Welcome to the digital edition of the September 2015 issue of *CERN Courier*.

It is now 60 years since the antiproton was discovered at Berkeley in September 1955 and 20 years since the first antihydrogen atoms were made at CERN. Over the decades, antiprotons have become a standard tool in particle physics, and antihydrogen is now a miniature laboratory for investigations in fundamental physics, as this month’s anniversary feature describes. Recently, the BASE collaboration at the Antiproton Decelerator reported on a new comparison of the proton and antiproton to test a basic symmetry. Also at CERN, the ALICE experiment is investigating how loosely bound objects, including antinuclei, can survive the hot and dense heavy-ion collisions at the LHC.

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Covering current developments in high-energy physics and related fields worldwide
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Editor: Charlotte Cotton
News editor: Rob Kohn
CERN, 1211 Geneva 23, Switzerland
Tel +41 (0) 22 767 61 11, Fax +41 (0) 22 767 65 55
Web: cern-courier.com
Advisory board: Len Abrams-Cart, James Gillespie, Howard Morgan

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On the cover: A 600 MeV/amu antiproton interacts with a heavy nucleus in the downstream chamber of the P170 experiment at CERN’s Low Energy Antiproton Ring (LEAR) in the 1980s. It is now 60 years since the antiprotons were discovered at Berkeley and 20 years since the first antihydrogen atoms were made at LEAR (p.31). (Image credit: CERN-EX-9902017.)
In 1964, Murray Gell-Mann and George Zweig independently predicted a substructure for hadronic baryons would be comprised of three quarks, mesons of a quark–antiquark pair. They also said that baryons with four quarks and one antiquark were possible, as were mesons with two quarks and two antiquarks – dubbed, respectively, pentaquarks and tetraquarks, after the number of constituents. Since then, the picture for baryons and mesons has been thoroughly established within QCD, the theory of the strong interaction. Claims of the sighting of pentaquarks, meanwhile, have been thoroughly debunked. Nevertheless, their existence could cast important new light on QCD.

LHCb reports observation of pentaquarks

LHCb has subjected the results to a great deal of scrutiny. One interesting fact is that these events/(15 MeV) travels 3.9 cm before it decays into μ⁻K⁻ p, whose tracks are shown in the image below. The μ⁻ p are the decay products of the J/ψ. The horizontal band is indicative of the structure could be built up from two P+c states, with the belief that the structure could be built up from A⁺ interferences. This failed. The next attempt was with one P+c state, but the fit was deficient. Finally, a fit with two P+c states proved to be acceptable. The masses of the states are 4380±39 MeV and 4480±38 MeV, with widths of 20±5±8±6 MeV and 39±5±19 MeV, respectively. The states have opposite substructures for hadrons: baryons would be comprised of three quarks, mesons of a quark–antiquark pair. They also said that baryons with four quarks and one antiquark were possible, as were mesons with two quarks and two antiquarks – dubbed, respectively, pentaquarks and tetraquarks, after the number of constituents. Since then, the picture for baryons and mesons has been thoroughly established within QCD, the theory of the strong interaction. Claims of the sighting of pentaquarks, meanwhile, have been thoroughly debunked. Nevertheless, their existence could cast important new light on QCD.

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Pakistan becomes associate member state of CERN

The Islamic Republic of Pakistan became an associate member state of CERN on 31 July, following notification that Pakistan has ratified an agreement signed last December, granting this status to the country (CERN Courier January/February 2015 p6).

Pakistan’s new status will open a new era of co-operation that will strengthen the long-term partnership between CERN and the Pakistani scientific community.

Associate membership will allow Pakistan to participate in the governance of CERN through attending CERN Council meetings. Moreover, it will allow Pakistani scientists to become CERN staff members, and to participate in CERN’s training and career-development programmes. Finally, it will allow Pakistan industry to bid for CERN contracts, thus opening up opportunities for industrial collaboration in areas of advanced technology.

Collaboration

AIDA-2020 offers support to use facilities for detector development in Europe

The Advanced European Infrastructures for Detectors and Accelerators (AIDA-2020) is a cross-border, transnational project on joint detector development – as making financial support available for small development teams to carry out experiments and tests at one of 17 participating European facilities. The project, which started on 1 May, will run for four years. Its main goal is to bring the community together and push detector teams in the most efficient and efficient limits by sharing high-quality infrastructures provided by 57 partners from 34 countries, from Europe to Asia.

Building on the experience gained with the earlier AIDA project (CERN Courier April 2011 p6), the transnational access (TA) activities in AIDA-2020 are to enable small technical support teams to travel from one facility to another, to share existing infrastructures for efficient and reliable detector development. The support is organized around three different themes, providing access to a range of infrastructures: the Proton Synchrotron and Super Proton Synchrotron test beams, the IRRAD proton facility and the Gamma Irradiation Facility (GIF+üs) at CERN; the DESY test beam; the TRIGA reactor at the Jožef Stefan Institute; the Karlsruhe Compact Cyclotron (K-AZ); the Centre de Recherches du Cyclotron at the Université catholique de Louvain (UCLouvain); the MC 40 Cyclotron at the University of Birmingham; the Rudjer Boskovic Institute Accelerator Facility (RH–AP); and the electromagnetics compatibility facility (EMClab) at the Instituto Tecnológico de Aragón (ITAIÑOVA).

Access to high-energy particle beams (TA1) at CERN and DESY enables the use of test beams free-of-charge. Here the main goal is to attract more researchers to participate in beam tests, in particular supporting PhD students and postdoctoral researchers to carry out beam tests of detectors.

With the access to irradiation sources (TA2), the goal is to cover the range of particle sources needed for detector qualification for the High Luminosity LHC (HL–LHC) project. These include proton, neutron and mixed-field sources, as well as gamma irradiation. Through IRRAD, TRIGA, K-AZ and MC 40, it provides both the extreme fluxes of up to 10¹⁶ neq/cm² required for the forward region in HL–LHC experiments, and the lower fluxes of 10¹⁵ neq/cm² on 10 cm² objects for the outer layers of trackers. GIF+üs covers irradiation of large-scale objects such as muon chambers, while the Heavy Ion Irradiation Facility at UCLouvain is available for single-event-effect tests of electronics.

The third theme provides access to new detector-testing facilities (TA3). Semiconductor detectors will be one of the main challenges at the HL–LHC. Studying their behaviour with micro-ion beams at RH–AP will enhance the understanding of these detectors. Electromagnetic compatibility is a key issue when detectors have to be integrated in an experiment, and prior tests in a dedicated facility such as the EMClab at ITAIÑOVA will make the commissioning of detectors more efficient.

For more details on each facility and eligibility criteria, visit aida2020.web.cern.ch/content/transnational-access.

CPT

BASE compares charge-to-mass ratios of proton and antiproton to high precision

The Japanese/German BASE collaboration at CERN’s Antiproton Decelerator (AD) has compared the charge-to-mass ratios of the antiproton and proton with a fractional precision of 1.9 parts in a trillion (ppt). This high-precision measurement was achieved by comparing the cyclotron frequencies of antiprotons and negatively charged hydrogen ions in a Penning trap. The result is consistent with charge–parity–time-reversal (CPT) invariance, which is one of the cornerstones of the Standard Model of particle physics, and constitutes the most precise test comparing baryons and antibaryons performed to date.

In their experiment, the BASE collaboration has profited from techniques pioneered in the 1990s by the TRAP collaboration at the Low Energy Antiproton Ring at CERN (see p21). The advanced cryogenic Penning-trap system used in BASE consists of four traps, two of which were used in this measurement – a measurement trap and a reservoir trap (figure 1). When the experiment receives a pulse of 5.3 MeV antiprotons from the AD, they strike the degrader structure, which is designed to slow them down, and release hydrogen. Negatively charged hydrogen ions (H⁻) can form in the process, producing a composite cloud with the antiprotons that is used to fill the measurement trap. BASE has developed techniques to extract single antiprotons and negative hydrogen ions from this cloud whenever needed. Moreover, the reservoir has a lifetime of more than a year, making the BASE experiment almost independent of AD cycles.

Using this extraction technique, and taking into account the experiment’s limits, BASE prepares a single antiproton in the measurement trap, while an H⁻ ion is held in the downstream park electrode. The entire assembly is mounted in a cryogenic vacuum chamber. Above: Fig. 1. Schematic of the measurement (MT) and the reservoir (RT) Penning traps. Radio-frequency drives for particle manipulation make it possible to extract an appropriately positioned electrode of the measurement trap. The upstream and downstream park electrodes are used for the particle shunting scheme. The electron gun allows for electron cooling of the antiprotons. The entire assembly is mounted in a cryogenic vacuum chamber. Above: Fig. 2. (a) All 6521 values of the p⁻–H⁻ cyclotron frequency ratios measured in 35 days as a function of time. (b) The measured ratios projected onto a histogram.

![Comparison of cyclotron frequencies for protons (p) and antiprotons (p⁻)](image)

The high-sampling rate has also enabled the first high-resolution study of diurnal variations in a baryon/antibaryon comparison, which could be introduced by Lorentz-violating cosmic-background fields. The measurement set constraints on such variations at the level of less than 720 ppt. In addition, by assuming that CPT invariance holds, the measurement can be interpreted as a test of the weak equivalence principle using baryonic antimatter. If matter respects weak equivalence while antimatter experiences an anomalous coupling to the gravitational field, this gravitational anomaly would contribute to a possible difference in the measured cyclotron frequencies. Thus, by following these assumptions, the result from BASE can be used to set a limit on the gravitational anomaly parameter, αסור = 1.16×10⁻¹⁸.

The main goal for the BASE experiment, which was approved in June 2013, is to measure the magnetic moment of the antiproton with a precision of parts per billion. Using the double Penning trap system, the collaboration recently performed the most precise measurement of the magnetic moment of the proton (CERN Courier July/August 2014 p8).

Further Reading

The year 2015 began for the ATLAS experiment with an intense phase of commissioning using cosmic-ray tests and the first proton–proton collisions, allowing ATLAS physicists to test the trigger and detector systems as well as to align the tracking devices. Then the collection of physics data in LHC Run 2 started in June, with proton–proton collisions at a centre-of-mass energy of 13 TeV (CERN Courier July/August 2015 p28). Measurements at this new high-energy frontier were among the highlights of the many results presented by the ATLAS collaboration at EPS-HEP 2015.

