WELCOME

CERN Courier – digital edition

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

Following the restart of the LHC in April, commissioning is proceeding well, but as the news from the LHC experiments highlights, there is still plenty to harvest from the data collected during the collider's first long run. There is also still plenty to study away from the energy frontier. The observation of a new particle state by the COMPASS experiment is a reminder that there is more to CERN than the LHC, while at Fermilab, the Mu2e experiment will focus on a different potential avenue to new physics.

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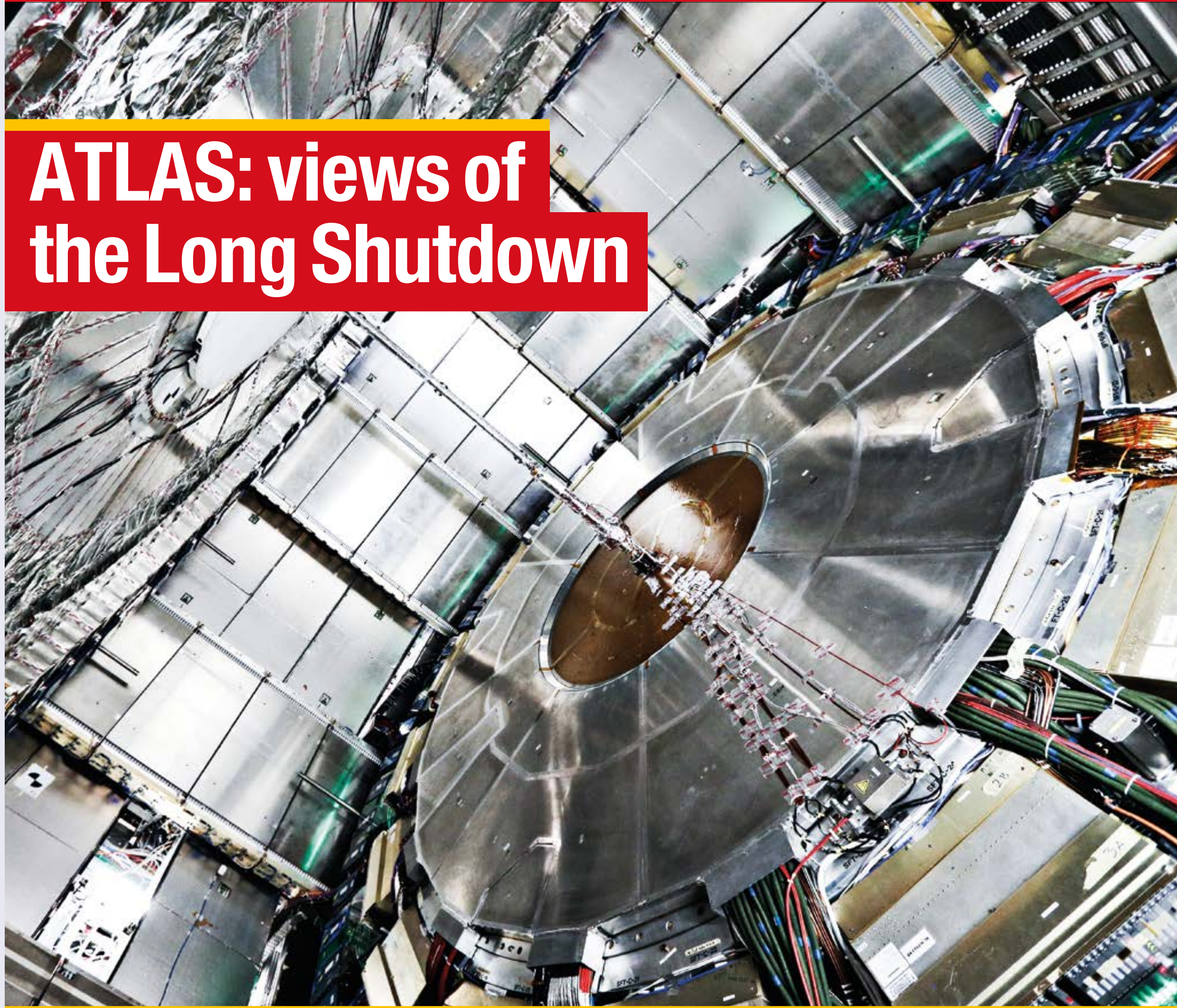
EDITOR: CHRISTINE SUTTON, CERN
DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 55 NUMBER 5 JUNE 2015



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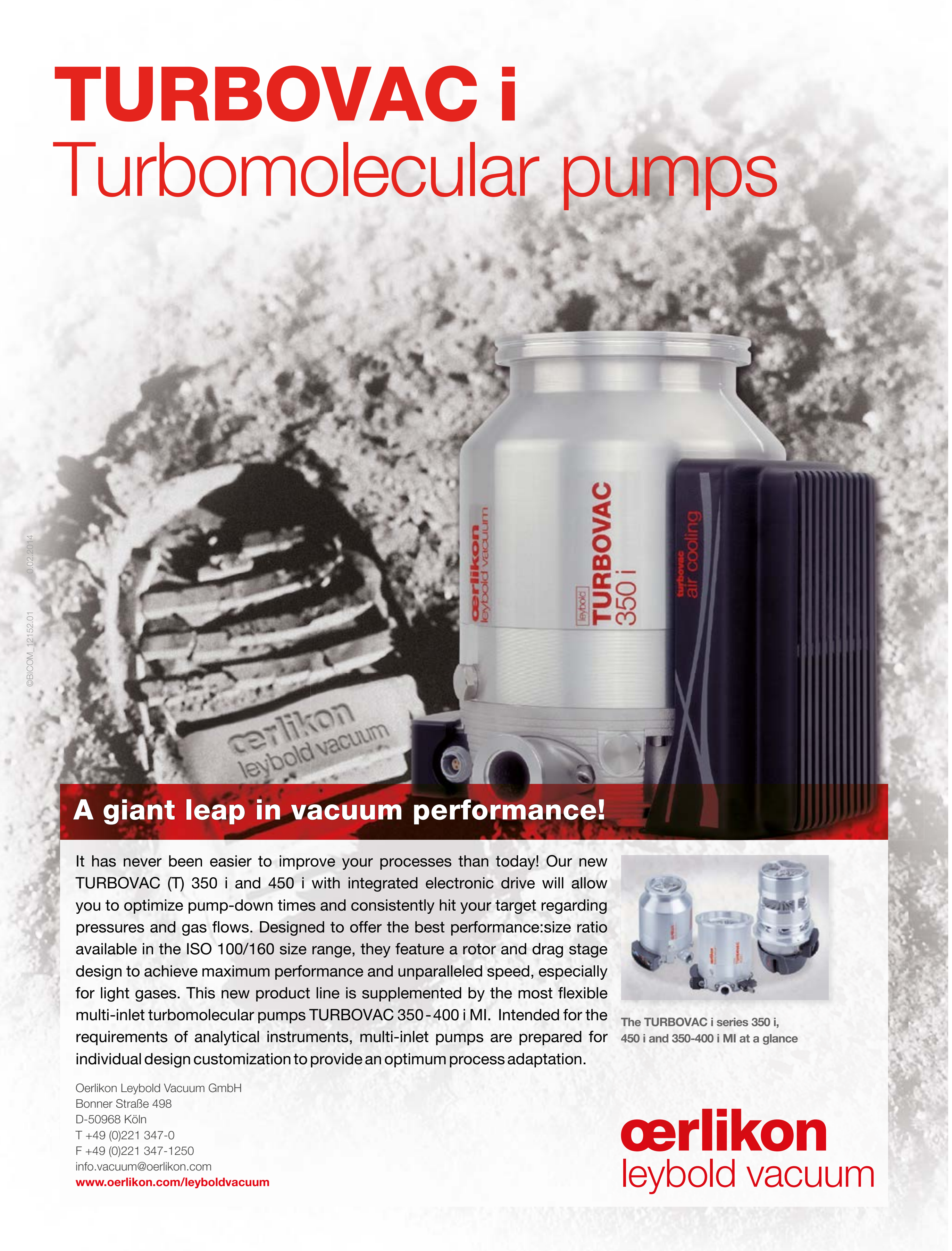

Covering current developments in high-energy physics and related fields worldwide

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by IOP Publishing Ltd
IOP Publishing Ltd, Temple Circus, Temple Way,
Bristol BS1 6HG, UK
Tel +44 (0)117 929 7481

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or +44 (0)117 930 1164 (for recruitment advertising);
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General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland
E-mail: courrier-adressage@cern.ch
In certain countries, to request copies or to make address changes, contact:
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PO Box 918, Beijing 100049, People's Republic of China
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UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ
E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive,
St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,
St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN,
1211 Geneva 23, Switzerland
Tel +41 (0) 22 767 61 11. Telefax +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

ISSN 0304-288X

IOP Publishing

CERN

CERN COURIER

VOLUME 55 NUMBER 5 JUNE 2015

On the cover: A view of the ATLAS calorimeters seen from below as they were being moved to their final position before the detector closed for Run 2 at the LHC (p21). (Image credit: Claudia Marcelloni.)

News

CERN

The LHC prepares for high-energy collisions

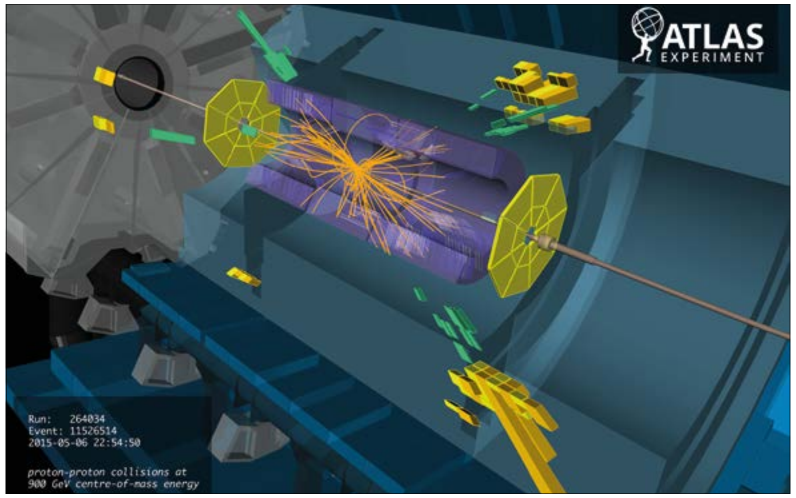
Following the restart of CERN's flagship accelerator in early April, commissioning the LHC with beam is progressing well. In the early hours of 10 April, the operations team successfully circulated a beam at 6.5 TeV for the first time – a new world record – but this was only one of many steps to be taken before the accelerator delivers collisions at this beam energy.

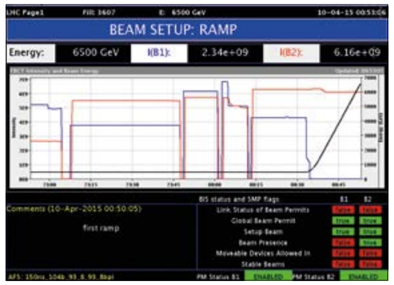
The operators reached another important milestone on 21 April, when they succeeded in circulating a nominal-intensity bunch. The first commissioning steps in particular take place with low-intensity (probe) beams – single bunches of 5×10^9 protons. The nominal intensity, in contrast, is a little over 1×10^{11} protons per bunch, and when the LHC is in full operation later this year, some 2800 bunches will circulate in each beam.

To handle the higher number of protons per bunch and the higher number of bunches safely, a number of key systems have to be fully operational and set up with beam. These include the beam-dump system, the beam-interlock system and the collimation system. The latter involves around 100 individual pairs of jaws, each of which has to be positioned with respect to the beam during all of the phases of the machine cycle. Confirmation that everything is as it should be is made by deliberately provoking beam losses and checking that the collimators catch the losses as they are supposed to.

On 2 May, this set-up procedure allowed a nominal-intensity bunch in each beam to be taken to 6.5 TeV. Four days later, collisions were produced at the injection energy of 450 GeV, enabling the experiment teams to record events and check alignment and synchronization of the detectors. One of the important steps in reaching this stage is to commission the "squeeze" – the final phase in the LHC cycle of injection, ramp and squeeze. During this phase, the strengths of the magnetic fields either side of a given experiment are adjusted to reduce the beam size at the corresponding interaction point.

● To find out more, see the LHC reports in CERN Bulletin: bulletin.cern.ch.




LHC Page1 Fill: 3607 E: 6500 GeV 10-04-15 00:53:06
BEAM SETUP: RAMP
Energy: 6500 GeV I(B1): 2.34e+09 I(B2): 6.16e+09
Comments (10-Apr-2015 00:50:05)
first ramp

Above: A proton–proton collision recorded by ATLAS on 6 May at 900-GeV collision energy. (Image credit: ATLAS-PHO-Event-2015-008-1.) Left: "LHC page 1" shows the status of the LHC as the beam energy (the black line) reached 6.5 TeV on 10 April. (Image credit: LHC/CERN.)

