams back in the LHC in late February and running through to mid-December. There will then be a short technical stop before resuming in early 2012.

● See also comments by CERN's director-general, Rolf Heuer, on p54.

FERMILAB

Tevatron to shut down after 26 historic years

The final particles will collide in Fermilab's Tevatron this September at the end of the machine's historic 26-year run. The Tevatron, the world's largest proton-antiproton collider, is best known for its role

in the discovery in 1995 of the top quark, the heaviest elementary particle known to exist.

The Tevatron has out-performed expectations, achieving record-breaking levels of luminosity. Fermilab had planned to shut down the collider in the autumn of 2011 but in August 2010 the laboratory's international Physics Advisory Committee endorsed an alternative idea: extend the run of the Tevatron through into 2014. The US government's advisory panel on high-energy physics agreed with the committee's

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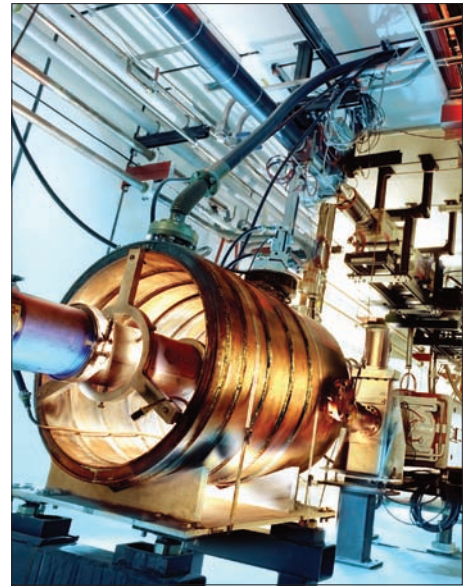
recommendation, provided that US funding agencies could increase annual support for the field by about \$35 million for four years. This would have maintained the laboratory's ability to continue with its variety of other high-energy physics experiments, some of them being in their critical first stages.

However, this was not to be. In January, Bill Brinkman, director of the US Office of Science, announced that the agency had not located the additional funds required to extend the Tevatron's operations. The decision disappointed Tevatron physicists, but it also made more secure funding for the other experiments that will carry Fermilab into the future.

Following the closure of the Tevatron, Fermilab will continue on course with a world-leading scientific programme, addressing the central questions of 21st century particle-physics on three frontiers:

the energy frontier, the intensity frontier and the cosmic frontier. At the energy frontier, the laboratory will continue its close collaboration with CERN and the international LHC community and will also pursue R&D for future accelerators. At the intensity frontier, Fermilab already operates the highest-intensity neutrino beam in the world and researchers there are about to begin taking data with the laboratory's largest neutrino detector yet. At the cosmic frontier, Fermilab scientists will continue the search for dark matter and dark energy.

Inside the tunnel of the Main Injector accelerator at Fermilab. The Main Injector, which accelerated protons and antiprotons for injection into the Tevatron, will continue to supply protons to generate the world's most intense neutrino beam. (Image credit: Peter Ginter.)



LHC PHYSICS

CMS studies energy imbalance in jets in heavy-ion collisions

The CMS experiment has released results of a new study that sheds more light on the phenomenon known as di-jet energy imbalance, which was recently observed in lead–lead collisions at the LHC (*CERN Courier* January 2011 p6). Indeed, during the first days of the heavy-ion run in November last year both the ATLAS and CMS experiments observed collisions with the production of jets – streams of particles collimated in a small cone around a given direction. In particular, they saw collisions containing two high-energy jets (di-jets), produced more or less back to back, in which there is an unusually large imbalance in the jet energy. In other words, the energy of the jet on one side was much less than that of the jet on the other side.

This energy imbalance could result from a modification of the energy and showering properties of the partons (quarks and gluons) created in the hard scattering collision, as they traverse quark–gluon plasma that may have formed in the head-on collisions. The results on this large di-jet asymmetry, shown in figure 1 for the CMS experiment, were presented publicly by the LHC experiments at a special seminar on 2 December. The measurements were based on the detection of high-energy deposits in the calorimeters by particles emerging from the collision,

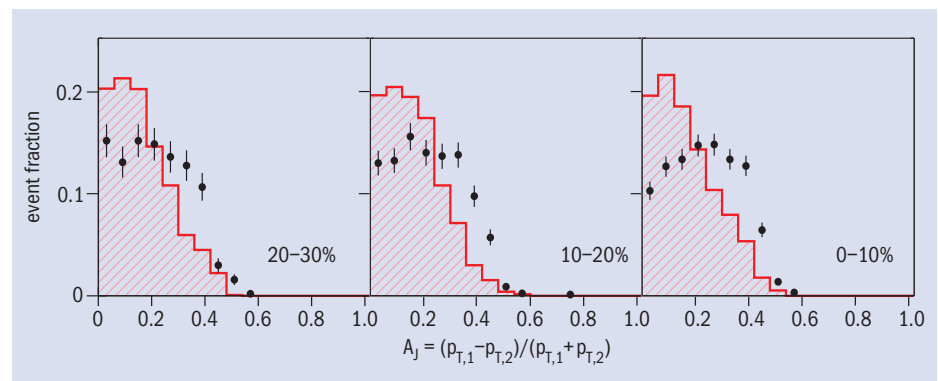


Fig 1. Di-jet asymmetry ratio, A_J , for 2.76 TeV lead–lead collisions. Data are shown as black points, while the histograms show simulated lead–lead collisions.

which were used to characterize the jets. The momentum imbalances observed in the data are significantly larger than those predicted by the simulations, especially for collisions that have a large “centrality”, i.e. for the most violent head-on collisions.

Since then the CMS collaboration has continued its efforts to try to understand this phenomenon in more detail, in particular by also studying the tracks of charged particles produced in head-on lead–lead collisions. Such an analysis can address basic questions. For example, how does the energy redistribution in the lowest-energy jet

work? Does the energy flow sideways, out of the jet cone? Or does it end up as low-energy particles that remain within the jet cone, but become difficult for the calorimeters to detect efficiently?

The new data analysis suggests that in fact both effects are present.

Based on the analysis of the charged particles correlated with the jets, CMS observes that the lowest-energy jet indeed becomes wider and the particles in the jet become softer in energy. An important question is then how the energy of the most energetic jet becomes exactly balanced in

these collisions. Figure 2 shows the result of the energy-balance study, with the total missing transverse momentum projected onto the jet axis of the leading jet, as a function of the di-jet energy asymmetry, for the most central type of collisions. The contribution to the missing momentum is decomposed in contributions from particles in different intervals of particle momentum, to gain insight into what sort of particles contribute.

The top row shows Monte Carlo predictions, which do not include any physics effects that lead to asymmetries in jet energy; the bottom row shows the CMS data. The left plots sum only the momenta of particles within the jet cone – the right ones the momenta of particles outside the cones. These distributions show clearly that part of the energy of the most energetic jet becomes balanced by particles on the opposite side, outside the jet cone. They also reveal that in the data – but not in the simulation – a large fraction of the balancing momentum is carried by particles with rather low momenta.

These results provide qualitative constraints on the nature of the jet modification in lead-lead collisions and a quantitative input to models of the transport properties of the medium created in these collisions. However, this is just the proverbial tip of the iceberg towards a detailed understanding of this phenomenon and many more studies can be expected soon.

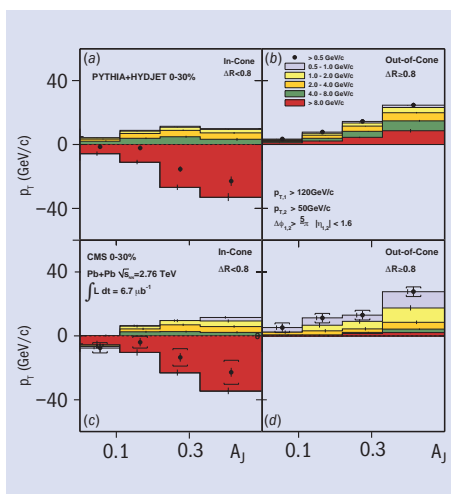


Fig 2. Average missing transverse momentum, for charged particles, along the highest energy jet axis, as a function of the di-jet asymmetry. The data points show the total asymmetry, while the histograms show the decomposition of these data points from particles belonging to different momentum ranges. Top, Monte Carlo simulation; bottom, CMS data.

EU PROJECTS

CERN launches AIDA project

A new, 4-year project co-funded by the European Union FP7 Research Infrastructures programme and worth €26 million began on 1 February. The AIDA project (Advanced European Infrastructures for Detectors at Accelerators) will develop detector infrastructures for future particle-physics experiments in line with the European Strategy for Particle Physics (*CERN Courier* September 2006 p29).

The project, which is co-ordinated by CERN, has more than 80 institutes and laboratories involved either as beneficiaries or as associate partners, thus ensuring that the whole European particle detector community is represented. The project will receive a contribution of €8 million from the European Commission.

The particle detectors developed in the AIDA project will be used in a planned upgrade to the LHC; at the proposed International Linear Collider, which will study the Standard Model of physics and

beyond with higher precision; Super-B factories, which aim to understand the matter-antimatter asymmetry in the universe; and neutrino facilities.

The AIDA project is divided into three main activities: networking, joint research and transnational access. The networking activity will study promising new technologies, such as 3D detectors and vital electronics, as well as specifying technological needs for the future. Interactions with appropriate industrial partners will also be planned.

The joint research activity will see many of the beneficiary institutes working together to improve beam lines that already exist to test particle detectors. The equipment and technology needed to produce these detectors will also be upgraded.

The transnational access activity will see access to beam lines for testing particle detectors at CERN, DESY and irradiation facilities across Europe opened up to new users. Experts in this area can contribute to the field through their findings made at these facilities.

• For details about the project and the full list of participants, see <http://cern.ch/aida>.

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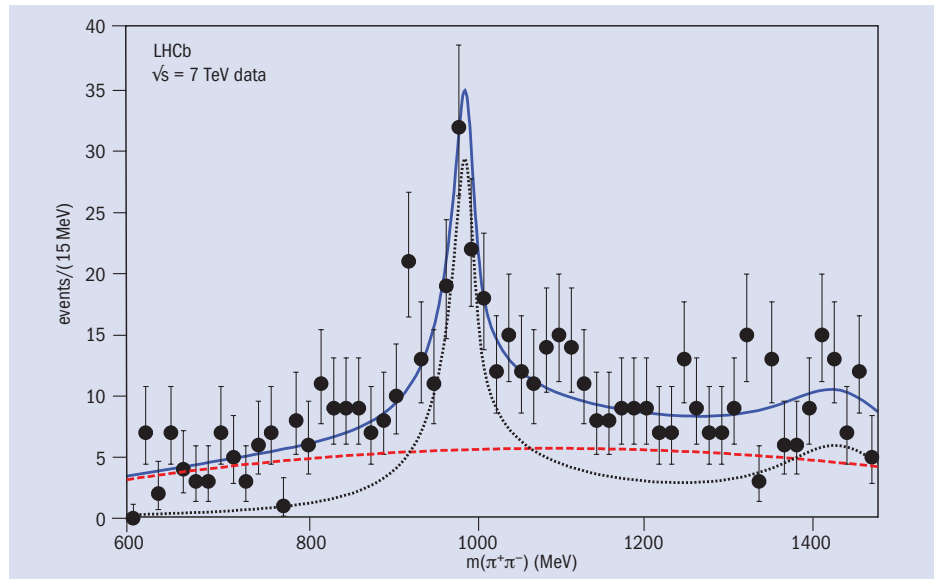
LHC PHYSICS

LHCb makes first observations of interesting B_s^0 decays

Using data collected in proton–proton collisions at the LHC at a centre-of-mass energy of 7 TeV, the LHCb experiment has observed new rare decay modes of B_s^0 mesons for the first time. The decay $B_s^0 \rightarrow J/\psi f_0(980)$ will be important for studying CP violation in the B_s^0 system, while the semileptonic decay $B_s^0 \rightarrow D_{s2}^* X \mu^+ \nu$ will be valuable for testing QCD-based theoretical predictions.

The first new decay mode observed is of the hadronic decay $B_s^0 \rightarrow J/\psi f_0(980)$. This is particularly interesting because it is to a CP eigenstate, which means that it can be used in measuring mixing-induced CP violation. The B_s^0 consists of a b antiquark (\bar{b}) bound with an s quark, and can decay to a J/ψ ($\bar{c}c$) together with an $\bar{s}s$ state, which can be a ϕ or, more rarely, an f_0 . While the ϕ decays to K^+K^- , the f_0 decays to $\pi^+\pi^-$. The collaboration analysed $J/\psi K^+K^-$ and $J/\psi \pi^+\pi^-$ events to search for the relevant decay candidates. Finally, using a fit to the $\pi^+\pi^-$ mass spectrum with two interfering f_0 resonances ($f_0(980)$ and $f_0(1370)$), they measured a ratio of the B_s^0 decays to $J/\psi f_0(980)$ and $J/\psi \phi$ of $0.252 \pm 0.046 - 0.032(\text{stat.}) + 0.027 - 0.033(\text{syst.})$ (LHCb collaboration 2011a). The events close to the $f_0(980)$ could be used to measure the CP-violating phase for B_s^0 decays, which is some 20 times smaller than in B^0 mixing and hence much more sensitive to physics beyond the Standard Model.

The LHCb collaboration has also made the first observation of another decay, $B_s^0 \rightarrow D_{s2}^* X \mu^+ \nu$. The most frequent decays of the B_s^0 involve the \bar{b} quark changing into a \bar{c} quark, resulting in a $\bar{c}s$ charm hadron, such as a D_s^- or D_s^{*-} , or other excited states. The relative proportion of such final states provides valuable information for testing theoretical models based on QCD. To investigate decays of this kind, the collaboration looked for final states in which the decay $\bar{D}^0 \rightarrow K^- \tau^+$ formed a vertex with a K^- and a μ^+ . The analysis revealed two structures in the $\bar{D}^0 K^-$ mass spectrum at masses consistent with the $D_{s1}(2536)^-$ and $D_{s2}^*(2573)^-$ mesons (LHCb collaboration 2011b). While the $D_{s1}(2536)^-$



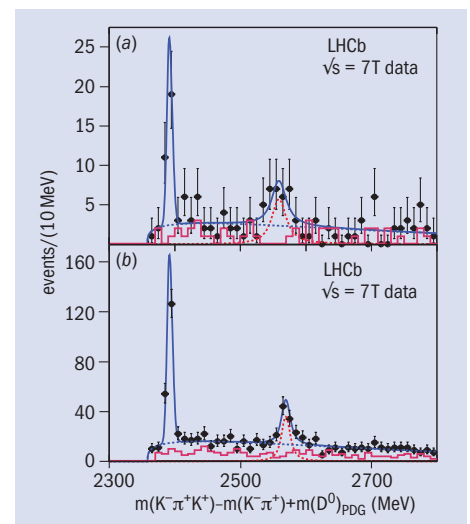
The invariant mass of $\pi^+\pi^-$ combinations when the $J/\psi \pi^+\pi^-$ is required to be within ± 30 MeV of the B_s^0 mass, with a peak corresponding to the $f_0(980)$.

has been observed previously in B_s^0 decays by the D^0 collaboration at Fermilab's Tevatron, LHCb's result marks the first observation of the $D_{s2}^*(2573)^-$ state in B_s^0 decays. The measured branching fraction relative to the total B_s^0 semileptonic rate for the $D_{s2}^*(2573)^-$ comes out at $3.3 \pm 1.0(\text{stat.}) \pm 0.4(\text{syst.})\%$, while the value for the $D_{s1}(2536)^-$ is measured to be $5.4 \pm 1.2 \pm 0.5\%$. These values agree well the prediction of the updated Isgur-Scora-Grinstein-Wise quark model, ISGW2.

The observation of these two new decay modes demonstrates that the LHCb experiment is already competitive in the field of heavy flavour physics. Great progress is expected with the larger data sample due from the coming run, with the potential to constrain, or even observe, new physics.

Further reading

LHCb Collaboration 2011a arXiv:1102.0206 [hep-ex].
LHCb Collaboration 2011b arXiv:1102.0348 [hep-ex].



The $D^0 K^+$ invariant mass for selected events in (a) a 3 pb^{-1} data sample and (b) for a 20 pb^{-1} sample (with different trigger conditions). The peaks are consistent with the $D_{s1}(2536)^-$ and $D_{s2}^*(2573)^-$ mesons.

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 proposals to the editor at cern.courier@cern.ch.

Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Quantum coherence for birds

Some migrating birds, such as the European robin, seem to detect the Earth's magnetic field using light-triggered chemical processes. The idea is that the absorption of a photon excites two electrons on a molecule and that one of these is then passed on to another part of the same molecule, forming a "radical pair". The pair is produced in a singlet state – but separated in space. The spin of a nucleus in the molecule can couple to one of the electrons and induce singlet-triplet mixing, which is in turn affected by the strength and orientation of an external magnetic field. Subsequent chemical reactions then distinguish between singlet and triplet states, providing information about the magnetic field.



Do birds have the edge on humans when it comes to quantum entanglement? (Image credit: Tomatito26/Dreamstime.com.)

Erik Gauger of the University of Oxford and colleagues studied this phenomenon in light of recent experimental work on the European robin species and found that superposition and entanglement of this spin system are maintained for tens of microseconds or more.

This result is far better than the best similar man-made systems can achieve and it suggests that living things, despite the usual claim that they are too "warm and wet" to maintain coherence for long, could well teach scientists some important tricks for quantum computing.

● **Further reading**

E M Gauger 2011 *Phys. Rev. Letts.* **106**040503.

Stimulated Hawking radiation in the lab

Condensed-matter analogues of black or white holes (a time-reversed black hole) can be simulated in laboratory systems by the propagation of water waves in moving fluid if the local fluid-flow speed exceeds the speed of wave propagation. Silke Weinfurter of the University of British Columbia and colleagues put a streamlined obstacle into a channel of flowing water that produced a region of high flow velocity and created an effective horizon for surface waves.

They found that long-wavelength surface waves that flow upstream towards the region are converted into shorter-wavelength deep-water waves, mimicking stimulated emission by a white hole. The converted waves show a thermal distribution as expected. Because – as Albert Einstein showed long ago – stimulated emission and spontaneous emission are closely related, this is really a significant demonstration of a Hawking-like process in a laboratory system.

● **Further reading**

S Weinfurter *et al.* 2011 *Phys. Rev. Letts.* **106**021302.

Relativity and the car battery

The lead-acid battery in every car has been around for more than 150 years, but it turns out that a proper understanding needs to include the effects of relativity. Rajeev

Atmospheric accelerators

Thunderstorms have long been known to produce bursts of X-rays and gamma rays, presumably from electron bremsstrahlung, but now it seems that the energies involved extend further than previously expected.

New data from the Italian Space Agency's AGILE satellite show that the high-energy spectrum reaches up to 100 MeV, with the higher energy part described by a power law without the exponential suppression with energy that is seen below around 10 MeV. It remains an open and puzzling question as to how gamma rays of such high energies are produced because present models do not provide for differences large enough to accelerate electrons to these energies, let alone for such energetic bremsstrahlung photons.

● **Further reading**

M Tavani *et al.* (AGILE Team) 2011 *Phys. Rev. Letts.* **106**018501.

Ahuja of Uppsala University worked out the energies of the solid reactants in the battery (lead oxide and lead sulphate) using *ab initio* nonrelativistic calculation, as well as including the effects of relativity. The correctly calculated voltage comes out to be 2.13 V, which is in good agreement with the measured value of 2.11 V – but amazingly

1.7–1.8 V of this comes from relativistic effects (mainly involving the lead oxide).

It has long been known that relativistic effects lie at the root of explaining why mercury is liquid and why gold has the colour that it does. However, this is the first time that it has been shown to have a significant, and in this case huge, effect in a battery.

● **Further reading**

R Ahuja 2011 *Phys. Rev. Letts.* **106**018301.

Grape varieties are more similar than you think

The wine grapes of various types that have been domesticated over the past 6000 years are more genetically close to each other than anyone had imagined. This is according to research by Sean Myles of Cornell, Stanford, and Acadia universities and the Nova Scotia Agricultural College, and colleagues.

Looking at more than 9000 genetic markers in the world's 583 cultivated varieties they find them all to be closely related, regardless of where they are grown. Indeed, 383 of the 583 types form a single pedigree network. It seems that crossing has occurred between a limited range of cultivars, so there remains a huge potential for new disease-resistant strains and, happily for oenophiles, types of wine not tasted before.

● **Further reading**

S Myles *et al.* 2011 *Proc. Natl. Acad. Sci.* published online, doi:10.1073/pnas.1009363108.

Astrowatch

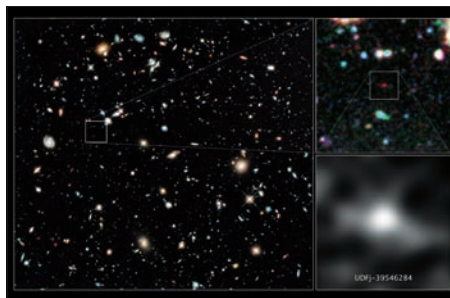
COMPILED BY MARC TÜRLER, ISDC AND OBSERVATORY OF THE UNIVERSITY OF GENEVA

Did Hubble find the most distant galaxy?

The Hubble Space Telescope has been pushed to its limits to find a galaxy candidate at a record distance of 13.2 thousand million light-years. The tiny, dim object observed by Hubble could be a compact galaxy of blue stars that is seen as it was only 480 million years after the Big Bang. In addition to the discovery of this galaxy candidate at a redshift, z , of around 10, the study published in *Nature* shows that the rate of star formation was 10 times lower – at a redshift of $z=10$ – than it is about 200 million years later, at $z=8$.

The quest for the most distant object in the universe has reached a legendary milestone: a redshift of 10. The redshift, z , measures the relative shift in the wavelength of light that results from the expansion of the universe during the journey from the remote galaxy to the telescope. It is therefore also a measure of the scale factor of the universe: at a redshift of $z=10$, distances between the seeds of the massive galaxy clusters of today would have been typically closer to each other by a factor of $1+z=11$.

The first claim for a galaxy at a z of around 10 was later disproved (*CERN Courier* May 2004 p13). In 2006, the record redshift approached $z=7$ (*CERN Courier* November 2006 p10), a benchmark that was itself overridden in less than two years (*CERN Courier* April 2008 p11). In 2003–2004, Hubble accumulated a total exposure of more than 10 days from an apparently empty region in the Fornax constellation. This original Hubble Ultra Deep Field (HUDF) revealed about 10 000 remote galaxies up to z of about 6. After the recent installation of the Wide Field Camera 3 (WFC3), which allows



One of the furthest and very earliest galaxies ever seen in the universe appears as a faint red blob in this ultra-deep-field exposure taken with NASA's Hubble Space Telescope. (Image credit: NASA, ESA, G Illingworth (University of California, Santa Cruz), R Bouwens (University of California, Santa Cruz, and Leiden University) and the HUDF09 Team.)

additional infrared measurements, the HUDF was observed again in the summers of 2009 and 2010, offering an unprecedented glimpse of the very first galaxies.

Rychard J Bouwens of Leiden University and the University of California, Santa Cruz, has analysed this unique dataset together with collaborators in Europe and the US. In 2010, based on the first-year data, they published the detection of three galaxies at z of around 8, one of which was confirmed spectroscopically at a redshift of $z=8.6$ by the European Very Large Telescope. With the addition of the 2010 data, they have now also found a galaxy that would be at z of around 10. The ultraviolet light emitted by this tiny galaxy only one hundredth the size of the Milky Way is measured in the

infrared channel at $1.6 \mu\text{m}$. It is detected neither at shorter wavelengths because of hydrogen absorption in the early universe, nor by the Spitzer Space Telescope at longer wavelengths – thus excluding a dusty galaxy at lower redshift.