An important early goal for ATLAS was to record roughly 100 pb–1 of inelastic proton–proton collisions with a very low level of secondary collisions within the same event (“pile-up”). This data sample allowed ATLAS physicists to perform detailed studies of the tracking detector. The “Insertable B-layer” (IBL) was a key component of these studies. ATLAS physicists measured the performance of electron, muon and tau-lepton reconstruction, the reconstruction and energy calibration of jets, and the identification of displaced “decays in flight” of long-lived particles, such as weakly decaying hadrons containing a bottom quark. The precision of the position measurements of displaced decay locations (vertices) is significantly improved by the new IBL detector.

ATLAS also measured the angular correlation among pairs of the produced charged particles, confirming the appearance of a so-called “ridge” phenomenon in events with large particle multiplicity at a centre-of-mass energy of 13 TeV. The “ridge” (figure 3) consists of long-range particle–particle correlations not predicted by any of the established theoretical models describing inelastic proton–proton collisions. After the low-luminosity phase, the LHC operators began to increase the intensity of the beams. By the time of EPS-HEP 2015, ATLAS had recorded a total luminosity of 100 fb–1, of which up to 85 fb–1 could be exploited for physics and performance studies. ATLAS physicists measured the performance of electron, muon and tau-lepton reconstruction, the reconstruction and energy calibration of jets, and the identification of displaced “decays in flight” of long-lived particles, such as weakly decaying hadrons containing a bottom quark. The precision of the position measurements of displaced decay locations (vertices) is significantly improved by the new IBL detector.

ATLAS used these data to classify the production of jet pairs at 13 TeV in terms of their immediate (“prompt”) and delayed (“non-prompt”) origin. While non-prompt jet production is believed to be well understood via the decay of b-hadrons, prompt production continues to be mysterious in some aspects.

Furthermore, the ATLAS Collaboration presented the results of a first study of the production of energetic, isolated photons in a single region of the detector. These results are consistent with the expectations of the Standard Model and provide important information about the possible existence of new physics.

For more information on the ATLAS collaboration’s results at 13 TeV, please visit the CERN website at https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LHC13TeV.
First results at 13 TeV and more from Run 1

The highlight of EPS-HEP 2015 for the CMS collaboration was the publication of the first physics results exploring the new territory at the LHC energy of 13 TeV: the measurement of the charged-hadron multiplicity (dN/dη), where η, the pseudorapidity, is a measure for the direction of the particle track. When protons collide at the LHC, more than one of their constituents (quarks or gluons) can interact with another one, so every collision produces an underlying spray of charged hadrons, such as pions and kaons, and the greater the energy, the higher the number of produced particles. Knowing precisely how many charged hadrons are created at the new collision energy is important for ensuring that the theoretical models used in the simulations employed in the physics analyses describe these underlying processes accurately. The publication from CMS and LHCb reports the differential multiplicity distribution for values of η = 2, and a measurement for central charged hadrons (with |η| < 0.5) of 5.49±0.01 (stat)±0.17 (syst). Figure 1 shows a comparison of the distribution and the energy dependence of the new measurement compared with earlier data at lower energies. CMS has, in addition, produced a full suite of performance plots covering a range of physics objects and event variables, using up to 43pb of 13 TeV data. Figure 2 shows the dimuon mass spectrum obtained from the sum of η–μ scattering resonances from the D meson to the Z boson can be seen clearly. The B physics group in CMS has also published a full suite of performance plots covering a range of physics objects and event variables, using up to 43pb of 13 TeV data. Figure 2 shows the dimuon mass spectrum obtained from the sum of η–μ scattering resonances from the D meson to the Z boson can be seen clearly. The B physics group in CMS has also published a full suite of performance plots covering a range of physics objects and event variables, using up to 43pb of 13 TeV data. Figure 2 shows the dimuon mass spectrum obtained from the sum of η–μ scattering resonances from the D meson to the Z boson can be seen clearly.

The physics groups in CMS have also started to study several processes at 13 TeV in some detail. One highlight is a first look for searches in the dijet invariant-mass spectrum, which so far reaches up to approximately 5 TeV (figure 3). Some of the recent analysis on Run 1 data were released only in spring, but CMS is already continuing the search where it ended at 8 TeV up to 13 TeV, thus demonstrating the collaboration’s readiness for discovery physics in the new energy regime. The TOP group has studied top–antitop (tt) events in the dilepton and lepton jets channels, in addition to tagging a first look at events consistent with the production of single top quarks.

While eagerly jumping on the new data, CMS continues to produce world-class physics results on the Run 1 data collected at 7 and 8 TeV. The collaboration has recently approved more than 30 new results, which were shown at the conference. These include searches for new physics as well as precision Standard Model measurements. The results presented include measurements of the tt-production rate, which are the third-time for W boson pairs through the interaction of two photons, the electroweak production of a W boson accompanied by two jets, production rates for particle jets at 2.76 TeV compared with 8 TeV, as well as the production of two photons along with jets.

At EPS-HEP 2015, the LHCb collaboration presented the first measurement of the J/ψ production cross-section in proton–proton (pp) collisions at 13 TeV. Using this measurement, they also determined the b-quark cross-section at this new, higher energy. J/ψ mesons can be produced both "promptly", in the pp collision, and as a product of decays of B hadrons, dubbed "B→J/ψ+...". The two components are visible in figure 1, which shows the J/ψ decay-time distribution with respect to the pp collision time. The black points with error bars show the data, the solid red line indicates the best fit to the data, and the prompt J/ψ contribution is shown in blue. The black line indicates the J/ψ→B→J/ψ contribution. These results are used to compute the b-quark pair total cross-section. The data at 13 TeV confirm the expected rise of the B→J/ψ production rate of about a factor two with respect to 7 TeV. This increase will enable LHCb to obtain even more precise, interesting and, hopefully, surprising results in LHC Run 2.

In addition to Run 1, the LHCb collaboration reported new results on long-range correlations in proton–lead (pPb) collisions. LHCb’s latest measurements show that the so-called “ridge” seen in the most violent collisions span across even larger longitudinal distances, as figure 2 shows at ∆φ = 0 below the (truncated) peak at 0.0. This is the first time that the effect has been seen in the forward direction (LHCb 2015c). Moreover, because of its acceptance, the LHCb experiment distinguishes between configurations where the lead-ion enters from the front and those where it is the proton. Somewhat unexpectedly, the ridge is seen in both cases.

J/ψ mesons, b decays and more

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Further reading

The photometric technique used in PAUCam is very precise for determining redshifts, but at the expense of much longer exposure times. Furthermore, only the spectra of previously selected objects are analysed, while the photometric technique determines, in principle, the redshift of all the objects in the region of the sky being imaged. In the case of PAUCam, the expectation is to measure the redshift of about 50,000 objects every night of observation. The camera covers the entire field of view of the WHT (1 square degree) with a mosaic of 18 Hamamatsu Photonic red-sensitive CCDs, each with 4000 × 2000 pixels.

PAUCam has been designed and built over the past six years by a fruitful collaboration between astronomers, cosmologists and particle physicists in a consortium of Spanish institutions. The idea to build an instrument capable of contributing significantly to cosmological measurements arose in 2007, in the context of the Consolider Ingenio 2010 project financed by the Spanish government. This programme had as its objective the achievement in Spain of highly innovative projects.

The PAUCam team is now being joined by other European groups to conduct a survey, named PAUS, with the objective of scientifically exploiting the capabilities of the camera. Aside from the survey, observation time with PAUCam will be made available to the international scientific community, for astronomical as well as cosmological measurements.

PAUCam was designed and built by a consortium comprising the Instituto de Física d’Altes Energies (IFAE), the Institut de Ciències de l’Espai (ICE-CSIC/IEEC) and the Instituto de Física Teórica (IFT-UAM/CSIC), both in Madrid.
Most animals have tails with round cross-sections, but tails of seahorses have square ones. Michael Porter of Clemson University in South Carolina and colleagues have now explained why. Using 3D printing to make articulated models of square and circular tails and test them, they found that while cylindrical tails could twist better, the square cross-section provides more contact area and helps the tail to relax, reducing the energy the animal has to expend to grasp things. The square cross-section is also three times stiffer and four times stronger under compression.

**Further reading**
M. Porter et al. 2015 Science 349 aaa6683-1.

### Scientific Topics

- **New Detector Developments in**
  - Particle physics
  - Astro-particle physics
  - Nuclear physics

- **Applications in**
  - Biology
  - Medicine
  - Neutron scattering
  - Synchrotron radiation

*Abstract Submission Deadline: 16 October 2015*

### Scientific Articles

#### Buckyballs in Space

*Buckyballs are famous for their soccer-ball-like structure, with 60 carbon atoms (Image credits: NASA/JPL-Caltech.)*

Numerous “diffuse interstellar bands” (DIBs) in the absorption spectra of the interstellar medium have been puzzling astronomers since their discovery nearly 100 years ago. Now, thanks to Ewen Campbell of the University of Basel and colleagues, two infrared lines (at 9632.7 ± 0.1 Å and 9577.5 ± 0.1 Å) have been matched up with laboratory measurements of spectra of buckminsterfullerene or “buckyball” C₆₀ in the gas phase cooled to 5.6 K. Buckminsterfullerene has a low ionization potential, so finding it as an ion is not surprising, but the origin of the molecule itself in space and the nature of the rest of the DIBs are still mysterious.

**Further reading**

#### Weyl point seen

Back in 1929, Hermann Weyl proposed an equation for massless particles with a conical point in its dispersion relation – the “tip” of the mass shell, also called the “Weyl point”. Neutrinos have mass, so do not fit his equation, but now the Weyl point has turned up in a solid-state system. Following earlier theoretical suggestions, Su-Yang Xu of Princeton University and colleagues used photoemission spectroscopy to show that TaAs is a Weyl semimetal, with Weyl fermions as emergent quasiparticles. They clearly demonstrated “Weyl cones” and the Weyl point for propagation in the bulk, as well as Fermi arcs on the surface. The work is generating great excitement because this is, in many ways, a 3D analogue of graphene, and promises a range of applications.