Sommaire en français

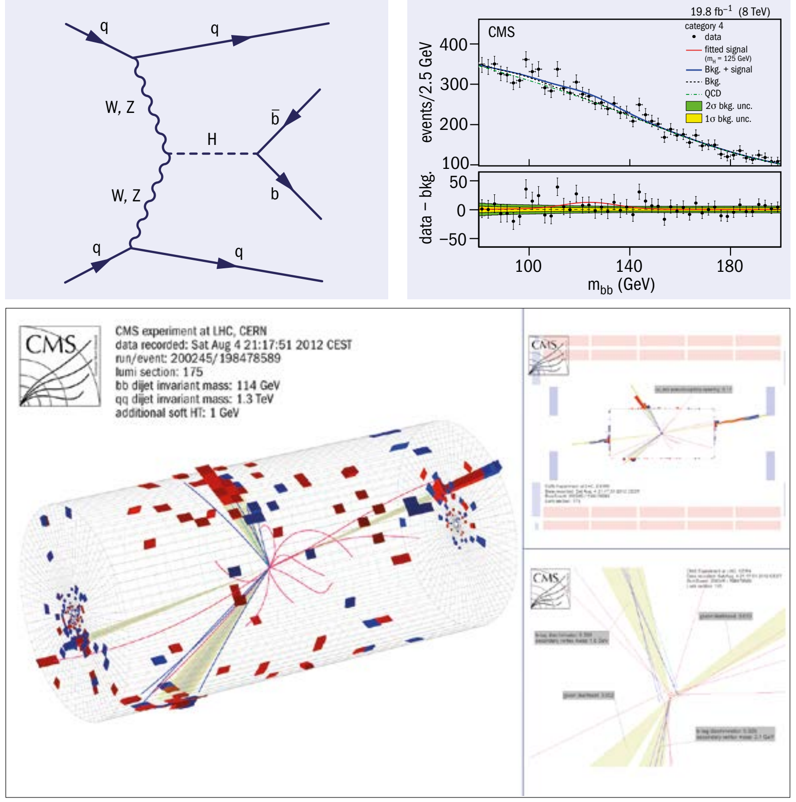
Turkey becomes associate member state of CERN

The Republic of Turkey became an associate member state of CERN on 6 May, following notification that Turkey has ratified an agreement signed last year, granting this status to the country (*CERN Courier* July/August 2014 p35).

Turkey's new status will strengthen the long-term partnership between CERN and the Turkish scientific community. Associate membership will allow Turkey to attend meetings of the CERN Council. Moreover, it will allow Turkish scientists to become members of the CERN staff, and to participate in CERN's training and career-development programmes. Finally, it will allow Turkish industry to bid for CERN contracts, thus opening up opportunities for industrial collaboration in areas of advanced technology.

LHC EXPERIMENTS

CMS identifies Higgs bosons decaying to bottom quarks



Top left: Feynman diagram showing the production of a Higgs boson through vector-boson fusion, and decaying to bottom quarks. Top right: Fit of the invariant mass of the two b-jet candidates for a Higgs-boson signal with a mass of 125 GeV, with events selected in the best signal category. Above: A CMS proton–proton collision event at $\sqrt{s} = 8$ TeV, featuring a central di-jet system with invariant mass 114 GeV and a forward–backward di-jet system with invariant mass 1.3 TeV. The main display shows a 3D view of the event, the top right display is an rz view, and the bottom right display is a zoomed rϕ view, where b-decay secondary vertices are visible within the two central jets.

The mass of the Higgs boson discovered at CERN is close to 125 GeV. If it really is the Standard Model Higgs boson (H), it should decay predominantly into a bottom quark–antiquark pair ($b\bar{b}$), with a probability of about 58%. Therefore, the observation and study of the $H \rightarrow b\bar{b}$ decay, which involves the direct coupling of H to fermions and in particular to down-type quarks like d-, s- and b-quarks, is essential in determining the nature of the discovered boson. The inclusive observation of the decay $H \rightarrow b\bar{b}$ is currently not achievable at the LHC: in proton–proton collisions, $b\bar{b}$ pairs are produced abundantly via the strong force as described via QCD, providing a completely irreducible background.

An intriguing and challenging way to search for $H \rightarrow b\bar{b}$ is through the mechanism of vector-boson fusion (VBF). In this case, the signal features a four-jet final state: two b-quark ($b\bar{b}$) jets originating from the Higgs-boson decay, and two light quark (qq) jets, predominantly in the forward and backward directions with respect to the beamline – a distinctive signature of VBF in proton collisions. An additional peculiar feature of VBF is that no QCD colour is exchanged in the processes. This leads to the expectation of a "rapidity gap" – that is, reduced hadronic activity between the two tagging qq jets, apart from Higgs boson decay products.

CMS has searched for these VBF-produced Higgs bosons decaying to b quarks in the 2012 8-TeV proton–proton collision data. This is the only fully hadronic final state that is employed to search for a Standard Model Higgs boson at the LHC. A crucial dedicated data-triggering strategy was put in place, both within standard "prompt" data streams and, in parallel, within "parked" data streams that were reconstructed later, during the LHC shutdown. Candidate events are required to have four jets with transverse momenta above optimized thresholds. Separation in terms of pseudorapidity (angle) and b-quark tagging criteria are employed to assign two jets to the $b\bar{b}$ system and the other two jets to the qq VBF-tagging jet system.

Selected events are passed to a multi-variate boosted decision tree (BDT) trained to separate signal events from the large background of multi-jet events produced by QCD. The events are categorized according to the output values of the BDT, making no use of the kinematic information of the two b-jet candidates. Subsequently, the invariant-mass distribution of two bjets is analysed in each category, to search for a signal "bump" on top of the smooth background shape. The figure shows the results of the fit in the best signal category. They reveal an observed (expected) significance of the signal of 2.2 (0.8)σ, for a Higgs-boson mass of 125 GeV. A parallel measurement of $Z \rightarrow b\bar{b}$ decays in the selected data samples, using the same signal-extraction technique, has been performed to validate the analysis strategy.

The results of this search have been combined with results of other CMS searches for the decay of the Higgs boson to bottom quarks, produced in association with a vector boson, or with a top-quark pair. For $m_H = 125$ GeV, the combination yields a fitted $H \rightarrow b\bar{b}$ signal strength $\mu = 1.03 + 0.44$, relative to the expectations of the Standard Model, with a significance of 2.6σ. This is a convincing hint from the LHC for the coupling of the discovered boson to bottom quarks.

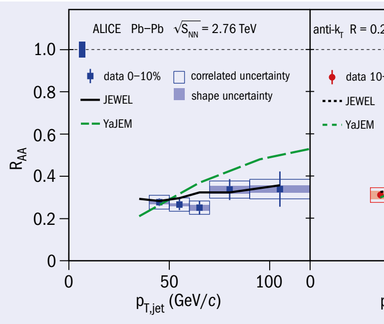
● Further reading

CMS Collaboration CMS-HIG-14-004, CERN-PH-EP-2015-121.

First full jet measurement in Pb–Pb collisions with ALICE

In high-energy collisions at the LHC, quarks and gluons occasionally scatter violently and produce correlated showers of particles, or "jets". In proton–proton collisions, the rate of such scatters is precisely calculable using perturbative QCD. However, in heavy-ion collisions, jets should be modified, because the scattered quarks and gluons are expected to interact with the surrounding hot nuclear matter, the quark–gluon plasma (QGP). Jet measurements, together with model calculations of the "jet quenching" phenomenon, therefore provide important information about the properties of the QGP.

Fully reconstructed jets are measured in ALICE by high-precision tracking of charged particles in the central barrel, and by measuring the energy deposits of neutral particles in the electromagnetic calorimeter. This method of reconstructing jets differs from the more traditional approach with hadronic and electromagnetic calorimetry. It was first applied in ALICE to determine the production rate for jets in the case of proton–proton collisions (*CERN Courier* May 2013 p31). In heavy-ion collisions, measurements of jets are more challenging, because a single event contains multiple jets from independent nucleon–nucleon scatters, as well as combinatorial jets from the large and partially correlated underlying background of particles with low transverse momentum (p_T).



The nuclear modification of the jet yield R_{AA} for the 0–10% and 10–30% most-central Pb–Pb collisions, together with the two model calculations, revealing that jets in Pb–Pb are strongly suppressed, almost independent of jet p_T.

ALICE has recently published results from the 2011 lead–lead (Pb–Pb) run, down to low jet p_T, where jet quenching is expected to be most dramatic. Jets were reconstructed using the anti-k_T algorithm with a resolution parameter of R = 0.2. Even for this rather small cone size, the average contribution of the background was measured to be 25±5 GeV/*c* in the 0–10% most central (highest multiplicity) Pb–Pb events. To deal with the background, the analysis first subtracted the average contribution in a given event jet-by-jet, and then corrected the resulting reconstructed jet spectrum for the background fluctuations and instrumental resolution via an unfolding procedure. This led to an overall systematic uncertainty of about 15–20%.

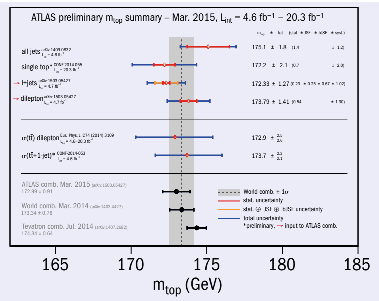
The nuclear modification of the jet yield (R_{AA}) is quantified by the ratio of the jet spectrum measured in Pb–Pb to that in proton–proton collisions scaled by the number of independent nucleon–nucleon collisions. The figure shows R_{AA} for the 0–10% and 10–30% most central Pb–Pb collisions, together with the two model calculations. It reveals that the jets in Pb–Pb are suppressed strongly, almost independent of jet p_T, with an average nuclear modification factor of 0.28±0.04 in 0–10% and 0.35±0.04 in 10–30% of Pb–Pb collisions. Both model calculations were able to predict the level of jet suppression, while one of them expected a slightly steeper increase with p_T than the data. This new measurement, which uses jet constituents down to a few hundred GeV/*c*, even in Pb–Pb collisions, opens new perspectives for studying the QGP with ALICE.

● Further reading

ALICE Collaboration 2015 *Phys. Lett. B* **746** 1.

ATLAS's paths to the top-quark mass

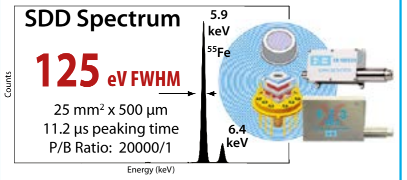
The top quark is the heaviest elementary particle known currently, and its mass (m_{top}) is a fundamental parameter of the Standard Model. Its precise determination is essential for testing the consistency of the Standard Model and to constrain models of new physics. Now, ATLAS has released new measurements of m_{top} using events with one or two isolated charged leptons and jets in the final state – the lepton+jets and dilepton channel. The new results are based on proton–proton collision data taken at a centre-of-mass-energy of 7 TeV.

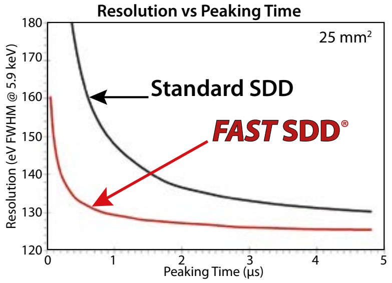


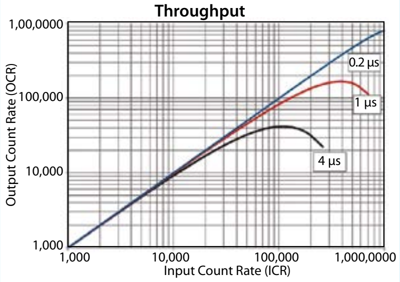
Overview of the latest top-quark mass results from ATLAS, compared with the recent world and Tevatron combinations.

The measurements were obtained from the direct reconstruction of the top-quark final states, and use calibrations based on Monte Carlo simulation. In the analysis, for the first time, the lepton+jets channel m_{top} is determined simultaneously with a global jet-energy scale factor, thus exploiting information from the hadronically decaying W boson and a separate b-to-light-quark jet-energy scale factor – a technique that reduces the corresponding systematic uncertainties on m_{top} significantly. The measurement in the dilepton channel is based on the invariant mass of the two charged-lepton and b-quark-jet systems from top-quark-pair decays. The measurements in the two channels are largely uncorrelated, which allows their combination to yield a substantial improvement in precision. The result, $m_{top} = 172.99 \pm 0.91$ GeV, corresponds to a relative uncertainty of 0.5% (ATLAS 2015a).

These new measurements, together with the results from the fully hadronic decay channel (ATLAS 2015b), complete the suite of m_{top} results based on 7-TeV data that exploit top-quark-pair signatures. They are complemented by a result based on single-top-quark-enriched topologies, using ▷







8-TeV data (ATLAS 2014a).

In the direct mass-reconstruction techniques described above, the extracted value of m_{top} corresponds to the parameter implemented in the Monte Carlo ($m^{\text{MC}}_{\text{top}}$) whose relationship with the top-mass parameter in the Standard Model Lagrangian is not completely clear. The uncertainty relating the top mass in the Standard Model to $m^{\text{MC}}_{\text{top}}$ is a matter of debate, but is often estimated to be about 1 GeV, which is comparable to the present experimental precision.