How confident is the team that the faint smudge of light seen in a single channel is not spurious? Bouwens and colleagues first checked that the source is visible in both the 2009 and 2010 datasets, as well as in two random subsets, each containing 50% of the data. Using Monte-Carlo simulations they find a probability of about 80% that the candidate is, indeed, real. Regardless of the uncertainty of this detection the main surprise comes from the fact that this is the only candidate at z around 10. Based on the extrapolation from $z=6-7$ towards $z=10$, the team should have found about three galaxies. So, instead of finding an upturn of star formation between $z=8$ and $z=10$, there seems to be a downturn in the already decreasing trend of star formation towards higher redshift. It therefore seems that galaxies at z around 10 are not only extremely difficult to observe but are also much less luminous and/or numerous than the galaxies observed later in cosmic time. Galaxies that are less luminous would be expected by a hierarchical growth of galaxies and would better suit Hubble's successor, the James Webb Space Telescope – scheduled for launch in 2014 – which has a reduced field of view but high sensitivity to faint sources at very high redshift.

● Further reading

R J Bouwens *et al.* 2011 *Nature* **469** 504.

Picture of the month

The Orion Nebula is the nearest star-forming region in our galaxy. Also known as Messier 42, this most popular celestial object is visible to the unaided eye from a distance of 1350 light-years. This image was taken by the Wide Field Imager on the 2.2-m telescope at the La Silla site of the European Southern Observatory (ESO) in Chile. It is an almost-true colour composite of images taken through five different filters. The amateur astronomer Igor Chekalin from Russia recognized the value of this dataset by participating in ESO's Hidden Treasures 2010 astrophotography competition. He originally proposed a more dramatic false-colour view of this nebula but was awarded first prize for polishing another gem found in archive observations of the Orion constellation: the reflection nebula Messier 78. (Image credit: ESO and Igor Chekalin.)



CERN Courier Archive: 1968

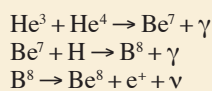
A LOOK BACK TO CERN COURIER VOL. 8, MARCH 1968, COMPILED BY PEGGIE RIMMER

NEWS FROM ABROAD

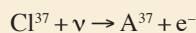
First catch your neutrino

A team of scientists from Brookhaven Laboratory, led by R Davis, has set up a large tank of cleaning liquid, 6.6 m in diameter and 14.8 m long, 1470 metres down the Homestake Gold Mine in South Dakota, to catch neutrinos. Their paradoxical purpose in going deep into the Earth is to find out what is going on deep in the Sun, surely one of the most imaginative experiments ever devised.

Nuclear physics explains solar energy generation in terms of the fusion of the lighter chemical elements, and among the interaction products is a high flux of neutrinos, estimated at over 10^{37} per second. One interaction chain, (helium \rightarrow beryllium; beryllium+proton \rightarrow boron \rightarrow beryllium)



yields neutrinos with energies up to 14.2 MeV, just about susceptible to a reasonably high rate of detection. These are the particles that the Brookhaven team aims to catch, in the interaction



by setting up a 380 000-litre volume of tetrachloroethylene to provide the chlorine and filtering out the radioactive isotope argon-37 produced [half-life 35 days].

After long exposure in the underground laboratory, where only neutrinos can penetrate, helium gas is passed through to purge the liquid of argon. A charcoal trap cooled to almost -200°C is then used to absorb the argon. This takes about 10 hours and argon extraction efficiencies of over 90% can be achieved.

The argon is then conveyed to Brookhaven and the number of A^{37} atoms is measured in a low-level proportional counter by counting the Auger electrons, with a characteristic energy of almost 3 keV, as the A^{37} decays. This counter is located inside the 40 cm bore of an old navy gun-barrel, which acts as a shield from cosmic radiation. Made of "old" iron, these guns contain a very small level of residual radioactivity.

Theoretical calculations of the expected neutrino flux give forecasts ranging from about 6×10^6 to 21×10^6 neutrinos $\text{cm}^{-2} \text{sec}^{-1}$.

Knowing the efficiency of neutrino capture in their tank, the Brookhaven team could expect to catch from about 1.5 to 5 neutrinos per day, according to which theory was correct. Their very preliminary results seem to point to the lower end of this range with a rate of less than 2 per day.

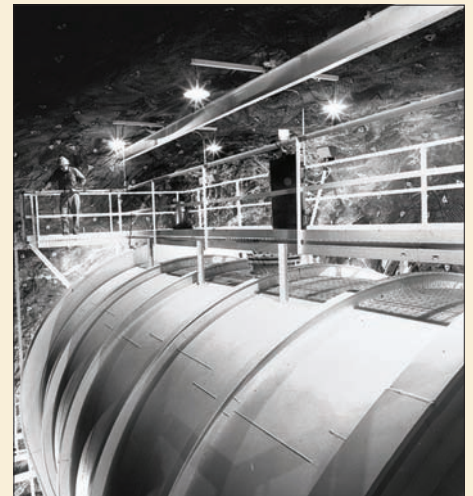
An indication of how refined the detection technique has to be is that when A^{37} is being produced at the same rate as it decays, only about 300 atoms of A^{37} will be present in the 380 000 litres of tetrachloroethylene. Thus this unusual alliance of physics and chemistry is plucking each argon atom from over a million, million, million, million others.

● Compiled from texts on pp54–55.

CERN 37th Session of Council

The selection of the site for the proposed 300 GeV Laboratory [that became CERN Lab II] is one of the most difficult decisions ever to face the CERN Council. An enormous effort, both by experts in the nine Member States [out of 13] who are offering sites and by representatives of the Organization, has gone into compiling information, technical and social, on which to base the final decision.

The latest stage of this work has been the report of the Site Evaluation Panel consisting of three Council delegates (JH Bannier, JK Boggild, A Chavanne) from States not offering sites. An evaluation such as this cannot help but be subjective in



One end of the huge tank of tetrachloroethylene catching neutrinos down a South Dakota gold mine. (Image credit: BNL.)

some of its elements and practically all the States offering sites have some comment on points where they disagree with the Panel's findings. Differences of opinion are inevitable. Pressures and disappointments are unavoidable.

The spirit in which this potentially very acrimonious problem is being approached is perhaps as fine an example as could be given of what successful international cooperation, which has always been a hallmark of the European Organization for Nuclear Research, really means.

● Compiled from texts on p46.

Compiler's Note



Turning swords into ploughshares – or gun-barrels into shields in Brookhaven's case – is not an activity commonly associated with particle physics, but it does happen occasionally and a recent example demonstrates the level of co-operation and trust that can be reached in international collaboration for pure scientific research.

The huge absorber plates of the CMS endcap hadron calorimeter (HCAL) contain more than a million Second World War brass shell casements retrieved from Russian military storage. The 50-year-old shells were designed to withstand internal high stress and transport aboard 1940s navy vessels. Melted down, they provided high-quality material meeting the stringent stress requirements of the heavy HCAL endcaps. When this amount fell short of the 600 tonnes of brass needed, the US agreed, on an amicable "handshake" basis, to provide a further \$1 million in copper to complete the endcaps.



IEEE Nuclear Science Symposium and Medical Imaging Conference

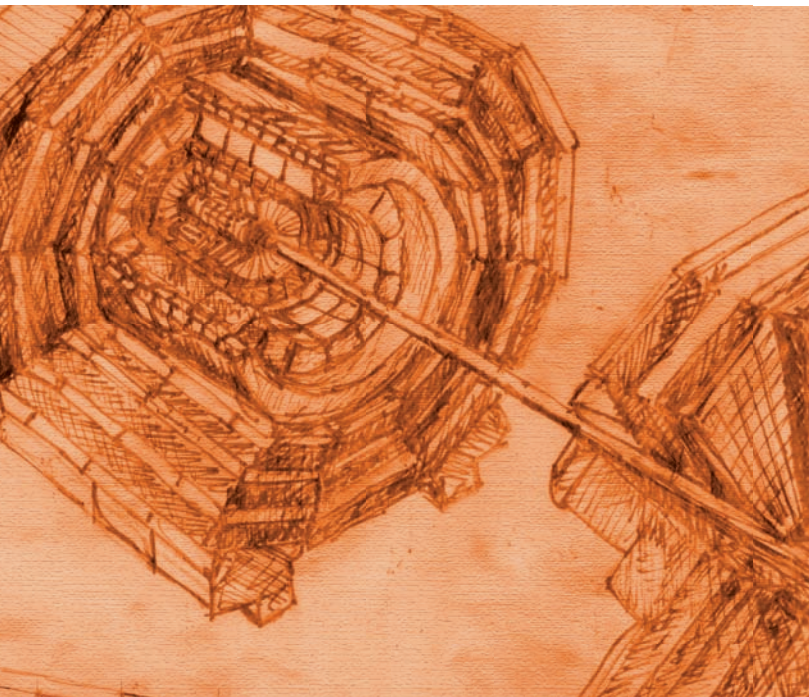
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ALPHA collaboration gets antihydrogen in the trap

The ALPHA collaboration has achieved one of the long-stated goals of the physics programme at CERN's Antiproton Decelerator: magnetic trapping of antihydrogen atoms.

On 17 November 2010 the ALPHA collaboration at CERN's Antiproton Decelerator (AD) reported online in the journal *Nature* that they had observed trapped antihydrogen atoms by releasing them quickly from the magnetic trap in which they were produced and detecting the annihilation of the antiproton – the nucleus of the antihydrogen atom (Andresen *et al.* 2010a). This exciting result from a proof-of-principle experiment paves the way to detailed study of antimatter atoms.

Do matter and antimatter obey the same laws of physics? One intriguing way to test this would be to compare the spectra of hydrogen and its antimatter twin: antihydrogen. Such studies would build on almost a century of detailed theoretical and experimental investigation of the hydrogen atom, from the Bohr model to the ultraprecise measurements of Nobel laureate Theodor Hänsch and colleagues (*CERN Courier* 2006 June p30). The frequency of the 1s–2s transition in hydrogen has been measured with a precision of about 2 parts in 10^{14} . The CPT theorem requires that this frequency must be exactly the same in antihydrogen. The goal of the ALPHA experiment is to test this claim – at least from the high-energy physics point of view. To the atomic physicist, for whom hydrogen is the basic, elegant workhorse of the evolution of quantum mechanics, the question is perhaps: “How could you possibly have access to antihydrogen and *not* try to measure that?”

While our colleagues at the LHC have been busily setting new records for the highest energy stored hadrons, we at the AD have been headed in the other direction – setting a new record for the lowest energy anti-hadrons. The antihydrogen atoms in ALPHA can be trapped only if their kinetic energy, in temperature units, is less than 0.5 K. This corresponds to about 9×10^{-5} eV, or 3×10^{-17} times the energy of protons in the LHC, which represents quite a dynamic range for CERN.

The low temperature necessary has been a daunting challenge for the ALPHA experimenters. Antihydrogen is formed by mixing antiprotons from the AD with positrons from a special accumulator fuelled by a ^{22}Na positron emitter. The particles are mixed in

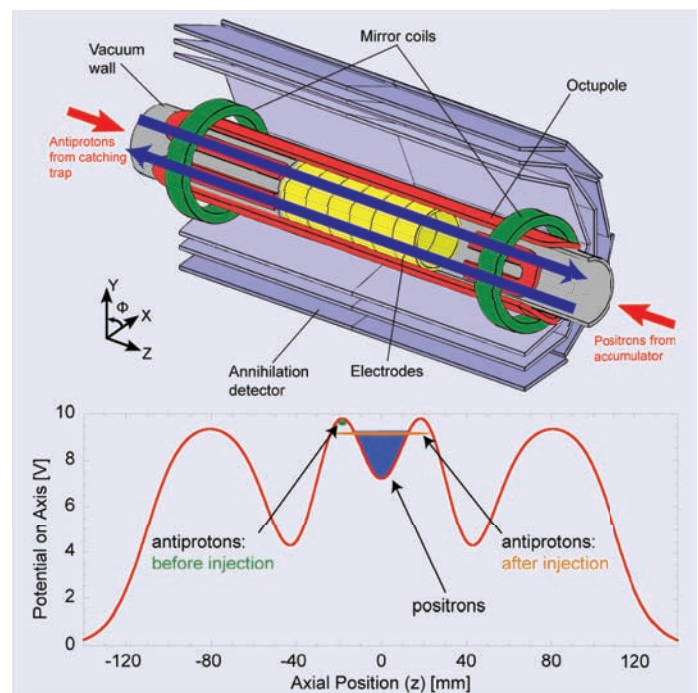


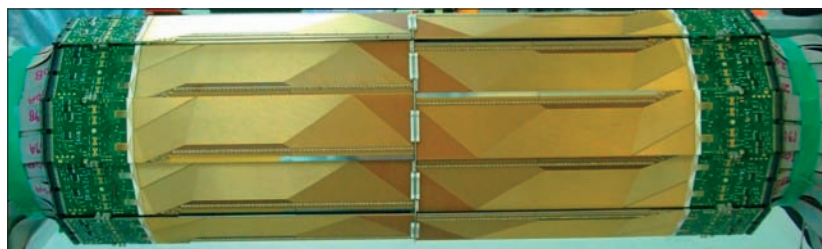
Fig. 1. Top: A cut-away, schematic diagram of the ALPHA central apparatus showing the Penning trap electrodes, magnets for the atom trap and the silicon vertex detector. The blue arrows indicate alternate electric “bias” fields applied to distinguish antiprotons from neutral antihydrogen (see text). Bottom: The potentials used for the mixing of antiprotons and positrons to produce antihydrogen (Andresen *et al.* 2010a.).

cryogenic Penning traps, which feature strong solenoidal magnetic fields for transverse confinement and electrostatic fields for longitudinal confinement (figure 1). The resultant antihydrogen, which is electrically neutral, can be confined only by the weak interaction of its magnetic dipole moment with an external magnetic trapping-field. The strength of this dipole interaction is such that, for ground state antihydrogen, a 1 T deep magnetic well can confine atoms with kinetic energy up to 0.7 K.

The atom trap in ALPHA comprises an octupole magnet and two solenoidal “mirror coils” (figure 1). These produce a magnetic minimum at the position at which the antihydrogen atoms are formed. If the atoms are formed with a kinetic energy of less than about 0.5 K (in temperature units), they are trapped. (This is for the ground state; excited atoms can have a larger magnetic moment ▷

Antihydrogen

Fig. 2. View of the outer layer of the three-layer annihilation vertex detector. (Image credit: P Pusa, ALPHA/University of Liverpool.)



and experience a deeper well.)

The difficulty lies in the transition from plasmas of charged particles to neutral atoms. The space-charge potential energies in the plasmas can be of order 10 eV – about 120 000 K in temperature equivalent. So one of the experimental challenges for antihydrogen trapping has been to learn how to cool and carefully manipulate the charged species to produce cold, trappable atoms.

At ALPHA, we mix about 30 000 antiprotons with about two million positrons in each attempt to trap antihydrogen. The two plasmas are placed in adjacent potential wells, as in figure 1, and the antiprotons are then driven into the positron plasma using a frequency-swept, axial electric field (Andresen *et al.* 2011). This drive is “autoresonant”, i.e. the amplitude of the antiproton oscillation automatically matches the corresponding drive frequency in the nonlinear potential well. The idea is to control the energy of the antiprotons precisely by carefully tailoring the drive frequencies. The antiprotons enter the positron cloud with low relative energy and do not heat the positron cloud on entry.

The positrons themselves are self-cooling: they lose energy by radiation in the 1 T magnetic field in the Penning trap. We supplement this process using evaporative cooling. Starting with an equilibrated positron plasma in a potential well, we lower one side of the well, allowing the hottest positrons to escape. The remaining positrons re-equilibrate through collisions, settling to a lower temperature. The technique, which is well known in the field of Bose-Einstein condensation for neutral atoms, was also demonstrated by ALPHA on antiprotons in 2009 (Andresen *et al.* 2010b). After evaporative cooling, the positrons in ALPHA are at about 40 K. Under ALPHA conditions, the antiprotons can enter the positron plasma and come into thermal equilibrium before making antihydrogen. Thus, only a small fraction of the antihydrogen atoms produced will have a kinetic energy equivalent to less than 0.5 K.

Antiprotons and positrons are allowed to interact or “mix” for 1 s to produce antihydrogen, after which we remove any charged particles that remain trapped in the potential wells and then ground the electrodes of the Penning trap. The decisive step is to shut down the magnetic atom trap quickly to see if there are any trapped antihydrogen atoms that escape and annihilate on the walls of the device. However, even with the Penning trap’s electric fields turned off, there is still a small chance that antiprotons could be magnetically trapped due to the mirror effect in the strong magnetic field gradients in the atom trap. To eliminate this possibility, we apply pulsed electric fields along the axis of the trap, in alternating directions, so as to kick any stubborn antiprotons out of the trapping volume.

The ALPHA experiment’s superconducting atom-trap magnets, manufactured at Brookhaven National Laboratory, can be turned off with a time constant of about 9 ms (CERN Courier July/August

2007 p13). This fast shutdown helps to discriminate between antihydrogen annihilations and cosmic rays.

Antiproton annihilations are detected by an imaging, three-layer silicon vertex detector (see figure 2) that surrounds the cryostat for the traps and magnets. To be absolutely sure that any annihilations observed come from neutral antimatter and not from charged antiprotons, we apply an axial electric “bias” field to the trap while it is shutting off. While antiprotons would be deflected by this field, antihydrogen is not, and we can see the result using the position-sensitive silicon vertex detector. The silicon detector is also extremely useful in topologically rejecting cosmic rays.

The result of many trapping attempts is shown in figure 3, reproduced from the article in *Nature*. Each trapping attempt takes about 20 minutes of real time. In 335 trapping attempts, we observed 38 annihilations consistent with the controlled release of trapped antihydrogen atoms. The spatial distribution of these annihilations is not consistent with the expected behaviour of charged particles (figure 3). We can conclude that neutral antihydrogen atoms were trapped for at least 172 ms, which is the time it took to eject the charged particles from the trap and to apply the multiple field pulses to ensure the clearing of mirror-trapped antiprotons.

In subsequent experiments, we made good progress on improving the trapping probability and investigated the storage lifetime of antihydrogen atoms in the trap. At holding times up to 1000s, we still see the signal for release of trapped atoms. This is an encouraging result that leads us to be optimistic about the future of spectroscopic studies with trapped antihydrogen.

When the AD starts up again in 2011, we hope to pick up where we left off in 2010. The first step is to continue to improve the trapping probability for produced antihydrogen atoms, by, for example, working on reducing the positron temperature and studying improvements in the mixing manipulations to make colder antihydrogen. As regards the spectrum of antihydrogen, the 1s to 2s laser-frequency transition described above is not the only game in town. Microwaves can interact with antiatoms in the magnetic trap, either with the positron spin (positron spin resonance) or with the antiproton spin (antinuclear magnetic resonance). Paradoxically, using rare atoms of antimatter can offer a detection bonus for such experiments, as a resonant interaction can lead to loss and annihilation of the trapped atom – an event that can be detected with high efficiency. At ALPHA we hope to take the first steps towards microwave spectroscopy – the first resonant look at the inner workings of an antiatom – in 2011. At the same time we will be working on a new atom-trapping device that is optimized for precision measurements with both lasers and microwaves.

Having demonstrated trapping of antihydrogen atoms, the ALPHA collaboration was able to finish off the year by celebrat-

Antihydrogen

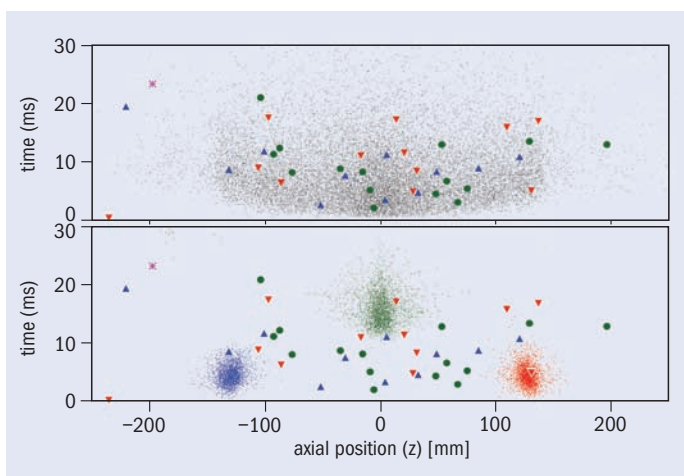


Fig. 3. Distributions of released antihydrogen atoms and antiprotons. Top: Measured t - z distribution for annihilations obtained with no bias (green circles), left bias (blue triangles) and right bias (red triangles). The grey dots are from a numerical simulation of antihydrogen atoms released from the trap during the shutdown. Bottom: t - z distribution shown with results of a numerical simulation of mirror-trapped antiprotons released from the trap, colour codes as above (Andresen et al. 2010a.).

ing the honour of being recognized as the Physics Breakthrough of the Year for 2010 by *Physics World* magazine (CERN Courier January/February 2011 p7). We shared this honour with our friends across the wall at the AD in the ASACUSA collaboration, who produced antihydrogen in a new type of device that could lead to in-flight studies of the antiatoms. Finally, the American Physical Society news staff named our trapping of antihydrogen as one of the top ten physics-related news stories of 2010. All in all, 2010 was a vintage year for antimatter at the AD.

• Further reading

- G B Andresen *et al.* (ALPHA collaboration) 2010a *Nature* **468** 673.
 G B Andresen *et al.* (ALPHA collaboration) 2010b *Phys. Rev. Lett.* **105** 013003.
 G B Andresen *et al.* (ALPHA collaboration) 2011 *Phys. Rev. Lett.* **106** 025002.

Résumé

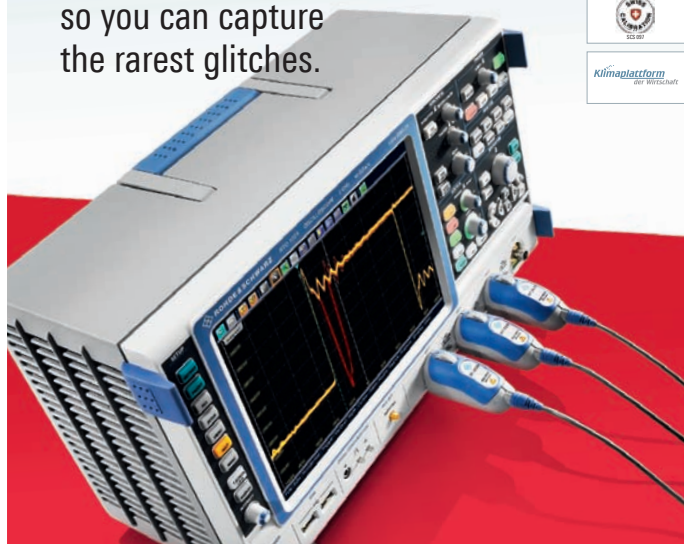
ALPHA piège l'antihydrogène

Le 17 novembre 2010, l'équipe d'ALPHA travaillant auprès du Décélérateur d'antiprotons (AD) du CERN annonçait dans la revue *Nature* qu'elle avait observé des atomes d'antihydrogène piégés, en les libérant rapidement de leur piège magnétique et en détectant la désintégration des antiprotons (les noyaux des atomes d'antihydrogène). La collaboration ALPHA a ainsi atteint l'un des objectifs du programme de recherche du Décélérateur d'antiprotons : la capture d'atomes d'antihydrogène dans un piège magnétique. Cette formidable avancée ouvre la voie à l'étude détaillée des atomes d'antimatière, qui s'effectuera en comparant les spectres des atomes d'hydrogène et des atomes d'antihydrogène.