**Further reading**
S-Y Xu et al. 2015 Science 349 aaa6683-1.

#### Mining waste

Sewage in the US could be a useful source of high-value metals. Paul Westerhoff of Arizona State University and colleagues have found that the amounts of the 13 most lucrative elements – Ag, Cu, Au, P, Fe, Pb, Mn, Zn, Ir, Al, Cd, Ti, Ga and Cr – add up to be worth a total of $280 for each tonne of sludge. This corresponds to around $8 million per million people, or more than $2.3 billion per year for the country as a whole. The metals enter the wastewater system from a variety of industries and the challenge will be to extract them from the sludge in an economical way.

**Further reading**
Based on optical observations, a team of astronomers has, for the first time, demonstrated a link between a very long-lasting gamma-ray burst (GRB) and an unusually bright supernova explosion. The results show that the supernova was not driven by radioactive decay, as expected, but most likely by the spin down of a magnetar, a neutron star with an extremely strong magnetic field.

GRBs have intrigued astronomers since their discovery nearly 50 years ago by US military satellites intended to detect nuclear test explosions conducted by the Soviet Union. Mysterious gamma-ray flashes were detected, not from Earth, but from random directions in the sky. It was only some 30 years later that the detection of their precise locations and the measurement of their redshifts by follow-up observations proved them to be very luminous events from remote galaxies. The further evidence that some of them are associated with supernova explosions settled the issue of their true nature as being a manifestation of the core collapse of a massive star (CERN Courier September 2003 p3).

Astronomers usually distinguish two main classes of GRBs: the short ones that flare up for less than about 2 s and the longer ones. Among the latter, there are a few outstanding bursts lasting more than 10,000 s, which have been proposed to originate in the explosion of giant stars with much larger radii (CERN Courier June 2015 p12). A team led by Jochen Greiner of the Max-Planck-Institut für extraterrestrische Physik in Garching, Germany, has now shown that a supernova explosion is associated with one of these rare ultra-long-duration GRBs, namely GRB 111209A. The supernova’s presence has been derived from observations of the afterglow emission by two telescopes of the European Southern Observatory in Chile: the GROND instrument on the 2.2 m telescope at La Silla and the X-shooter instrument on the Very Large Telescope at Paranal.

The supernova’s spectral and timing properties are both very peculiar. Its luminosity is intermediate between the supernovas usually associated with GRBs and a new class of super-luminous supernovas discovered in 2011. The exceptional luminosity of the latter would be due to energy injection from a rapidly rotating magnetar—a neutron star with a huge magnetic field of up to about 10¹⁵ T. The same process could be at play in the supernova of GRB 111209A. Indeed, the huge amount of nickel needed to explain the observed light curve by radioactive decay of ⁵⁶Ni is not compatible with the rather featureless spectral shape, which suggests a star of low metallicity. While Greiner and colleagues cannot prove that a magnetar is at the origin of the ultra-long GRB of 9 December 2011, nor the source of the luminous and peculiar supernova they observed, they can rule out alternative possibilities, leaving this as the most likely one. Magnetars have already been invoked to explain the long-lasting afterglow emission of some GRBs (CERN Courier May 2007 p11). Now they seem to be needed to account for powering the prompt emission of some of these powerful flashes of gamma rays. Their advantage is that they would provide a continuous power supply, from hours to months, by losing rotational energy through magnetic dipole radiation. The flexibility of the magnetar model fits peculiar GRBs and supernovas well, but what about the more standard GRBs? Could they also be powered by a new-born magnetar rather than by a black hole?

**Further reading**
J Greiner et al. 2015 Nature 523 189.

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**Picture of the month**

Welcome to Pluto! Thanks to NASA’s New Horizons mission, astronomers and the general public alike now know what the dwarf planet Pluto looks like. Even with the eye of the Hubble Space Telescope, Pluto can only be seen as a little patchy marble. A journey of more than nine years was needed from Earth to this previously outermost planet – now called a dwarf planet – to take this snapshot. Unlike ESA’s Rosetta spacecraft, which orbits the comet 67P/Churyumov–Gerasimenko (CERN Courier October 2014 p17), New Horizon was not planned to go into orbit around Pluto, but just flew by on 14 July. This high-resolution true-colour image was assembled from four images taken by the Long Range Reconnaissance Imager (LORRI). It shows a bright region in the shape of a heart contrasting with darker areas harbouring mountains rising more than 3000 m above the surface. The brightest area is an intriguing craterless, frozen plain, which is possibly still being shaped by geologic processes. (Image credit: NASA/JHUAPL/SwRI.)
CERN Courier: 1972

Shots from the CERN/BBTV film to be released in November: hadrons (vehicles), pions (boys) and kaons (adults) prepare for interactions. The last two carry zero hadronic charge. They are black, grey and white for negative, zero, and positive electric charge. Unfortunately, from a photograph it is not possible to hear the hypercharge!

(Image credits: CERN/BBTV.)

CERN News

Pop physics

How to give insight into the concepts of particle physics? How to show the general public something of the inherent fascination and fundamental importance of a subject that seems so far removed from ordinary affairs and so dependent on advanced mathematics? This was the problem confronting Denis Postle of Tattooist International, the producer of a film that CERN and the British Broadcasting Corporation (BBC) have made as a co-production.

The project started nearly three years ago, after Postle had come to Geneva to make a film for the regular BBC science programme Horizon. This film, like others before it, talked about CERN, the machines and the physicists, but the physics remained for the most part in the background, intangible and inaccessible.

We needed a new style, a new approach, and we had to see in the phenomena described. It was pointless to try to cram into forty minutes of film a physics course that most students find difficult enough spread over as many months. In any case, few members of the public wish to become physicists overnight. They are interested in knowing what particle physics has to do with them, how it relates to their day-to-day affairs and what this research reveals.

In producing the film, CERN had provided the physics know-how and many people have spent a lot of time and effort trying to explain the principal themes of present-day research in simple terms – none more so than R Hagedorn. The BBC, in the person of Peter Goodchild, editor of Horizon, had provided expertise on presentation and has been the final arbiter on audience acceptance. Postle as producer has turned the talk into a theme, pictures and text. Composers have become bubble rah rah, iconic hall shaps, proton motors, pions small boys, interactions, dances, and quarks a series of moves in a special game of chess. The accelerators, the ISR and the big detectors remain in the background, giving place to a machine gun and paper target that provided the participants at least a few of fun. The music has been composed and is played by Pete Townshend of The Who.

The film is meant to be entertaining, but it is, nevertheless, a serious attempt to show something of the methods behind the research, and to give some impact of the surprising order and harmony underlying the disorders and divisions usually more apparent in our daily lives.

For the BBC, it represented a new approach, both in technique and organization. For Tattooist, it was a challenge to get to grips with a subject that must be one of the most difficult to portray. For CERN, it is another experiment – if not in physics, at least in physics communication.

Comment from a physicist: “We risk making high-energy physics crystal clear to the public and totally obscure to the physicists!”

Compiled from texts on pp 288–289.
Sixty years after the discovery of the antiproton at Berkeley, a look at some of the ways that studies with antiprotons at CERN have cast light on basic physics and, in particular, on fundamental symmetries.

On 21 September 1955, Owen Chamberlain, Emilio Segrè, Clyde Wiegand and Tom Ypsilantis found their first evidence of the antiproton, gathered through measurements of its momentum and its velocity. Working at what was known as the “RadLab” at Berkeley, they had set up their experiment at a new accelerator, the Bevatron—a proton synchrotron designed to reach an energy of 6.5 GeV, sufficient to produce an antiproton in a fixed-target experiment (CERN Courier November 2005 p27). Soon after, a related experiment led by Gerson Goldhaber and Edoardo Amaldi found the expected annihilation “stars”, recorded in stacks of nuclear emulsions (figure 1). Forty years later, by combing antiprotons and protons, an experiment at the Low Energy Antiproton Ring (LEAR) at CERN gathered evidence in September 1995 for the production of the first few atoms of antihydrogen.

Over the decades, antiprotons have become a standard tool for studies in particle physics; the word “antimatter” has entered into mainstream language; and antihydrogen is fast becoming a laboratory for investigations in fundamental physics. At CERN, the Antiproton Decelerator (AD) is now an important facility for studies with antiprotons at CERN have cast light on basic physics and, in particular, on fundamental symmetries.

Back at the Bevatron, the discovery of the antineutron through neutral particle annihilation followed in 1956, setting the scene for studies of real antimatter. Initially, everyone expected perfect symmetry between matter and antimatter through the combination of the operations of charge conjugation (C), parity (P) and time reversal (T). However, following the observation of CP violation in 1964, it was not obvious that nuclear forces were CPT invariant and that antinucleons should bind to build antinuclei. These doubts were laid to rest with the discovery of the antideuteron at AD in 1964, it was not obvious that nuclear forces were CPT invariant and that antinucleons should bind to build antinuclei. These doubts were laid to rest with the discovery of the antideuteron at AD in 1964.

Exit baryonium, enter new mesons
Back in 1949, before the discovery of the antiproton, Enrico Fermi and Chen-Ning Yang predicted the existence of bound nucleon--antinucleon states (baryonium), when they noted that certain repulsive forces between two nucleons could become attractive in the nucleon--antinucleon system. Later, quark models based on dual-ity predicted the existence of states made of two quarks and two antiquarks, which should be observed when a proton annihilates with an antiproton. In the 1970s, nuclear-potential models went on to predict a plethora of bound states and resonance excitations around the two-nucleon mass. There were indeed reports of such states, among them narrow states observed in antiproton–proton
The construction of LEAR took advantage of the antiproton facility that was built at CERN in 1980 to search for the W and Z bosons at the Super Proton Synchrotron (SPS) operating as a p+p collider (CERN Courier December 1999 p15). The antiprotons originated when 26 GeV protons from the PS struck a target. Emerging with an average momentum of 3.5 GeV/c, they were collected in the Antiproton Accumulator (AA), and a pure antiproton beam with small transverse dimensions was generated by stochastic cooling. Up to 10^11 antiprotons a day could be generated and stored. The antiprotons were then extracted and injected into the PS. After acceleration to 26 GeV, they were transferred to the SPS where they circulated in the same beam pipe as the protons, but in the opposite direction. After a final acceleration to 270 GeV, the antiprotons and protons were brought into collision. For injection into LEAR, the 3.5 GeV/c antiprotons from the AA were decelerated in the PS, down to 600 MeV/c. Once stored in LEAR, they were further decelerated to 60 MeV/c and then slowly extracted with a typical intensity of 10^10. LEAR started up in 1982 and saw as many as 16 experiments before being decommissioned in 1986. The LEAR magnet ring lives on in the Low Energy Ion Ring, which forms part of the injection chain for heavy ions into the LHC. LEAR also benefited from the Initial Cooling Experiment (ICE), a storage ring designed in the late 1970s to test Simon van der Meer’s idea of stochastic cooling on antiprotons, and later to investigate electron cooling. After essential modifications, the electron cooler from ICE went on to assist in cooling antiprotons at LEAR, and is now serving at CERN’s current antiproton facility, the AD (CERN Courier September 2009 p13). ICE also contributed to measurements on antiprotons, when in August 1978, it successfully stored antiprotons at 2.1 GeV/c – a world first – keeping them circulating for 32 hours. The previous best experimental measurement of the antiproton lifetime, from bubble-chamber experiments, was about 10^14 s; now, it is known to be more than 10^16 years. 