ATLAS follows complementary paths to measure m_{top} by comparing the measurements of cross-sections for inclusive (*CERN Courier* September 2014 p7) and differential top-quark-pair production with the corresponding theoretical calculations, which depend on the top-quark-pole mass $m^{\text{pole}}_{\text{top}}$. To date, the most precise $m^{\text{pole}}_{\text{top}}$ determination is obtained from the differential cross-section measurements of top-quark-pair events with one additional jet. Using 7-TeV data, the measurement yields $m^{\text{pole}}_{\text{top}}$ = 173.7^{+2.3}_{–2.1} GeV (ATLAS 2014b), which is compatible to the results from the direct reconstruction of the top-quark decays. The figure shows the ATLAS results for m_{top}, together with results from the Tevatron and the world average.

Upcoming results exploiting the full 8-TeV data set, and data from LHC Run 2, will further improve understanding of the mass of the top quark and its theoretical interpretation.

● Further reading

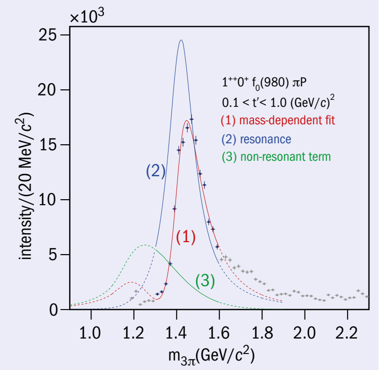
ATLAS Collaboration 2015a arXiv:1503:05427, submitted to *Eur. Phys. J. C.*

ATLAS Collaboration 2015b arXiv:1409.0832, *Eur. Phys. J. C.* **75** 158.

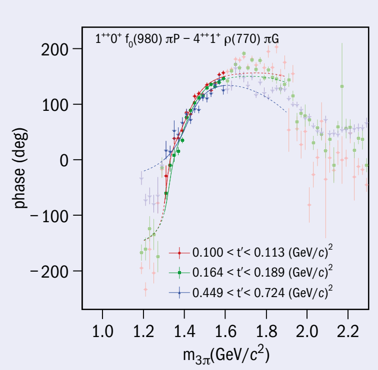
ATLAS 2014a ATLAS-CONF-2014-055.

EXOTICS

COMPASS observes a new narrow meson



The mass spectrum for the $f_0(980)$ contribution to the 1^{++} quantum state.



The mass-dependent phase variation with respect to a reference system (4^{++}).

The bulk of visible matter originates from the strong interactions between almost massless fundamental building blocks: quarks and antiquarks bound together by gluons. Although these interactions are described by QCD, the understanding of the underlying principle – of how exactly these building blocks form observable matter (hadrons), and which configurations are or are not realized in nature – has been a major challenge for a long time. The question of how hadrons are formed relates directly to the excitation spectrum of hadrons, in particular, mesons, which are made from quark–antiquark pairs. Theoretical predictions on the nature of hadronic bound-states, their masses and decays, have long been based on models, but direct QCD calculations performed on high-performance computers using a discretized space–time lattice are now also reaching a predictive level for new hadron states.

For many years, experiments have searched for hadronic bound states with exotic contents, such as gluon-only states (glueballs) or multi-quark states with a molecular nature. Some candidates had been found in studying systems with light quarks (glueballs, hybrids) or, most recently, with heavy quarks, revealing the first evidence for explicit multi-quark systems, based on the characteristic combination of charge and flavour (*CERN Courier* May 2014 p5 and June 2014 p12).

The COMPASS collaboration has recently observed the existence of an unusual meson made from light quarks at a mass of 1.42 GeV/c^2. Since this mass region had been investigated for half a century, this new particle comes as a surprise, and its finding is by virtue of the world's largest data sample for such studies. The particle is called the $a_1(1420)$, reflecting its properties of unit spin/isospin and positive parity, characteristic of the "a" mesons. The finding was made using the COMPASS spectrometer to study peripheral (diffractive) reactions of pions with a momentum of 190 GeV/c on a liquid-hydrogen target at CERN's Super Proton Synchrotron. Despite its production rate of only 10^{-3} with respect to known mesons, the existence of the $a_1(1420)$ was clearly unravelled using an advanced complex analysis technique that allows a produced superposition of individual quantum states to be disentangled into the individual contributing components, both in terms of quantum numbers and decay paths. The unique signature for this particular observation is a strong narrow enhancement in the mass spectrum of this $J^{PC} = 1^{++}$ quantum state (figure) in conjunction with an observed phase delay of about 180^0 – which any wave undergoes when its frequency (mass) passes a resonance.

The $a_1(1420)$ is observed decaying only into the $f_0(980)$, which is often discussed as a molecular-type state, and an additional pion, so rendering it unique. Following first announcements of the finding, several explanations have already been put forward. They cover the interpretation of the $a_1(1420)$ as a molecular/tetraquark state partnering another known state $f_1(1420)$, as well as scenarios in which the $a_1(1420)$ is generated by long-range effects of different sorts, all involving the light meson $a_1(1260)$. However, despite some remarkable features, not all of the experimental findings can be reproduced by those explanations. Thus, the $a_1(1420)$ enters the club of resonances that are unexplained, although experimentally well established.

● Further reading

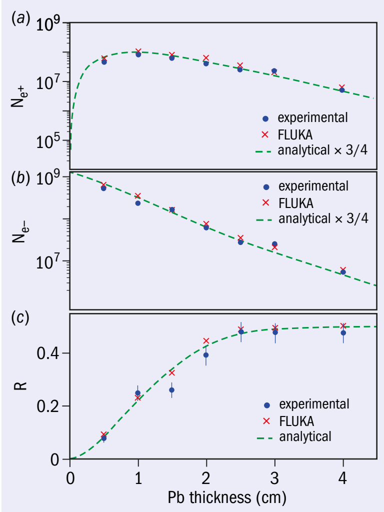
COMPASS Collaboration 2015 arXiv:1501.05732 [hep-ex], to be published in *Phys. Rev. Lett.*

PLASMA PHYSICS

Laser set-up generates electron–positron plasma in the lab

More than 99% of the visible universe exists as plasma, the so-called fourth state of matter. Produced from the ionization of predominantly hydrogen- and helium-dominated gases, these electron–ion plasmas are ubiquitous in the local universe. An exotic fifth state of matter, the electron–positron plasma, exists in the intense environments surrounding compact astrophysical objects, such as pulsars and black holes, and until recently, such plasmas were exclusively the realm of high-energy astrophysics. However, an international team, led by Gianluca Sarri of Queen's University of Belfast, together with collaborators in the UK, US, Germany, Portugal and Italy, has at last succeeded in producing a neutral electron–positron plasma in a terrestrial laboratory experiment.

Electron–positron plasmas display peculiar features when compared with the other states of matter, on account of the symmetry between the negatively charged and positively charged particles, which in this case have equal mass but opposite charge. These plasmas play a fundamental role in the evolution of extreme astrophysical objects, including black holes and pulsars, and are associated with the emission of ultra-bright gamma-ray bursts. Moreover, it is likely that the early universe in the leptonic era – that is, in the minutes following approximately one second after the Big Bang – consisted almost exclusively of a dense electron–positron plasma in a hot photon bath.



Experiment vs theory for electron (a) and positron (b) yield, and positron percentage (c).

While production of positrons has long been achievable, the formation of a plasma of charge-neutral electron–positron pairs has remained elusive, owing to the practical difficulties in combining equal numbers of these extremely mobile charges. However, the recent success was made possible by looking at the problem from a different perspective. Instead of generating two separate electron and positron populations, and recombining them, it aimed to generate an electron–positron plasma directly, *in situ*.

In an experiment at the Central Laser Facility at the Rutherford Appleton Laboratory in the UK, Sarri and colleagues made use of a laser-induced plasma wakefield to accelerate an ultra-relativistic electron beam (*CERN Courier* November 2004 p5). They focused an ultra-intense and short laser pulse (around 40 fs) onto a mixture of nitrogen and helium gas to produce, in only a few millimetres, electrons with an average energy of the order of 500–600 MeV. This beam was then directed onto a thick slab of a material of high atomic number – lead, in this case – to initiate an electromagnetic cascade, in a mainly two-step process. First, high-energy bremsstrahlung photons are generated as electrons or newly generated positrons propagate through the electric fields of the nuclei. Then, electron–positron pairs are generated during the interactions of the high-energy photons with the same fields. Under optimum experimental conditions, the team obtained, at the exit of the lead slab, a beam of electrons and positrons in equal numbers and of sufficient density to allow plasma-like behaviour.

These results represent a real novelty for experimental physics, and pave the way for a new experimental field of research: the study of symmetric matter–antimatter plasmas in the laboratory. Not only will it allow a better understanding of plasma physics from a fundamental point of view, but it should also shed light on some of the most fascinating, yet mysterious, objects in the known universe.

- The Central Laser Facility is supported by the UK's Science and Technology Facilities Council. This experiment is supported by the UK's Engineering and Physical Science Research Council.

● Further reading

G Sarri *et al.* 2015 *Nat. Commun.* **6** 6747.

BROOKHAVEN

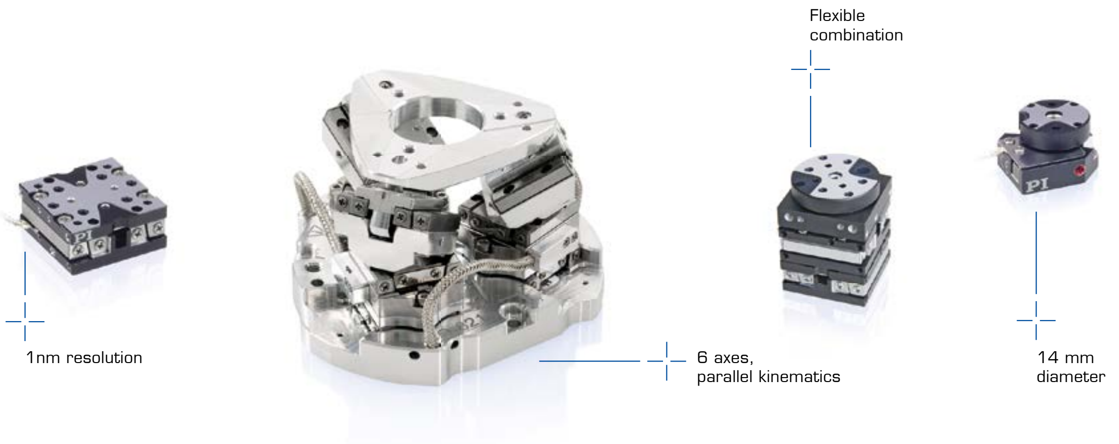
RHIC smashes record for polarized-proton collisions at 200 GeV

Aerial view of RHIC – set for another bumper year. (Image credit: Brookhaven Lab.)

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory has shattered its own record for producing polarized-proton collisions at 200 GeV collision energy. In the experimental run currently underway, accelerator physicists are delivering 1.2×10^{12} collisions per week – more than double the number routinely achieved in 2012, the last run dedicated to polarized-proton experiments at this collision energy.

The achievement is, in part, the result of a method called "electron lensing", which uses negatively charged electrons to compensate for the tendency of the positively charged protons in one circulating beam to repel the like-charged protons in the other beam when the two oppositely directed beams pass through one another in the collider. In 2012, these beam–beam interactions limited the ability to produce high collision rates, so the RHIC team commissioned electron lenses and a new lattice to mitigate the beam–beam effect. RHIC is now the first collider to use electron lenses for head-on beam–beam compensation. The team also upgraded the source that produces the polarized protons to generate and feed more particles into the circulating beams, and made other improvements in the accelerator chain to achieve higher luminosity.

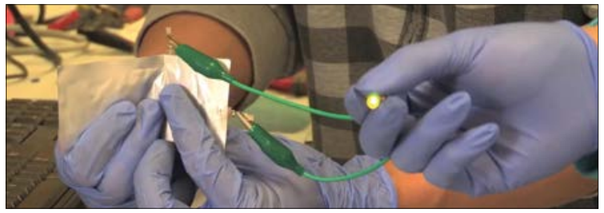
With new luminosity records for collisions of gold beams, plus the first-ever head-on collisions of gold with helium-3, 2014 proved to be an exceptional year for RHIC (*CERN Courier* December 2014 p19). Now, the collider is on track towards another year of record performance, and research teams are looking forward to a wealth of new insights from the data to come.



Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Aluminium offers safe option for batteries



The prototype aluminium-ion battery under test. (Image credit: Stanford University.)

A breakthrough in battery technology could replace lithium-ion batteries with cheaper and safer ones that use aluminium instead. Meng-Chang Lin of Stanford University and Green Energy and Environment Research Laboratories in Hsinchu and colleagues use an aluminium metal anode, a 3D graphitic foam cathode and a non-flammable ionic liquid electrolyte. The battery works by electrochemical deposition and dissolution of aluminium at the anode, and intercalation/de-intercalation of chloroaluminate anions in the graphite.