Jeffrey Hangst, Aarhus University, spokesperson of the ALPHA collaboration.

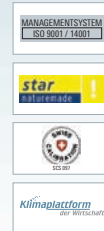
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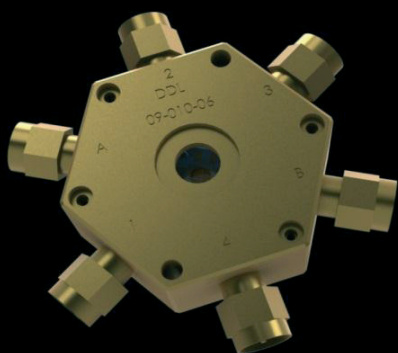
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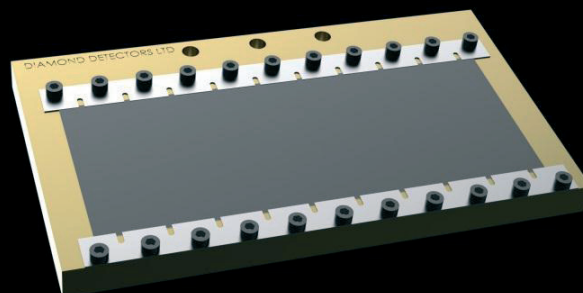
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Technology and Instrumentation in Particle Physics 2011 (TIPP 2011), Chicago, 9 to 14 June

<http://conferences.fnal.gov/tipp11/index.html>

At the cusp in ASACUSA

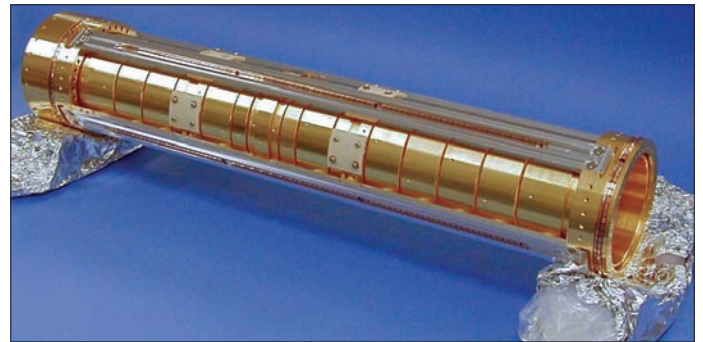
The ASACUSA collaboration has successfully demonstrated its cusp trap, designed not to trap antihydrogen atoms but to extract them as beams for high-precision spectroscopy. Yasunori Yamazaki explains how it works.

Last December, the cusp-trap group of the Japanese–European ASACUSA collaboration demonstrated for the first time the efficient synthesis of antihydrogen, in a major step towards the production of a spin-polarized antihydrogen beam. Such a beam will allow, for the first time, high-precision microwave spectroscopy of ground-state hyperfine transitions in antihydrogen atoms, enabling tests of CPT symmetry (the combination of charge conjugation, C, parity, P, and time reversal, T) – the most fundamental symmetry of nature. The new experiment may also shed light on some of the most profound mysteries of our universe: the asymmetry of matter and antimatter in our universe. Why is it that the universe today is made up almost exclusively of matter, and not antimatter? Scientists believe that the answer may lie in tiny differences between the properties of matter and antimatter, manifested in violations of CPT symmetry.

Testing CPT symmetry

Antihydrogen, made up of an antiproton and a positron, is attractive for testing CPT symmetry given its simple structure. In particular, comparisons of antihydrogen's transition frequencies with those of ordinary hydrogen atoms will provide stringent tests of CPT symmetry. For this purpose, the ATRAP and ALPHA experiments under way at CERN's Antiproton Decelerator (AD) aim to make high-precision measurements of the transition frequency between the ground state (1s) and first excited state (2s) of antihydrogen, which is close to 2466 THz, in the realm of laser spectroscopy. The ALPHA collaboration made an essential breakthrough in this approach when they successfully trapped antihydrogen for the first time in November (p13).

The ASACUSA experiment, also at the AD, is taking the complementary approach of measuring precisely the transition frequency between the two substates of the ground state that arise from hyperfine splitting as a result of the interaction between the two magnetic moments associated with the spins of the antiproton and the positron. The collaboration aims to measure the ground-state hyperfine transition frequency, which is about 1420 MHz in the microwave region, by extracting a spin-polarized antihydrogen beam in a field-free region. Last December, the cusp-trap group of ASACUSA reported that the cusp trap, which is designed not



A stack of multi-ring electrodes for the ASACUSA cusp trap. (Image credit: ASACUSA.)

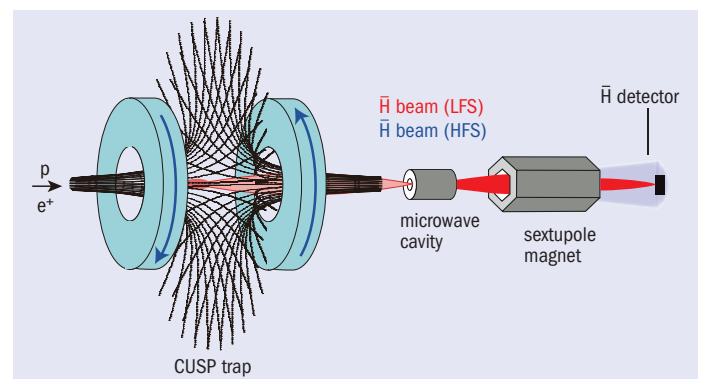


Fig. 1. Conceptual drawing of the experimental set-up for the ground-state hyperfine transition measurements of antihydrogen atoms with the cusp-trap scheme. A spin-polarized antihydrogen beam in low-field-seeking states is focused by the cusp magnetic field around the microwave cavity. This is then injected into the sextupole magnet for spin analysis.

to trap antihydrogen but to concentrate spin-polarized antiatoms into a beam, succeeded in synthesizing antihydrogen atoms with an efficiency as high as 7%. This is a big step towards the realization of high-precision microwave spectroscopy of the ground-state hyperfine transition in antihydrogen.

The cusp trap uses anti-Helmholtz coils, which are like Helmholtz coils but with the excitation currents antiparallel rather than parallel to each other. This arrangement yields a magnetic quadrupole field that has axial symmetry about the coil axis: a so-called cusp magnetic field (figure 1). In addition, an axially symmetric electric field is generated by an assembly of multi-ring electrodes (MREs) that is coaxially arranged with respect to the coils. Having axial symmetry, these magnetic and electric fields guarantee the stable storage and manipulation of a large number of antiprotons and positrons simultaneously – one of the unique features of the cusp trap. Furthermore, the magnetic field distribution of the ▷

Antihydrogen

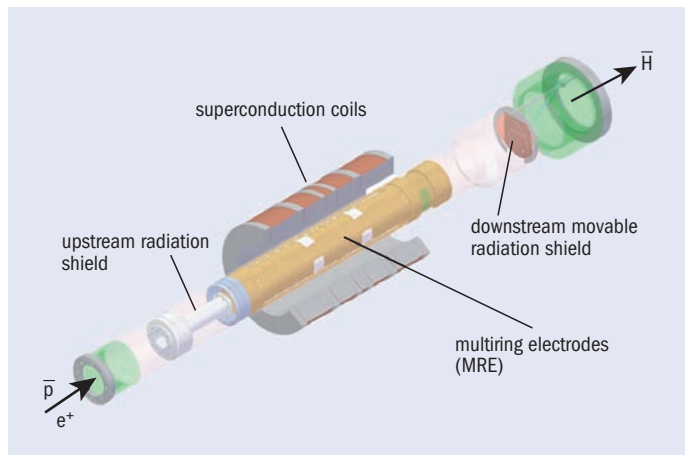
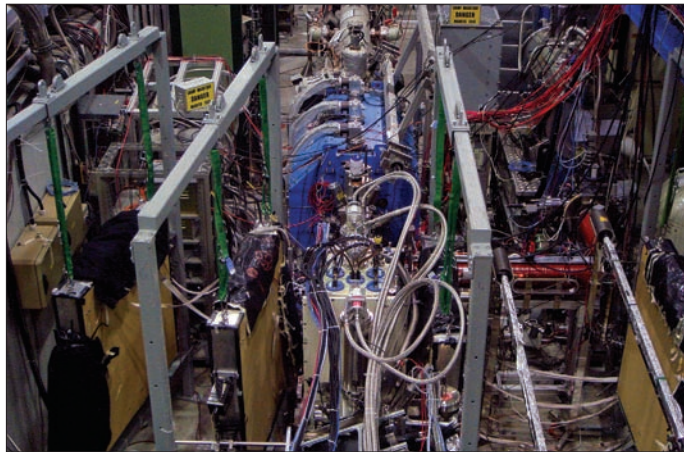


Fig. 2. A schematic drawing of the central part of the cusp trap. A stack of multi-ring electrodes is housed in a cryogenic ultrahigh-vacuum tube. Four superconducting coils of the cusp magnet provide the cusp-magnetic field.



The experimental set-up around the cusp trap in the AD hall at CERN. (Image credit: ASACUSA.)

cusp trap can produce an intensified antihydrogen beam with high spin-polarization in low-field-seeking (LFS) states. In other words, antihydrogen atoms can be tested for CPT symmetry in a field-free (or weak field) region – a vital condition for making high-precision spectroscopy a reality. These properties are exclusive to the cusp-trap scheme.

As figure 1 (p17) shows, the extracted beam is injected into a microwave cavity, followed by a sextupole magnet and a spin analyser, and then focused on an antihydrogen detector (shown in red). When the microwave frequency is in resonance with one of the hyperfine transition frequencies, it induces a spin flip, which converts the LFS state into a high-field-seeking (HFS) state. In this case, the antihydrogen beam becomes defocused (shown in purple), a transition that is easily monitored by an intensity drop in the antihydrogen detector. As is evident from this description, the cusp trap scheme does not need to trap antihydrogen atoms, but it can do so if necessary. The big advantage is that a large number of antihydrogen atoms with higher temperatures can participate in the measurements.

The AD at CERN supplies a pulsed antiproton beam of around

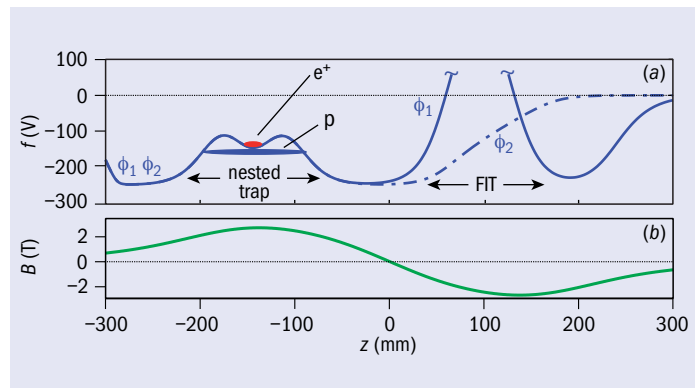


Fig. 3. (a) The electrical potential ϕ along the beam axis. ϕ_1 is for mixing of antiprotons and positrons. The mixing region in the upstream part is called the nested trap and the harmonic part in the downstream is called the field-ionization trap (FIT). ϕ_2 is for extraction of antiprotons accumulated in the FIT that originate from field-ionized antihydrogen atoms. (b) The magnetic field B along the beam axis.

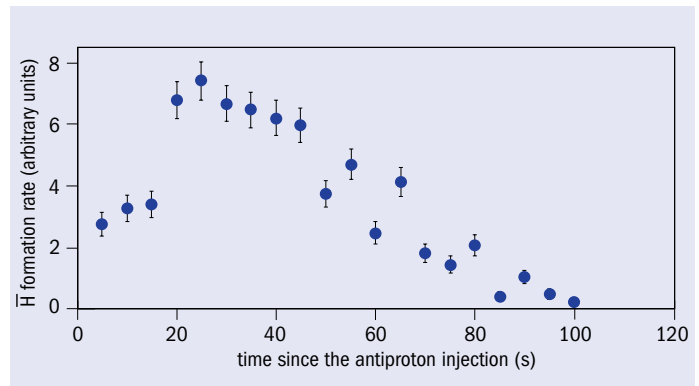


Fig. 4. The number of field-ionized antihydrogen atoms accumulated in the FIT monitored by opening the FIT every 5 s for 3×10^5 antiprotons mixed with 3×10^6 positrons.

3×10^7 particles per pulse at 5.3 MeV, which is slowed down to 120 keV in ASACUSA by the radio-frequency quadrupole decelerator. For the antihydrogen experiments the beam is then injected into an antiproton catching trap (previously called the MUSASHI

In other words, antihydrogen atoms can be tested for CPT symmetry in a field-free region.

trap) through two layers of thin degrader foil. In this way, about 10^6 antiprotons per AD shot are accumulated in the trap where they are cooled with preloaded electrons. The antiproton cloud is then radially compressed by a “rotating wall” technique to allow efficient transportation into the cusp trap. The positrons that make up the antihydrogen are supplied via a compact all-

in-one positron accumulator that was designed and developed for this research. Both antiprotons and positrons are then injected into the cusp trap to synthesize cold antihydrogen atoms. A 3D track detector monitors the cusp track to determine the annihilation

Antihydrogen

position of antiprotons by tracking charged pions. The detector comprises two pairs of two modules, each with 64 horizontal and 64 vertical scintillator bars that are 1.5 cm wide.

Inside the cusp trap

Figure 2 shows schematically the structure of the central part of the cusp trap. The MRE is housed in a cryogenic ultrahigh vacuum tube held at a temperature of several Kelvin with a good heat contact, while still being insulated electrically. Thermal shields at 30 K located on both ends of the MRE prevent room-temperature radiation creeping in from the beamline. Outside the MRE part of the bore tube, five superconducting coils installed symmetrically with respect to the MRE centre provide the cusp magnetic field. On the downstream side, the bore diameter is expanded for efficient extraction of the antihydrogen beam.

In the recent experiment, antihydrogen atoms were synthesized by mixing antiprotons and positrons at the nested trap region, as shown by the blue solid line (ϕ_1) in figure 3. As antihydrogen atoms are neutral, they are not trapped and move more or less freely so some of them reached the field-ionization trap (FIT). If the antihydrogen atoms were formed via a three-body-recombination process in high Rydberg states, i.e. relatively loosely bound, they are field-ionized and their antiprotons are accumulated in the FIT. During the experiment, the FIT was opened (as indicated by the dashed line, ϕ_2) every 5 s and the antiprotons accumulated were released and counted by the 3D tracker through their annihilations. This gave the antihydrogen synthesis rate as a function of time since the start of the mixing process. Figure 4 shows an example of the evolution of the synthesis rate for 3×10^5 antiprotons and 3×10^6 positrons, in which the rate grew in the first 20–30 s, and then gradually decreased. In this case, a total of around 7×10^3 antihydrogen atoms were synthesized.

The ASACUSA collaboration is now looking forward to starting the microwave spectroscopy of hyperfine transition frequencies – which may lead to groundbreaking insights into the nature of antimatter and symmetry.

• Further reading

Y Enomoto *et al.* 2010 *Phys. Rev. Letts.* **105** 243401.

Résumé

ASACUSA sur la bonne voie

En décembre dernier, le groupe travaillant sur le piège à étranglement de la collaboration Europe-Japon ASACUSA a réussi pour la première fois la synthèse efficace de l'antihydrogène, une avancée majeure en vue de la production d'un faisceau d'antihydrogène polarisé. Un tel faisceau permettra à la collaboration d'effectuer une spectroscopie micro-onde haute précision des transitions hyperfines dans les atomes d'antihydrogène à l'état fondamental. Cette approche, complémentaire de l'expérience ALPHA, servira également à étudier la violation de CPT, la symétrie la plus fondamentale de la nature.

Yasunori Yamazaki, RIKEN and University of Tokyo, on behalf of the ASACUSA cusp trap group.



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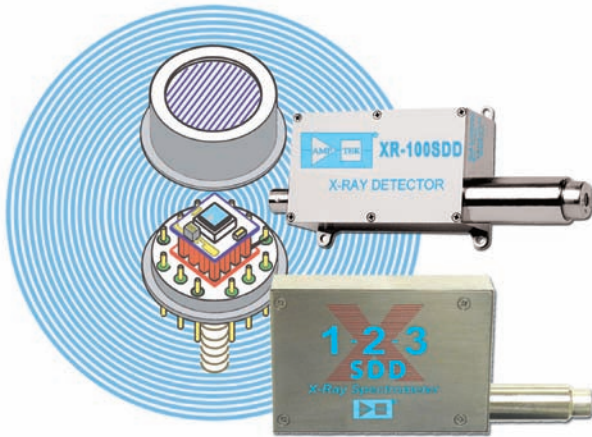
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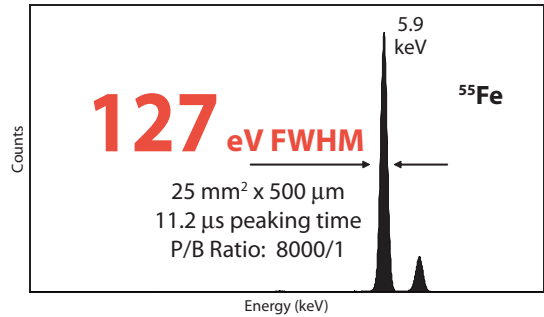
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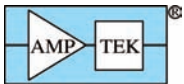


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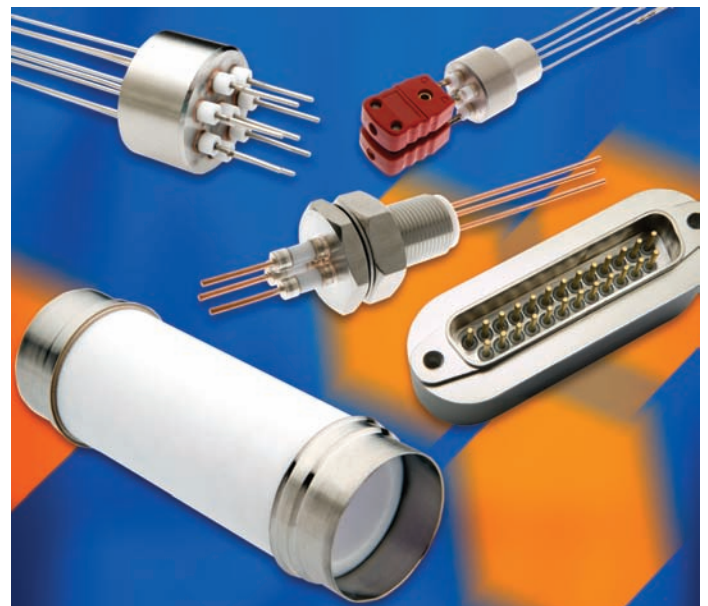
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Exploring the low-energy precision frontier

The PSI2010 workshop provided a showcase for a diverse range of high-precision measurements at low energies, which offer an important complementary route to new physics in the era of the LHC.

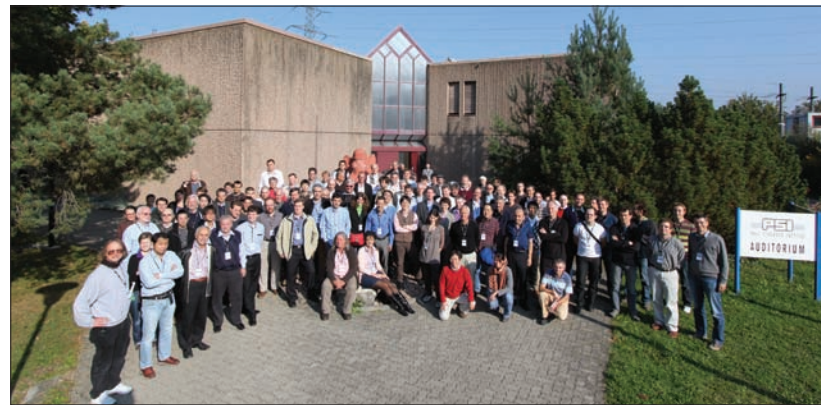
PSI2010, the 2nd International Workshop on the Physics of Fundamental Symmetries and Interactions at low energies and at the precision frontier, brought together experimentalists and theoreticians, united by a common quest for experimental precision using probes as diverse as neutrons, antiprotons, muons, atoms, molecules and even condensed-matter samples. The meeting, which was aimed at consolidating recent results and planning future directions in the field, took place at the Paul Scherrer Institut (PSI) on 11–14 October and was supported by PSI and the Swiss Institute for Particle Physics (CHIPP).

With 146 participants from 17 countries, the form of the workshop led to lively discussions, helping to promote the transfer of information within the community. Results were presented in 65 plenary talks and some 30 posters, most of which related to experiments. PSI being a world-leading centre for muon, pion and neutron physics, many presentations were related to investigations with neutrons (40%) and pions or muons (30%). This reflected both the high local interest as well as the strength of the worldwide community – about three-quarters of the presentations were on work at facilities other than PSI.

Gearing up for new physics

The workshop began with a talk on “How to look at low-energy precision physics in the era of the LHC” given by Daniel Wyler of the University of Zurich. He described how low-energy precision physics is complementary to the search for new physics at the LHC and how it can even answer specific questions that reach beyond the LHC – a theme that was highlighted in other talks. The final results from the TRIUMF Weak Interaction Symmetry Test (TWIST) experiment on muon decay demonstrate the impact of precision results on, for example, left–right symmetric models or sterile neutrinos, as TRIUMF’s Glen Marshall explained.

Fundamental neutron physics, introduced by Torsten Soldner of Institut Laue-Langevin (ILL), cropped up in several sessions.



Under a sunny Argovian sky the PSI2010 participants gather around the famous pink mammoth at PSI. (Image credit: PSI.)

These covered recent controversial results on neutron-lifetime measurements in storage bottles and results on neutron decay at ILL and the Los Alamos National Laboratory (LANL), as well as new proposals for measurements with higher sensitivity. Peter Golden of ILL provided a special twist to the topic with his results on the efficient guiding capabilities for ultracold neutrons (UCNs) using coated commercial Russian water hoses.

The search for permanent electric dipole moments (EDMs) of fundamental particles was discussed by several speakers, who covered the majority of the present worldwide efforts. Michael Ramsey-Musolf of the University of Wisconsin discussed the paramount importance of permanent EDMs and their cosmological implications, and he set the scene for several talks on the experimental searches for a neutron EDM at ILL, the Spallation Neutron Source, PSI, Osaka and TRIUMF. Ben Sauer of Imperial College showed new data on the search for the electron EDM in ytterbium fluoride, while Blayne Heckel reported on activities to improve on the present world record in the experiment on mercury at the University of Washington. Future directions for EDM searches and co-magnetometers using ^{129}Xe or neutron crystal-diffraction were introduced in further talks, as well as in posters.

Part of the workshop was devoted to violations of space–time symmetry. Ralf Lehnert of Universidad Nacional Autónoma de México outlined the theoretical framework of the extension to the Standard Model that causes oriented universal fields, which could typically manifest themselves in daily or yearly time variations of physics observables. On the experimental side, Michael Romalis of Princeton University and Werner Heil of the University of ▷

PSI2010

Mainz presented impressive new limits from searches for violations in Lorentz symmetry in clock-comparison experiments using, respectively, the $K\text{-}^3\text{He}$ system and ^{129}Xe and ^3He .