Small length scales, and could lead to slight differences between the properties of particles and antiparticles, such as lifetime, inertial mass and magnetic moment. 

At LEAR, the TRAP collaboration (PS96) performed a series of pioneering experiments to compare precisely the charge-to-mass ratios of the proton and antiproton, using antiprotons stored in a cold electromagnetic (Penning) trap. The signal from a single stored antiproton could be observed, and antiprotons were stored in the trap for up to two months. By measuring the cyclotron frequency of the orbiting antiprotons with an oscillator and comparing it with the cyclotron frequency of H+ ions in the same trap, the team finally achieved a result at the level of 9 x 10^-9. The experiment used H+ ions instead of protons to avoid biases when reversing the signs of the electric and magnetic fields. 

Under the assumption of CPT invariance, the violation of CP symmetry first observed in the neutral kaon system in 1964 implies that T invariance is also violated. However, in 1998 the CPLEAR experiment demonstrated the violation of T in the neutral kaon system without assuming CP conservation (CERN Courier March 1999 p2). The K0 and K0* (1.9 GeV/c) were produced in high-intensity p+p annihilation at CERN’s Proton Synchrotron (PS) and in measurements of the p+p cross-section as a function of energy (the S-meson with a mass of 1940 MeV/c2). Baryonium was the main motivation for the construction at CERN of LEAR, which ran for more than a decade from 1982 to 1996 (see box). However, none of the baryonium states were confirmed at LEAR. The S meson was not observed with a sensitivity 10 times below the signal reported earlier in the p+p total cross-section. Monoenergetic transitions to bound states were also not observed. The death of baryonium was a key topic for the Anti-proton 86 Conference in Thessaloniki. What had happened? The high quality of the antiproton beams from LEAR meant that all events indicate the presence of intermediate resonances that dynamically contribute to the decay (dashed curves). The data and the spin-2 mesons f2(1270) and f2(1565). The f0(1500) is a good candidate for a glueball. 

**Fundamental symmetries**

The CPT theorem postulates that physical laws remain the same when the combined operation of CPT is performed. CPT invariance arises from the assumption in quantum field theories of certain requirements, such as Lorentz invariance and point-like elementary particles. However, CPT violation is possible at very small length scales, and could lead to slight differences between the properties of particles and antiparticles, such as lifetime, inertial mass and magnetic moment. 

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Antiprotons

Antiprotons have so far failed, as a result of strap electric or magnetic fields. In contrast, the electrically neutral antihydrogen atom is an ideal probe to test the WEP. The AEgIS collaboration at the AD plans to measure the sagging of an antihydrogen beam over a distance of typically 1 m with a two-grating deflectometer. The displacement of the moiré pattern induced by gravity will be measured with high resolution (around 1 μm) by using nuclear emulsions (figure 6) – the same detection technique that was used to demonstrate the annihilation of the antiproton at the Bevatron, back in 1956.

The future is ELENA

Future experiments with antimatter at CERN will benefit from the Extra Low ENergy Antiproton (ELENA) project, which will become operational at the end of 2017. The capture efficiency of antiprotons in experiments at the AD is currently very low (less than 0.1%), because most of them are lost when degrading the 5 MeV beam from the AD to the few kiloelectron-volts required by the confinement voltage of electromagnetic traps. To overcome this, ELENA – a 3m circumference electron-cooled storage ring that will be located in the AD hall – will decelerate antiprotons down to, typically, 100 keV. Fast extraction (as opposed to the slow extraction that was available at LEAR) is foreseen to supply the trap experiments.

One experiment that will profit from this new facility is GRAR, which also aims to measure the gravitational acceleration of antihydrogen. Positrons will be produced by a 4.3 MeV electron linac and used to create positive antihydrogen ions (i.e. an antiproton with two positrons) that can be transferred to an electromagnetic trap and cooled to 10 mK. After transfer to another trap, where one of the positrons is detached, the antihydrogen will be launched vertically with a mean velocity of about 1 m/s (CERN Courier March 2014 p11).

It is worth recalling that the discovery of the antiproton in Berkeley was based on some 60 antiprotons observed during a seven-hour run. The 1.2 GeV/c beam contained 5×10⁶ more pions than antiprotons. Today, the AD delivers pure beams of some 3×10⁷ antiprotons every 100 μs (at 100 MeV/c), which makes the CERN laboratory unique in the world for antimatter studies. Over the decades, antiproton beams have led to the discovery of new mesons and enabled precise tests of symmetries between matter and antimatter. Now, the properties of hydrogen and antihydrogen are being compared, and accurate tests will be performed with ELENA. The odds to see any violation of exact symmetry are slim, but the AEgIS collaboration is enthusiastic about the surprising discovery of the non-conservation of parity in 1957 and CP violation in 1964 – experiments that, ultimately, have the last word.

Further reading

For more about symmetries and the experiments described here, see Nuclear and Particle Physics by Claude Amstler (2015 IOP Publishing), available in print and as an ebook, see http://iopscience.iop.org/book/978-0-7503-1140-3.

Résumé

Dans le sillage de l’antiproton

Quarante ans exactement après la première observation d’antiprotons à Berkeley, une expérience menée au CERN a réuni des indices probants de la production des premiers atomes d’antihydrogène. Au fil des années, les antiprotons sont devenus un outil standard de la physique des particules ; le mot « antimatière » est entré dans le langage courant ; l’antihydrogène est en voie de devenir un véritable laboratoire de la physique fondamentale. L'article s'intéresse à certains faits marquants des recherches relatives au monde de l'antimatière au CERN, et nous en dit plus sur ce que nous pouvons attendre du Décelateur d’antiprotons.

– Claude Amstler, Albert Einstein Center for Fundamental Physics, University of Bern, and Christine Sutton, CERN.

CERN Courier September 2015

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The main goal of the ALICE experiment at the LHC is to produce and study the properties of matter as it existed in the first few microseconds after the Big Bang. Such matter consists of fermions and bosons, the fundamental entities of the Standard Model. Depending on the temperature, $T$, only particles with mass much less than $T$ are copious. For $T \leq 600$ MeV, they are the $u$ and $d$ quarks and the gluons of the strong interactions. In addition, there are of course photons, leptons and neutrinos.

This “cosmic matter” can be produced in the laboratory by collisions at relativistic energies between very heavy atomic nuclei, such as lead at the LHC and gold at Brookhaven’s Relativistic Heavy Ion Collider (RHIC). In these collisions, a fireball is formed at (initial) temperatures up to 600 MeV, with a volume exceeding 1000 fm$^3$ – about the volume of a lead nucleus – and with lifetimes exceeding 10 fm/$c$, about $3 \times 10^{-23}$ s. This space–time volume is macroscopic for strong interactions, but charged leptons, photons and neutrinos leave the fireball without interacting and play no part in the following discussion. (However, charged leptons and photons do have a role as penetrating probes of the produced matter.) Such deconfined cosmic matter is referred to as quark–gluon plasma (QGP) because its constituents carry colour and can roam freely within the volume of the fireball. At LHC energies, the QGP comprises, in addition to gluons, essentially equal numbers of quarks and antiquarks, i.e. it carries no net baryon number, as would also have been the case in the early universe.

The produced fireball expands and cools until it reaches the (pseudo-)critical temperature, $T_c$, of the deconfinement–confinement transition. Solving the strong-interaction equations on a discrete space–time lattice leads, in the most recent predictions, to $T_c \approx 155$ MeV. The yields of hadrons produced in central lead–lead (Pb–Pb) collisions at LHC energies and measured with the ALICE detector can indeed be quantitatively understood by assuming that they all originate from a thermalized state described with a grand-canonical thermal ensemble at $T_{\text{chem}} = 156$±2 MeV; the “chemical freeze-out” temperature $T_{\text{chem}}$ is therefore very close to or coincides with $T_c$ (see figure 1). While the overall agreement between data and model predictions is excellent, there is a 2.8o discrepancy for (anti)protons, which is currently under scrutiny. Because the volume of the fireball is fixed by the number of particles produced, the temperature $T_{\text{chem}}$ is the principal parameter determined in the grand-canonical analysis.

Such Pb–Pb collisions produce not only hadrons in the classical sense but also composite and even fragile objects such as light nuclei (d, 3 He, 4 He) and light A-hypernuclei, along with their antiparticles. Their measured yields decrease strongly with increasing (anti)baryon number – the penalty factor for each additional (anti) baryon is about 300 – hence anti($\pi$)/He production is a very rare process. Note that, because the fireball carries no net baryon number, the yields of the produced antiparticles closely coincide with the corresponding particle yields.

An interesting question is whether the yields of composite objects can be understood in the same grand-canonical scheme as discussed above, or whether such loosely bound objects follow a different systematics. The deuterons binding energy, for example, is only 2.23 MeV, and the energy needed to separate the A hyperon from a hypernucleus – a bound state of a proton, neutron and A – is only about 130 keV, which is much smaller than the chemical freeze-out temperature, $T_{\text{chem}} = 156$ MeV.

Furthermore, the radii of such loosely bound objects are generally very large, even exceeding significantly the range of the nuclear force that binds them. The rms radius of the deuterons is 2.2 fm, for example. Even more dramatically, because of the molecular structure of the hypernucleon ($\pi^- + A$), its rms radius, which in this case is the rms separation between the d nucleus and the A hyperon, is about 10 fm — that is, larger than the radius of the whole fireball.