Delivering about 2 V, and with a specific capacity of $70\,\mathrm{mA\,h\,g^{-1}}$ and a Coulombic efficiency of 98%, the battery can be charged quickly – in around one minute, which is equivalent to a power density of some $3000\,\mathrm{W\,kg^{-1}}$. The battery is bendable and, storing an energy density of around $40\,\mathrm{W\,h\,kg^{-1}}$, is competitive with lead–acid batteries. It can be recharged more than 7500 times without degradation. The group also demonstrated the battery's safety aspects by drilling through one while it was being used, with no hazard arising.

● **Further reading**
M-C Lin *et al.* 2015 *Nature* **520** 325.

Monopole discovered in Bose–Einstein condensate

While the magnetic monopoles searched for by particle physicists have not been found yet, an analogue has been seen experimentally in a quantum field whose fundamental degrees of freedom include no such particle. Mikko Möttönen of Aalto University in Finland and colleagues have optically trapped a spin-1 Bose–Einstein condensate of about 21,000 ^{87}Rb atoms. The spin-1 order parameter follows an external magnetic field, and the researchers were able to ramp up a suitable field so as to twist the spins to produce a single point defect corresponding to a monopole. It is an extended object – analogous to a grand-unified-theory monopole – and, remarkably, is isolated, being created without being associated with an antimonopole.

● **Further reading**
M W Ray *et al.* 2015 *Science* **348** 544.

Stabilizing stereoisomers with deuterium

Many drugs occur in more than one stereoisomer, often with significantly differing effects. Some, even when stereochemically pure initially, will spontaneously undergo "chiral switching" and become racemic, with equal amounts of the left- and right-handed versions, or enantiomers. Other drugs, such as thalidomide, can change in this way in the body, with only one enantiomer being responsible for birth defects. Thalidomide and analogues have seen a resurgence of interest as anticancer drugs, and now a trick has been found to slow their racemization. Sheila DeWitt of DeuteRx in Andover, Massachusetts, and colleagues there and at Kalexsyn in Kalamazoo, Michigan, replaced the acidic proton at the stereocentre of thalidomide analogues with deuterium. The deuteration slowed the racemization dramatically, as expected from a primary kinetic isotope effect, stabilizing the original, correct stereoisomer, while hardly changing the pharmacokinetics of the drugs.

● **Further reading**
V Jacques *et al.* 2015 *Proc. Nat. Acad. Sci.*, published online, E1471.

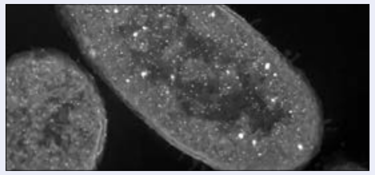
Pluck to regrow

Want to grow more hair? The solution might be to pluck out what is there, at least if you are a mouse. Cheng Ming Chuong of the University of Southern California and National Yang-Ming and National Taiwan Universities found that plucking hair at sufficiently high densities (hairs per unit area) can trigger regeneration of up to five times more unplucked resting hairs. Plucked follicles secrete CCL2, which brings macrophages to the plucked region. They, in turn, release TNF-α, and a form of quorum sensing with a range of about 1 mm decides whether there has been a mild injury, which could be ignored, or a more serious one, requiring a vigorous response. The difference is striking: complete plucking of all 200 hairs from a 2.4-mm circular area leads to regeneration 12 days later, while plucking 200 hairs in a 12-mm-diameter area does not lead to follicle regeneration, even 30 days later.

● **Further reading**
C-C Chen *et al.* 2015 *Cell* **161** 277.

Zombie bacteria

Sometimes dead bacteria can kill off other bacteria, a phenomenon that has been dubbed the "zombies" effect. Racheli Ben-Knaz Wakshlak of the Hebrew University of Jerusalem and colleagues killed *Pseudomonas aeruginosa* PA01 with silver nitrate, and then subjected live bacteria to them – and as many as 99.99% of them died. Electron microscopy revealed that the dead bacteria had built up reservoirs of silver nanoparticles as they died. This silver could then leach out and kill other bacteria. Aside from its obvious novelty, the work could lead to improvements in the many silver-infused medical products now in use.



Silver deposition kills bacteria, turning them into killers too. (Image credit: Racheli Ben-Knaz Wakshlak, Rami Pedahzur and David Avnir.)

● **Further reading**
R B Wakshlak *et al.* 2015 *Scientific Reports* **5** 9555.

Astrowatch

Compiled by Marc Türler, ISDC and Observatory of the University of Geneva, and CHIPP, University of Zurich

Magnetic fields cast light on black hole's edge

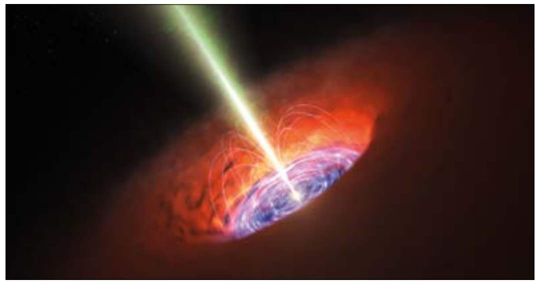
The Atacama Large Millimetre/submillimetre Array (ALMA) has revealed an intense magnetic field at the base of the relativistic jet powered by a supermassive black hole. Probing the physical conditions of a jet so close to the black hole is unprecedented, and confirms that magnetic fields have a driving role in the formation and collimation of the jet.

Supermassive black holes, often with masses billions of times that of the Sun, are located at the heart of almost all galaxies in the universe. These black holes can accrete huge amounts of matter from a surrounding disc. While most of this matter is fed into the black hole, some can escape moments before capture and be flung out into space at close to the speed of light in twin plasma jets, which can extend hundreds of thousands of light-years from their host galaxy (Picture of the month, *CERN Courier* January/February 2013 p14). How this happens is not well understood, although it is thought that strong magnetic fields, acting very close to the event horizon, play a crucial role in this process.

Up to now, only weak magnetic fields far from black holes – several light-years away – have been probed. A new study by astronomers from Chalmers University of Technology and Onsala Space Observatory in Sweden used ALMA to detect a polarization signal related to the strong magnetic field in a distant galaxy named PKS 1830-211. This quasar was chosen because it is located at a relatively high redshift and is gravitationally lensed. The redshift of $z = 2.5$ allows submillimetre emission from the distant source to be probed at frequencies 3.5 times higher than reachable by ALMA. An observation at 300 GHz (around 1 mm) therefore probes the terahertz frequency range (around 0.3 mm), where synchrotron self-absorption no longer hides the most intense jet region closest to the black hole.

The gravitational lens splits the remote source into two components, so that Ivan Martí-Vidal and colleagues could study the relative polarization of the two lensed images. This strategy allows them to be free of many calibration-related artefacts that would otherwise limit the analysis. Through repeated observations at different wavelengths, they found clear signals of Faraday rotation that are hundreds of times stronger than previously found in the universe. The strength of this wavelength dependence of the rotation of the polarization angle is given by the rotation measure (RM), which depends on the magnetic field strength multiplied by the electron density integrated along the line of sight.

The RM derived with ALMA in PKS 1830-211 is around 10^8 rad/m^2, which is about 100,000 times greater than in the radio cores of other quasars. This huge difference is owing to the new observations being performed at much higher frequencies, thus probing a region only light-days away from the black hole, instead of light-years when observing in the radio domain. Assuming that both the magnetic field and the electron density increase by about a factor of 300 from the radio core to the apex of the jet, the team obtains a magnetic field of at least a few tens of gauss near the base of the jet. While this is only an order-of-magnitude estimate, its relatively high value – although many billions of times weaker than in neutron stars – reinforces the idea that magnetic fields play an important role in the mechanism that launches the jet.



Artist's impression of a supermassive black hole surrounded by an accretion disc and a dusty torus, and powering a relativistic jet via processes that are likely to involve a strong magnetic field. (Image credit: ESO/L Calçada.)

- **Further reading**

I Martí-Vidal *et al.* 2015 *Science* **348** 311.

Picture of the month

On 24 April 1990, the NASA/ESA Hubble Space Telescope was sent into orbit aboard the space shuttle *Discovery*, as the first space telescope of its kind. It offered a new view of the universe and has, for 25 years, reached and surpassed all expectations, beaming back data and images that have changed scientists' understanding of the universe and the public's perception of it. This colourful image of the star cluster Westerlund 2 has been released to celebrate this 25th anniversary. The giant cluster of about 3000 stars is located 20,000 light-years away in the constellation Carina. Surrounded by dust, it appears clearly only in infrared light, but the intense ultraviolet emission and the strong stellar winds of the heftiest stars are already clearing the view. They carve deep cavities in the surrounding material, and are responsible for the wonderful shapes of the gas and dust clouds in the image. (Image credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA), A Nota (ESA/STScI), and the Westerlund 2 Science Team.)

CERN Courier Archive: 1972

A look back to CERN Courier vol. 12, June 1972, compiled by Peggie Rimmer

CERN

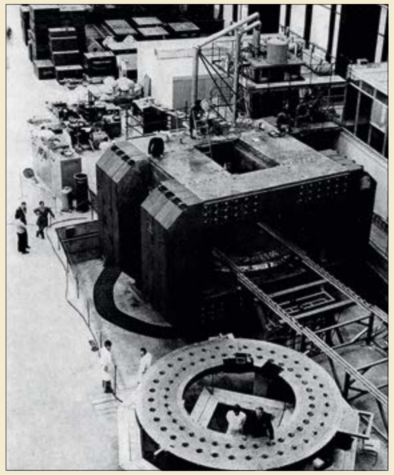
On the way to Omega experiments

Two more important steps have been taken *en route* to the start of experiments in the Omega spectrometer. One coil of the superconducting magnet has been successfully tested and beam has reached the target in the West Experimental Hall.

On 25 May a proton beam was slow ejected from the 28 GeV proton synchrotron (PS) using the new system, SQUARE. It was guided along the tunnel towards the ISR, deflected towards the West Hall and, finally, steered through a shielded channel in the hall to the Omega target.

The beam could be steered as designed and the spot size was as predicted. Beam-intensity monitors had not been calibrated, so the intensity at the target is not known precisely. Beginning in the first week of June, the teams preparing to use Omega will intermittently receive beam to help in the setting up of their detection systems.

- Compiled from texts on pp200–202.



Right: Assembly of the Omega spectrometer. Top right is the refrigerator, which furnishes the helium to maintain the magnet coils at superconducting temperature. In the centre is the magnet yoke (note the demountable sides) with its very large aperture and one coil in place. In the foreground, the second coil is being made ready. (Image credit: CERN 328.3.72.)

Men will be boys!

A Bombay/Bucharest/CERN/Cracow team has carried out a nuclear emulsion experiment in intersection region I1 of the ISR, studying charged particles produced in the proton–proton collisions.

Since the emulsions collect tracks from charged particles regardless of whether or not they emanate from the interactions under study, it was important to keep them shielded when conditions in the ISR were not stable.

A model railway proved a reliable and inexpensive way of doing this. The emulsions were kept outside the shielding wall until conditions were right, and then a train pulled them into the intersection region on a goods wagon. An automatic signalling system proved a very simple way of stopping the emulsions at precisely the required position. In addition, use of the model railway increased the fun of doing the experiment by a factor of two.

- Compiled from texts on p204.

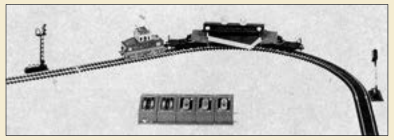


Image credit: CERN 54.4.72.

Los Alamos

LAMPF all the way

On 9 June, a proton beam was taken all the way along the 850 m of the linear accelerator at Los Alamos, reaching the design energy of 800 MeV for the first time. LAMPF (Los Alamos Meson Physics Facility) thus becomes the first of the "meson factories" to come into action (the others being TRIUMF in Canada and SIN in Switzerland).

LAMPF is a high-intensity accelerator designed to provide 900 μA average proton current and 100 μA average negative hydrogen ion current (accelerated simultaneously). The design involved several new approaches, such as the use of side-coupled cavities and unusually extensive computer control. All the more credit is therefore due to the LAMPF team for bringing the machine into operation on schedule.

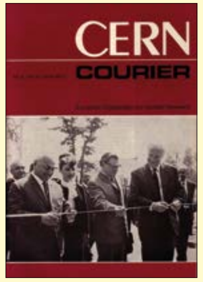
Design and construction has been under the leadership of Louis Rosen, who handled the job so skillfully that it just never seemed possible (at least to outsiders) that the project would not go well. In particular, he showed great talent and awareness in securing and sustaining support for LAMPF in hard times.

Research at LAMPF will cover nuclear and particle physics, and there will also be sizable programmes of solid-state physics, biology, medicine and isotope production. Over 60 experiments have already been assigned beam time.

- Compiled from texts on pp 204–205.

A huge sign (each letter taking a gallon of paint) on the cliff facing the road leading to the accelerator site told it like it is. (Image credit: LAMPF.)