Searches for extra forces were introduced by Hartmut Abele of the Technical University Vienna, who described using gravitational states of UCNs, while Anatoli Serebrov of the Petersburg Nuclear Physics Institute (PNPI) discussed the potential of stored UCNs for detecting dark matter. Several presentations also covered the search for tensor-type weak currents in nuclear beta-decay, using the WITCH experiment at ISOLDE at CERN and the LPCTrap facility at GANIL. Seth Hoedl of the University of Washington showed new results of an axion search based on a torsion pendulum. There were also reports on the status of the ALPHA and ASACUSA experiments at CERN, which aim at atomic spectroscopy of antihydrogen and related CPT tests and CERN's Michael Doser explained the AEGIS experiment to probe gravity with antihydrogen.

On the facilities side, a special session provided an excellent overview of the present status of UCNs – a flourishing global area. This included reports on the performance of UCN sources in operation at LANL and the University of Mainz, as well as on the status of construction at the Technical University Munich and commissioning at PSI. Proposals for future UCN sources at the Japan Proton Accelerator Research Complex (J-PARC), TRIUMF and the PNPI were also shown at the workshop.

Several sessions were devoted to muon physics. Peter-Raymond Kettle of PSI reported on the latest results of the MEG experiment searching for the lepton-flavour violating $\mu \rightarrow e + \gamma$ decay (*CERN Courier* July/August 2004 p21). The community is currently planning ahead for the next generation of searches for rare muon decays, as became clear when Bob Bernstein from Fermilab explained the Mu2e proposal, which will search for the neutrinoless conversion of muons to electrons, and Andre Schöning of Heidelberg University suggested a new $\mu \rightarrow 3e$ search at PSI. Efforts towards considerably higher muon beam intensities were presented for the Research Centre for Nuclear Physics at Osaka, J-PARC and PSI, and Harry Van der Graaf of Nikhef presented new silicon-gas detectors that could be used at such future facilities.

In one of the highlights, Dave Hertzog from University of Washington presented the newly released final result on the muon lifetime from the MuLan experiment at PSI, which gives a new determination to 0.6 ppm of the Fermi weak coupling constant. The competing muon lifetime experiment at PSI, FAST, was presented by Eusebio Sanchez of CIEMAT, who showed the current status of the analysis and gave the outlook for results expected soon.

Laura Marcucci of the University of Pisa explained the motivations for precision measurements in muon capture in the context of theoretical efforts in effective field theory, while Peter Winter of the University of Washington detailed the on-going MuSun experiment to determine precisely the rate of muon capture in deuterium. Results and opportunities from pion decays were discussed by Dinco Pocanic of Virginia.

The new proton charge radius result from the muonic hydrogen Lambshift experiment, presented by Aldo Antognini of the Swiss Federal Institute of Technology (ETH) Zurich, revived a heated discussion about the results published earlier in 2010. Theory still struggles to explain the discrepancy between the muonic and ordi-

The conference dinner was accompanied by Swiss traditional alphorn sounds. Participants were also allowed to test their ability on these unique instruments.
(Image credit: PSI.)



nary hydrogen Lambshift results, both of which involve QED calculations. While optical hydrogen spectroscopy and QED appear to be in agreement with electron scattering data, the muonic hydrogen result, which is far more precise, is 5σ from the CODATA value. Antognini went on to explain how all systematic errors in the muonic experiment are found to be far below the observed difference.

Aside from the programme of talks, the poster session provoked lively discussions among participants, enhanced by locally brewed draught beer and grilled specialities. There was also the opportunity to gather at organized evening events. In particular, a special trumpet concert linked music to physics through the performance of modern interpretations of Baroque master-works and through the demonstration of acoustic phenomena in a special quadrophonia opus composed by one of the performers, Eckhard Kopetzki. The workshop dinner took place at the local historic grape-pressing cellar (Trotte), an easy stroll from the workshop site. The Swiss speciality of raclette cheese was served freshly melted accompanied by the sounds of alphorns.

Many participants expressed their wish for a repeat of this low-energy precision physics workshop at PSI – the best indication of the workshop's success. This also showed the growing interest in the field, in which various experiments and particle sources will soon come online.

Résumé

Aux frontières de la précision à basses énergies

PSI2010, le deuxième Atelier international sur la physique des symétries et des interactions fondamentales, dédié à la précision à basses énergies, a rassemblé plus de 140 expérimentateurs et théoriciens à l'Institut Paul Scherrer (PSI). Le thème central de cette rencontre était la recherche de la précision expérimentale, la matière étant sondée par différents moyens : neutrons, antiprotons, muons, atomes, molécules et même échantillons de matière condensée. Cela a été l'occasion de présenter toute une gamme de mesures de haute précision à basses énergies, qui pourraient constituer un axe de recherche important pour la nouvelle physique à l'ère du LHC.

Klaus Kirch, ETH Zurich and PSI, **Bernhard Lauss** and **Stefan Ritt**, PSI.

FACET shows the way in accelerator research

By addressing key questions for a plasma wakefield accelerator, the Facility for Accelerator Science and Experimental Tests (FACET) at SLAC will help a scientific concept with extraordinary potential to become the accelerator technology of the 21st century.

In their quest to learn more about the fundamental nature of matter, high-energy physicists have developed particle accelerators to reach ever higher energies to allow them to “see” how matter behaved in the extreme conditions that existed in the very early universe. The LHC at CERN has set the latest record for this “energy frontier” in particle physics, but looking beyond the LHC affordable colliders operating at ever larger centre-of-mass energies will call for new – perhaps even radical – approaches to particle acceleration.

In the past decade, the plasma wakefield accelerator (PWFA) has emerged as one such promising approach, thanks to the spectacular experimental progress at the Final Focus Test Beam (FFTB) facility at the SLAC National Accelerator Laboratory. Experiments there have shown that plasma waves or wakes generated by high-energy particle beams can accelerate and focus both high-energy electrons and positrons. Accelerating wakefields in excess of 50 GeV/m – roughly 3000 times the gradient in the SLAC linac – have been sustained in a metre-scale PWFA to give, for the first time using an advanced acceleration scheme, electron energy gains of interest to high-energy physicists (*CERN Courier* June 2007 p28).

To develop the potential of the PWFA and other exploratory advanced concepts for particle acceleration further, the US Department of Energy recently approved the construction of a new high-energy beam facility at SLAC: the Facility for Accelerator Science and Experimental Tests (FACET). It will provide electron and positron beams of high energy density, which are particularly well suited for next-generation experiments on the PWFA (Hogan *et al.* 2010).

In 2006 the FFTB facility was decommissioned to accommodate the construction of the Linac Coherent Light Source (LCLS) – the world’s first hard X-ray free-electron laser (*CERN Courier* December 2010 p17). The new FACET facility is located upstream

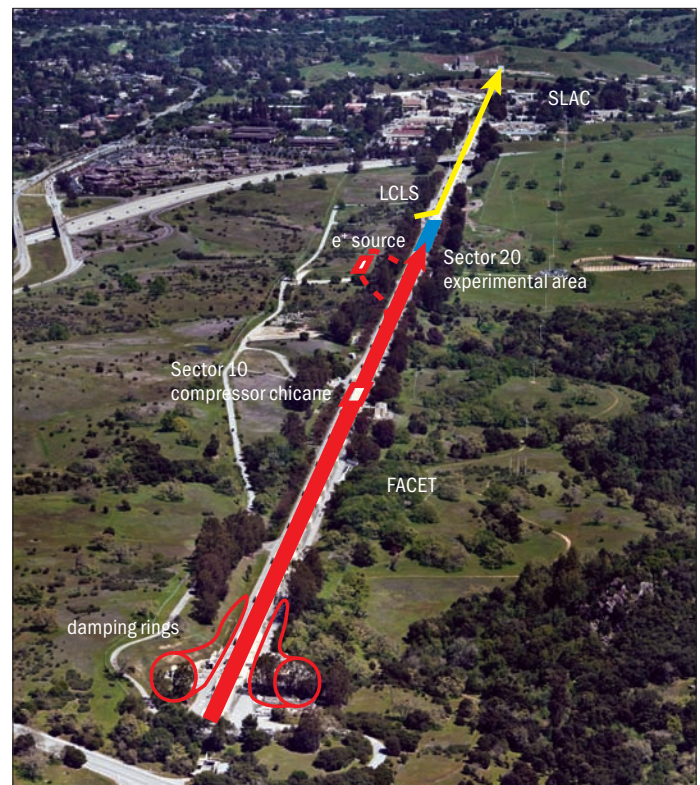


Fig. 1. Aerial view of SLAC showing the location of FACET, which will use the first 2 km of the main linac (red) to deliver high-energy electron and positron beams to a new experimental area (blue). The LCLS X-ray laser (yellow) uses the final kilometre of the SLAC linac. (Image credit: SLAC.)

of the injector for the LCLS (figure 1). It uses the first 2 km of the SLAC linac to deliver 23 GeV electron and positron beams to a new experimental area at Sector 20 in the existing linac tunnel. By installing a new focusing system and compressor chicane at Sector 20, the electron beam can be focused to 10 μm and compressed to less than 50 fs – dimensions appropriate for research on a high-gradient PWFA. Comparable positron beams will be provided with the addition of an upstream positron bunch-compressor in Sector 10. Peak intensities greater than 10^{21} W/cm² at a pulse repetition rate of 30 Hz will be routinely available at the final focus of FACET. Electron and positron beams of such high energy-density are not available to researchers anywhere else in the world.

The construction phase of the FACET project started in July ▷

Advanced accelerators

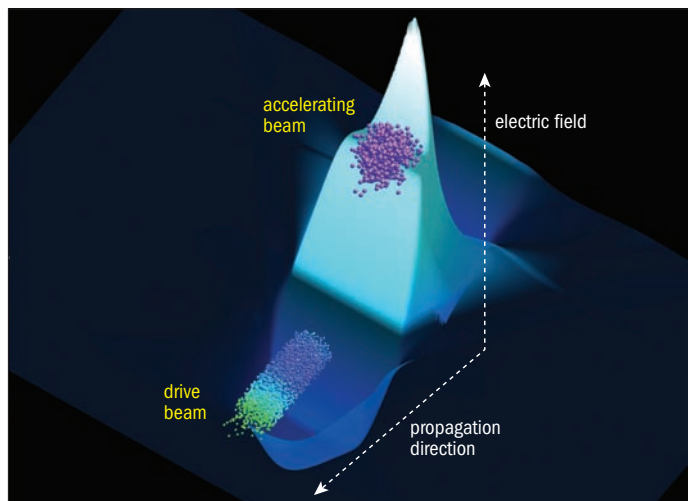


Fig. 2. The principle of plasma wakefield acceleration. The propagation of a short but intense electron drive-beam through a plasma produces a wake. The beam particles in the drive beam lose energy in exciting the wake, whereas the particles at the back – the accelerating beam – gain energy as the longitudinal electric field reverses its sign. (Image credit: F Tsung/UCLA.)

2010 and should finish in April this year. Beam commissioning will follow and the first experiments are expected to begin in the summer. A recently completed shielding wall at the end of Sector 20 allows simultaneous operation of FACET and the LCLS.

The FACET beam will offer new scientific opportunities not only in plasma wakefield acceleration but also in dielectric wakefield acceleration, investigation of material properties under extreme conditions and novel radiation sources. To get a head start on the research opportunities, university researchers and SLAC physicists met at SLAC in March 2010 for the first FACET Users Workshop. This was the first opportunity for SLAC to unveil details about FACET's capabilities and for the visiting scientists to outline their research needs. Beam time will be allocated using an annual, peer-reviewed proposal process.

The plasma wakefield technique

In the PWFA a short but dense bunch of highly relativistic charged particles produces a space-charge density wave or a wake as it propagates through a plasma. As figure 2 shows, the head of the single bunch ionizes a column of gas – lithium vapour – to create the electrically neutral plasma and then expels the plasma electrons to set up the wakefield. As the plasma electrons rush outward, they create a longitudinally decelerating electric field that extracts energy from the head of the bunch. The plasma ions that are left behind create a restoring force that draws the plasma electrons back to the beam axis. When the electrons rush inwards, they create a longitudinally accelerating field in the back half of the wake, which returns energy to the particles in the back of the same bunch or alternately to a distinct second accelerating bunch. The plasma thus acts as an energy transformer.

The FFTB plasma wakefield experiments used a single 20 kA electron drive bunch to excite 50 GeV/m wakes in plasma of density $2.7 \times 10^{17} \text{ e}^-/\text{cm}^3$. Energy was transferred from the particles in

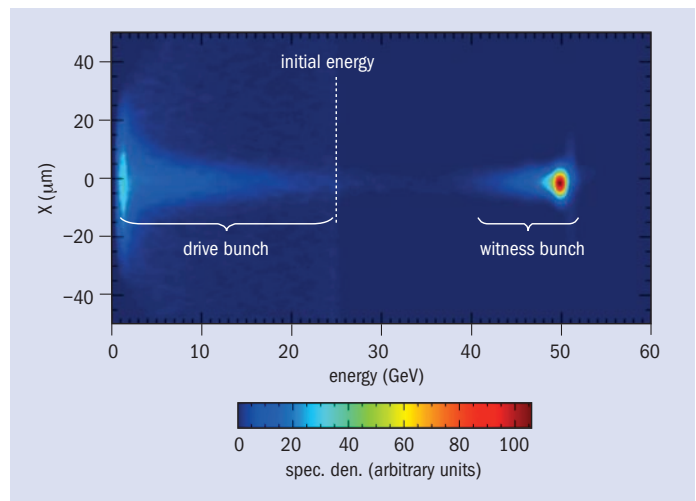


Fig. 3. Computer simulations of the change in energy experienced by drive and trailing beams, initially of 23 GeV, as they propagate through a metre-scale plasma. The drive beam loses nearly all of its energy in exciting the wake, whereas the trailing beam doubles its energy to nearly 50 GeV while maintaining a narrow energy spread (Hogan et al. 2010).

the front of the bunch to the particles in the tail of the same bunch via the wakefield. These experiments verified that the accelerating gradient scales inversely with the square of the bunch length and demonstrated that these large fields can be sustained over distances of a metre, leading to doubling of the energy of the initially 42 GeV electrons in the trailing part of the drive bunch.

Plasma wakefield acceleration will be a major area of research at FACET. Simply put, this research will strive to answer most of the outstanding physics issues for high-gradient plasma acceleration of both electrons and positrons, so that the potential for a PWFA as a technology for a future collider can be realistically assessed. The main goal of these future experiments is to demonstrate that plasma wakefield acceleration can not only provide an energy gain of giga-electron-volts for electron and positron bunches in a single, compact plasma stage, but can also accelerate a significant charge while preserving the emittance and energy spread of the beam.

The plasma wakefield experiments on FACET will need two distinct bunches, each about 100 fs long separated by about 300 fs. The first contains about 10 kA of peak current both to produce a uniform, metre-long column of plasma and then to drive the wake. The second bunch, which extracts energy from the wake, has a variable peak current. The sub-100 fs bunches needed for plasma wakefield acceleration are generated at FACET through a three-stage compression process that continually manipulates the longitudinal phase space so as to exchange correlated energy spread for bunch length, in a process called “chirped pulse compression”. There will be an additional collimation system within the final compression stage at FACET and the collimation in the transverse plane will result in structures in the temporal distribution of the final compressed bunch(es).

In this way FACET will produce two co-propagating bunches. By adjusting the charge and duration of the witness bunch, FACET will be able to pass from the regime of negligible beam-loading

Advanced accelerators

that has been studied so far to beam acceleration with strong wake-loading. By loading down or flattening the accelerating wakefield, FACET will accelerate the witness bunch with a narrow, well defined, energy spread as the simulation in figure 3 shows.

Key beam properties

High-energy physics applications require not only high energies but also high beam power to deliver sufficient luminosity. For a linear collider with an energy of tera-electron-volts in the centre-of-mass this translates to nearly 20 MW of beam power for a luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. When combined with the efficiencies of other subsystems (wall-plug to klystron to drive beam), maximizing the efficiency of the plasma interaction will be a crucial element in keeping down the overall costs of the facility. For example, a recent conceptual design for a PWFA-based linear collider (PWFA-LC) used a drive-beam-to-witness-beam coupling of 60% to achieve an overall efficiency of 15% (Seryi *et al.* 2009). Theoretical models and computer simulations have estimated the efficiency of the plasma interaction to be on the order of 60% for Gaussian beams and approaching 90% for specifically tailored current profiles (Tzoufras *et al.* 2008).

Improving accelerator performance using spatially and temporally shaped pulses is one of the forefronts of research in beam physics that can be explored at FACET. Tailoring the current profile of the drive beam allows the plasma to extract energy at a uni-

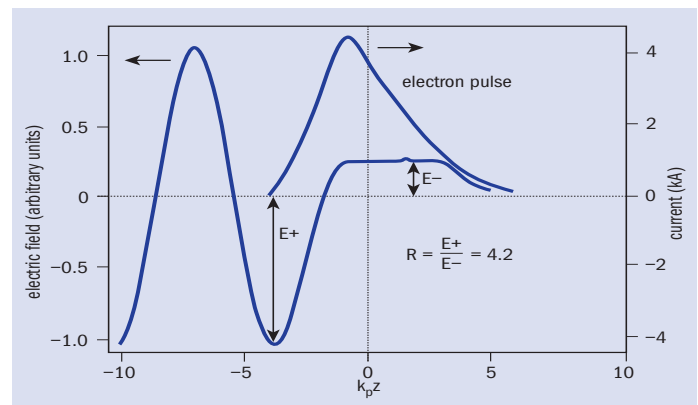


Fig. 4. Shaped electron bunches – with a long rise time and a shorter fall time – can be generated at FACET. Such bunches can produce wakes that have a transformer ratio, $R > 4$.

form rate along the bunch so as to maximize the overall efficiency. Figure 4 shows an example of such a tailored current profile for FACET and the accompanying simulated plasma wake. Bunch shaping has the added benefit of increasing the transformer ratio – that is, the ratio of the peak accelerating field divided by the peak decelerating field. A larger transformer ratio will lead to more energy gain per plasma stage. Finally, tailoring the profile of the witness beam loads the accelerating wakefield to produce the ▷

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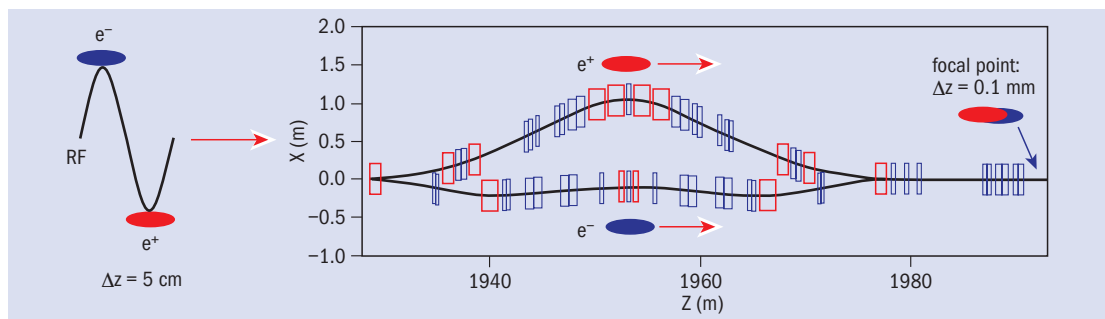


Fig. 5. A possible upgrade to the FACET beamline will add a second (top) chicane to the existing (bottom) chicane, allowing precise positioning of a positron bunch behind an electron bunch or vice versa.

desired narrow energy spread.

In addition to high beam power, the luminosity needed to do physics at the energy frontier will require state-of-the-art emittance with final beam sizes in the nanometre range. The ion column left in the wake of the drive beam provides a focusing channel with strong focusing gradients (MT/m for 10^{17} e-/cm³) that are linear in radius and constant along the bunch. This ion column allows a trailing witness bunch to propagate over many betatron wavelengths in a region free of geometric aberrations and emittance growth. There are however other sources of emittance growth in the PWFA. For instance, hosing instability (in which any transverse displacement of the beam slices grows as the beam propagates) between the beam and the wake, motion of the plasma ions in response to the dense beam, synchrotron radiation and multiple-Coulomb scattering can all lead to emittance growth. For a plasma accelerator at a few tera-electron-volts, the latter two effects have been shown to be negligible for appropriately injected beams. Experiments at FACET will determine the influence of the electron hose instability and the ion motion on emittance growth.

Positron acceleration

Although plasma wakefield acceleration may find applications in areas other than high-energy physics, such as compact X-FELs, collider applications will require plasmas to accelerate not only electrons, but also positrons. Studies have already shown that relatively long positron bunches can create wakefields analogous to the electron case, which can be used to accelerate particles over distances of a metre or so with energy gains approaching 100 MeV (Blue *et al.* 2003). The response of the plasma to the incoming positron beam is different than for an electron beam. In the positron case, the plasma electrons are drawn in towards the beam core. This leads to fields that vary nonlinearly in radius and position along the bunch, resulting in halo formation and emittance growth (Hogan *et al.* 2003 and Muggli *et al.* 2008). FACET will be the first facility in the world to deliver compressed positron bunches suitable for studying positron acceleration with gradients of giga-electron-volts per metre in high-density plasmas.

Recent studies have shown that there may be an advantage in accelerating positrons in the correct phase of the periodic wakes produced by an electron drive beam. A simple yet elegant study of this concept will be done at FACET by placing a converter target at the entrance of the plasma cell and allowing the trailing witness beam to create an e-/e+ shower. The positrons born at the correct phase will ride the wake of multi-giga-electron-volts/metre through the plasma and emerge from the downstream end with a potentially

narrow energy spread and emittance (Wang *et al.* 2008). In the longer term, FACET has been designed to allow an upgrade to the Sector 20 beam line, called a “sailboat chicane”, which will allow electron and positron bunches from the SLAC linac to be delivered simultaneously to the plasma entrance with varying separation in time (figure 5). By switching the bunch order and delivering the compressed positron beam to the plasma first, FACET can also study the physics of proton-driven plasma wakefield acceleration (CERN Courier March 2010 p7). The combination of high energy, and high peak-current electron and positron beams will make FACET the premier facility in the world for studying advanced accelerator concepts and lead the way in turning plasma wakefield acceleration into a future accelerator technology.

• Work supported by the US Department of Energy under contract numbers DE-AC02-76SF00515 and DE-FG02-92ER40727.

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Résumé

FACET : à la pointe de la recherche sur les accélérateurs

Durant la dernière décennie, la technique d'accélération par champ de sillage plasma (PWFA) est apparue comme une voie prometteuse pour atteindre des énergies dépassant les limites actuelles de la technologie des collisionneurs. Afin de développer le potentiel de ce mode d'accélération, ainsi que d'autres concepts d'avant-garde pour l'accélération des particules, le ministère de l'Énergie des États-Unis a récemment approuvé la construction d'une nouvelle installation pour faisceau de haute énergie au SLAC National Accelerator Laboratory. FACET (Installation pour la science des accélérateurs et les essais expérimentaux) fournira des faisceaux d'électrons et de positons à haute densité d'énergie, qui seront particulièrement adaptés aux expériences de la prochaine génération sur l'accélération par champ de sillage plasma.