**Identification is the key**

Before answering the question of how such exotic and fragile objects are produced, it is important to discuss how well such rare particles can be measured in the hostile environment of a Pb–Pb collision. In a central Pb–Pb collision at LHC energies, more than 15,000 charged particles are produced and up to 3000 go through the central barrel of the ALICE detector, making the task of tracking and identifying all of the different particle species quite a challenge. With ALICE, the identification of all of the produced particles and, in particular, the measurement of light nuclei and A-hypernuclei, is only possible because of the experiment’s excellent tracking and particle-identification capabilities via dE/dx and time-of-flight measurements. This is demonstrated in figure 2, which shows an event display from the ALICE time-projection chamber (TPC) for a central Pb–Pb collision. The highlighted black track corresponds to an antihypernucleon, identified via dE/dx and time-of-flight measurements. This demonstrates the key role played by ALICE in identifying these particles.

Figure 3 shows the clean identification achieved for anti-hepta particles. At first glance it is surprising that, as figure 1 shows, the measured yields of deuteron and hypertriton and their antiparticles agree very well with the yields calculated using the approach described above for hadrons at the same chemical freeze-out temperature, $T_{\text{chem}} = 156$ MeV. This implies that the yields of these loosely bound objects are determined at the phase boundary from the QGP to a hadron gas. How is this possible for such loosely bound objects whose sizes are much larger than the inter-particle separation at the time of chemical freeze-out?
To understand this, thermodynamics comes to the rescue. If there are no more inelastic collisions after chemical freeze-out, then the transition from the QGP to hadronic matter is followed by an isentropic expansion (i.e. with no change in entropy). Early studies of nucleus–nucleus collisions at the Berkeley Bevalac already showed that, for systems with isentropic expansion, the entropy/nucleon is proportional to $\log(d/p)$, implying that the yield of deuterons and antideuterons is determined by the entropy in the hot phase of the fireball. The same mechanism is at play at LHC energies: in this way, the “snowballs” can survive “hell”, as the experimental data from the ALICE collaboration show.

These facts can be used to search for even more exotic states. ALICE has performed a search for two hypothetical strange dibaryon states. The first one is the $\Lambda$–$\Lambda$ dibaryon, which is a six-quark bound state of $\Lambda$ mesons, first predicted by Robert Jaffe in a “bag” model in 1977. This early calculation led to a binding energy of 41 MeV. Recent non-perturbative QCD calculations (on the lattice) suggest either a loosely bound state or a resonant state with a maximum of 7.3 MeV, with the most preferred value around 1 MeV. The second hypothetical bound state investigated by ALICE is a possible $\Lambda$–$\bar{p}$ bound state.

The two searches are performed in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in the decay modes $\Lambda$–$p\pi^{-}$ and $\Lambda\rightarrow p+\Lambda\pi^{-}$, respectively. No signals are observed in either of the measured invariant-mass distributions, therefore setting upper limits for the production yields. These limits are well below the yields predicted using the grand-canonical scenario discussed above with $T_{\text{beam}} = 156$ MeV (see figure 1). In fact, the difference between the upper limit at 99% CL obtained for the $\bar{p}$–$\Lambda$ bound state is a factor of around 50 below the prediction, whereas the factor between the upper limit at 99% CL and the model prediction for the $\Lambda$–$\bar{p}$ dibaryon is close to 25. Given the success of the model in predicting deuteron and hypertriton yields, it appears that the existence of such bound states is very unlikely.

With the LHC’s Run 2, which has just started, and much more with the upgraded ALICE apparatus in LHC Run 3, it is expected that ALICE can measure hypernuclei with still higher masses, such as $\Lambda$–$\Lambda$ or $\Lambda$–$\bar{p}$, as well as other exotic di-baryons.

In summary, the success in describing the production of different hadrons and the yields of loosely bound objects with the same temperature, $T$, provides strong evidence for isentropic expansion after the transition from the QGP to a hadron gas. This scenario naturally explains the observed yields for loosely bound objects. On the other hand, the upper limits obtained for the $H$–$\bar{p}$ dibaryon and the An bound state are well below the model prediction using the same temperature, $T = 156$ MeV, casting serious doubts on their existence. The ALICE data on light antinucleus production in pp, p–$\bar{p}$ and Pb–Pb collisions shows that very loosely bound objects are produced with significant yields for all systems, with the thermodynamic limit reached for the $p$–$\bar{p}$ system. The measured yields are expected to increase with beam energy similar to the way that the overall multiplicity density does. This implies significant production of antideuterons from high-energy cosmic rays, with potential consequences for searches for dark matter. Their yields can be well predicted within the scenario described here.

Further reading

For details concerning analysis and interpretation of the production of nuclei, hypertriton and exotica, see the following:


Résumé

L’omelette norvégienne d’ALICE.

Il n’y a pas seulement des hadrons ordinaires dans les débris des “boules de feu” produites par les collisions d’ions lourds effectuées à l’expérience ALICE auprès du LHC : on y trouve aussi des objets composites, aux liaisons lâches, tels que deutérons et hypernècles légers et leurs antiparticules. Des études montrent que la production de ces particules, telle qu’elle peut être mesurée, concorde très bien avec les résultats calculés avec la même méthode que pour les hadrons, ce qui implique que les taux de production des objets à liaison lâche sont déterminés à la limite de phase entre le plasma quark–gluon de la boule de feu et un gaz hadronique. Comment est-ce possible ? La réponse est donnée par la thermodynamique.

Peter Braun-Munzinger, EMMI, GSI, FAAS und Universität Heidelberg, Benjamin Dönigus, Johann Wolfgang Goethe-Universität Frankfurt, and Nicole Löhr, TU Darmstadt, EMMI, GSI.

Heavy ions

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Massimo Tarenghi fell in love with astronomy at age 14, when his mother took away his stamp collection – on which he spent more time than on his schoolbooks – and gave him a book entitled *Le Stelle* (The Stars). By age 17, he had built his first telescope and become a well-known amateur astronomer, meriting a photo in the local daily newspaper with the headline “Massimo prefers a bigger telescope to a Ferrari.” Already, his dream was “to work at the largest observatory in the world”. That dream came true, because Massimo went on to build and direct the world’s most powerful optical telescope, the Very Large Telescope (VLT), at the European Southern Observatory (ESO)’s Paranal Observatory in Chile.

“I was born as a guy who likes to do impossible things and I like to do them 110%,” says Massimo, who decided to study physics at the University of Milan in the late 1960s “because [Giuseppe] Occhialini was the best in the world and allowed me to do a thesis in astronomy”. His road to the stars began in 1970, when he gained his PhD with a thesis on the production of gamma rays by Sagittarius A – at the time a mysterious radio source, which is now known to harbour the supermassive black hole at the centre of the Milky Way. This was at the time of the first observations in X rays and in infrared of the centre of the Galaxy, and the first of many examples of far-sighted intuition in Massimo’s career.

Following his PhD, Massimo convinced his colleagues at Milan to support the construction of an infrared telescope on the Gornergrat in the Swiss Alps. He was then sent to the Steward Observatory at the University of Arizona, where he did pioneering work in infrared astronomy. He quickly made himself known with a daring request for telescope time involving all of the instruments. “At that time,” he recalls, “there was a clear separation between astronomy for infrared, spectroscopy or photography, and there were three levels of use of an instrument: astronomer without assistant, assistant astronomer, or general (university) public. I asked for all of the instruments – and in particular for the bolometer, which no one had ever dared ask for!” After a three-hour meeting, his proposal to observe infrared galaxies was judged “very interesting but totally crazy”. So the committee suggested a compromise: 10 of his candidate objects would be observed during the telescope’s spare time and then they could review the request. Massimo accepted, and two weeks later seven of his objects had been found to be infrared emitters. “So they gave me the whole bolometer three-months later. I was lucky!” he says with the same enthusiasm as the 28-year-old postdoc he was at the time.

It was, once again, pure intuition. Massimo had chosen his 10 objects based on M82, a galaxy that interacts with its larger neighbour M81. “M82 is a beautiful galaxy with explosions and I thought, when two galaxies interact, they trigger explosions. So I simply had a collection of interacting galaxies and it came out that this is just what they did.” This intuition was to be confirmed by what has become a pillar of astrophysics: when two galaxies interact, the gas inside is compressed, creating a large number of new stars, which produce a large amount of infrared emission as they form.

While still in Arizona, Massimo decided to work on the optical identification of radio galaxies. “At the time, the Hercules cluster was not very well explored, with a redshift of 11,000 km/s. Compared to the well-known Coma cluster, with a redshift of 5000 km/s, it is much further and very difficult to observe between Arizona’s summer storms,” he explains. “Astronomers came to me saying that the cluster was ‘theirs’, as they had started work on it three years earlier. But they had done no observations. So I offered to collaborate, and we decided that whoever took more galaxies would be the first author on the publication. They found 19, I took all of the rest: 30!” That paper is now a cornerstone in astronomy.

Massimo Tarenghi: a lifetime in the stars

The man who built the largest observatory in the world talks about his many achievements.
determination and audacity are indeed the distinctive marks of his work. In the way that telescopes are conceived of and built. Intuition, not just in the way that astronomy is done, but by bringing innovation and tradition together. Dubbing himself “a difficult person,” Massimo broke new ground and set records.

Massimo’s contribution to the field of astronomy is immense. He was involved in the invention of the system, but Massimo was involved from early on, and he invented the system, the 2.2 m. Built for the Max Planck Institute, it had been destined for Namibia originally, but with Italy and Switzerland about to join ESO in 1981, the decision was taken to install it at ESO’s site at La Silla. “The Italians are very aggressive astronomers,” Massimo explains, “so we needed to increase telescope time, and I was asked to take the 2.2 m telescope from Heidelberg, put it in place at La Silla, and run the team.” They had to do everything: they had no dome, no foundations, and a budget of only DM 5 million, which was a very limited amount compared with other projects of a similar size. But, as Massimo says, “when you have no money you do great things,” and he had an idea. “I saw a thin aluminium dome on the last page of an amateur astronomers’ magazine, and I asked an engineer in my team to design a scaled-down version of our dome.” With the concrete foundations laid almost manually, and the help of three engineers recruited from Zeiss to build a new electronic system, they succeeded in installing the telescope for a total cost of DM 7 million.