Compiler's Note



Throughout the 1960s, photographic bubble chambers played a paramount role in experimental particle physics, engendering considerable technical advances, notably in computing and data handling. However, by the 1970s, with the burgeoning need for specific triggers and high data-collection rates, pride of place was being ceded to "electronic bubble chambers". The first of these at CERN was the Omega spectrometer, an ancestor of today's LHC giants. With a large magnetic volume initially filled with spark chambers and later with wire chambers, Omega operated for 25 years, first at the Proton Synchrotron then at the Super Proton Synchrotron, with a variety of triggers and incident beams, for studies ranging from hadron spectroscopy to glueball searches and strangeness production.

The road from CERN to space

A year after becoming president of the Italian Space Agency, **Roberto Battiston** talks about the connections between physics at accelerators and in space.

Roberto Battiston, from CERN to space. (Image credit: ASI.)

The Agenzia Spaziale Italiana (ASI) – the Italian Space Agency – has the tag line "The road to space goes through Italy." Make a simple change and it becomes a perfectly apt summary of the career to date of the agency's current president. For Roberto Battiston, the road to space goes through CERN.

As a physics student at the famous Scuola Normale in Pisa, which has provided many of CERN's notable physicists, he studied the production of dimuons in proton collisions at the Intersecting Storage Rings, under the guidance of Giorgio Bellettini. For his PhD, he moved in 1979 to the University of Paris IX in Orsay, where his thesis was on the construction of the central wire-proportional chamber of UA2, the experiment that went on, with UA1, to discover the W and Z particles at CERN. Until 1995, his research focused on electroweak physics, first at the SLAC Linear Collider and then, back at CERN, at the L3 experiment at the Large Electron–Positron collider. However, at the point when the LHC project was on its starting blocks, his interest began to turn towards cosmic rays. With Sam Ting, who led the L3 experiment, Battiston became involved in the Alpha Magnetic Spectrometer, which as AMS-02 has now been taking data on board the International Space Station (ISS) for four years (*CERN Courier* July/August 2011 p18). Three years after the launch of AMS-02, Battiston found himself closer to space, at least metaphorically, when he was appointed president of ASI in May 2014.

The decision to move away from experiments at the LHC will surprise many people. How do you explain your unconventional choice?

The LHC, a machine of extraordinary importance, as its results have shown, was the obvious choice for someone who wanted to continue a research career in particle physics. But I chose to take a less beaten path. In space, less has been researched and less has been discovered than at accelerators. I realized that, in both neutral and charged cosmic rays, we are presented with information that is waiting to be decoded, potentially hiding unforeseen discoveries. The universe is, by definition, the ultimate laboratory of physics, a place where, in the various phases of its evolution, matter and energy have reached all of the possible conditions one could imagine – conditions that we will never be able to reproduce artificially. For this reason, when I was discussing with Sam Ting in 1994 about what would be the most interesting new project – whether to go for an LHC experiment or, radically, for a new direction – I had no hesitation: space and space exploration immediately triggered my enthusiasm and curiosity. I absolutely do not regret this choice.

Was your experience and know-how as a high-energy physicist useful for the construction and, now, the operation of AMS?

The AMS detector was designed exactly like the LHC experiments. It has an electromagnetic spectrometer with a particle tracker and particle identifiers. Subdetectors are positioned before and after the magnet and the tracker, to identify the types of particles passing through the experiment. We use the same approach as at accelerators – 99% of the events are thrown away, the interesting ones being the few that remain. However, within these data, processes that we still do not know about remain potentially hidden. The challenge is to find new methods to look at this radiation and extract a signal, exactly as at the LHC. The difference is that the trigger rate is kilohertz in space, rather than gigahertz at the LHC: AMS gets one or two particles at a time instead of hundreds of thousands per event. Moreover, space offers some advantages and optimal conditions for detecting particles: surprisingly, it provides stable environmental conditions, so detectors that on the ground would suffer from environmental changes – such us too much heat or atmospheric pressure changes or humidity – enjoy ideal conditions in space. Silicon detectors, transition-radiation detectors, electromagnetic calorimeters and Cherenkov detectors have performed much better than the best detectors on the ground.

But in space you must face more complex challenges that put constraints on your instrument's design?

Given the complexity of the current LHC experiments, the situation is comparable. Repairing a huge detector 100 m below ground is as difficult as repairing a detector in space. If something breaks down underground, dismantling the whole structure of a detector might require months if not a year. Everything in both environments must have sufficient reliability to operate for a long time. In space, radiation doses are relatively small compared with the doses that the detectors can sustain, but there are problems of the shock at launch, pressure drops, extreme temperatures and the ability to operate in a vacuum, so the tests that a detector must pass to be able to perform in space are severe. Shock and stress resistance at launch require the detectors to be more robust than those built to stay on Earth. Another huge difference is weight and power. On Earth there are no limits. In space, we must use low-weight instruments – a few tonnes compared with the 10,000 tonnes of the large LHC detectors. And because detectors in space are powered by solar panels, there are power limits – a few kilowatts compared with tens of megawatts at the LHC. So in space, resources are optimized to the last small part.

What about the choice of leading technology vs reliability, for an experiment in space?

It is true that in space we have instruments that are dated, technologically speaking. But AMS is an exception: we made the effort of bringing to space technology developed at CERN since 2000, which has shown itself to be 10–100 times more powerful and effective than current space standards.

Now, with AMS-02 successfully installed on the ISS and reaping promising results, you have been appointed president of the ASI, one of the large European space agencies. What can a physicist like yourself bring to the management of the space industry at the European and international level?

Space is a place where human dreams converge: from photographing the Moon, to walking on Mars, to taking a snapshot of the first instants of the universe – these are global dreams of humanity. Yet, space is a different world from physics. In certain aspects, it's wider. Particle physics is an international discipline, but is so focused that the bases for discussion are limited, however fascinating and however important might be the consequences of finding a new brick in the construction of the universe. Space is particle physics multiplied to the nth power. It is a context, not just one discipline. Many different sectors interact, but each has its own dynamics – my leitmotiv is "interdisciplinarity". Many different things happen at a fast pace, which requires a great capacity for synthesis and ability to process a lot of data in a short time. Decisions must be taken so fast that a well-trained brain is needed. I can only thank my tough training in physics research for this. The tough discipline at the basis of research at CERN and in astroparticle physics, the continuous challenge of having to solve complex problems, the requirement of working in a large community made of people with different characters, cultures and languages, typical of experimental physics, are an asset within the context of a space agency.

AMS-02 installed on the ISS. (Image credit: NASA.)

How do large collaborations work in space research? Is it as global as the LHC?

The capability to keep the construction effort of very large accelerators or extremely complex detectors under direct control is still, today, an essential aspect of the high-energy physics community. Space research has not made the transition to a global collaboration in the same way as CERN, because it is still dominated by a strong element of international politics and national prestige. The amount of funding involved and the related industrial aspects and business pressures are so big, that decisions must be taken at the level of heads of state and government.

Is there a difference in approach between NASA and ESA?

They're both huge agencies, although NASA has four times the budget of ESA. In the past, they've collaborated on large projects, but in the past 10 years this collaboration has dimmed, as is the case for LISA [the Laser Interferometer Space Antenna]. Sometimes, such projects are even done in competition, as in the case of WMAP and Planck. The US pulled out of Rosetta long ago, and is now focused on the James Webb Space Telescope. To do so, the US basically chose to stop most international collaborations in science, except for the ISS and exploration. The ISS exists because of a precise political will. It is a demonstration that collaboration in space is decided top-down instead of bottom-up, and it can hold or break according to politics.

AMS will soon be joined in space by new powerful instruments to study cosmic rays. Are we witnessing a change of focus, from particle physics in the lab back to the sky?

Space is a less-frequented frontier, and it is understandable that it is now attracting many physicists. Astroparticle physics is a bridge ▷

between the curiosity of particle physicists who try to understand fundamental problems and the tradition of astronomy to observe the universe. Two different aspects of physics converge here: deciphering vs photographing and explaining. In astroparticle physics we try to find traces of fundamental phenomena, in astrophysics, to explain what we are able to see.

So what would your advice be to young physics graduates? Where would they best fulfil their research ambitions today?

Physics in space is becoming enormously interesting, not just in the understanding of both the infinitely small and the infinitely large. In the coming decades, astrophysics and particles studied in space radiation will be the place from where surprises and important discoveries could come, although this will take time and more sophisticated technologies, because the limits of technology are farther from the limits of the observable phenomena in the universe than in the case of particle accelerators. Building a new accelerator will require decades and big investments, as well as new technologies, but most of all it will need a discovery indicating where to look. The resources required are so considerable that we will not be able to build such a machine just to explore and see what there is at higher energies, as we did many times in the past. This is less true in astrophysics. There will surely be decades of discoveries with more sophisticated instruments, the frontiers are not completely explored at all. However, physics keeps its outstanding fascination. With current computing capacity, latest technologies, the present understanding of quantum mechanics, the interactions between physics and biology, the amount of physics that you can do at atomic and subatomic level, using many atoms together, cold systems and so on – there are so many sectors in which an excellent physicist can find great satisfaction.

And after ASI, will you go back to particle physics?

For the moment I need to put all of my energy into the job that has just started. I have not lost the pleasure of discovery, and the main objective of the years ahead is to support the best ideas in space science and technology, trying to get results as quickly as possible. And of course, I will keep following AMS.

Résumé

Du CERN à l'espace

Roberto Battiston a commencé sa carrière de chercheur en physique des particules comme étudiant, sur une expérience auprès des Anneaux de stockage à intersections (ISR) du CERN. Il a ensuite collaboré à l'expérience UA2, qui a codécouvert les bosons W et Z, puis à l'expérience L3 auprès du Grand collisionneur électron-positon (LEP), et enfin à l'expérience sur les rayons cosmiques AMS-02, arrimée à la Station spatiale internationale. Il y a un an, en mai 2014, il est devenu président de l'Agence spatiale italienne. Dans cet entretien, il compare les défis qui se posent à la recherche avec accélérateurs et à la recherche dans l'espace, et explique ce qu'un physicien des hautes énergies peut apporter aux spécialistes de l'espace.

Paola Catapano, CERN.

The Mu2e experiment: a rare opportunity

A new experiment at Fermilab will look for the neutrinoless transformation of a muon into an electron.

The Mu2e experiment at Fermilab recently achieved an important milestone, when it received the US Department of Energy's critical-decision 2 (CD-2) approval in March. This officially sets the baselines in the scope, cost and schedule of the experiment. At the same time, the Mu2e collaboration was awarded authorization to begin fabricating one of the experiment's three solenoids and to begin the construction of the experimental hall, which saw ground-breaking on 18 April (figure 1). The experiment will search with unprecedented sensitivity for the neutrinoless conversion of a muon into an electron.

Some history

The muon was first observed in 1937 in cosmic-ray interactions. The implications of this discovery, which took decades of additional progress in both experiment and theory to reveal, were profound and ultimately integral to the formulation of the Standard Model. Among the cornerstones of the model are symmetries in the underlying mathematics and the conservation laws they imply. This connection between theory (the mathematical symmetries) and experiment (the measurable conservation laws) was formalized by Emmy Noether in 1918, and is fundamental to particle physics. For example, the mathematics describing the motion of a system of particles gives the same answer regardless of where in the universe this system is placed. In other words, the equations of motion are symmetric, or invariant, to translations in space. This symmetry manifests itself as the conservation of momentum. A similar symmetry to translations in time is responsible for the conservation of energy. In this way, in particle physics, observations of conserved quantities offer important insights into the underlying mathematics that describe nature's inner workings. Conversely, when a conservation law is broken, it often reveals something important about the underlying physics.

In the Standard Model there are three families of quarks and three families of leptons. Generically speaking, members of the same family interact preferentially with one another. However, it has long been known that quark families mix. The Cabibbo–Kobayashi–Maskawa matrix characterizes the degree to which a particular quark interacts with quarks of a different family. This phenomenon has profound implications, and plays a role in the electroweak interactions that power the Sun and in the origin of CP violation. For decades it appeared that the lepton family did not mix: the lepton family number was always conserved in experiments. This changed with the observation that neutrinos mix (Fukuda *et al*. 1998, Ahmad *et al*. 2001). This discovery has profound implications; for example, neutrinos must have a finite mass, which requires the addition of a new field or a new interaction to the original Standard Model – the updated Standard Model is sometimes denoted the νSM. Indeed, the implications of neutrino mixing have yet to be revealed fully, and a vigorous worldwide experimental programme is aimed at further elucidating the physics underlying this phenomena. As often happens in science, the discovery of neutrino oscillations gave rise to a whole new set of questions. Among them is this: if the quarks mix, and the neutral leptons (the neutrinos) mix, what about the charged leptons? ▷

Fig.1. Top: The ground-breaking ceremony for the Mu2e experimental hall took place 18 April. (Image credit: Reidar Hahn/Fermilab.) Bottom: A rendering of the Mu2e building, with the Mu2e experiment in place.