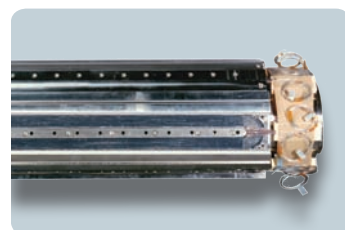
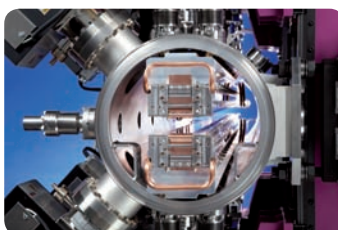
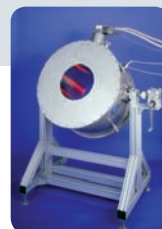
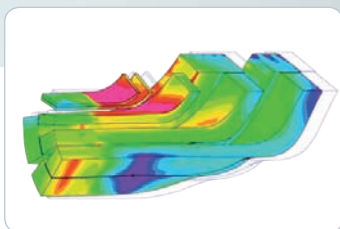
Mark Hogan, SLAC, Chan Joshi, University of California Los Angeles, and Patric Muggli, University of Southern California.



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The world's biggest IceC

Embedded deep in the ice at the South Pole, the kilometre-sized IceCube detector is now fully functioning after six years of construction in a challenging and harsh environment. It is already delivering some intriguing results.

On 18 December 2010, just after 6 p.m. New Zealand time, seven austral summers of construction came to an end as the last of 86 optical sensor strings was lowered into the Antarctic ice – IceCube was complete, a decade after the collaboration submitted the proposal. A cubic kilometre of ice has now been fully instrumented with 5160 optical sensors built to detect the Cherenkov light from charged particles produced in high-energy neutrino interactions.

The rationale for IceCube is to solve an almost century-old mystery: to find the sources of galactic and extragalactic cosmic rays. Neutrinos are the ideal cosmic messengers. Unlike charged cosmic rays they travel without deflection and, as they are weakly interacting, arrive at Earth from the Hubble distance. The flip side of their weak interaction with matter is that it takes a very large detector to observe them – this is where the 1 km³ of ice comes in. The IceCube proposal argues that 1 km³ is required to reach a sensitivity to cosmic sources after several years of operation. This volume will allow IceCube to study atmospheric muons and neutrinos while searching for extra-terrestrial neutrinos with unprecedented sensitivity.

How it works

The concept is simple. A total of 5160 optical sensors turn a cubic kilometre of natural Antarctic ice into a 3D tracking calorimeter, measuring energy deposition by the amount of Cherenkov light emitted by charged particles. Each sensor is a complete, independent detector – almost like a small satellite – containing a photomultiplier tube 25 cm in diameter, digitization and control electronics, and built-in calibration equipment, including 12 LEDs.

Designing these digital optical modules (DOMs) was not easy. As well as the requirement for a high sampling speed of 300 million samples a second and a timing resolution better than 5 ns across the array (the actual time resolution is better than 3 ns), the DOMs needed to have the reliability of a satellite but on a much smaller budget. They were designed with a 15-year lifetime and operate from room temperature down to –55 °C, all the while using less than 5 W. This power per DOM may not sound like much, but it mounts up to about 10 planeloads of fuel a year. Nevertheless,

the design was good, and 98% of the IceCube DOMs are working perfectly, with another 1% usable. Since the first deployments in January 2005, only a few DOMs have failed, so the 15-year lifetime should be met easily.

Building the DOMs was only the first challenge. Because the shallow ice contains air bubbles, the DOMs must be placed deep, between 1450 and 2450 m below the surface. The sensors are deployed on strings, each containing 60 DOMs spaced vertically at 17 m intervals. Pairs of DOMs communicate with the surface via twisted pairs that transmit power, data, control signals and bidirectional timing calibration pulses. The 78 “original” strings are laid out on a 125 m triangular grid, covering 1 km² on the surface. The remaining eight strings are then placed in the centre of IceCube, with a dense packing of 50 high-quantum-efficiency DOMs covering the bottom 350 m of the detector. This more densely instrumented volume, known as DeepCore, will be sensitive to neutrinos with energies as low as 10 GeV, which is an order of magnitude below the threshold for the rest of the array.

Speed was vital because the construction season is necessarily short in Antarctica.

The key to assembling the detector was a fast drill. Hot water does the trick: a 200 gal/min stream of 88°C water can melt a hole 60 cm in diameter and 2500 m deep in about 40 hours. It takes another 12 hours to attach the DOMs to the cable and lower them to depth. This proved fast enough to drill 20 holes in roughly two months.

Speed was vital because the construction season is necessarily short in this region – the Amundsen-Scott South Pole Station is accessible by plane for only four and a half months a year. Add the time to set up the drill at the start of the season and take it down at the end, and less than two months are left for drilling.

This brief description does not do justice to the host of difficulties faced by the construction crew. First, hot water drills are not sold at hardware stores – many human-years of effort went into developing a reliable, fuel-efficient system. Second, the South Pole is one of the least hospitable places on Earth. Every piece of equipment and every gallon of fuel is flown in from

McMurdo station, 1500 km away on the Antarctic coast. The altitude of 2800 m and the need to land on skis limited the cargo that could be carried: everything had to fit inside an LC130 turboprop plane. The weather also complicates operations. Typical summer temperatures are between –15 °C and –45 °C, which is hard on both people and equipment. The need for warm



Cube is ready for action



Making their mark: the final digital optical module to be deployed on IceCube was signed by members of the crew. (Image credit: IceCube.)

clothing further exacerbates the effect of the high altitude; many tasks become challenging when you are wearing thick gloves and 10 kg of extreme cold weather gear.

Against the odds

Nevertheless the collaboration succeeded. From the humble single string deployed in 2005 (and, incidentally, adequate by itself to see the first neutrinos), construction ramped up every year, reaching a peak of 20 strings deployed during the 2009/2010 season. This was good enough to allow for a shorter season this final year, leaving time to clean up and prepare the drill for long-term storage.

Even though IceCube has just been completed, the collaboration has been actively analysing data taken with the partially completed detector. This is also no simple matter. Even at IceCube's depths, there are roughly a million times as many downwards-going

muons produced in cosmic-ray air showers as there are upwards-going muons from neutrino interactions in the rock and ice below IceCube. To avoid false neutrino tracks, IceCube analysts must be extremely efficient at avoiding misreconstructed events. Worse still, IceCube is big enough to observe two or more muons, from different cosmic-ray interactions, simultaneously. Still, with stringent cuts to reject background events, it is possible to select an almost pure neutrino sample. In a one-year sample, taken with half of the full detector, IceCube collected more than 20 000 neutrinos. This sample was used to extend measurements of the atmospheric neutrino spectrum to an energy of 400 TeV. The events are being scrutinized for any deviation from the anticipated flux that would mean evidence of new neutrino physics or, on the more exotic side, deviations in neutrino arrival directions that could signal a breakdown of Lorentz invariance or Einstein's equivalence principle. ▷

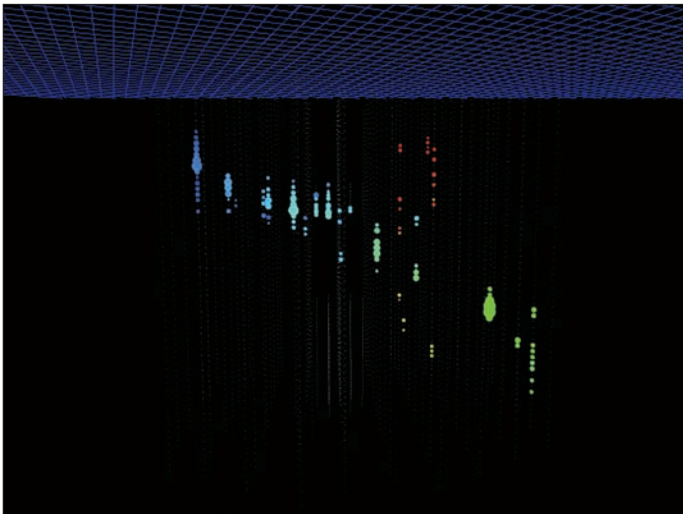
Neutrinos



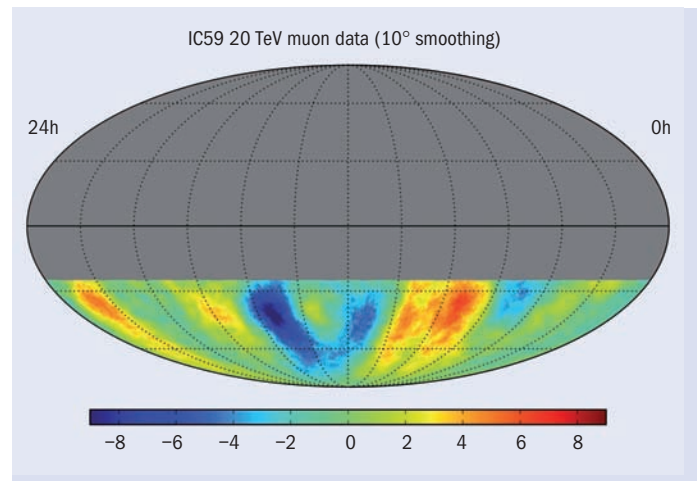
IceCube drillers wrestle the drill hose sections into position. (Image credit: Jim Haugen.)



The drill head being removed from Hole 80, the final IceCube hole to be drilled. (Image credit: Jim Haugen.)



An early upwards-going muon observed by the full 86-string detector. Each dot is one DOM. The size of the circle represents the number of photoelectrons observed, while the colour shows the time, going from the earliest (red) to the latest (blue).



A muon sky map made with 32 million muons observed with 59 detector strings. Cosmic-ray anisotropies are clearly apparent.

With the 40-string event sample the collaboration has produced a map of the neutrino sky that has been examined for evidence of suspected cosmic-ray accelerators. None have been found, although it is important to realize that at this stage no signal is expected at a significant statistical level. For instance, we have reached a sensitivity that can observe a single cosmogenic neutrino for the higher end of the range of fluxes calculated. We have also started to probe the neutrino flux predicted from gamma-ray bursts, assuming that they are the sources of the highest-energy cosmic rays.

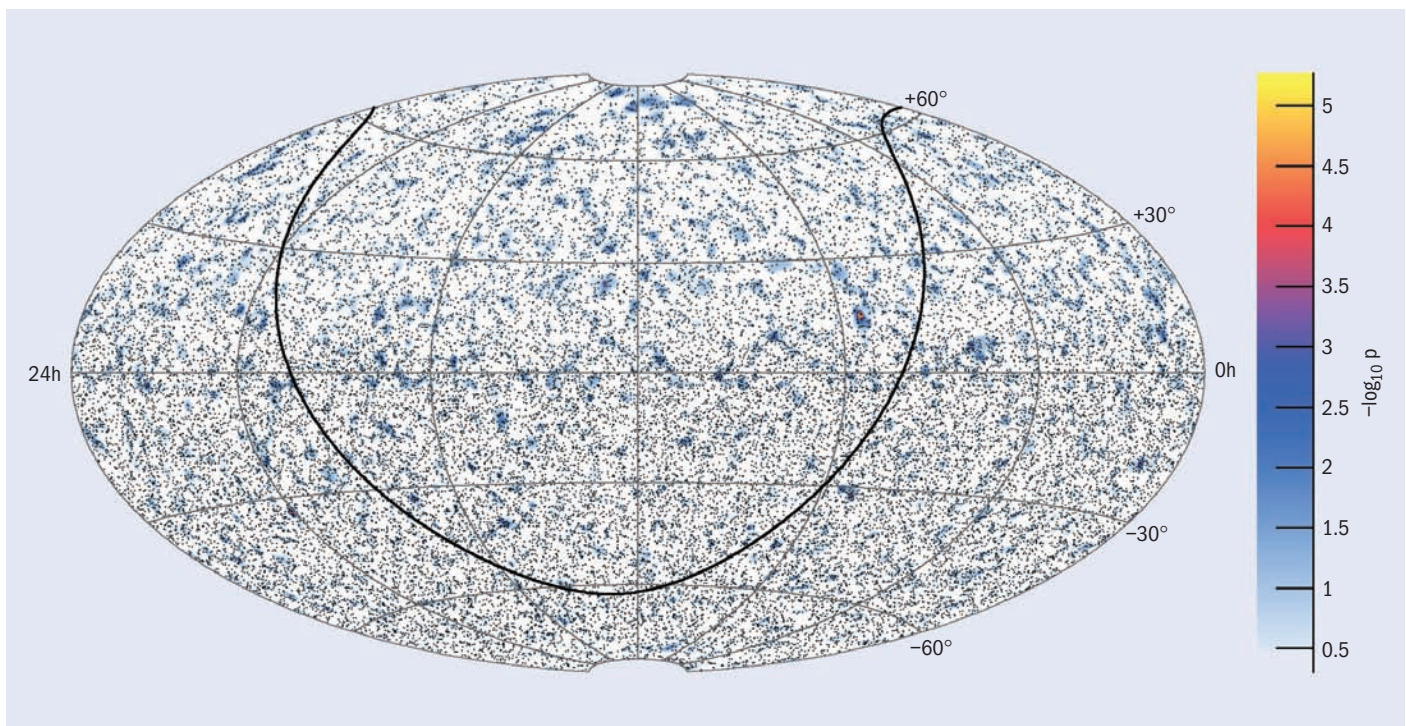
The first surprise from IceCube does not involve neutrinos at all. IceCube triggers on cosmic-ray muons at a rate of about 2 kHz, thus collecting billions of events a year. These muons have energies of tens of tera-electron-volts and are produced in atmospheric interactions by cosmic rays with energies of hundreds of tera-electron-volts, i.e. the highest-energy Galactic cosmic rays. A skymap of well reconstructed muons with an average energy of 20 TeV reveals a rich structure with a dominant excess in arrival directions pointing at the Vela region. These muons come from cosmic

rays with energies of many tens to hundreds of tera-electron-volts; the gyroradius of these particles in the microgauss field of the galaxy is in the order of 0.1 parsec, too large to be affected by our solar neighbourhood. However, these radii are too small to expect that the cosmic rays would point back even to the nearest star,

Analysing and simulating data from an instrument that changed every Antarctic season has been a challenge.

never mind a candidate source like the Vela pulsar or any other distant source remnant at more than 100 parsec.

There is some mystery here: either we do not understand propagation in the field, or we do not understand the field itself. Does the detector work? Definitely: we observe in the same data sample the Moon's shadow in cosmic rays at more than 10σ , as well as the dipole



A neutrino sky map (in declination and right ascension) based on a year of data taken with 40 IceCube strings. The northern hemisphere contains 14 139 neutrino candidates (which are mostly atmospheric neutrinos). The southern hemisphere includes 23 151 events selected on the basis of high-energy deposition; these are mainly downwards-going neutrinos. None of the “hot spots” are statistically significant. The thick, solid line is the galactic plane. (Image credit: Jon Dumm.)

resulting from the motion of the Earth around the Sun relative to the cosmic rays.

Additionally, IceCube has established the tightest limits yet on the existence of dark matter, which consists of weakly interacting massive particles that have spin-dependent interactions with ordinary matter. In the alternative case – dominant spin-independent interactions – IceCube’s limits are almost competitive with direct searches. In addition, by monitoring the signal rates from its photomultiplier tubes, IceCube will be sensitive to million-electron-volt energy neutrinos from supernova explosions anywhere in the galaxy.

Looking forward

Now the 220-strong IceCube collaboration – with members from the US, Belgium, Germany, Sweden, Barbados, Canada, Japan, New Zealand, Switzerland and the UK – is eagerly looking forward to analysing data from a complete and stable detector. Analysing and simulating data from an instrument that changed every Antarctic season has been a challenge.

At the same time, neutrino astronomers are thinking about the future. Even IceCube is too small to collect a significant number of events at the highest energies. This has already been pointed out in the case of cosmogenic neutrinos with typical energies in excess of 10^6 TeV. These are produced when ultra-high-energy cosmic rays interact with photons in the cosmic microwave background. To observe these neutrinos requires a much larger detector. Physicists are aiming for a volume of 100 km^3 . This will require a new technology, and several groups are already deploying antennas to observe the brief coherent radio Cherenkov pulses emitted

by neutrino-induced showers. The advantages of radio detection are that the signal is coherent, so it scales as the neutrino energy squared. Also, the radio signals have larger attenuation lengths than light, allowing detectors to be placed on a 1 km, rather than 125 m, grid. The cost is that radiodetectors have energy thresholds that are much higher than IceCube.

● Further reading

For more about IceCube see the recent review article: F Halzen and S Klein 2010 *Rev. Sci. Instrum.* **81** 081101, and visit the website <http://icecube.wisc.edu>.

Résumé*

IceCube : un colosse dans les glaces

Le 18 décembre 2010 marquait la fin de la construction du détecteur IceCube, qui a duré sept saisons d’été austral dans un environnement rude et semé d’embûches. La dernière ligne de 86 capteurs de détection optique était descendue dans les glaces de l’Antarctique pour achever ce cube gigantesque. Un kilomètre cube de glace est maintenant équipé de 5160 capteurs optiques, qui détecteront le rayonnement Tchérenkov émis par des particules chargées provenant des interactions de neutrinos de haute énergie. Le détecteur géant a déjà produit des résultats, révélant notamment une étonnante structure sur une carte du ciel des muons cosmiques.

Francis Halzen, University of Wisconsin, and Spencer Klein, LBNL and University of California, Berkeley.



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Women in science through the decades

To celebrate the 100th anniversary of the first International Women's Day, we look at the crucial role that women have played in nuclear and particle physics during the past century.

Our story begins in 1911, with the first International Women's Day celebrated in Austria, Denmark, Germany and Switzerland. That same year, Marie Skłodowska-Curie won the Nobel Prize in Chemistry for the discovery of two new elements: radium and polonium. This was the second time that she had been called to Stockholm – eight years earlier, she received the Nobel Prize in Physics, which she and her husband Pierre Curie shared with Henri Becquerel for their research on radioactivity. The Nobel Prize in Chemistry has only been awarded to three other women: Curie's daughter Irène Joliot-Curie in 1935, Dorothy Crowfoot-Hodgkin in 1964 and Ada Yonath in 2009. The only other woman to receive the Nobel Prize in Physics is Maria Goeppert Mayer for her work on the structure of atomic nuclei (1963).

Marie Curie achieved several “firsts”. She was the first woman to receive the Nobel Prize (in 1903), the first person to receive it twice, the first female professor at the University of Paris and, as the photograph on this page shows, the only female among the 24 participants at the first international physics conference – the Solvay Conference – held in Brussels in 1911. A century later, the situation has changed. At the recent International Conference on High-Energy Physics, ICHEP2010 (*CERN Courier* November 2010 p19), 15.4% of the participants were women.

Nuclear physics pioneers

The 1940s and 1950s were exciting years in physics. The first accelerators were being built, and with them physicists took the first steps towards the current understanding of particle physics. At this challenging time after the Second World War, many women joined physics groups around the world and helped to open doors for the future generations of women in science.

Marietta Blau (1894–1970) pioneered work in photographic methods to study particle tracks and was the first to use nuclear emulsions to detect neutrons by observing recoil protons. Her request for a better position at Vienna University was rejected because she was a woman and a Jew. Blau left Austria and was



The Solvay Conference, 1911. Marie Curie, seated second from the right, was the only woman to attend the first international physics conference in Brussels. (Image credit: Photographie Benjamin Couprie, Institut International de Physique Solvay, courtesy AIP Emilio Segrè Visual Archives.)

appointed professor in Mexico City after the war. She was nominated for the Nobel Prize several times.

Nella Mortara (1893–1988), one of the most beloved assistant professors of physics at the University of Rome in the late 1930s, faced a similar ordeal and was expelled for being Jewish. She escaped to Brazil but returned secretly during the war to be reunited with her family in Rome, living in great danger. After the war Mortara

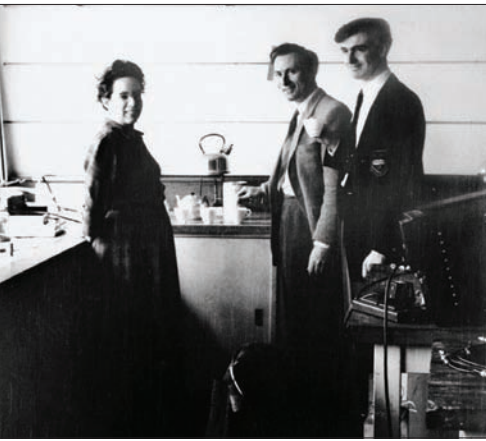
was reappointed as a professor, to the great joy of her students, many of whom were women.

Lise Meitner (1878–1968) also suffered from this double discrimination. She became the second woman to obtain a PhD from Vienna in 1903. She moved to Berlin where she was

Meitner was “allowed” by Max Planck to attend his lectures

“allowed” by Max Planck to attend his lectures – the first woman to be granted this privilege – and then later became his assistant. Many believe that Meitner should have been co-awarded the Nobel Prize in Chemistry with Otto Hahn in 1944 for the discovery of nuclear fission. She had the courage to refuse to work on the ▷

International Women's Day



Maria Fidecaro at the synchrocyclotron in Liverpool in 1955 with colleagues Alec Merrison and Alan Wetherell.



Hildred Blewett in the control room of the Proton Synchrotron at the start-up in November 1959, with (left to right): John Adams, Hans Geibel, Chris Schmelzer, Lloyd Smith, Wolfgang Schnell and Pierre Germain.



A typical CERN scene from the 1960s of women scanners hard at work on projection and measuring machines.

Manhattan Project, saying: "I will have nothing to do with a bomb!"

Maria Goeppert Mayer (1906–1972) lectured at prestigious universities, published numerous papers on quantum mechanics and chemical physics, and collaborated with her husband on an important textbook. Despite her accomplishments, antinepotism rules forbade Mayer from receiving an official post and for many years she taught physics at universities as an unpaid volunteer. Finally, in 1959, four years before receiving the Nobel Prize, the University of California at San Diego offered her a full-time position.

Leona Marshall Libby (1919–1986) was an innovative developer of nuclear technology. She built the tools that led to the discovery of cold neutrons and she also investigated isotope ratios. Libby was the first woman to be part of Enrico Fermi's team for the Manhattan Project and eventually became professor of physics at that institution, leaving a legacy of exploration and innovation.

Closer to particle physics, Hildred Blewett (1911–2004) was an accelerator physicist from Brookhaven. In the early 1950s she contributed to the design of CERN's first high-energy accelerator, the Proton Synchrotron, while also working on a similar machine proposed for Brookhaven (*CERN Courier* November 2009 p19).

Maria Fidecaro has spent her life dedicated to her research at CERN, where she still works. She arrived at CERN in 1956 after working in Rome on cosmic-ray experiments and, for a year, at the synchrocyclotron in Liverpool. Maria remembers fondly what it was like to be a physics student just after the war, the challenges of balancing a career with family and collaborating with other pioneers of modern physics from all over the world, including many women. "I remained dedicated to research throughout the changing circumstances," she says, "and always to the best of my ability."

These are just a few of the women physicists who were around during the mid-20th century; courageous women dedicated to their science, they served as role models for later generations.

Women and the growth of CERN

CERN was founded in 1954 during the post-war period of renewal. The CERN Convention was very modern because it mentioned all of the professional categories needed to form a large international

organization such as that which exists today. Women were initially recruited in supportive administrative positions, but this changed as they began to enter all areas of university training, physics and technical professions. CERN was willing to provide and encourage working opportunities for women, which they needed to be able to flourish in these new areas.