The 2.2 m telescope saw its first light in June 1983, with a record-breaking angular resolution of 0.6 arc seconds. “The reason is simple,” says Massimo. “The dome was so small that we had to move all the electronics underneath, so there was no source of heat coming from the telescope, and that’s how we learnt how to remove heat from the dome.” It was also the first telescope to be operated remotely.

“We took the controls from the upper floor to the lower floor, and when we saw that it worked, with the software engineer we decided to do remote control from La Serena. So, instead of waiting for my call, and he waited five, six hours before he decided to call me, asking whether he could… go to the toilet!”

In 1983, Massimo was asked to be project manager for the New Technology Telescope (NTT), a 3.6 m optical telescope that saw first light six years later. With a record-breaking resolution of 0.33 arc seconds, it produced sharper images of stellar objects than ever obtained with a ground-based telescope. The NTT was the prototype for a new type of telescope that would make the VLT possible. The main revolutionary feature was the application of active optics, in which a thin and flexible primary mirror is key, and it is its correct shape by a support system that responds to continual real-time analysis of a stellar image. It was ESO’s Ray Wilson who invented the system, and Massimo was involved from early on, and his former institute in Milan built the first test bench with which the system was shown to work in the early 1980s. The thin-mirror technology allowed by active optics was the breakthrough that enabled the construction of the next generation of much larger telescopes. In particular, the VLT, built on a second ESO site in Chile, on the mountain of Cerro Paranal in the Atacama desert.

The VLT was proposed in 1986 and approved in 1987. Massimo was given the responsibility to build it in March 1988 by ESO’s director-general Harry van der Laan, and was later fully supported by the following director-general, Riccardo Giacconi. He was part of the team that decided to go from 4 m to 8 m mirrors that could be combined as an astronomical interferometer—a technique that was still in its early days. With four fixed 2.5 m-diameter Unit Telescopes (UTs) and four 1.8 m-diameter movable Auxiliary Telescopes (ATs), the VLT is today the most advanced optical observatory in the world. The UTs work either individually or in a combined mode using interferometry, while the ATs are entirely dedicated to interferometry. “I had under me 250 technicians. It was the craziest project I ever managed,” Massimo remembers, “and I learnt a lesson: if you want to work in the biggest observatory in the world you have to build it!”

Building the Paranal Observatory was not just a scientific experience for Massimo, he is also at the origin of the award-winning futuristic Residencia, chosen as the set for the James Bond film Quantum of Solace. “I wanted something that could make astronomers at Paranal become human again after 13 or 14 hours of observation, to experience the pleasure of water, and of green, red and all the colours missing in the desert,” he explains. “This is the dream we recreated in this place, water in the desert, for the people working at the most advanced telescope in the world.”

After the VLT, Massimo went on to direct another “crazy” astronomy project, the Atacama Large Millimeter/submillimeter Array (ALMA), the first truly global collaboration in astronomy (CERN Courier October 2007 p23). He also conducted the exploration work for the site of the next-generation facility, the European Extremely Large Telescope (E-ELT), with a record-breaking 39 m-diameter mirror. Construction work started at the Cerro Armazones, chosen as the site for E-ELT, in March 2014. Massimo, who celebrated his 70th birthday at the end of July, officially retired from ESO in 2013, but he has not stopped working for European astronomy. He still commutes between the ESO sites in Chile, Santiago and Munich, supporting ESO’s public relations activities in Chile—and spending endless nights photographing the unique sky above the Atacama desert.

Résumé

Massimo Tarenghi : une vie parmi les étoiles

Massimo Tarenghi est tombé amoureux de l’astronomie à l’âge de 14 ans, le jour où sa mère lui a confié sa collection de timbres pour lui donner un livre intitulé Le Stelle (Les étoiles). À 17 ans, il avait construit son premier télescope et son rêve était déjà de “travailler dans le plus grand observatoire du monde”. Son rêve s’est réalisé puisqu’il a fini par construire et diriger le télescope optique le plus puissant jamais produit, le Very Large Telescope (VLT), à l’observatoire Paranal (Chili), dépendant de l’Observatoire européen austral (ESO). Il évoque ici les nombreux défis qu’il a dû relever au cours de sa carrière.

Paoletta Catapano, CERN, met with Massimo Tarenghi during a visit to the Paranal observatory in July.
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CERN and Sri Lanka have formed a partnership with the aim of formalizing and broadening their co-operation. To this end, CERN’s director-general, Rolf Heuer, and Sri Lanka’s permanent representative at the United Nations in Geneva, Ravinatha Aryasinha, signed an expression of interest on 25 June 2015.

The agreement incorporates Sri Lanka in CERN’s High School Teachers and Summer Student programmes. It also aims at preparing a platform that will allow more scientists from Sri Lanka to participate in CERN’s cutting-edge research programmes. Several scientists from Sri Lanka universities have already participated in LHC experiments within frameworks such as subatomic leave, while others have participated as visiting scientists employed by universities in other countries. To allow for broader and more sustained participation, discussions have begun on forming a “cluster” of Sri Lankan universities and research institutes with the aim of joining one of the LHC collaborations.

Amber Boehnlein takes charge of IT at Jefferson Lab

Amber Boehnlein is the new chief information officer (CIO) at Jefferson Lab. As CIO, she is responsible for the Information Technology (IT) Division as well as the IT systems, including scientific data analysis, high-performance computing, IT infrastructure and cyber security. Bohneinlein arrived at Jefferson Lab in June, having led the Computing Division at SLAC from 2011. At SLAC she gained expertise in computational physics relevant to light sources and large-scale databases for astrophysics, as well as overseeing the hardware computing systems for the high-energy physics programme. Prior to her time at SLAC, she served a three-year assignment as the US Department of Energy’s Office of High Energy Physics’s programme manager for the US Large Hadron Collider Detector Operations programme.

Having gained a PhD in physics in 1990 at Florida State University, Boehnlein was a member of the DØ collaboration at Fermilab from 1991 to 2013, and served as the collaboration’s computing and software co-ordinator from 1999 to 2006. As a staff scientist in the Computing Division at Fermilab, she was responsible for the computing and application support for all Fermilab-based experiments.

CERN receives Hermes Innovation award

CERN’s leading role in international scientific co-operation has been recognized with a 2015 Hermes Innovation award. The European Institute for Creative Strategies and Innovation makes the awards for “humanistic innovation” annually to selected organizations and companies that have excelled in offering more satisfaction to society through their products and services. The awards, which are linked to up to eight themes, are named after Hermes — in Greek mythology an ingenious and inventive god who supports human ventures.

For more about the event, see www.rencontre-innovation.com.

Frédéric Bordry, centre with the Hermes award, Marc Giger, right, and Sylvie Borzakian, left, respectively, founders president and director of the Club de Paris des Directeurs de l’Innovation and the European Institute for Creative Strategies and Innovation. (Image credit: M Iesci/ Hermes Award.)
The “founding fathers” of CMS, Michel Della Negra of CERN and now Imperial College, and Tejinder Virdee of Imperial College, have been awarded, respectively, the 2014 André Lagarrigue Prize and the 2015 Glazebrook Prize.

Della Negra is cited as “a leader with a deep understanding of physics, in Lagarrigue’s lineage” and for “his outstanding qualities as a builder of experimental devices of great complexity” in his role as a major player in the discoveries at CERN of the W, Z and Higgs bosons. Virdee is cited for “his leadership of the CMS experiment at the LHC, where evidence for the Higgs boson was revealed after 20 years of research” and for “his prominent role in the innovative design and lengthy construction of the CMS experiment, in particular the scintillating-crystal-based electromagnetic calorimeter, a vital piece of the ‘toolbox’ necessary to discover the Higgs boson”.

Della Negra started his career at the College de France with a thesis in 1967 on a bubble-chamber study of proton–antiproton annihilations at rest. He then pursued physics at the Intersecting Storage Rings at CERN, where he convinced the Split Field Magnet collaboration to focus on high-pT physics. Having there demonstrated the capabilities of a 4x multi-purpose detector, he became involved in the proposed proton–antiproton collider in the Super Proton Synchrotron, and made decisive contributions to the design of UA1 – another 4x detector. Virdee carried out his graduate studies at Imperial College London, on the hybrid bubble-chamber at SLAC. In 1979, as a CERN fellow he worked on the NA14 photo-production experiment, where the fractional electric charge of the quarks was measured. Virdee also collaborated on the UA1 experiment at CERN. His keen interest in hadron–collider physics and precision calorimetry in UA1 led to his prominent role in the CMS experiment.

Della Negra and Virdee were among the first physicists to support the project that became the LHC. In 1989, they started thinking of a 4x detector for the new machine, based on a strong magnetic field produced by a large solenoid capable of containing the inner tracker and the calorimeters. Della Negra focused on the optimization of the moon and trigger systems, and Virdee on a high-precision electromagnetic calorimeter, with a view to discovering the Higgs boson through its decay into four muons and two photons. In 1992, Della Negra was elected the CMS collaboration’s first spokesperson, with Virdee as his deputy, until 2006. This period saw the conception, R&D and prototyping, and much construction of the CMS experiment. During this period, Della Negra and Virdee took many critical and difficult decisions to ensure the optimal performance and success of the CMS experiment. In 2006, Virdee was elected spokesperson for three years, during which he oversaw the complex tasks of the completion of construction, installation and commissioning underground, and the first collision data-taking. The discovery of the Higgs boson by both the ATLAS and CMS experiments at the LHC was announced in July 2012. The Lagarrigue award, established in 2005 under the aegis of the French Physical Society, pays tribute to André Lagarrigue, director of the Laboratory of Linear Accelerator (LAL, Orsay) from 1969 to 1975, who had a major role in the discovery of neutral weak interactions with the Gargamelle bubble-chamber at CERN. Co-funded by the CEA, CERN, École Polytechnique, IN2P3-CNRS, LAL and Université Paris-Sud, the prize is awarded every two years.