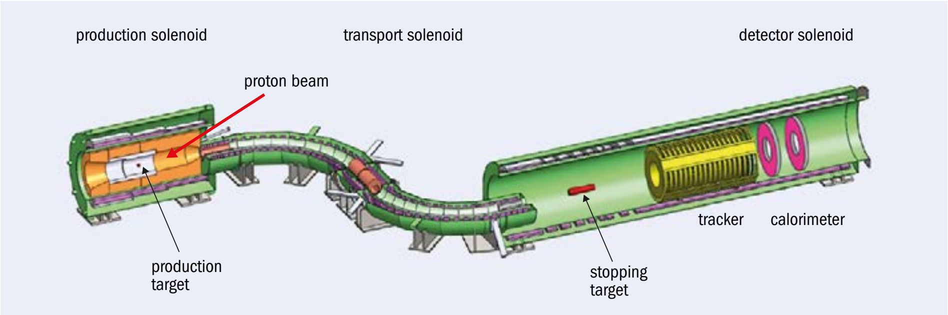


Fig. 2. The Mu2e apparatus is about 2 m in diameter at its largest and 25 m end to end. The proton beam enters from the right, as depicted by the red arrow. Not shown are cosmic-ray veto and beam-monitoring systems.

A probe of new physics

Searches for charged-lepton flavour violation (CLFV) have a long history in particle physics. When the muon was discovered, one suggestion was that it might be an excited state of the electron, and so experiments searched for $\mu \rightarrow e\gamma$ decays (Hicks and Pontecorvo 1948, Sard and Althaus 1948). The non-observation of this reaction, and the subsequent realization that there are two distinct neutrinos produced in traditional muon decay, led physicists to conclude that the muon was a new type of lepton, distinct from the electron. This was an important step along the way to formulating a theory that included several families of leptons (and, eventually, quarks). Nevertheless, searches for CLFV have continued ever since, and it is easy to understand why. In the Standard Model, with massless neutrinos, CLFV processes are strictly forbidden. Therefore, any observation of a CLFV decay would signal unambiguous evidence of new physics beyond the Standard Model. Today, even with the introduction of neutrino mass, the situation is not significantly different. In the νSM, the rate of CLFV decays is proportional to $[\Delta m^2_{ij}/M^2_W]^2$, where Δm^2_{ij} is the mass-squared difference between the ith and jth neutrino, and M_W is the mass of the W boson. The predicted rates are therefore in the region of 10^{-50} or smaller – far below any experimental sensitivity currently conceivable. Therefore, it remains the case that any observation of a CLFV interaction would be a discovery of new physics.

The case for pursuing CLFV searches is compelling. A wide variety of models of new physics predict large enhancements relative to the νSM (30–40 orders of magnitude) for CLFV interactions. Extra dimensions, little Higgs, lepto quarks, heavy neutrinos, grand unified theories, and all variety of supersymmetric models predict CLFV rates to which upcoming experiments will have sensitivity (see, for example, Mihara *et al.* 2013). Importantly, ratios of various CLFV interactions can discriminate among the different models and offer insights into the underlying new physics complementary to what experiments at the LHC, neutrino experiments, or astroparticle-physics endeavours can accomplish.

The most constraining limits on CLFV come from $\mu \rightarrow e\gamma$ muon-to-electron conversion, $\mu \rightarrow 3e$, $K \rightarrow ll'$, and τ decays. In the coming decade the largest improvements in sensitivity will come from the muon sector. In particular, there are plans for dramatic improvements in sensitivity for the muon-to-electron conversion process, in which the muon converts directly to an electron in the presence of a nearby nucleus with no accompanying neutrinos, $\mu^-N \rightarrow e^-N$. The presence of the nucleus is required to conserve energy and momentum. The process is a coherent one and, apart from receiving a small recoil energy, the nucleus is unchanged from its initial state. The Mu2e experiment at Fermilab (Bartoszek *et al.* 2015) and the COMET experiment at the Japan Proton Accelerator Research Complex (Cui *et al.* 2009) both aim to improve the current state-of-the-art by a factor of 10,000, starting in the next five years.

The Mu2e experiment

The Mu2e experiment will use the existing Fermilab accelerator complex to take 8-GeV protons from the Booster, rebunch them in the Recycler, and slow-extract them to the experimental apparatus from the Muon Campus Delivery Ring, which was formerly the anti-proton Accumulator/Debuncher ring for the Tevatron (*CERN Courier* December 2013 p24). Mu2e will collect about 4×10^{20} protons on target, resulting in about 10^{18} stopped muons, which will yield a single-event sensitivity for $\mu^-N \rightarrow e^-N$ of 2.5×10^{-17} relative to normal muon nuclear capture ($\mu^-N \rightarrow \nu_\mu N'$). The expected background yield over the full physics run is estimated to be less than half an event. This gives an expected sensitivity of 6×10^{-17} at 90% confidence level and a discovery sensitivity of 5σ to all conversion rates larger than about 2×10^{-16}. For comparison, many of the new-physics models discussed above predict rates as large as 10^{-14}, which would yield hundreds of signal events. This projected sensitivity is 10,000 times better than the world's current best limit (Bertl *et al.* 2006), and will probe effective mass scales for new physics up to 10^4 TeV/c^2, well beyond what experiments at the LHC can explore directly.

The Mu2e experimental concept is simple. Protons interact with a primary target to create charged pions, which are focused and collected by a magnetic field in a volume where they decay to yield an intense source of muons. The muons are transported to a stopping target, where they slow, stop and are captured in atomic orbit around the target nuclei. Mu2e will use an aluminium stopping target: the lifetime of the muon in atomic orbit around an aluminium nucleus is 864 ns. The energy of the electron from the CLFV interaction $\mu^-N \rightarrow e^-N$ – given by the mass of the muon less the atomic binding energy and the nuclear recoil energy – is 104.96 MeV. Because the nucleus is left unchanged, the experimental signature is a simple one – a mono-energetic electron and nothing else. Active detector components will measure the energy and momentum of particles originating from the stopping target and discriminate signal events from background processes.

The projected sensitivity is 10,000 times better than the world's current best limit.

Because the signal is a single particle, there are no combinatorial backgrounds, a limiting factor for other CLFV reactions. The long lifetime of the muonic-aluminium atom can be exploited to suppress prompt backgrounds that would otherwise limit the experimental sensitivity. While the energy scale of the new physics that Mu2e aims to explore is at the tera-electron-volt level, the physical observables are at much lower energy. In Mu2e, 100 MeV is considered "high energy", and the vast majority of background electrons are at energies $< M_\mu/2 \sim 53$ MeV.

Mu2e's dramatic increase in sensitivity relative to similar experiments in the past is enabled by two important improvements in experimental technique: the use of a solenoid in the region of the primary target and the use of a pulsed proton beam. Currently, the most intense stopped-muon source in the world is at the Paul Scherrer Institut in Switzerland, where they achieve more than 10^7 stopped-μ^-/s using about 1 MW of protons. Using a concept first proposed some 25 years ago (Dzhilkibaev and Lobashev 1989), Mu2e will place the primary production target in a solenoidal magnetic field. This will cause low-energy pions to spiral around the target where many will decay to low-energy muons, which then spiral down the solenoid field and stop in an aluminium target. This yields a very efficient muon beamline that is expected to deliver three-orders-of-magnitude-more stopped muons per second than past facilities, using only about 1% of the proton beam power.

A muon beam inevitably contains some pions. A pulsed beam helps to control a major source of background from the pions. A low-energy negative pion can stop in the aluminium target and fall into an atomic orbit. It annihilates very rapidly on the nucleus, producing an energetic photon a small percentage of the time. These photons can create a 105 MeV electron through pair production in the target, which can, in turn, fake a conversion electron. Pions at the target must be identified to high certainty or be eliminated. With a pulsed muon beam, the search for conversion electrons is delayed until almost all of the pions in the beam have decayed or interacted. The delay is about 700 ns, while the search period is about 1-µs long. The lifetime of muonic aluminium is long enough that most of the signal events occur after the initial delay. To prevent pions from being produced and arriving at the aluminium target during the measurement period, the beam intensity between pulses must be suppressed by 10 orders of magnitude.

The Mu2e apparatus consists of three superconducting solenoids connected in series (figure 2). Protons arriving from the upper right strike a tungsten production target in the middle of the production solenoid. The resulting low-energy pions decay to muons, some of which spiral downstream through the "S"-shaped transport solenoid (TS) to the detector solenoid (DS), where they stop in an aluminium target. A strong negative magnetic-field gradient surrounding the production target increases the collection efficiency and improves muon throughput in the downstream direction. The curved portions of the TS, together with a vertically off-centre collimator, preferentially transmit low-momentum negative particles. A gradient surrounding the stopping target reflects some upstream-spiralling particles, improving the acceptance for conversion electrons in the detectors.

Fig 3. This prototype Mu2e tracker panel consists of 96 straw tubes arranged in two layers. Postdoctoral research associates (left to right) Jason Bono, Dan Ambrose and Richie Bonventre install the read-out electronics. (Image credit: Reidar Hahn/Fermilab.)

When a muon stops in the aluminium target, it emits X-rays while cascading through atomic orbitals to the 1s level. It then has 61% probability of being captured by the nucleus, and 39% probability of decaying without being captured. In the decay process, the distribution of decay electrons largely follows the Michel spectrum for free muon decay, and most of the electrons emitted have energies below 53 MeV. However, the nearby nucleus can absorb some energy and momentum, with the result that, with low probability, there is a high-energy tail in the electron distribution reaching all of the way to the conversion-electron energy, and this poses a potential background. Because the probability falls rapidly with increasing energy, this background can be suppressed with sufficiently good momentum resolution (better than about 1% at 105 MeV/c).

Detector components

Inside the DS, particles that originate from the stopping target are measured in a straw-tube tracker followed by a barium-fluoride (BaF_2) crystal calorimeter array. The inner radii of the tracker and calorimeter are left un-instrumented, so that charged particles with momenta less than about 55 MeV/c, coming from the beamline or from Michel decays in the stopping target, have low transverse momentum and spiral downstream harmlessly.

The tracker is 3-m long with inner and outer active radii of 39 cm and 68 cm, respectively. It consists of about 20,000 straw tubes 5 mm in diameter, which have 15-µm-thick mylar walls and range in length from 0.4–1.2 m (figure 3). They are oriented perpendicular to the solenoid axis. Conversion-electron can- ▷

didates make between two and three turns of the helix in the 3-m length. The tracker provides better than 1 MeV/*c* (FWHM) resolution for 105 MeV/*c* electrons.

Situated immediately behind the tracker, the calorimeter provides sufficient energy and timing resolution to separate muons and pions from electrons with energy around 100 MeV. The BaF$_2$ crystals have a fast component (decay time around 1 ns) that makes the Mu2e calorimeter tolerant of high rates without significantly affecting the energy or timing resolutions. Surrounding the DS and half the TS is a four-layer scintillator system that will identify through-going cosmic rays with 99.99% efficiency. A streaming data acquisition (DAQ) architecture will handle about 70 GB of data a second when beam is present. A small CPU farm will provide an online software trigger to reduce the accept rate to about 2 kHz. A dedicated detector system will monitor the suppression of out-of-time protons, while another will determine the number of stopped muons.

Having cleared the CD-2 milestone in March, the Mu2e collaboration is now focused on clearing the next hurdle – a CD-3 "construction readiness" review in early 2016. In preparation, prototypes of the tracker, calorimeter, cosmic-ray veto, DAQ and other important components are being built and tested. In addition, the fabrication of 27 coil modules that make up the "S" of the transport solenoid will begin soon, and the building construction will continue into 2016. The final solenoid commissioning is scheduled to begin in 2019, while detector and beamline commissioning are scheduled to begin in 2020.

Further reading

Q Ahmad *et al.* (SNO Collaboration) 2001 *Phys. Rev. Lett.* **87** 7.
L Bartoszek *et al.* 2015 *Mu2e Technical Design Report* arXiv:1501.05241 [physics.ins-det].
W Bertl *et al.* (SINDRUM-II Collaboration) 2006 *Eur. Phys. J.* **47** 337.
Y G Cui *et al.* 2009 *COMET Conceptual Design Report* KEK-2009-10.
R M Dzhilkibaev and V M Lobashev 1989 *Sov. J. Nucl. Phys.* **49** 384.
Y Fukuda *et al.* (Super-Kamiokande Collaboration) 1998 *Phys. Rev. Lett.* **81** 1562.
E P Hincks and B Pontecorvo 1948 *Phys. Rev.* **73** 257.
S Mihara *et al.* 2013 *Annu. Rev. Nucl. Part. Sci.* **63** 531.
R D Sard and E J Althaus 1948 *Phys. Rev.* **74** 1364.

Résumé

L'expérience Mu2e : une aventure exceptionnelle

L'expérience Mu2e au Fermilab a récemment franchi une étape importante : elle a été approuvée en mars par une décision dite CD-2 (critical-decision 2) du département de l'Énergie des États-Unis, qui fixe officiellement les bases de l'expérience (portée, coûts et calendrier). D'une sensibilité sans précédent, Mu2e cherchera à observer la conversion d'un muon en électron sans production de neutrino. La collaboration Mu2e a également été autorisée à commencer la fabrication de l'un des trois solénoïdes de l'expérience, ainsi que la construction du hall d'expérimentation, pour lequel les travaux d'excavation ont commencé le 18 avril. La mise en service du détecteur et de la ligne de faisceau est prévue pour 2020.

Douglas Glenzinski, Fermilab, and **James Miller**, Boston University.