Between the 1960s and the mid-1980s, dozens of women worked at CERN and elsewhere as scanners. Their job consisted of finding interesting events among the many tracks left by particles in bubble chambers and captured on photographs. Madeleine Znoy recalls how tedious it was: "Initially, the work was done manually, using a pencil and a sheet of paper to note down the co-ordinates where the interactions had taken place. Scanning took place round

Initially, women were recruited in supportive administrative positions, but this changed.

the clock, because the quantity of films to be scanned was enormous. From 7 am to 10.00 p.m., female scanners studied the films, and from 10.00 p.m. until 7.00 a.m., men (often students) took over," she explains. Each shift lasted only four hours due to the work being so strenuous, working in complete darkness with three projectors illuminating the film. Znoy once beat a record, scanning more than 750 photographs in one day. "At first, some physicists thought that this was impossible, that surely I had missed interesting events. But all was fine and they were very surprised!"

Anita BJORKEBO started as a scanner in 1965. After her scanning shift she compiled data and classified events, all by hand, and even made the histograms.

Later, as scanning became more automated, the scanners moved on to operating the computers connected to the measuring equipment. Some, including BJORKEBO and Znoy, would set them up for other scanners or streamline the operation for new experiments. BJORKEBO became so interested in her work that she signed up for

International Women's Day



Many women scientists and engineers are working at CERN on the LHC and its experiments, as seen in these photos taken to celebrate International Women's Day in March 2010. Left: in the control room of LHCb. Right: in the CERN Control Centre.

two particle-physics classes, attending lectures and doing homework after work. "A Swedish physicist only had five students here so he invited the technical staff to join in," she explains.

Even though these women did not get their names on publications, they felt appreciated. "We were part of the team, we had a role to play," says Znoy proudly. "With the scanning, we could

really see the particles. I really enjoyed working with the physicists and technicians, and collaborating with other laboratories. We were young and full of enthusiasm. It was a great period."

Nevertheless, after more than 50 years, the situation for women at CERN could still be improved, especially in the intermediate administrative categories where they are most represented. ▷

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International Women's Day



More photos from International Women's Day 2010. In the control rooms of, from left to right, ALICE, ATLAS and CMS.

Recruitment in this area is now often based on standardized job criteria that leave less room to appreciate the level of education and professional skills needed for a post. However, the administrative staff category is essential to the day-to-day life of CERN. To function properly CERN depends on good communication within the organization, the dedication of its staff and proper advancement prospects at all levels. Danièle Lajust, an administrative assistant who joined CERN in 1978, is quick to add: "We are proud of belonging to an organization that now welcomes a gender mix at all levels and of participating in our own way in its great and passionate adventure."

Showing the way

CERN also has an important part to play in educating young scientists and hence providing role models. In 2000, Melissa Franklin, an alumna of the CERN Summer Student programme in 1977, returned as a lecturer on Classic Experiments. She then became the first tenured female professor of physics at Harvard University, and now works on the ATLAS experiment at CERN. Franklin's is just one of the many amazing careers experienced by former CERN summer students.

Started in 1962 by the then director-general of CERN, Viki Weisskopf, the Summer Student programme began with just 70 students. Nowadays, walk through any of the buildings at CERN in mid-July and you can see evidence of about 140 students participating in the programme. Although half of the students today are women, there are still only a handful of female lecturers – in 2010, only three of the 31 lecturers were women. Providing the summer students with adequate role models is just as important as enhancing diversity in their ranks, because the teachers, authors and educators that we encounter have a great influence on our lives and careers.

Today, women make up about 17% of the many thousand scientists, engineers and technicians who work on the LHC experiments, from graduate students to full professors. Nearly half of these women are students or post-docs, showing that more women are joining the field.

The day-to-day operation of the LHC is in the hands of eight "engineers in charge", half of whom are women. One of them, Giulia Papotti, thanks the management for having an open mind: "They were looking for someone with radio-frequency expertise, which is my field. Other considerations such as nationality or gender were secondary." It proved to be the greatest challenge of her career, training to be an LHC operator during the high-intensity

period of the first days of operation. "I had to learn fast," she recalls. The workload was additionally taxing because two people were still in training and two were on parental leave. "Our work is to think about how to improve things. We are meant to be critical. We are paid to think," says Papotti.

Amalia Ballarino, a scientist working on superconductivity, designed and managed the production of the high-temperature superconducting components that power the LHC magnets. For this work she won the international Superconductor Industry Person of the Year award in 2006 (*CERN Courier* July/August 2007 p37). "We had to work to a tight schedule," she says of building a system that consists of 3000 components made across the world. "Working at CERN gives you the opportunity to contribute to innovative projects. Basic science is the primary driver of innovation." Ballarino adds: "Working here is an opportunity to create something new." Lene Norderhaug, a CERN fellow working on software development and looking towards the future says enthusiastically: "In five years I hope to have my PhD and my second job at CERN. We like it here!"

Women in science have been passionate about their chosen field, undertaking tasks with great responsibility and continuously striving to push science and technology beyond their limits. Looking back on 100 years of International Women's Day, we have progressed from just one woman at a conference to females representing 17% of the field. What will the next 100 years bring?

Résumé

Les femmes de sciences du XX^e siècle

À l'occasion de la 100^e Journée internationale de la femme, cet article rend hommage aux femmes de sciences ayant joué un rôle déterminant en physique nucléaire et en physique des particules au siècle dernier. D'abord Marie Curie, qui recevait son deuxième prix Nobel il y a tout juste cent ans, puis les pionnières des années 30 et 40. Il est également question du rôle crucial des femmes chargées de détecter les événements produits dans les chambres à bulles. Enfin, à l'ère du LHC, les femmes apportent une contribution de plus en plus importante à la physique.

Pauline Gagnon (editor), Doris Chromek-Burckhart, Alessandra Ciocio, Lucie de Nooij, Monica Dunford, Paula Eerola, Despina Hatzifotiadou, Kerstin Jon-And, Danièle Lajust, Chiara Mariotti, Morna Robillard, Sarah Seif El Nasr Storey, Claudia-Elisabeth Wulz and Chiara Zampolli.

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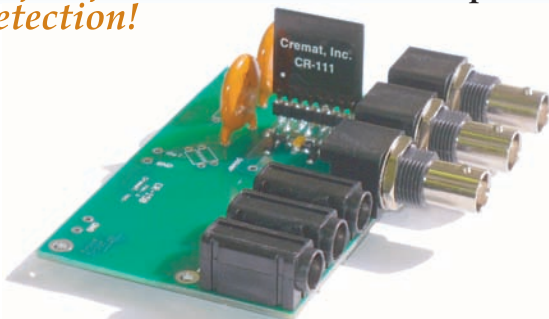
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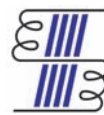
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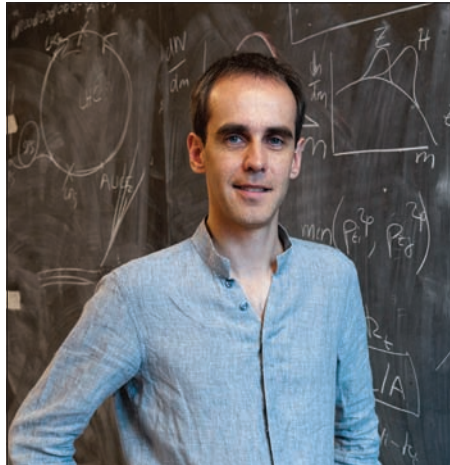
AWARDS

CNRS medals for particle and nuclear physics

The winners of the silver medals awarded for 2010 by the Centre national de la recherche scientifique (CNRS) include two researchers in the field of particle and nuclear physics. The awards are to recognize researchers for their originality and contributions on the national and international stages.

At 37, Gavin Salam is youngest of the 2010 medal winners. After studying at Cambridge University, where his thesis was on the energy distribution of quarks and gluons within high-energy protons, he moved on to the complementary problem of understanding the distribution of energy in quark fragmentation. He joined CNRS in 2000, in the Laboratory of Theoretical and High-Energy Physics attached to the University Pierre et Marie Curie in Paris. He is currently on a five-year attachment to CERN where he is continuing his research work in QCD.

Olivier Sorlin, of the Le Grand Accélérateur National d'Ions Lourds



Left: G Salam. Right: O Sorlin. (Image credit: CNRS Photothèque/Cyril Frésillon.)

(GANIL), submitted his thesis at the frontier of nuclear physics and astrophysics at the Institute of Nuclear Physics at Orsay in 1991. He joined GANIL in 2004 to search

for neutron-rich nuclei as found in stars and supernovae, as well as to put together a research programme for Spiral2, which is scheduled to start up in 2013.

CERN wins prizes for communication

Three different aspects of communication at CERN have received prizes for excellence.

In December, members of the Communication Group were in Prague to receive an EU European Excellence Award on behalf of CERN for the LHC First Physics event, during which the eyes of the world were on CERN as the first collisions at a total energy of 7 TeV took place in the LHC on 30 March (*CERN Courier* May 2010 p27). The prize, for the category on science and education, “rewards the cream of communications” in these areas.

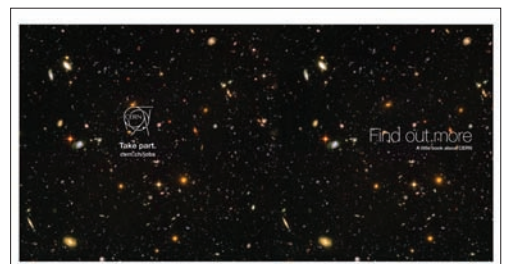
Earlier in the year, the website of the UK's Institute of Physics, *physics.org*, set out on a quest to find the best physics sites on the web, asking readers as well as a team of judges to vote for sites in various categories. The “people's choice” award for the best kids' site went to *CERNland*, CERN's interactive site for young people (*CERN Courier* May 2009 p35). The judges' award went to the *NASA Kids' Club* site.

Finally, one of the first awards to CERN for 2011 has gone to the Human Resources Department. Their new recruitment



Marie Anne Bugnon and Antonella del Rosso receive the European Excellence Award on behalf of the CERN Communication Group. (Image credit: European Excellence Awards.)

campaign, devised together with the agency Work Communications, took the top prize in two categories of the UK's Recruitment



Pages from the award-winning booklet, designed in conjunction with Work Communications.

Advertising Awards for 2011: recruitment literature and print advertisement (commercial).

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Faces & Places

**Lebrun named
Engineer of the Year**

Each year the French magazines *L'Usine Nouvelle* and *Industrie & Technologies*, in partnership with the National Council of the Engineers and the Scientists of France, organize the Engineers of the Year awards to honour exceptional engineers and highlight an often overlooked sector of society.

In December, CERN's Philippe Lebrun was one of eight scientists and engineers who were in Paris to receive the awards for



Philippe Lebrun (right) receives his award from Paul Boursier of InfoPro Communications. (Image credit: Pascal Guittet.)

2010. Lebrun received the Science prize for his work on the LHC's superconducting magnets and cryogenic cooling systems.

LIGHT SOURCES

**NSRRC celebrates 10th anniversary
of beamlines at SPring-8**

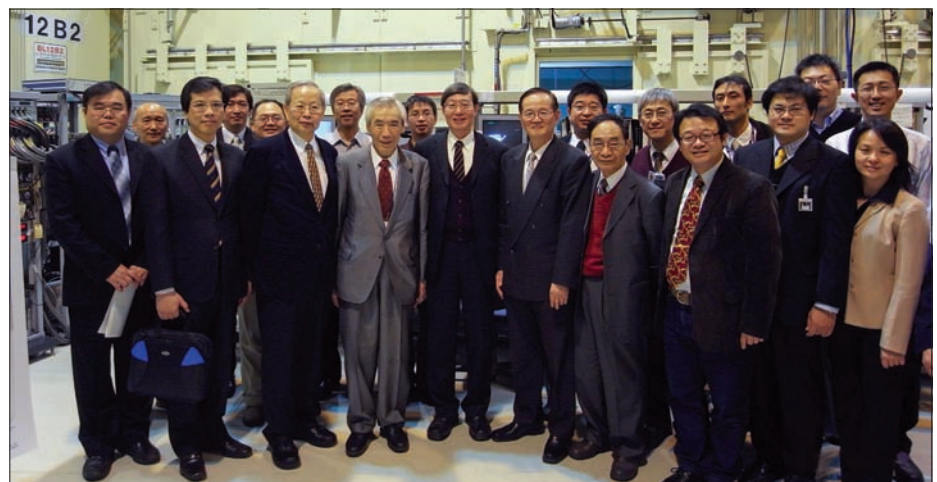
When the Taiwan Light Source (TLS) started up at the National Synchrotron Radiation Research Center (NSRRC) in 1993, it was clear that the need for a complementary high-energy photon flux would become increasingly urgent. The only realistic possibility pointed to the SPring-8 third-generation synchrotron-radiation facility of the Japan Synchrotron Radiation Research Institute (JASRI).

Chien-Te Chen, director of NSRRC from 1998 to 2005, the NSRRC management and governmental officials put together a proposal to build the Taiwan Beamlines (TW-BLs) at SPring-8 at a cost of \$9 million. This led to a memorandum for JASRI and the Asia and Pacific Council for Science and Technology (APCST), which was followed by agreements between APCST and NSRRC. These were signed on 18 December

1998, giving NSRRC control of 75–80% of the beam time, with the remaining time managed by SPring-8 for general users.

The first TW-BL (12B2), designed to provide time-resolved protein crystallography, was completed in 2000; the second (12XU) in 2002 was for inelastic X-ray scattering; and a side line (12XU) for hard X-ray photoemission spectroscopy started up in 2009.

On 22 December 2010, a celebration of the 10th anniversary of the TW-BLs was organized at SPring-8 by Di-Jing Huang, the deputy director, and hosted by Wen-Chang Chang, chair of the Board of Trustees, and Shih-Lin Chang, the director of NSRRC. The event gathered current and former staff from both facilities to reaffirm the long-lasting friendship and the effort to pursue further scientific collaboration.



Current and former members of staff gathered on 22 December to celebrate the 10th anniversary of the Taiwan Beamlines in SPring-8. (Image credit: NSRRC.)

ECFA STUDY

ECFA extends its linear collider study for another three years

The European Committee for Future Accelerators (ECFA) has extended the mandate of its Study of Physics and Detectors for a Linear Collider for another three years, from January 2011 to the end of 2013. The committee has also appointed a new chair to lead the study. Juan Fuster of Valencia has taken over from François Richard of the Laboratoire de l'Accélérateur Linéaire, Orsay, who was in charge from 2005. Fuster was responsible for high-energy physics funding in Spain during the period 2007–2010. A member of the ATLAS collaboration, he has been involved in the organization of ECFA workshops for this study for many years.

The ECFA study began in 1996 as the first Joint ECFA/DESY Study on Physics and Detectors for a Linear Collider, which held several workshops and reported the following year. A second joint study began in 1998 and was extended until 2003 (*CERN Courier* July/August 2001 p11). Since then, the study has continued as the ECFA study with regular workshops during two mandates, 2003–2005 and 2005–2010.

What has happened during the most recent period? The physics case for a light Higgs scenario has been studied to a high degree of realism using two detector concepts – named SiD and ILD – developed by international collaborations. This work demonstrated that by using the channel $e^+e^- \rightarrow ZH$, precise measurements can be achieved for the mass (to <100 MeV), cross-section (a few per cent) and branching ratios (a few per cent for all fermionic modes) of a Higgs particle with a mass of around 120 GeV, as predicted by theory and suggested from precision electroweak data. The case for top physics has also received growing attention because a linear collider allows precise and unique measurements of the mass (<100 MeV) and electroweak couplings (fraction of a per cent), giving a sensitive test for theories beyond the Standard Model. Searches for physics beyond the Standard Model have also been studied for a large variety of scenarios and have confirmed the potential of a linear collider for discovery and precision measurements.

Detector studies for a linear collider have received a considerable boost during this period, with the support of EU contracts



Juan Fuster (right) takes over from François Richard (left) as chair of the ECFA Study of Physics and Detectors for a Linear Collider. (Image credit: F Richard (left) and IFIC.)

(previously EUDET and now AIDA) and the creation of international collaborations such as CALICE, LC-TPC and others. These collaborations aim to develop ambitious subdetectors for both SiD and ILD, so as to achieve unprecedented performances for the tagging of flavours, momentum resolution and jet-energy reconstruction. The teams have built large prototypes and tested them at CERN, DESY, Fermilab, KEK and SLAC. Remarkably, these detectors – developed for the International Linear Collider (ILC) project operating at up to 1 TeV – are also able to satisfy the needs of a multi-tera-electron-volt collider, such as the Compact Linear Collider (CLIC) concept.

The regional studies (ECFA, ACFA in Asia and ALCPG in the Americas) are now co-operating more closely, with the installation of a research directorate for ILC detectors in 2007. This co-operation is also visible in the publication of the letters of intent from the detector groups in 2008, resulting in the approval of the ILD and SiD concepts.

The ECFA workshop in Valencia in 2006, with more than 400 participants, was for the first time a common meeting on activities for machine, detectors and physics. The Global Design Effort, in charge of preparing the technical design report for the ILC, has joined forces with the detector part, allowing the community to define better the requirements for the machine and in particular to strengthen activities at the “machine–detector interface”, which are extremely important for a linear collider. A

big challenge in this context was the decision to plan the ILC with only one interaction region, but serving two detectors in a so-called “push–pull” scheme.

Recognizing the need for a truly global approach towards the timely realization of a linear collider, the decision was made to have a common meeting under ECFA between CLIC and ILC at CERN in 2010. The resulting International Workshop on Linear Colliders (IWLC2010) was held in October, attracting around 500 participants (*CERN Courier* December p7). Building on its success, from now on there will be an annual common meeting among all linear-collider concepts organized in a global context. The next such meeting will take place this year in Granada on 26–30 September.

What are the prospects for these studies? As Rolf Heuer, CERN’s director-general, pointed out during IWLC2010, the future relies on the successful start of the LHC and discoveries there. This implies that the international linear-collider community should be ready by 2012 to propose a viable project for a machine with two detectors. CLIC will produce a Conceptual Design Report in 2011 based on modified SiD and ILD concepts, with the active participation of contributors from the ILC. By the end of 2012, the ILC will have both a Technical Design Report, for the machine, and a Detailed Baseline Design, for the two detectors.

● For more about the ECFA Study of Physics and Detectors for a Linear Collider, see www.desy.de/conferences/ecfa-ic-study.html.

Faces & Places

CONFERENCE

Montpellier QCD conference celebrates 25 years

The 15th High-Energy Physics International Conference on Quantum Chromodynamics, which was held in Montpellier last year, marked the 25th anniversary of the QCD Montpellier Conferences. It also provided the opportunity to celebrate the discovery 31 years ago of the powerful analytic method of QCD spectral-sum rules for hadron physics found by Mikhail Shifman, Arkady Vainshtein and Valentin Zakharov in 1979. The SVZ sum rules earned their discoverers the JJ Sakurai Prize of the American Physical Society in 1999.

This series of conferences was initiated by Stephan Narison in 1985 as the Montpellier Conference on Non-perturbative Methods. It regularly hosts around 100–120 participants, composed of equal numbers of theorists and experimentalists, mainly young doctoral and post-doctoral physicists from laboratories around the world that work actively in QCD.

Besides the part dedicated to the SVZ sum rules, the topics discussed in the most recent meeting covered new results from the LHC as well as other, more traditional experiments; different aspects of hadron physics (the nature of scalar mesons, gluonia,



Left to right: Mikhail Shifman, Valentin Zakharov, Hans Günther Dosch and Stephan Narison at the conference in Montpellier. (Image credit: Rindra Narison.)

new charmonium states, B-physics etc.); and some more formal problems related to the non-perturbative aspects of QCD (large N_c , lattice calculations, confinement etc.).

The QCD Montpellier conferences

were named as Euroconferences from 1994 to 2000. They are regularly supported by IN2P3-CNRS, the Region of Languedoc-Roussillon and the University of Montpellier 2.

NEW PRODUCTS

Aerotech has released a wide-base version of its ABL1500 air-bearing linear translation stage for high-precision positioning of heavy and offset loads. The new ABL1500WB has a nominal width of 400 mm and is available in four travel options, from 200 mm to 500 mm. The stage can support a direct load of 60 kg with submicron resolution and accuracy, with speed/acceleration up to 2 m/s and 2 g. For further details, contact Simon Smith, tel +44 118 940 9400, fax +44 118 940 9401, e-mail ssmith@aerotech.com, or visit www.aerotech.com.

Chamois Metrology has introduced the Martell Electronics BetaProbe TI high-precision, small-sized digital thermometer. This compact, low cost instrument features a probe that rotates through 90°, making it easy to use in locations where space is restricted. It is an ideal replacement for liquid-in-glass thermometers and allows for a temperature range of –50 to 160°C with $\pm 0.06^\circ\text{C}$ accuracy and a resolution of 0.1°C, 0.01°C and 0.001°C. For more information, contact Dave Pretty, tel +44 1926 812 066, e-mail info@chamois.net or see their website, at www.chamois.net.

Elsys Instruments has expanded its line of LAN-controlled transient recorders to include high-speed modules that offer sampling speeds of 240 MS/s or 120 MS/s at 14-bit or 16-bit vertical resolution. Housed in a single-width PCI slot, the TPCX-24014 and TPCX-12014 series transient recorders feature analogue bandwidth at Nyquist frequency of 120 MHz for 240 MS/s versions and 60 MHz for 120 MS/s versions. For further details, contact Peter Wilhelm, tel +41 56 496 01 10, e-mail peter.wilhelm@elsys-instruments.com or visit their website, at www.elsys-instruments.com.

Heason Technology has launched a new range of manual translation stages for linear and rotary multi-axis micropositioning applications. The “Mini Stage” range from GMT Global includes a diverse selection of bearing technologies, mounting/assembly configurations and build specifications. The new linear stages are available with cross-roller, linear ball and dovetail slide bearings with typical travel from 13 mm to over 100 mm. For more information, contact Jon Howard, tel +44 1403 755 800, fax +44 1403 755 810, e-mail jhoward@heason.com or see www.heason.com.

Keithley Instruments Inc has introduced several enhancements to its line of S350 Parametric Test Systems. These include the addition of Keithley’s new high-throughput switch mainframe for high-integrity signal switching, greater low-ohm accuracy, new hardware protection modules that safeguard sensitive system instruments from high voltages and a complete range of “probes up” system specifications and diagnostic tools. For further details, tel +1 440 248 0400, fax +1 440 248 6168, e-mail info@keithley.com or visit www.keithley.com.

Wavelength Electronics has announced the new RHM5K-CH Precision Unipolar Temperature Controller, which can be used to achieve precision control at off-ambient temperatures. The PID control loop drives resistive heaters or thermoelectric coolers. The RHM offers a high level of stability and can supply up to 5 A with a small footprint. On-board 12-turn trimpots control-temperature set-point, proportional gain and output voltage limit. A single 10-pin terminal strip provides easy access to connections. For more information, tel +1 406 587 4910, e-mail sales@teamwavelength.com or see www.teamwavelength.com.

CELEBRATION

Brookhaven honours Radeka with a VeljkoFest

On 9 December, colleagues from Brookhaven and institutions as far away as California, Switzerland and France, as well as members of his family and friends, attended a symposium to celebrate the influence of Veljko Radeka in many scientific fields. At the VeljkoFest, organized by Howard Gordon, Paul O'Connor and Graham Smith, colleagues in diverse areas of science discussed Radeka's past and planned future contributions to their work.

Radeka joined the Instrumentation Division at Brookhaven in 1962, and a decade later became head of the division – a title he has retained to this day. Since then he has influenced developments in detection and instrumentation in a variety of subjects.