The Glazebrook medal and prize is the most prestigious award of the UK Institute of Physics (IOP), and is named after its first president. Peter Higgs, professor emeritus at the University of Edinburgh, has been elected the 2015 Glazebrook Prize winner. He has been named in the ranks of Charles Darwin, Humphry Davy and Albert Einstein by winning the world’s oldest scientific prize, the Royal Society’s Copley Medal, which was first awarded in 1731. Higgs receives the 2015 award for his work that contributed to what is known as the Brout–Englert–Higgs (BEH) mechanism, which endows fundamental particles with mass. The particle known as the Higgs boson – the emissary of this mechanism – was discovered by the ATLAS and CMS experiments at the LHC in 2012.

The Royal Society has also recognized research in particle physics and at the LHC with the awarding of one of its Royal Medals to Chris Llewellyn Smith, who was director-general of CERN from 1994 to 1998. Llewellyn Smith is renowned for his major contributions to the development of the Standard Model, particularly his success in making the case for the building of the Large Hadron Collider®. The Royal Medals, founded by King George IV in 1825, are awarded for the most important contributions in the physical, biological, and applied sciences.

Amanda Cooper-Sarkar is cited “for her study of deep-inelastic scattering (DIS) of leptons on nuclei, which has revealed the internal structure of the proton” As a world expert in DIS, her career has covered all forms of lepton–proton scattering and the study of QCD to elucidate the structure of the nucleon. Cooper-Sarkar has distinguished herself in devising techniques to distil the experimental data into knowledge that could be interpreted and extrapolated in QCD. She was recently a leading figure in preparing the final papers in the area of DIS from the Hadron Electron Ring Accelerator at DESY, and also plays a leading role in the ATLAS groups at CERN that are making new measurements of the proton’s structure function.

The Royal Society honours particle physics

For distinguished work in particle physics, Amanda Cooper-Sarkar of Oxford University has been awarded the IOP’s Chadwick Medal and prize. She receives the award for “her study of deep-inelastic scattering (DIS) of leptons on nuclei, which has revealed the internal structure of the proton”. As a world expert in DIS, her career has covered all forms of lepton–proton scattering and the study of QCD to elucidate the structure of the nucleon. Cooper-Sarkar has distinguished herself in devising techniques to distil the experimental data into knowledge that could be interpreted and extrapolated in QCD.
MoEDAL takes monopoles to London

The MoEDAL experiment at the LHC and its “Monopole Quest” were on show at the Royal Society’s 2015 Summer Science Exhibition on 30 June–5 July. The week-long display of the most exciting cutting-edge science and technology in the UK took place, as customary, at the society’s base in London. The exhibition featured 22 exhibits, where hundreds of visitors could meet the scientists, try some of the hands-on activities or attend inspiring talks and events.

Visitors to the MoEDAL exhibit could design their own monopole detector, take part in the “Citizen Science” project to search online for monopole tracks in exposed MoEDAL plastic nuclear-track detectors, and test MoEDAL trapping volumes for captured monopoles. They could also visualize a Dirac monopole and investigate radioactivity on their mobile phones using a MoEDAL TimePix Chip. Involvement was awarded with gifts and prizes, which included a MoEDAL medal. There was fun for all, including the team looking after the exhibit, despite the unusual London temperatures that soared to higher than 30°C.

The MoEDAL groups involved in proposing, designing and eventually staffing the exhibit were from Imperial College London, King’s College London, CERN, the University of Alberta, Langton Star Centre and the Simon Langton Grammar School for Boys.

QCD–Montpellier celebrates 30th anniversary

Every one to two years, Montpellier hosts the International Conference on Quantum Chromodynamics (QCD). Initiated in 1985 by Stephan Narison, director of research of the French National Research Centre for Scientific Research at the Laboratory of Universe and Particles of Montpellier, as a conference on non-perturbative methods, it took on the name QCD in 1990, and since 2001 has alternated with the International Conference on Quantum Chromodynamics (QCD). Initiated in 1985 by Stephan Narison, director of research of the French National Research Centre for Scientific Research at the Laboratory of Universe and Particles of Montpellier, as a conference on non-perturbative methods, it took on the name QCD in 1990 and, since 2001 has alternated with the International Conference on Non-perturbative Methods (HEPMAD) in Madagascar. This year, QCD–Montpellier celebrated its 30th anniversary at its 18th edition, which took place on 29 June–3 July.

During its 30 years, the conference has welcomed many world experts to Montpellier, including Nobel prize winners – Jack Steinberger attended in 1997, David Gross in 1998 and Gerald ’t Hooft in 1998 and 2002 – as well as winners of the J J Sakurai prize: Stanley Brodsky in 1990 and 2014, Mikhail Shifman in 2008 and 2010, and Valentin Zakharov, who has been a member of the International Committee and 2010, and Valentin Zakharov, who has been a member of the International Committee and regular participant since 1996.

The conference also provides training for doctoral students and young postdocs, who are often present and talk for the first time in front of international QCD experts. The meeting’s size of around 100 attendees, with equal numbers of theorists and experimentalists, allows participants to interact in a relaxed atmosphere, created by the well-organized social events and by the beauty of Montpellier and its surroundings, which favour discussions and the initiation of future collaborations.

Unlike other workshops, QCD–Montpellier covers all aspects of QCD including those related to searches for new physics beyond the Standard Model. It is also a meeting where new experimental results are often presented before the large international particle-physics conferences – or at the same time, as with the special session that took place on 4 July 2012 to present the Higgs discovery by ATLAS and CMS by video conference.

For more on QCD 15, visit www.lupm.univ-montp2.fr/users/qcd/qcd15/Welcome.html. For HEPAMD 15, which will take place on 17–22 September, see www.lupm.univ-montp2.fr/users/qcd/heapmad15/Welcome.html.
On 1 October 1954, Physical Review published the seminal paper by Chen-Ning Yang and Robert Mills that was to become a cornerstone of theoretical physics. The Yang–Mills gauge field theory laid the foundation of the Standard Model of particle physics, and also went on to have widespread applications in statistical physics, condensed-matter physics, atomic and nonlinear optics and nonlinear systems. In May, the Institute of Advances Studies, Nanyang Technological University in Singapore, held a major conference on “60 years of Yang–Mills gauge field theories”, attracting more than 180 participants from around the world. Many eminent speakers attended to present results related to Yang–Mills gauge theories, including, in particular, Yang himself. (Sadly, Mills died in 1999.) The presentations included interdisciplinary talks by Paul Chu on “A possible paradigm shift in the search for higher Tc”, Robert Crease on “Yang–Mills for historians and philosophers” and Antti Niemi on “Folding proteins at the speed of life”. There were also interesting reminiscences by Yu Shi and Zhong Qi Mao of the immense contributions by Yang to physics in general. In addition, David Gross, Michael Fisher and Yang gave public lectures on personal perspectives on physics. Because the famous paper was written when Yang and Mills shared an office during the summer at Brookhaven Laboratory, the conference also included a round-table discussion on the role of regional labs and hubs in promoting collaboration in theoretical and fundamental physics. Various suggestions were made during the discussion, including strong arguments for creating an Asian version of CERN, where Asian countries could work with scientists from the rest of the world to uncover new levels of fundamental physics.

For more about the conference, see www.ntu.edu.sg/ias/upcomingevents/Yang-Mills60/. The proceedings will be published by World Scientific.
Bernard Hyams, a distinguished scientist who worked at CERN for 32 years, died on 15 May at the age of 90.

EDUCATION

Hyams studied physics at Cambridge, earning his BSc in 1944 and his DPhil in 1948. He then worked for 4 years at the Institute of Nuclear Physics in Cracow, where he joined the teaching staff in 1950 and worked on a magnetic spectrometer to measure the momentum of single cosmic-ray particles. He went on to lead the group that set up a cosmic-ray experiment at the Pic du Midi Observatory, which in 1953–1955 observed eight well-identified unstable particles having properties consistent with the Kπ hadron. He submitted his PhD thesis on a search for antiproton production by high-energy cosmic-ray particles, in 1955.

ACADEMIC CAREER

Visiting CERN on sabbatical in 1958, Bernard participated in an experiment conducted in the Lötschberg Tunnel in the Swiss Alps, which showed that the nucleon lives longer than 2 × 10^26 years—a subject that was to gain importance many years later. He accepted a staff appointment at CERN in 1959 and performed one of the first experiments at the Proton Synchrotron to investigate in detail in pion decay the muon’s spin behavior as expected after studying vector meson decay. After studying vector meson decays, he moved into muon pairs, where he spent several years working on precision measurements with pions. In France, in collaboration with Georges Chabaud of the University of Paris and Bernard Sterlin of MIP Munich, he organized a group specializing in muon spectroscopy, which, according to Hyams, was “a very pleasant environment”.

At the beginning of 1965, Hyams became interested in the study of their decays using silicon-microstrip detectors, which were implemented in the NA 32 experiment. Around 1974, the CERN–Munich group joined forces with others to form a wellequipped group that operated a number of experiments in this field. Among these was the Super Proton Synchrotron, first in the West Area (WA3), before moving to the North Area (NA11 and NA32). With the discovery of charmed particles, Bernard became interested in the study of their decays using silicon-microstrip detectors, which were implemented in the NA32 experiment. This experiment, which ran up to 1990, became a pioneer in the use of silicon microstrip detectors for precision vertex measurements at particle colliders, in particular applying the technique in the DELPHI detector at CERN’s Large Electron–Positron (LEP) collider. During a sabbatical year at SLAC, in collaboration with Sherwood Parker and James Walker, he developed the VLSI chip for microstrip read-out, allowing compact vertex detectors to be built for collider experiments. The proposal for the DELPHI device was put forward, and part of the microstrip vertex detectors collected data during the first LEP run in August 1989. It was completed for the next running period in 1990 and upgraded successfully a number of times.

While continuing his research work, Bernard was leader of the CERN Experimental Physics Division from 1984 to 1997. Overall, he spent 32 years at CERN before retiring in April 1990. In 2002, he received the title of Honorary Professor of the Institute of Nuclear Physics at Cracow for his role in bringing Cracow’s physicists into modern experiments at CERN. The laudatio forms an excellent tribute to Bernard’s career in general, recognizing “the outstanding achievements in experimental particle physics, his role in introducing many scientists to the mysteries of modern physics and his great contribution to the development of scientific collaboration between CERN and national physics institutions”.