Snapshots from the Long Shutdown

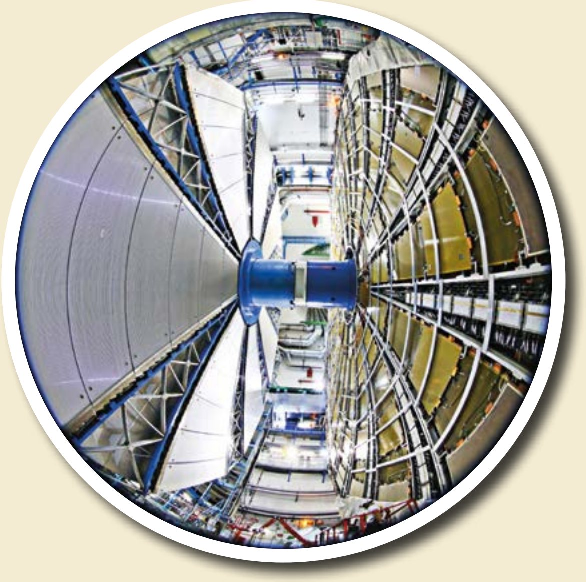
As ATLAS gears up to record data from proton collisions delivered by the Large Hadron Collider (LHC) at an unprecedented energy level, here are glimpses from the past two years of preparations.

Résumé

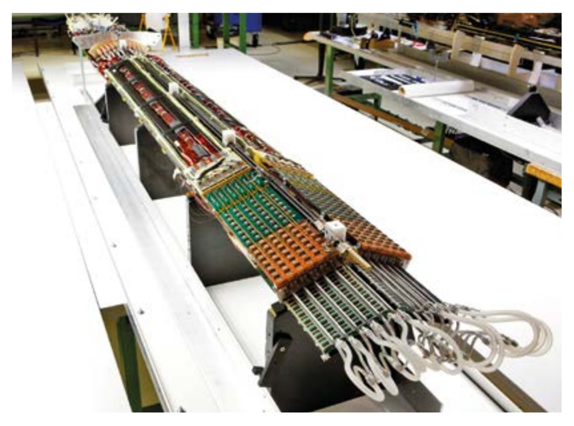
Instantanés du long arrêt

Alors qu'ATLAS se prépare à enregistrer les données des collisions de protons produites au Grand collisionneur de hadrons (LHC), à une énergie sans précédent, cette série de photographies nous donne un aperçu des préparatifs menés ces deux dernières années. Les travaux ont concerné un grand nombre d'éléments, du détecteur à pixels situé au cœur d'ATLAS aux immenses roues extérieures du spectromètre à muons.

Abha Eli Phoboo, University of Manchester.

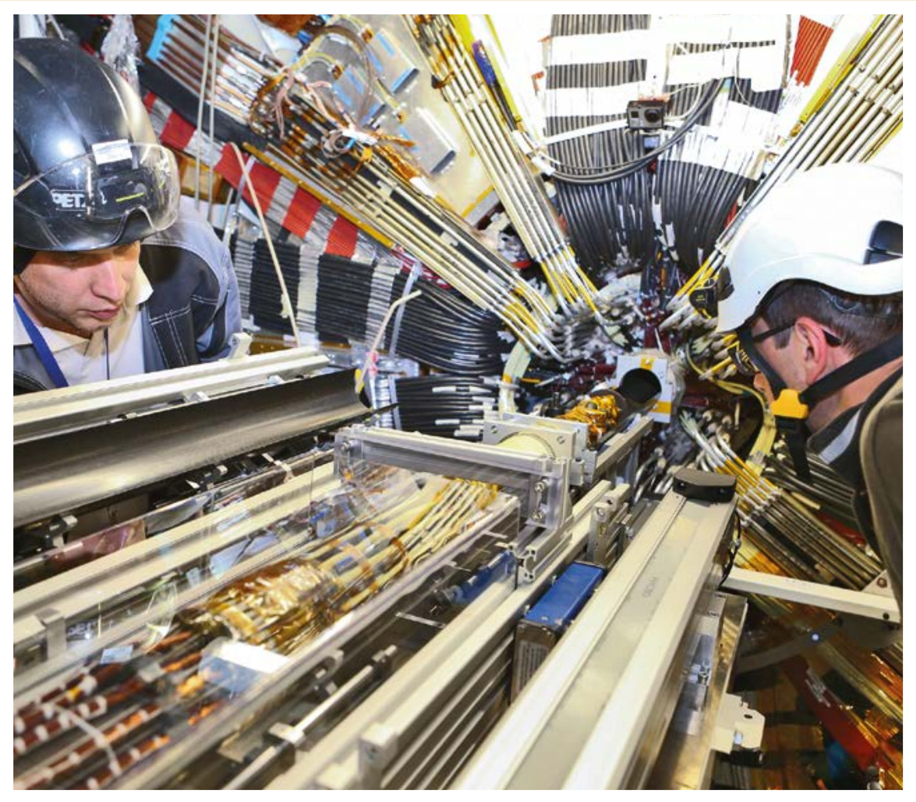


Above: A view from the bottom of the ATLAS cavern, up to the LHC beam pipe as the experiment prepares for Run 2 of the LHC at full energy. (Image credit: Claudia Marcelloni/ATLAS-PHO-Site-2015-002.)



Above: Construction of new panels of the pixel detector. The pixel detector is the innermost of ATLAS's many layers, lying closest to the interaction point where particle collisions occur. (Image credit: Claudia Marcelloni.)

Below: View of the ATLAS calorimeters from below as they were being moved to their final position before the detector closed for the LHC's second run. Calorimeters measure energy carried by neutral and charged particles. (Image credit: Claudia Marcelloni.)



Left: The ATLAS team watches as the first part of the Insertable B-Layer (IBL), a new component of the pixel subdetector, enters its support tube. The IBL was installed in May 2014, becoming the innermost layer of ATLAS's inner detector region. It will provide an additional point for tracking particles. An additional point closer to the collision vertex significantly improves precision. (Image credit: Claudia Marcelloni.)

Below: An ATLAS member vacuums the different sectors inside the 7000 tonne detector. Before the toroid magnets can be turned on for tests, the detector must be thoroughly cleaned. In December 2014, 110 ATLAS members worked in 10 different shifts for five days, cleaning and inspecting the detector and the cavern that houses it, to make sure that no object, however miniscule, may have been left behind during the months of upgrade and maintenance. (Image credit: Claudia Marcelloni.)

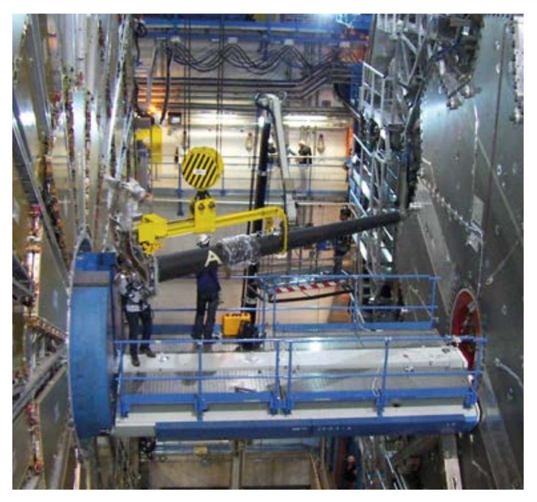
Left: A thin gap chamber on one of the big wheels being replaced. The big wheels are the final layer of the muon spectrometer, which identifies muons and measures their momenta as they pass through the ATLAS detector. The muon spectrometer is the outermost component of the 25-m tall and 46-m long ATLAS detector. (Image credit: Claudia Marcelloni.)

Below right: Members of the ATLAS muon team inspect the monitored drift tubes of the muon spectrometer before the shielding that encircles the beam pipe, where collisions occur, is installed. The shielding is designed to maintain the integrity of the beam and to protect the sensitive components of the detector near the beamline. (Image credit: Claudia Marcelloni.)

In May, the IBL became the innermost layer of ATLAS.

Above: ATLAS physicists Vincent Hedberg, left, and Giulio Avoni glue optical fibers for the construction of the LUCID calibration system. LUCID is a detector that will help ATLAS continue to measure luminosity with very high precision during the increased collision rates and increased energy expected in the next LHC Run. (Image credit: Giulio Avoni.)

Below: The vacuum group's team members lead the installation of LUCID and the LHC beam pipe. The beam pipe delivers the proton–proton collisions to the heart of the detector. (Image credit: Vincent Hedberg.)



Above: Raphaël Vuillermet, the technical co-ordination team's engineer, supervises the separation of the muon spectrometer's big wheels from the cavern balcony. There are four moveable big wheels at each end of the ATLAS detector, each measuring 23 m in diameter. The wheels are separated to access the interior of the muon stations to change faulty chambers. (Image credit: Claudia Marcelloni.)

COLLABORATION

US–CERN agreement paves the way for new era of scientific discovery

A new agreement between the US and CERN, signed on 7 May, will pave the way for renewed collaboration in particle physics, promising to yield new insights into fundamental particles and the nature of matter and the universe. The agreement, signed in a White House ceremony by the US Department of Energy (DOE), the US National Science Foundation (NSF) and CERN, will enable continued scientific discoveries in particle physics and advanced computing. It not only enables US scientists to continue their vital contribution to the important work at CERN, but it also formalizes, for the first time, CERN's participation in US-based programmes such as prospective future neutrino facilities.

The agreement aligns European and American long-term strategies for particle physics, which emphasize close international co-operation. This global relationship has already generated remarkable results, through instruments such as the LHC at CERN and the Tevatron collider at Fermilab. Now, CERN and the US can look forward to fruitful long-term collaboration, in particular in guiding the LHC to its full potential through the series of upgrades planned across many years to come.


Left to right: US energy secretary, Ernest Moniz, CERN's director-general, Rolf Heuer, and NSF director France Córdova, sign a US–CERN agreement at the White House. (Image credit: Ken Shipp/DOE Photo.)

CERN and the US have a long history of collaboration: American physicist Isidor Rabi was one of CERN's founders, and American scientists have been involved in CERN projects since the organization's creation in the early 1950s. CERN has provided equipment for US projects, such as Brookhaven's Relativistic Heavy Ion Collider, while European scientists have been critical to the success of US-based colliders, such as the Tevatron. This agreement will automatically renew every five years, unless one of the signatories indicates a need to modify or end the agreement.

GSI

Horst Stöcker returns to research


Horst Stöcker, left, is stepping down as scientific director at GSI. Karlheinz Langanke is taking over, ad interim. *(Image credits: G Otto, GSI.)*

After 8 years as scientific director at GSI Helmholtzzentrum für Schwerionenforschung GmbH, Horst Stöcker is planning to focus once again on his research activities. The supervisory board of GSI has granted his request to resign from his office, expressed some time ago, and thanked him for his commitment and successful work. The board has appointed Karlheinz Langanke as scientific director *ad interim*.

Stöcker has led the GSI research centre since 2007. During his tenure he fostered close collaborations between GSI and universities and international research institutions, to bring together know-how for research and technical development activities for the international Facility for Antiproton and Ion Research (FAIR), and to promote young scientists. He plans to continue his research activities, focusing on relativistic heavy-ion collisions, elementary-particle physics, and the study of hot dense nuclear matter, neutron stars and black holes, as well as the development of energy-efficient high-performance computers.

Langanke studied and gained his doctorate at the University of Münster, and from 1992 to 1996 was a member of the faculty at the California Institute of Technology. He later held a chair for theoretical physics at the University of Aarhus. Since 2005, he has been head of the theory division at GSI, and professor for theoretical physics at the Technische Universität Darmstadt. In 2006 he was appointed research director of GSI.

JEFFERSON LAB

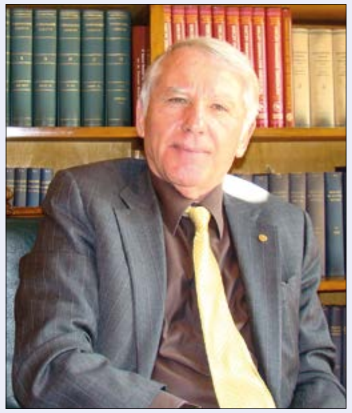
Weisenberger takes on role as chief technology officer

Andrew "Drew" Weisenberger, head of the Radiation Detector and Imaging Group in Jefferson Lab's Experimental Nuclear Physics Division, has accepted the additional role of chief technology officer (CTO) for the laboratory. As CTO, Weisenberger aims to help researchers at Jefferson Lab to see how their work can benefit society and lead to new or improved commercial applications. In addition to this new role, he will continue to lead the detector group.

As a member of the detector group, Weisenberger has spent years advancing research to improve particle-detector technology, and seeking ways that discoveries in the field can be applied outside Jefferson Lab's basic research programme. He is, for example, part of the team that developed a molecular-imaging camera for use in breast-cancer diagnostics, which is now produced commercially and used in hospitals and medical diagnostic centres around the world.

Jefferson Lab's previous CTO, Roy Whitney, retired on 1 August 2014.


Andrew "Drew" Weisenberger. (Image credit: Jefferson Lab.)