In particle physics, Bill Willis of Columbia University recalled that Radeka and his team built the first electromagnetic calorimeter in the 1970s, later followed by liquid-argon calorimeters, first used at the Intersecting Storage Rings at CERN in 1976 (*CERN Courier* January/February 2011 p32). Now, Radeka and Brookhaven's Instrumentation Division have a leading role in the design of

the 100-tonne, liquid-argon time-projection chamber for MicroBooNE, which will enable high-precision neutrino measurements.

Christophe de la Taille, of the Linear Accelerator Laboratory, Orsay, praised Radeka and his team for developing low-noise electronics for detectors in the 1960s. The technology for eliminating much of the background noise proved to be a critical ingredient for numerous experiments, from Ray Davis's pioneering solar neutrino experiment in the Homestake Mine to calorimetry for ATLAS at the LHC.

A month earlier, Radeka received the 2010 Radiation Instrumentation Outstanding Achievement Award from the IEEE Nuclear and Plasma Sciences Society's Radiation Instrumentation Technical Committee. He was presented with the award at the Nuclear Science Symposium and Medical Imaging Conference in Knoxville on 1 November. The citation recognized Radeka for "breakthroughs in radiation-detector development, which enabled discoveries in many areas of science, in a career of sustained productivity spanning 50 years".

INSTITUTES

Karlsruhe marks 50 years of particle and astroparticle physics

On 14 December the Karlsruhe Institute of Technology (KIT) marked the 50th anniversary of research in particle and astroparticle physics at the institute. Half a century ago, research on nuclear and particle physics was initiated jointly by the former University of Karlsruhe and the Forschungszentrum Karlsruhe, which are now combined in the KIT Center for Particle and Astroparticle Physics (KCETA). This soon led to a range of theoretical and experimental activities. Anselm Citron and Herwig Schopper were the founding fathers of the experimental branch, while Gerhard Hühler laid the foundation for particle phenomenology and was later joined by Julius Wess to cover research on all facets of quantum field theory.

At the celebration, Schopper recalled the historical development of nuclear and particle physics at Karlsruhe. In a lively talk he described the original plans of the Karlsruhe groups and their fundamental contributions to a variety of experiments performed both at Karlsruhe and at other laboratories, including Dubna, the Rutherford Appleton Laboratory, CERN and DESY. Research at the high-energy frontier was complemented by precision studies in low-energy neutrino physics, cosmic-ray experiments and technological developments, for example on superconducting cavities.

The following three talks were devoted to ongoing research at KCETA. Steen Hannestad cast light on the role of neutrinos in the cosmos and in the laboratory, emphasizing the important role of an absolute measurement of neutrino mass, as the KATRIN experiment will perform in the near future. Wolfgang Hollik then described the importance of precision calculations for experiments at the Large Electron-Positron Collider, the LHC and the International Linear Collider, together with their amazing success in determining the fundamental constants of the Standard Model, predicting the mass of the top quark and limiting the mass of the Higgs boson. Joachim Mnich presented the status of the LHC machine as well as the experiment, pointing in particular to the KCETA's contributions to the CMS



Howard Gordon, far left, organizer of the VeljkoFest and Veljko Radeka (third from right, front row) are pictured with the VeljkoFest speakers (from left): Christophe de la Taille, University of Paris XI, Orsay; Peter Siddons, BNL Photon Sciences; Steven Kahn, SLAC National Accelerator Laboratory; Pier Oddone, Fermilab; Dieter Schneider, BNL Biology Department; Bill Willis, Columbia University; and Paul Vaska, BNL Medical Department.

Faces & Places

experiment as well as to the importance of GridKa, the German Tier 1 centre for Grid computing. The audience was impressed by the rapid increase in LHC luminosity as well as the quality and large variety of the physics results.

Two years ago, the KCETA decided to establish the Julius Wess Award in memory of Julius Wess, who for more than two decades devoted himself to the advancement of theoretical and experimental physics at Karlsruhe. The final highlight of the celebration was therefore the presentation of the Julius Wess Award for 2010 to Valery Rubakov for his outstanding contributions in theoretical physics, in particular for his work connecting the appearance of anomalies in quantum field theory with experimentally testable predictions, for high-energy interactions as well as for cosmology. In his lecture, Rubakov described the latest progress towards understanding the inhomogeneities in the universe, thus connecting the latest data from cosmological observations with recent advances in quantum field theory.



Left to right: Johannes Blümer, spokesperson for KCETA, Detlef Löhe, vice president of KIT, Valery Rubakov, the Julius Wess Award winner, Susanne Wess, the daughter of Julius Wess, and Johann Kühn, vice-spokesperson for KCETA. (Image credit: KIT.)

WORKSHOP

Precision: worthwhile but not free

“It is amazing to see what precision is in store at the LHC, which is commonly perceived as a discovery machine,” said Guido Altarelli in his concluding talk at a gathering of some 50 precision aficionados in Paris on 15–18 December. The meeting, aimed at broadening the awareness of the formidable challenges facing precision measurements in the environment of the LHC’s proton–proton collisions, naturally started with reviews of the impressive results on W and Z production achieved by the ATLAS, CMS and LHCb experiments on a record time-scale. This, together with the prospect of harvesting eventually hundreds of millions of events with leptonic W and Z decays, fosters prospects of significant improvements even beyond the epic precision results from the Large Electron-Positron (LEP) collider on parameters of the electroweak Standard Model, notably on the W mass and the electroweak mixing angle.

If only it were that simple. The LHC produces collisions between protons, so the understanding of W and Z production necessitates an adequate understanding of the proton’s structure in terms of its parton density functions (PDFs). In the course of the meeting, perspectives changed gradually from optimism to realism on two fronts.

First, it was realized that the PDFs

are perhaps less well understood than is necessary for precision experiments at the LHC. “Tensions” (a euphemism for mild discrepancies that became the catchword of the meeting) between PDFs from different data sets, or employing different concepts for their derivation, attest to this. Second, the advantage of the Tevatron’s proton–antiproton collisions over the LHC’s proton–proton collisions became apparent, for reasons of intrinsic error compensation and smaller contributions to W and Z production from heavy quarks.

Thus, the way to improve the precision

on the W mass over the LEP and Tevatron results is thorny rather than easy. There are a number of challenges to face on both the theoretical and the experimental sides. However, the commonly accepted and encouraging conclusion of the meeting was that the noble goal justifies major efforts in these directions, and the workshop participants appeared determined to live up to the challenge.

● For more about the workshop on Challenges for Precision Physics at the LHC see, www.lpthe.jussieu.fr/~kbenakli/FRIF2010.



Guido Altarelli and Bryan Webber moderating a lively debate. (Image credit: W Krasny.)

OBITUARIES

Boris Dolgoshein 1930–2010

Boris Dolgoshein, one of the most imaginative of experimental particle physicists, passed away in his office at the Moscow Engineering and Physics Institute (MEPhI) on 14 December.

Born in 1930 in Kazan, Boris studied at the Moscow Engineering and Physics University, where he graduated in 1954. He later became professor of the MEPhI and head of the particle-physics department.

In 1962 Boris and his colleagues invented the streamer chamber and went on to develop this novel technology to perfection. Unlike the bubble chamber, the streamer chamber could be triggered externally and thus was suited to the study of rare and complex events. In 1968 Boris and his team constructed the largest streamer chamber ever built, with a volume of $8 \times 2 \times 1 \text{ m}^3$, which operated for many years in Protvino at the 70 GeV synchrotron. It was used to search for the W boson in an experiment that identified prompt muons for the first time and measured their spectrum and polarization.

In 1977 Boris proposed the detection of high-energy neutrinos by measuring the acoustic signals from hadron showers created by neutrinos in water. This method was realized in prototypes in the US and in Lake Baikal, and it is currently being explored in the context of the ANTARES and IceCube neutrino telescopes (p28). Boris also proposed measuring the density distribution of the Earth using high-energy neutrino scattering.

Boris developed and pioneered transition radiation detectors (TRDs) for particle tracking and particle identification. His experience and expertise with this sophisticated detector dates back to the early 1970s and there is hardly a TRD in the world to which Boris has not significantly contributed. Among them are the TRDs of the HELIOS spectrometer at the Super Proton Synchrotron, the ZEUS and HERA-B experiments at HERA, the AMS spectrometer that will fly in space and the huge Transition Radiation Tracker (TRT)



Boris Dolgoshein. (Image credit: MEPhI.)

of the ATLAS experiment at the LHC. Most TRDs, whether at accelerator-based experiments or in space, were built following one or other of these examples and profited from the intensive and careful R&D programmes that Boris and his collaborators carried out.

As spokesperson of the RD6 collaboration at CERN, for many years – and through troubled waters – Boris led the design and performance studies of a TRT for the LHC based on drift tubes, also known as “straws”. His unmatched experience, brilliant ideas and the painstaking care that he continuously put into understanding fully the complex behaviour of the straws at high occupancies and in an extremely harsh radiation environment were invaluable in many aspects of this daunting project. Thanks in great part to Boris, the ATLAS TRT today provides excellent measurements of charged-particle trajectories and beautiful views of the tracks in the collisions at the LHC.

Parallel to the construction of the ATLAS TRT, Boris continued to develop ideas for new detectors. In 1993, in collaboration with DESY, he started to develop a new type of silicon photodetector with high gain, which he called the silicon photomultiplier (SiPM). Consisting of an array of miniaturized

silicon Geiger–Müller counters on a silicon wafer, the SiPM is sensitive to single photons but insensitive to magnetic fields. Boris immediately realized the enormous potential of this technology and put his creativity and energy into its development. It is to his merit that SiPMs today have a vast number of applications ranging from the read-out of highly segmented calorimeters and photodetectors for astroparticle physics to medical applications, such as positron-emission tomography.

From the late 1970s, Boris was a frequent visitor to CERN and DESY, where he not only worked on his experiments and detector developments but was also active in science policy. As a member of the CERN–Russia Committee in 1991–1996, he contributed to an agreement for scientific and technological co-operation, which enabled Russian research institutes with the assistance of sectors of Russian industry to provide major contributions to the construction and utilization of the LHC.

Boris’s creative and innovative work was recognized with numerous honours, including Academician of the Russian Academy of Natural Sciences, the Lenin Prize, the Kapitza Gold Medal and the Alexander-von-Humboldt Award. His advice was sought by many committees and he was member of the Advisory Editorial Board of *Nuclear Instruments and Methods in Physics Research Section A*, and member of the editorial board of the *Journal of Instrumentation*.

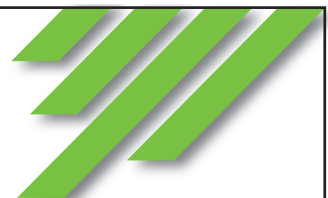
Boris’s creativity, knowledge and enthusiasm have been an inspiration and motivation for many scientists. Working with him has been an unforgettable experience. Georges Charpak in 1995 said: “I have a long-standing history of scientific contacts on particle detectors with Boris Dolgoshein’s team. I have great esteem for its ideas and achievements. Boris Dolgoshein is one of the most creative specialists in particle detectors science in the world.”

● *His friends and colleagues.*



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Faces & Places

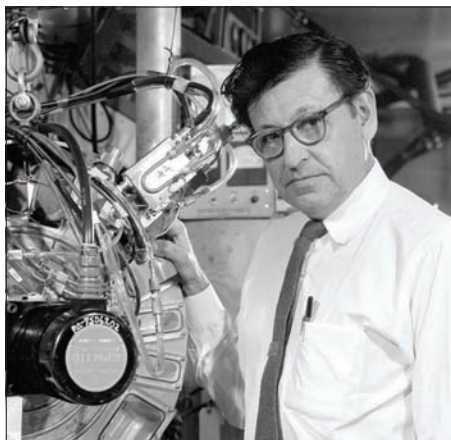
Albert Ghiorso 1915–2010

One of the last remaining veterans of the Manhattan project, Albert Ghiorso, passed away on 24 December 2010, at the age of 95.

Ghiorso was an astonishingly productive scientist whose successes go back to an earlier day, when science was done differently. Ghiorso began working in nuclear science in 1941 after receiving his bachelor's degree in electrical engineering from the University of California, Berkeley. His talents for building radiation detectors attracted him to Glenn Seaborg, and the two of them moved to Chicago in 1941. There, Ghiorso designed new instruments, including a 48-channel pulse-height analyser, which he and Seaborg used to discover two new artificial elements, americium (95) and curium (96), by irradiating plutonium with deuterium.

After the Second World War, they both returned to Berkeley, where they used the 60-inch cyclotron to produce elements 97 and 98. Ghiorso found the next elements, 99 and 100, in the debris collected after the first hydrogen-bomb test, in the Pacific. From there, it was back to the 60-inch cyclotron, where he found mendelevium (101) in 1955. This was discovered on the basis of 17 atoms, initiating the era of single-atom detection of new elements.

To cope with the steadily decreasing cross-sections, a new machine was needed, with more intense beams. Better detection techniques were also needed, to



Al Ghiorso in 1969, standing by the target wheel used to discover element 104, rutherfordium. (Image credit: LBNL.)

cope with the smaller cross-sections and shorter isotope lifetimes. Ghiorso led the construction of the Berkeley Heavy Ion Linear Accelerator (HILAC) and a later upgrade, the super-HILAC. These machines were used to discover five elements, from 102 (einsteinium) to 106 (seaborgium). This made a total of 12 elements, a record that earned Ghiorso a place in the *Guinness Book of World Records*.

By the 1970s, decreasing US support for heavy-element research rendered the Super-HILAC uncompetitive for discovering new elements and Ghiorso turned to a

new endeavour. He proposed coupling the ageing Super-HILAC with the also-ageing Bevatron, to produce the Bevalac, the first relativistic heavy-ion accelerator. It ushered in the field of relativistic ion collisions, laying the groundwork for experiments at Brookhaven's Alternating Gradient Synchrotron and CERN's Super Proton Synchrotron, as well as at Brookhaven's Relativistic Heavy Ion Collider and the lead-ion programme at the LHC.

Throughout his life, Ghiorso displayed enormous passion, curiosity and drive for physics. The lack of an advanced (post-bachelor) degree did not stop this remarkable scientist from helping to build, define and lead a field of nuclear science.

During his life, he was awarded a host of honours, including the Lifetime Achievement Award of the Radiochemistry Society, the Potts medal from the Franklin Institute, the GD Searle award from the American Chemical Society and an honorary doctorate from Gustavus Adolphus College. He was a fellow of the American Academy of Arts and Sciences and the American Physical Society.

Al Ghiorso is survived by his son, William Belt Ghiorso, an engineer at Lawrence Berkeley National Laboratory, and his daughter, Kristine Pixton, who is an artist and software designer.

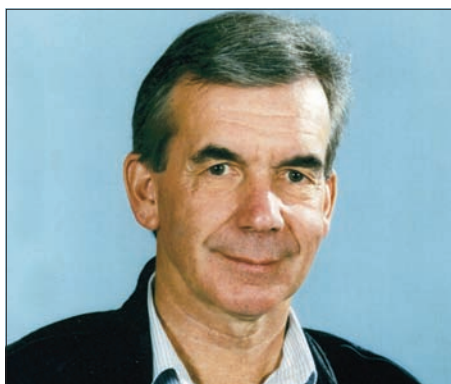
● *Spencer Klein, Lawrence Berkeley National Laboratory.*

Stuart Tovey 1939–2010

Stuart Tovey, who did much to bring about Australian participation in CERN, died on 21 October 2010 after a short illness.

Born in Southampton in 1939, Stuart grew up in Bristol. He studied physics at Trinity College, Cambridge, and received his BA in 1960. Returning to Bristol he joined Cecil Powell's cosmic-ray group and gained his PhD there in 1964. A series of fellowships followed at Bristol, University College London, CERN and the Rutherford Appleton Laboratory. He joined the University of Melbourne as a lecturer in 1975, being rapidly promoted to senior lecturer and then to reader and associate professor.

Stuart was prominent in the 1960s and 1970s in the study of hyperons and kaons and discovered a new baryon containing both charm and strange quarks. He put the many



(Image credit: University of Melbourne.)

interestingly named particles to good use in the numerous popular articles he wrote. He also studied antiprotons and participated

in the discovery of the W and Z bosons at CERN in the UA2 experiment. This experience further evolved into development of the ATLAS experiment at the LHC.

For many years Stuart co-ordinated the honours physics programme at the University of Melbourne, which was not for the faint hearted. He showed how adept and in-tune with people he was in this role, treading the fine line between encouragement and realism – in the latter case counselling students towards alternative directions when he thought that it be in their best interest. The honours students of the period were well served and many went on to PhD studies, often under Stuart's guidance.

Stuart's international engagement and solid personal and professional ties with CERN ensured strong participation in

ATLAS by Australia. While ATLAS and the LHC were being built, Stuart and his friend and colleague, Lawrence Peak from Sydney, shared a role as the fathers of modern high-energy physics in Australia. The Australian Institute for High Energy Physics was formed, for which Stuart was chair for many years. Australia also joined the NOMAD experiment at CERN, followed by the Belle experiment in Japan.

Fortunately, Stuart was able to share in the

excitement of the successful operation of the LHC and ATLAS. Although formally retired in 2001, he maintained an active interest in the project, being Australia's representative on the ATLAS Resource Review Board until recently. He also witnessed the successful establishment of a national Centre of Excellence in Particle Physics (CoEPP) in Australia, something that he strove for over many years. After writing a paper on collider physics together in 1984, Stuart and Allan

Clark of the University of Geneva pursued a role for Australia's participation in CERN and ATLAS. They were ahead of their time: the CoEPP gives justification to their early recognition of the need for such participation.

Stuart's untimely death is acutely felt by colleagues and friends at the University of Melbourne, and by those at the many institutions around the world who have worked with him. He will be missed.

● *Geoffrey Taylor, University of Melbourne.*

MEETINGS

The conference on **Technology and Instrumentation in Particle Physics (TIPP)** will take place on 9–14 June at the Sheraton Hotel and Towers in Chicago. This conference, the second in the series, will focus on all areas of detector development and instrumentation in particle physics and closely related fields, such as nuclear physics, particle astrophysics, synchrotron radiation sources and applications in biology, medicine and engineering. Registration is now open and the deadline is 1 April. For further information, see <http://conferences.fnal.gov/tipp1/>.

The **15th International Conference on RF Superconductivity** will take place on 25–29 July in Chicago. The goal of this conference is to provide a lively forum for SRF scientists, engineers, students and industrial partners to present and discuss the latest developments in the science and technology of superconducting RF for particle accelerators. Tutorial sessions preceding the conference will be held on 21–23 July at Argonne National Laboratory. Registration is now open and the deadline is 1 May. For more details, see <http://conferences.fnal.gov/srf2011/index.html>.

The **15th Lomonosov Conference on Elementary Particle Physics** will be held at Moscow State University on 18–24 August. These biennial conferences bring together around 300 theorists and experimentalists from different countries to review the current status and future prospects in elementary particle physics. The programme of the 15th conference will include neutrino physics, astroparticle physics, developments in QCD and heavy-quark physics. For further information and registration details (deadline 1 March), see www.icas.ru/english/15lomcon.htm.

Flip-Chip Service at X-ray Imatek S.L.

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PARTICLE PHYSICS.

DESY has openings for: DESY-Fellowships (m/f)

DESY

DESY is one of the world's leading centres for the investigation of the structure of matter. DESY develops, runs and uses accelerators and detectors for photon science and particle physics.

The position

Fellows in experimental particle physics are invited to participate in DESY's particle physics research.

- Analysis of HERA data
- Participation in the LHC experiments ATLAS and CMS
- Preparation of the International Linear Collider ILC (accelerator and experiments)
- Cooperation in the Analysis Centre of the Helmholtz Alliance „Physics at the Terascale“
- Participation in experiments like ALPS and OLYMPUS

Requirements

- PhD completed within the last 4 years
- Experience in experimental particle physics

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department. Three letters of reference shall be arranged to be sent to the DESY human resources department.

Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is an English-speaking Kindergarten on the DESY site.

Please send your application quoting the reference code, also by e-mail to:

Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: 1/2011
Notkestraße 85 | 22607 Hamburg | Germany
Phone: +49 40 8998-3392 | E-mail: personal.abteilung@desy.de
Deadline for applications: 31 March 2011
www.desy.de

The Helmholtz Association is Germany's largest scientific organisation.
www.helmholtz.de



WESTFÄLISCHE
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The Physics Department at the University of Münster invites applications for an

Assistant Professorship (W1) in Theoretical Physics - Elementary Particle Theory

with a teaching duty of 4 hours per week. The preferred starting date is October 1st, 2011. The initial term of appointment is three years. Subsequent to a positive intermediate evaluation, it can be renewed for another three years. A positive final evaluation may lead to a tenured position.

The successful candidate is expected to represent the field of Theoretical Physics in research and teaching. His/Her main research focus should be elementary particle phenomenology, in particular the physics beyond the Standard Model. Further research experience in the field of perturbative QCD and/or theoretical astroparticle physics is an advantage. Close collaboration with the other theoretical and experimental research groups active in particle physics is required. Participation in the teaching activities in theoretical physics is expected at all levels, i.e. within the B.Sc., M.Sc. and teacher training programs. Further duties include the participation in academic self-government and the advancement of the B.Sc. and M.Sc. programs as well as of the graduate school.

Prerequisites for the appointment are a Ph.D. degree in theoretical physics, pedagogical ability and further scientific, post-doctoral achievements accomplished at a public university or research institute.

Women are explicitly encouraged to apply and will be favored in case of equal ability and professional performance, unless this rule is outweighed by the personality of a competitor.

Seriously disabled persons will be favored in case of equal qualification.

Applications with the usual documents (curriculum vitae, list of publications, description of research and teaching experience, research plan, diplomas) should be sent before **April 30th, 2011** to:

Westfälische Wilhelms-Universität
Dekan des Fachbereichs 11 (Physik)
Herrn Prof. Dr. Tilmann Kuhn
Wilhelm-Klemm-Str. 9 - D-48149 Münster

www.uni-muenster.de



Tenure-Track Position in Experimental Nuclear Physics (ENP)

The Department of Physics at **The George Washington University** invites applications for the above position at the assistant/associate professor level. The incumbent must maintain vigorous, externally-funded research. Current research includes Compton scattering, meson photoproduction, few-nucleon photodisintegration, structure of the nucleon, and fundamental symmetries, however, applicants doing research in any ENP area are urged to apply. A Ph.D. (or equivalent) and two years of post-doctoral experience are required. Excellence in teaching and communication is expected.

Application Procedure: Applications must include a CV and statements describing research, teaching and overall goals. At least three reference letters should also be submitted. Applications should be sent to Professor William Briscoe, Chair, Search Committee, Department of Physics, The George Washington University, Washington, DC, 20052, USA. Review will begin on Feb 1, 2011. Only complete applications will be considered. Applications from women and underrepresented minorities are strongly encouraged.

The George Washington University is an Equal Opportunity/Affirmative Action Employer.



**University of
Zurich**^{UZH}

Faculty of Science

The Faculty of Science invites applications for a

Full Professor in Experimental Particle Physics

The new professor is expected to establish and lead a successful group pursuing vigorous research in the physics exploitation of the LHC and in the operation, maintenance and upgrade of the CMS detector. She or he will find a very stimulating environment including major experimental activities in particle and astroparticle physics.

The well-known research groups in particle physics phenomenology in Zurich provide excellent opportunities for cooperations in data analysis and interpretation. Detector research and development for the possible upgrade of the CMS detector or other experimental projects will be strongly supported by an excellent technical infrastructure.