Discussing a physics project with Bernard was always special. With his brilliant mind he would quickly grasp the essential points, making suggestions for improvements or criticizing, if warranted, with his keen British sense of humour. He was always attentive to the feelings of others, and visibly enjoyed CERN’s exciting research atmosphere and the contact with younger colleagues. Because of his wisdom and generosity, many requested his advice, especially when difficult decisions had to be made. He was scrupulously fair and never pushed himself to the forefront, preferring to work hard in the shadows for the good of the group and the institution. He was patient to know and work with him. His influence went far beyond the boundaries of CERN, and all of his colleagues, no matter where located, remember him as a great friend who will be sorely missed.

Bernard was very attached to his family, from his wife Hanna to his granddaughter Solongo. He died just one month after his beloved wife, surrounded by his family.

Our warmest thoughts and sympathy go to them and to the many others who have shared an important part of their professional lives with Bernard.

HIS FRIENDS AND COLLEAGUES

FlIR Systems has announced a new version 4.2 of ResearchIR, a powerful and easy-to-use research software. ResearchIR 4.2 provides researchers with a powerful tool for viewing, acquiring, analyzing, and sharing thermal image data. The software is compatible with FLIR’s scientific and R&D cameras. For the first time, users can direct access to Matlab scripts directly with specialized image-analysis and processing tools. For further information, tel +32 9665 5000, e-mail flirresearch@flir.com .

Intersil Corporation has announced a new high-voltage synchronous buck controller able to bypass the intermediate step-down converter to achieve high efficiency in industrial applications. The ISL817 synchronous step-down PWM controller’s low-duty cycle (40%) minimum on-time and direct step-down conversion from 48 V to 1 V point-of-load. This technical achievement makes it possible for designers to reduce system complexity in infrastructure applications. For more information, tel +1 865 482 4411, or visit www.ortec-online.com .

The ORTEC® Product Group of AMETEK Advanced R&D has announced the release of Profile “SP” Series P-type high-purity germanium (HPGe) detectors, providing premium resolution at low to medium energies for a range of demanding, radiation detection applications. The detectors employ a low-noise back contact combined with a semi-planar crystal geometry. The proprietary back contact technology reduces the load at lower energies, while supporting the same resolution at higher energies. PX detectors also provide superior energy resolution, allowing warm storage, simplified detector handling, and lower conversion costs. For more information, tel +1 865 422 4411, or visit www.ortec-online.com .

XP Power has announced the DDC15 and DDC30 series of low-profile 15 W and 30 W DC-DC point-of-load converters. The range is designed to offer additional voltages in DIN rail power systems, providing isolated outputs and noise immunity or support battery-powered or battery-backed applications. The single output converters accommodate 1–4 input range from 9–30 VDC, suiting 12 or 24 VDC nominal systems. They are available with a choice of a 5, 9, 12, or 15 VDC nominal output. The DDC15 model is available with a 3.3 VDC output. Input-to-output isolation is 1500 VDC. For further information, contact Steve Head, tel +44 118 984 5515, e-mail shedad@xp-power.com or visit www.xp-power.com .
Professor or Reader in Novel Methods of Particle Acceleration

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The Cockcroft Institute, a unique collaboration between the Universities of Lancaster, Liverpool, Manchester and Strathclyde, the Science and Technology Facilities Council and industry brings together the best accelerator scientists, engineers, educators and industrialists to combine, design, construct and use innovative instruments of discovery and to lead the UK's participation in flagship international agreements. The Cockcroft Institute has been involved in the development of the UK's first Free Electron Laser (FEL) and the MUSE accelerator test facility and is contributing towards development of an ambitious UK-based CLARA to advance worldwide health, energy, research. It has a strong collaboration with CERN in the areas of LHC and its future upgrades, with research and future developments in high energy accelerators, including the AWAKE experiment for proton-driven plasma wakefield acceleration, and with the GSI at Darmstadt. It is also developing a stronger relationship with the University of Strathclyde and their laser-driven plasma acceleration facility SEAFA. The Institute is housed in a dedicated building adjacent to the Diamond Laboratory, one of the two major national accelerator laboratories in the UK.

As a founding member of the Cockcroft Institute and with a very highly ranked Physics Department, Lancaster University is keen to appoint, depending on experience and profile, a Professor (equivalent to Full Professor) or Reader (equivalent to Associate Professor) in Novel Methods of Particle Acceleration who will hold a significant leadership position in the Institute with major responsibility for developing its programmes of research in novel acceleration techniques. The successful applicant will be expected to advance experimental research in novel methods of particle acceleration, including plasma wakefield acceleration, research and technology in technology in accelerators, photonic and particle technology. The Cockcroft Institute is committed to promoting diversity within its community as a source of excellence, cultural enrichment, and social strength. We welcome those who would contribute to the further diversification of our Institute and Department. The Cockcroft Institute will offer a competitive salary, a generous benefits package, and excellent research facilities.

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**Position:**

**DESY-Helmholtz Association:**

**Responsibilities:**

- Contributing to the development and operation of DESY's synchrotron research facilities
- Conducting research in high energy physics

**Requirements:**

- PhD degree in physics or related field
- Experience in high energy physics research

**Application Process:**

Applications should include a CV, a list of publications, and a letter of interest. Successful candidates will be offered a competitive salary and the opportunity to work on cutting-edge research projects.

**Website:**

[DESY](http://www.desy.de/jobs/jobsformen/index.html)
EMPLOYMENT OPPORTUNITIES AT THE CHERENOV TELESCOPE ARRAY PROJECT OFFICE, HEIDELBERG

The European XFEL GmbH (European XFEL) is a multi-national non-profit company. It will make available X-ray pulses of unique quality for studies in physics, chemistry, the life sciences, materials research, and other disciplines. Located in the Hamburg area, Germany, it will comprise scientific instruments for a wide range of experimental techniques exploiting the short duration of the ultra-high brilliance and the spatial coherence of the X-ray pulses. Construction of the European XFEL is underway, user operation starts in 2017.

The Chairperson of the Management Board

- has the overall responsibility in all scientific, technical and organisational matters,
- leads and coordinates the work of the Management Board,
- represents, together with the other Managing Director (the Director of Administration), the Company as Managing Director,
- acts as the primary contact at the Company for the shareholders, the international scientific community and the public,
- reports to the Council (assembly of shareholders),
- promotes internally the further development of leadership culture, diversity and equal opportunity policy,
- cooperates constructively with the Works Council.

The position of Managing Director and Chairperson of the Management Board (f/m) is due to be reoccupied in January 2017.

The Chairperson of the Management Board

- shall be expected to recruit an individual with a strong background in the management of technical and complex projects, preferably in the area of fundamental scientific research facilities, and the ability to work as part of a multidisciplinary team,
- shall be expected to be able to attract the highest calibre of dedicated individuals to the Company in order to develop and build the necessary expertise to run the European XFEL.

Responsibilities

- participates in the strategic development of the company,
- ensures the overall implementation of the strategy,
- oversees the day-to-day management of the business activities of the company,
- interfaces with the shareholder representatives on important decisions,
- coordinates and aligns the activities of project managers and their teams,
- has ultimate responsibility for financial matters of the company and their sustainability,
- represents the company towards the public and its stakeholders.

Requirements

- has previous experience in the management of large-scale research projects, preferably in the field of high energy physics or high energy physics facilities,
- is able to demonstrate strong leadership skills and an understanding of the role of the chairperson of the management board,
- has a proven track record of working with international partners,
- is fluent in spoken and written English and has a strong understanding of German or another language as required by the company,
- has strong interpersonal and organisational skills.

Applications are to be submitted via:

- www.xfel-info@egonzehnder.com
- http://www.xfel.eu/career/

The CTA Project Office in Heidelberg, Germany is responsible for coordinating the project and intends to recruit up to 20 individuals in the following disciplines/roles:

- Coordination of site infrastructure design and implementation
- Site Managers (to be located at array sites)
- Risk Manager/Project Support
- Project Office IT/Other
- Resource Coordination
- Systems Engineers/Requirements/VW/RAMS
- Systems Engineers/Coordinators (General, Mechanical, Electrical/Control System, Software/Array control)
- Maintenance and Operations Engineer
- CAD Modeler/Design Engineer
- Project/Manager for Production/Logistics/Assets

CTA welcomes speculative applications at various levels of experience (as well as some part-time internships). Contracts would initially be for two years with the strong possibility of renewal.

More information: www.cta-observatory.org

Information about how to apply for these studentships is available at the CTA bookshop.

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Particle Accelerators: From Big Bang to Hadron Therapy

By Ugo Amaldi

Paperback: £19.99 €16.01 $34.99


Available also at CERN Bookshop

There was a time when books on particle physics for the non-expert were a rarity, not quite as rare as Higgs bosons, but certainly as heavy quarks. Then, rather as the “November revolution” of 1974 heralded in the new era of charm, beauty and top, so the construction of the LHC became the harbinger of a wealth of “popular” books on particle physics, and the quest to find the final piece of the Standard Model and what lies beyond. These books can be excellent in what they set out to do, but few venture where Ugo Amaldi goes – to look at the basic tools that have made this whole adventure possible, and in particular, the accelerators and their builders. Without the cyclotron and its descendants, there would be no Standard Model, no CERN, no LHC. Nor would there be the applications, particularly in medicine, which Amaldi himself has done so much to bring about.

As the son of Eduardo Amaldi, one of CERN’s “founding fathers”, Ugo Amaldi must have the history of particle physics in his bones, and he writes with feeling about the development of particle accelerators, introducing names that are now part of our personal experiences, but not always of the people he admires. There is a passion here that makes the book interesting even for those who already know the basic story. Indeed, while particle physicists may not be the only ones in the world to think in mind, they can still learn from many chapters, “speed-reading” the parts they are familiar with, and picking up the threads of the historical gems – such as the rather sad story of the co-inventor of strong focusing, Nick Christofilos, about whom I had previously known little beyond his being Greek and a father.

For the non-expert, the book has much to absorb, the result of containing quite a thorough mini-introduction to the Standard Model and beyond – the author’s inner particle physicist could clearly not resist. Yet it is worth persevering and reading the chapters on “accelerators that care”, to use Amaldi’s phrase, to discover the medical applications of the 21st century.

So, this is a book for everyone, and in particular, I believe, for young people. Books like this inspired my studies, and I would like to think that Amaldi will inspire others with his passion for physics.

Christine Sutton, CERN.
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