In teaching at both undergraduate and graduate level the new professor will stimulate the interest of the students for basic physics research. Undergraduate teaching is in English or German, graduate education is in English.

Candidates are invited to submit by April 15, 2011 an application package including curriculum vitae, list of publications and personal conference contributions, outline of current and future research interests, teaching philosophy and names and addresses of three potential referees. Documents should be addressed to Prof. Dr. Michael Hengartner, Dean of the Faculty of Science, University of Zurich, and submitted as a single PDF file at www.mnf.uzh.ch/epp. For further information, please contact Prof. Dr. Ulrich Straumann at ulrich.straumann@physik.uzh.ch. Although the new position is foreseen to be filled at the full professor level, excellent applications from outstanding younger scientists will be considered for associate or assistant professor (tenure track).

The University of Zurich is an equal opportunity employer. Applications of female candidates are particularly encouraged.



**University of
Zurich**^{UZH}

Faculty of Science

The Faculty of Science invites applications for a

Professorship in Theoretical Physics

in the area of elementary particle physics with particular emphasis on theories beyond the Standard Model and their phenomenology in collider and astroparticle physics. Applications from outstanding candidates from other research areas will equally be considered.

The new professor is expected to pursue vigorous research and to contribute to teaching at both undergraduate (English or German) and graduate (English) level. She or he will find a very stimulating environment including major experimental activities in particle and astroparticle physics.

It is anticipated that the position will be filled at the Assistant Professor (tenure track) level, however exceptional candidates at any level will be considered.

Candidates are invited to submit by April 30, 2011 an application package including curriculum vitae, publication list, outline of current and future research interests, teaching philosophy and names and addresses of three potential referees. Documents should be addressed to Prof. Dr. Michael Hengartner, Dean of the Faculty of Science, University of Zurich, and submitted as a single PDF file at www.mnf.uzh.ch/tp. For further information, please contact Prof. Dr. Thomas Gehrman at thomas.gehrmann@uzh.ch.

The University of Zurich is an equal opportunity employer. Applications from female candidates are particularly encouraged.

DIRECTOR

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Cornell University, located in Ithaca, New York, is an inclusive, dynamic, and innovative Ivy League university and New York's land-grant institution. Its staff, faculty, and students impart an uncommon sense of larger purpose and contribute creative ideas and best practices to further the university's mission of teaching, research, and outreach.

A search has begun for a new director of the Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE). CLASSE is a major interdisciplinary research center whose mission includes the study of beam physics, photon science and particle physics. CLASSE has extensive resources that support its research mission. These include Newman and Wilson laboratories, their facilities, shops and computing infrastructure, the Cornell Electron Storage Ring accelerator complex, the CHESS National X-ray facility, and the supporting technical and administrative staff. A principal current focus of CLASSE is the development of an Energy Recovery Linac (ERL) as a next generation light source. At the same time, CLASSE continues to facilitate an array of other research projects in accelerator physics, photon science, and theoretical and experimental particle physics. CLASSE infrastructure and personnel are supported primarily through research grants.

The CLASSE Directorship is a dual appointment, as the chief executive officer of the Laboratory and a senior tenured member of the Cornell faculty with academic responsibilities in the Physics Department or one of the other academic units with significant faculty and student involvement in CLASSE based activities. The CLASSE Director is responsible for the management of the laboratory's administrative infrastructure, staff and research facilities so as to best support and promote the success of the broad range externally sponsored research projects that are carried out by the faculty and staff associated with CLASSE and that utilize CLASSE resources. The Director works in close consultation with the PIs for the major CLASSE projects to ensure the availability and proper allocation of resources necessary for success.

The Director is the principal advocate and ambassador for the evolving CLASSE programs and he or she is expected to articulate and promote that scientific vision within the university, at the federal funding agencies, particularly at NSF and DOE, and with the NY State and Federal legislatures and administrations. The Director is expected to maintain a national and international presence on review panels and advisory boards, and to keep well apprised of national and international developments in the fields of photon science and accelerator physics that could significantly impact current and future CLASSE projects and programs. The Director also has oversight responsibility for the graduate and postdoctoral educational mission of CLASSE and for its educational outreach activities.

Ph.D. required with a background in Physics or other appropriate discipline. The search committee welcomes applications or nominations for this position, preferably accompanied by curriculum vitae and other information bearing on the candidate's qualifications for the Directorship. Relevant qualifications include scientific stature, leadership, and management skills.

Applications will be accepted until the position is filled, however interviews will begin as soon as qualified applicants are identified. Applications and nominations should be sent to **Deborah Shigley, Research Division HR, 222 Day Hall, Cornell University, Ithaca, NY 14853**; or by e-mail attachment to **dks7@cornell.edu**



Cornell University

*Cornell University is an affirmative action/
equal opportunity employer and educator.*

California Institute of Technology

Computing and Software Systems Research Engineer

The Compact Muon Solenoid (CMS) is one of four experiments at CERN's Large Hadron Collider (LHC) in Geneva, Switzerland. The CMS collaboration, numbering over 2,000 physicists and engineers, makes use of a worldwide computing grid for the processing and analysis of the data taken by the experiment. Caltech hosts one of seven US-based "Tier2" High Performance Grid Computing clusters in CMS, which are part of this grid, in addition to two private HPC clusters for interactive use by local physicists.

The successful candidate will join the Caltech High Energy Physics group and the worldwide CMS community and will be tasked with ensuring that the Caltech Tier2 computing cluster maintains high levels of availability and efficiency. The Caltech group is one of the leading US institutes in CMS, and has an excellent track record in the field, and a first class reputation both in particle physics research and in research and state of the art development for scientific computing.

The successful candidate will also share responsibility for ensuring that the Tier2 cluster continues to be modernized and upgraded to meet the growing needs of the CMS collaboration. They will maintain the private CMS computing facilities at Caltech and work with local physicists to ensure that their computing needs are being met. In association with Caltech HEP network engineers, they may also be involved in state of the art network and distributed system developments.

Applicants should apply directly to Caltech using the following link: https://jobs.caltech.edu/applicants/jsp/shared/position/JobDetails_css.jsp?postingId=146878



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think forward





Full Professor (W2) in Experimental Physics Faculty of Mathematics, Informatics and Natural Sciences

We are seeking qualified applicants for teaching and research in the area of nuclear and particle physics. The starting date is October 1st 2011. We expect the candidate to take a leading role in joint experiments of the RWTH Aachen University and Forschungszentrum Jülich.

The joint professorship will be established at RWTH Aachen University for the first 5 years with tenure at Forschungszentrum Jülich. We expect the candidate to carry through experiments to search for electric dipole moments of the proton and light nuclei with COSY and to develop a future experiment with a dedicated storage ring.

The candidate is expected to participate in the teaching obligations of the physics section, particularly in the education of engineering students.

A Ph.D. degree is required; additionally, Habilitation (post-doctoral lecturing qualification), an exemplary record of research achievement as an assistant / an associate / a junior professor or university researcher and/or an outstanding career outside academia are highly desirable. Ability in and commitment to teaching are essential. German is not necessary to begin but will be expected as a teaching language within the first 5 years. The candidate should have a broad interest in physics and cooperate and coordinate interdisciplinary projects.

The application should include supporting documents regarding success in teaching.

Please send a cover letter stating research aims and a CV to: An den Dekan der Fakultät 1 der RWTH Aachen, Prof. Dr. Hiß, Templergraben 55, 52062 Aachen. The deadline for applications is April 15th, 2011.

This position is also available as part-time employment per request.

RWTH Aachen University is certified as a family-friendly university and offers a dual career program for partner hiring. We particularly welcome and encourage applications from women, disabled people and ethnic minority groups, recognizing they are underrepresented across RWTH



JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

The **Department of Physics, Mathematics and Computer Science at the Johannes Gutenberg-University of Mainz** invites applications to fill, at the earliest possible date, the position of a

Professorship in Experimental Atomic Physics (Full Professor, Bes.Gr. W3 BBesG)

We seek an expert in the field of atomic physics with international reputation and an outstanding record of experimental accomplishments in high-precision tests of fundamental interactions and symmetries.

The new professorship is established by the recently founded Helmholtz-Institute Mainz (HIM), a cooperation of the Johannes Gutenberg-University of Mainz with the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt.

The successful candidate is expected

- to teach the subject area of experimental physics in its entire scope,
- to head the research division "Symmetry of Matter and Anti-Matter" at HIM and to promote the scientific program of this section, and
- to take a leading role in activities promoting scientific excellence at the University of Mainz and in planning and implementing atomic physics experiments to be conducted at the future "Facility for Antiproton and Ion Research" (FAIR) at the GSI in Darmstadt for tests of fundamental interactions and symmetries.

Applicants must have a PhD in physics and a proven first-rate research record. Moreover, the formal regulations set out in § 49 Hochschulgesetz Rheinland-Pfalz must be fulfilled.

The State of Rhineland-Palatinate and the Johannes Gutenberg-University of Mainz promote the concept of intensive tutoring and thus requests a high level of presence at the University.

The Johannes Gutenberg-University of Mainz aims at increasing the percentage of women in academic positions and strongly encourages women scientists to apply. Disabled persons will be considered preferentially in the case of equal qualifications.

Please address any queries to the Director of the Helmholtz-Institute Mainz, Professor Dr. Frank Maas (e-mail: maas@uni-mainz.de).

Qualified candidates are asked to submit their application including the usual supporting documents (curriculum vitae, copy of diplomas, description of teaching activities, list of publications, list of successful third-party grant applications) and an outline of current and future research activities, as well as reprints of their five most important publications to the dean of the faculty:

**Johannes Gutenberg-Universität Mainz, Dekan des Fachbereichs 08
- Physik, Mathematik und Informatik -,
Staudingerweg 7, 55099 Mainz, Germany**

not later than 30 April 2011.



Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Research Associate Superconducting RF for Future Accelerators CLASSE, Cornell University

The Cornell Laboratory for Accelerator-based Sciences and Education (Cornell Laboratory for Accelerator Sciences and Education (CLASSE) has an opening for a Research Associate to work on a broad range of topics involving RF superconductivity for particle accelerators. Our activities cover research on cavities for the International Linear Collider (ILC), Energy Recovery Linac (ERL), Project-X for neutrino physics, and SRF cavities for the muon collider, as well as basic SRF issues related to high gradients, high Q and new materials for advanced accelerator applications. We have state-of-the-art facilities for cavity fabrication, preparation, tests, repair, and for basic research including a variety of surface-analytic instruments.

A successful applicant will participate in several of the above activities. This is a 3-year appointment with expectation for renewal, subject to mutual satisfaction and availability of funds. A PhD in Physics or Engineering is required, with related experience in one or more of the following areas: low temperature physics, materials, microwaves, high vacuum, and surface analysis.

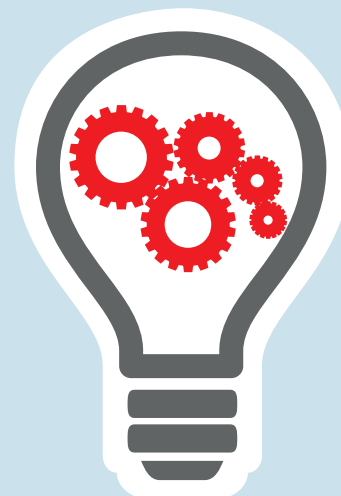
As an Ivy League University, Cornell provides an intellectually stimulating research environment with opportunities to work with undergraduate and graduate students. We also have strong collaborations with Fermilab, JLab, ANL, HZB/Berlin, Daresbury/UK, and TRIUMF/CA.

Please send a cover letter, including curriculum vitae and a publications list to Professor Georg Hoffstaetter, Newman Laboratory, Cornell University, Ithaca, NY 14853, and arrange for three letters of recommendation to be sent. Correspondence may be directed to search classe@cornell.edu.

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Bookshelf



BCS: 50 Years

By Leon N Cooper and Dmitri Feldman (eds.)

World Scientific

Hardback: £84 \$135

Paperback: £40 \$65

More than 50 years after John Bardeen, Leon Cooper and Robert Schrieffer – BCS – published their now famous theory of superconductivity, and 100 years since the discovery of superconductivity, the key concepts have become the basis of a vast and ever-increasing field of investigation, both theoretical and experimental.

This exceptionally well written and edited book celebrates and reviews the state of BCS theory and experiment. The many chapters on the history and early experiments (written by Bardeen, Cooper, and Schrieffer, as well as others) are all very clear and readily accessible to a high-energy physicist, despite containing a wealth of detail. The content continues well beyond the usual applications of BCS theory and there are extensive discussions of extensions of BCS, especially in the light of attempts to understand the new high T_c superconductors.

Experimentalists will especially enjoy the chapter by John Clarke on “SQUIDS: Then and Now”, which contains a beautiful discussion of the early development of the superconducting quantum interference device (SQUID), including some really makeshift laboratory set-ups. I particularly enjoyed his description of trying to get a

thin, mechanically stable insulating film for a Josephson junction and his colleague Paul Wraight saying: “How about a blob of solder on a piece of niobium wire? Solder is a superconductor and you keep telling me that niobium has a surface oxide layer.” Remarkably this simple idea worked, with several junctions formed on the crude device. Brian Pippard quipped that it looked as though a slug had crawled through the window overnight and died, and so the term SLUG came into use for what was dubbed a “superconducting low-inductance undulatory galvanometer”. The chapter goes on to cover applications including magnetocardiography, magnetoencephalography, precision gyroscopes, geophysics, qubits, and searches for galaxy clustering and axions.

There is plenty in this book for the particle physicist: Gordon Baym covers BCS theory for atomic nuclei, neutron stars and quark matter; Yiochiro Nambu discusses mass gaps and symmetry breaking; Frank Wilczek writes on BCS theory in QCD at high densities and gives a particularly nice discussion of colour-flavour locking, as well as abelian and nonabelian anyons. In the final chapter Steven Weinberg gives a personal overview “From BCS to the LHC” (*CERN Courier* January/February 2008 p17).

All 23 chapters are by outstanding physicists (including many Nobel prize-winners) and all were fascinating to read. I would highly recommend this book to anyone and everyone as a wonderful review of a powerful unifying concept that covers an enormous range of phenomena.

● John Swain, Northeastern University.

Books received

Exact Methods in Low-Dimensional Statistical Physics and Quantum Computing: Lecture Notes from the Les Houches Summer School: Volume 89, July 2008

By Jesper Jacobsen, Stephane Ouvry, Vincent Pasquier, Didina Serban and Leticia Cugliandolo (eds.)

Oxford University Press

Hardback: £45 \$85

Recent years have shown spectacular convergences between traditional techniques in theoretical physics and methods emerging from modern mathematics, such as combinatorics, topology and algebraic geometry. These

techniques, and in particular those of low-dimensional statistical models, are instrumental in improving the understanding of emerging fields, such as quantum computing and cryptography, complex systems, and quantum fluids. This book sets these issues into a larger and more coherent theoretical context than is currently available, through lectures given by international leaders in the fields of exactly solvable models in low-dimensional condensed matter and statistical physics.

Lectures on light: Nonlinear and Quantum Optics using the Density Matrix

By Stephen C Rand

Oxford University Press

Hardback £39.95 \$75

This book attempts to bridge in one step the enormous gap between introductory quantum mechanics and the research front of modern optics and scientific fields that make use of light. Hence, while it is suitable as a reference for the specialist in quantum optics, it will also be useful to non-specialists from other disciplines. With a unique approach it introduces a single analytic tool, the density matrix, to analyse complex optical phenomena encountered in traditional as well as cross-disciplinary research. It moves from elementary to sophisticated topics in quantum optics, including laser tweezers, laser cooling, coherent population transfer, optical magnetism and squeezed light.

NIST Handbook of Mathematical Functions

By Frank W J Olver, Daniel W Lozier, Ronald F Boisvert and Charles W Clark, (eds.)

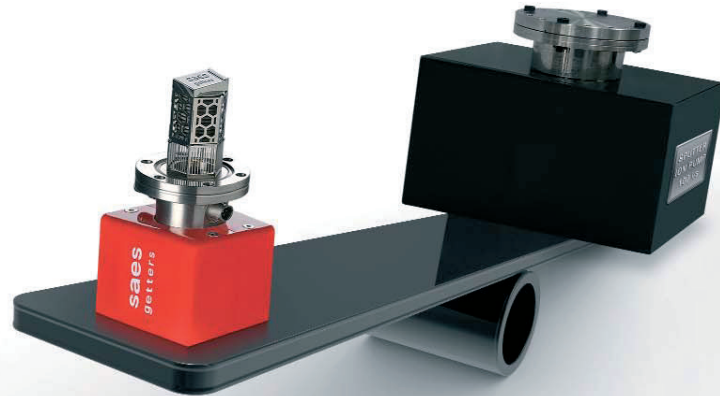
Cambridge University Press

Hardback £65 \$99

Paperback £35 \$50

Modern developments in theoretical and applied science depend on knowledge of the properties of mathematical functions, from elementary trigonometric functions to the multitude of special functions. Using them effectively requires practitioners to have ready access to a reliable collection of their properties. This handbook results from a 10-year project conducted by the National Institute of Standards and Technology with an international group of expert authors and validators. Printed in full colour, it is destined to replace its predecessor, the classic but long-outdated *Handbook of Mathematical Functions*, edited by Abramowitz and Stegun. It includes a DVD with a searchable PDF of each chapter.

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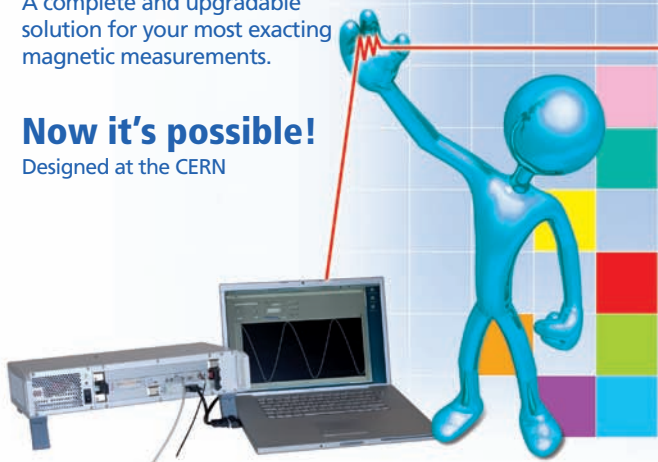
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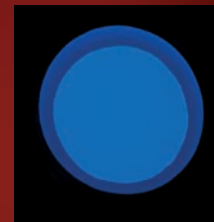
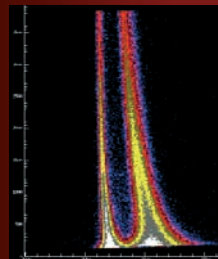
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Viewpoint

Optimizing potential

Rolf Heuer extols the value of consensus in deciding at what energy to run the LHC and for how long.

At the end of January, a small fraction of CERN decamped to Chamonix along with experts from around the world – not to ski but to work out the plans for the coming year's LHC run. It is a tradition that began with CERN's previous accelerator, the Large Electron–Positron (LEP) collider, and time and again it has proved its worth.

Chamonix is an important fixture on the CERN calendar, not only because it sets the agenda for the coming year but also because it is particle physics in microcosm. Chamonix embodies the spirit of our field. It is an intense week of discussion and debate, involving a wide community base drawn from CERN, the LHC experiments and beyond. The CERN machine advisory committee is there and everyone has the chance to air opinions, before the meeting invariably winds up with a broad consensus.

It is this ability to reach consensus that makes our science so remarkable. Particle physicists can be every bit as opinionated and attached to their own ideas as anyone else but, at the end of the day, we are all united by the overriding goal of doing our research and finding out more about this wonderful universe that we live in. That is what allows us to reach consensus – and always has. In the past, whenever a big

Taken together, the recommendations that emerged from Chamonix optimize the LHC's discovery potential.

particle-physics project involved 50 people or so – or even the 300 or so from my old LEP experiment, OPAL – consensus was maybe not so surprising. But with collaboration sizes today numbering in the thousands, this model still holds true and management gurus are beginning to take notice. My message to them? It is amazing what people can do when they are united by a common goal.

So what of this year's deliberations at Chamonix? They were all about maximizing discovery potential while minimizing risk to the LHC and the experiments. The problems with the LHC's high-current splices, which became so painfully evident in 2008 when one of them failed and put the machine out of action, are not completely resolved. That is why the LHC is not yet running at its full design energy of 7 TeV per beam. In 2010, 3.5 TeV per beam was selected as a safe energy to run at for the LHC's first physics, and experience has clearly demonstrated the wisdom of that choice.

The big question at Chamonix this year was whether we could safely move up a notch. Some argued for; others against. But at the workshop's conclusion the participants were united in recommending that we stay at 3.5 TeV until at least the end of 2011.

Why? Well, we know that the LHC performs fantastically at this energy, and that exciting new physics is potentially within our reach. We have also developed new techniques to sniff out bad splices that could spoil the show if we go to a higher energy. These will be in place by the end of 2011, giving us the input needed to take a fully informed decision on a possible increase in energy at next year's Chamonix meeting.

Which brings me to the next big question on the table at Chamonix: what about next year? It has long been clear that with lengthy warm-up and cool-down periods, an annual cycle does not make sense for major maintenance shutdowns at the LHC. And we also know that the first long shutdown involves substantial work to make good the high-current interconnects that will allow us to reach the design energy of 7 TeV per beam. Originally foreseen for 2012, it was almost a foregone conclusion that the Chamonix workshop would recommend postponing the first long shutdown to 2013, and that is indeed what happened.



The reason is that the LHC's performance in 2010 was so good, with the promise of much better to come. That led to simple extrapolations clearly showing that if there's new physics to be found in the 3.5 TeV-per-beam energy range, two years of running will be enough to find it. On the other hand, one year alone could leave us with just tantalizing hints. Under these circumstances, stopping at the end of 2011 makes little sense.

Taken together, the recommendations that emerged from Chamonix optimize the LHC's discovery potential, not just for 2011 but for the longer term as well, and they do it while minimizing the risk of damage to the LHC's infrastructure.

Being CERN's director-general is sometimes a tough job but the consensual model of particle physics makes some aspects easy, as Chamonix once again showed this year. Following a recommendation arrived at by consensus, which has the buy-in of the whole community, is a simple choice to make. That consensus is our strength.

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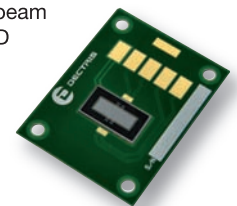
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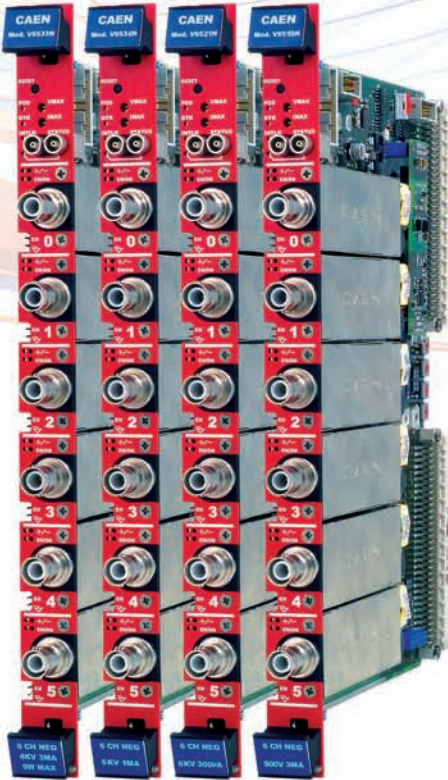
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