Dimitri Nanopoulos has been unanimously elected as the 90th president of the Academy of Athens for the year 2015. As the youngest-ever member of the Academy of Athens, elected in 1997, he has provided the institution with a new spirit of scientific and research thinking. A highly active theoretical physicist in high-energy physics, astroparticle physics and cosmology, he is also the current scientific delegate of Greece to the CERN Council. His many distinguished academic research roles include positions at Texas AM University and the Houston Advanced Research Center, as well as chair of theoretical physics, Division of Natural Sciences in the Academy of Athens. He is shown here in his office at the Academy of Athens. (Image credit: Ioanna Blatsou.)

AWARDS

EPS-HEPP announces 2015 prizewinners

The High Energy and Particle Physics (HEPP) Division of the European Physical Society (EPS) has announced the winners of its 2015 prizes. The awards recognize the efforts of young people in the field as well as those who have made many well-established contributions.

The 2015 High Energy and Particle Physics Prize, for an outstanding contribution to high-energy physics, recognizes seminal work in two areas related to the basic quark structure of matter. James Bjorken of SLAC receives the prize "for his prediction of scaling behaviour in the structure of the proton that led to a new understanding of the strong interaction". The prize also goes to Guido Altarelli of University of Roma Tre and CERN, Yuri Dokshitzer of the Laboratoire de Physique Théorique et Hautes Énergies and St Petersburg Nuclear Physics Institute, Lev Lipatov of St Petersburg Nuclear Physics Institute, and Giorgio Parisi of University of Rome La Sapienza "for developing a probabilistic field-theory framework for the dynamics of quarks and gluons, enabling a quantitative understanding of high-energy collisions involving hadrons".

The 2015 Giuseppe and Vanna Cocconi Prize, for an outstanding contribution to particle astrophysics and cosmology in the past 15 years, is awarded to Francis Halzen, University of Wisconsin-Madison, "for his visionary and leading role in the detection of very high-energy extraterrestrial neutrinos, opening a new observational window on the universe".

The 2015 Gribov Medal, for outstanding work by a young physicist in theoretical particle physics and/or field theory, goes to Pedro Vieira of the Perimeter Institute "for his groundbreaking contributions to the determination of the exact spectrum of anomalous dimensions of $N=4$ supersymmetric Yang–Mills theory and scattering amplitudes, for any interaction strength".

The 2015 Young Experimental Physicist Prize, for outstanding work by one or more young physicists in the field of particle physics and/or particle astrophysics, is awarded to young physicists at CERN. Jan Fiete Grosse-Oetringhaus is recognized "for his outstanding contributions to the investigation of particle collisions at the LHC through the analysis of jet quenching and multiparticle correlations in the ALICE experiment". Giovanni Petrucciani receives his share "for his outstanding contributions to the optimization of the tracking in the CMS detector, the Higgs boson discovery and the measurements of its properties".

Also this year recognizing the work of a young physicist, the 2015 Outreach Prize, for outstanding outreach achievement connected with high-energy physics and/or particle astrophysics, is awarded to Kate Shaw of the Abdus Salam International Center for Theoretical Physics "for her contributions to the International Masterclasses and for her pioneering role in bringing them to countries with no strong tradition in particle physics".

● The prizes will be awarded at the Europhysics Conference on High-Energy Physics (EPS-HEP 2015), which will take place in Vienna on 22–29 July. For more information on the conference, visit http://eps-hep2015.eu/.

CONFERENCE

Fundamental problems in quantum physics

Participants in Erice. (Image credit: Dirk-André Deckert.)

Around 80 experts and young researchers from across the world converged on the Ettore Majorana Foundation and Centre for Scientific Culture in Erice, on 23–27 March, for the international conference Fundamental Problems in Quantum Physics. This was the final meeting of the European COST (Collaboration on Science and Technology) Action MP1006 with the same name, co-ordinated by Angelo Bassi (*CERN Courier* June 2011 p32). The Action lasted four years, building up a strong and active international network in quantum foundations and related fields, through an intensive agenda based on staff exchanges, meetings, workshops and conferences.

The conference in Erice addressed the theoretical and experimental open problems in quantum physics. The common theme was: where are we with our understanding of the quantum world? What are the most relevant open issues and which are the directions for future research?

To answer such questions, presentations were organized in seven sessions. The quantum-interferometry session explored the state of the art in detecting quantum superpositions of large-mass objects. Discussions centred on the challenges in further increasing the mass and complexity of the objects, while preserving their quantum features. The session on mathematical physics and quantum field theory also looked at the state of the art, highlighting the problems of setting up a mathematically concise quantum field theory, and perspectives for future research.

The session on testing the fundamental principles collected up-to-date efforts in deciding the limits of validity of basic principles of physics such as the Pauli exclusion principle and the quantum-superposition principle. The quantum-foundations session explored recent advances in alternative formulations of quantum theory, such as Bohmian mechanics and collapse models. The session on quantum complex systems focused on the current understanding of quantum properties in complex, mainly biological, systems, and discussed the extent to which these systems behave in a truly quantum way, or in a simpler, classical one.

To close, the sessions on quantum gravity and gravity and cosmology explored the state of the art and difficulties in resolving perhaps the most fascinating open problem in modern physics: the unification of quantum mechanics and general relativity. The most popular answer is still string theory, but several other approaches were also represented.

On 26 March, a special session was organized to celebrate the 80th birthday of GianCarlo Ghirardi, one of the most influential figures in the foundations of quantum mechanics. There were presentations by Shelly Goldstein of Rutgers University, Hendrik Ulbricht of Southampton University, and Vahid Karimipour of Sharif University. Ghirardi himself presented a recollection of memories from his long and successful career.

The conference was organized by Angelo Bassi, University of Trieste, Catalina Curceanu, LNF-INFN, and Detlef Duerr, LMU-Muenchen. For more details, as well as the files of the presentations, visit www.lnf.infn.it/conference/QtG/.

The 7th International Conference on Physics and Astrophysics of Quark–Gluon Plasma (ICPAQGP-2015), which took place in February at the Kolkata Saha Institute and Variable Energy Cyclotron Centre campus, provided an opportunity to celebrate the 70th birthday of Bikash Sinha, who with Sibaji Raha and the late Bhaskar Dutta had organized the first meeting in the series in 1988, at the Tata Institute in Bombay. That meeting marked the beginning of a new and exciting adventure in India. Over the years, the country began to participate in heavy-ion experiments at CERN's Super Proton Synchrotron and later at the LHC, as well as at Brookhaven's Relativistic Heavy-Ion Collider. At the recent meeting, CERN's director-general, Rolf Heuer, gave a public talk and also joined the celebratory dinner at the Bengal Club of Kolkata. (Image Credit: Bengal Club.)

IPPOG

Reaching out with particle physics

IPPOG's participants in Paris. (Image credit: Dominique Longieras/ LAL-Orsay.)

How do we communicate about the LHC as a discovery machine, following the Higgs boson of 2012? How do we take the particle-physics masterclasses to new countries, age groups and settings? What makes a good educational game? How do we join in the existing national cosmic-ray-detector programmes, to take them further? These were some of the questions addressed at the 9th meeting of the International Particle Physics Outreach Group (IPPOG), which took place in Paris on 16–18 April.

IPPOG – which evolved from its European predecessor, EPPOG (*CERN Courier* April 2004 p42) – is a network based on a rare mix of scientists, science educators and communication specialists from prominent particle-physics laboratories and institutions around the globe, who are working in informal science education and outreach for particle physics. The desire to communicate science can take off early in a person's career, and the young people at IPPOG have great creativity and awareness of the social role of science.

IPPOG's meetings are intense, with panel discussions, working groups, and "wrap-ups" that involve the whole group. Brainstorming is the name of the game, and ideas are shared in the same way, no matter if they are for a common project or for an activity going on in only one country. Between the meetings, work continues and ideas are tested: do they work, for example, with real students and teachers? Other topics on the agenda of the recent meeting included discussions on how to boost the educational use of CERN open-access data, and how to bring science education and outreach to particle-physics conferences in a more effective way. There was also news on web resources, exhibits and programmes for teachers and students in the different countries.

The International Masterclasses in particle physics, IPPOG's flagship initiative, are now held in 42 countries, using data from the ALICE, ATLAS, CMS and LHCb experiments (*CERN Courier June* 2014 p37). Improvements, new measurements and new data are always being added. The TOTEM collaboration is now participating, and there are plans to include astroparticle-physics experiments such as the Fermi Gamma-ray Space Telescope, IceCube and the Pierre Auger Observatory. The new challenges are many and varied. The Australian state of New South Wales would like to have particle-physics masterclasses in all of its high schools. The so-called virtual masterclasses, based on virtual training tools and in which the communication between researchers, teachers and participants goes on across a longer timescale, may become particularly important. At the other end of the spectrum are the "masterclasses in a box", which are based on printed images and foreseen for settings where no computers are available.

There were also presentations on activities such as the most recent edition of the International Cosmic Day and the International Muon Week. These are crucial when the goal is to have more modern and experimental physics in high schools, and there is much to learn from sharing ideas and experiences.

The meeting also included inspiring and rewarding visits to the accelerator complex and Science ACO museum at the Laboratoire de l'Accélérateur Linéaire, which is now a European Physical Society historic site, and to the *Collider* exhibition, which is currently at the Palais de la Découverte (*CERN Courier* January/February 2014 p31 and p43).

● IPPOG's current members come from CERN's 21 member states, plus Ireland, Romania, South Africa, the US, DESY, CERN, and five of the LHC experiments. Marge Bardeen, of Fermilab, and Hans Peter Beck, of the University of Bern, are the current co-chairs.

VISITS

On 8 April, **Svetlana Kauzonienė**, left, Lithuania's deputy minister of science and education, met with the director-general, **Rolf Heuer**, during a day at CERN. Her visit included the laboratory's Central Workshop and LHC superconducting-magnet test hall, as well as the computer centre. (CERN-PHOTO-201504-066 – 7.)

Martin Tlapa, left, the Czech Republic's deputy minister of foreign affairs, came to CERN on 16 April. During his tour, he visited the CERN Control Centre, before seeing the ATLAS visitor centre and meeting members of the Czech community at CERN. (CERN-PHOTO-201504-070 – 27.)

Elmir Velizadeh, left, Azeirbaijan's deputy minister of communications and high technologies, was welcomed to CERN on 23 April by CERN's head of international relations, **Rüdiger Voss**, before taking in sights that ranged from the Synchrocyclotron exhibition to the CERN Control Centre. (CERN-PHOTO-200504-001 – 19.)

COLLABORATION

Towards future international projects

At the ILC Tokyo Symposium, held on 22 April, the Linear Collider Collaboration and more than 300 participants from around the world at the Asian Linear Collider Workshop 2015, together issued a statement confirming their conviction of the scientific justification for a prompt realization of the International Linear Collider (ILC). The statement points to the fact that "the project is now in a phase where governmental involvement should lead to a decision to realize the project," and expresses "appreciation of the ongoing project assessment being undertaken by the Japanese government." It also notes that the project's realization "requires the establishment of an international framework for sharing the cost and expertise among countries," and asserts the intention "to facilitate discussions between governments and funding authorities to achieve this goal as soon as possible."

At the same time, funding-agency representatives and laboratory directors were gathering at Fermilab on 20–21 April for the 2nd International Meeting on Large Neutrino Infrastructures, organized by Fermilab and the Astroparticle Physics European Consortium. The agencies were impressed by the convergence and momentum, since the first meeting, of the efforts of the community working on liquid-argon time-projection chambers to develop a programme based on three elements: a large infrastructure effort, consisting of a long-baseline beam and detector project (LBNF/DUNE) hosted at Fermilab and the Sandford Underground Research Facility (*CERN Courier* May 2015 p10); a medium-scale programme of short-baseline oscillation experiments at Fermilab to test the sterile neutrino hypothesis with unprecedented accuracy; and a rich R&D and prototyping programme in the CERN North Area, related to the above programme and other long-baseline efforts in the world.

The agencies also appreciated the progress towards the realization of the Hyper-Kamiokande experiment (*CERN Courier* April 2015 p9), and noted the complementarity of the techniques used by the large detectors here and in LBNF/DUNE (water, liquid argon and liquid scintillator) in the measurement of neutrino parameters, but above all for proton decay and neutrino astrophysics. Nevertheless, these larger efforts need to be complemented by smaller programmes to guarantee an understanding of whether the Standard Model with three neutrino flavours is realized in nature – or, conversely, to establish a groundbreaking discovery. Finally, a rich programme of single-beta and neutrinoless double beta decay experiments will explore the degenerate neutrino-mass region until the end of the decade. The goal for neutrinoless double-beta decay in the next decade, to cover the inverted mass-hierarchy region, will require tonne-scale detectors, and may demand large international collaborations for their construction.

● For more, visit www.linearcollider.org/ILC/Press/Press-releases/Tokyo-Statement and www.appec.org/9-features/126-towards-the-realization-of-a-global-neutrino-infrastructure.html.

OBITUARIES

José Mariano Gago 1948–2015

José Mariano Gago, particle physicist and former minister of science in Portugal, passed away on 17 April. He was the person who promoted science in Portugal after the long period of international isolation during the dictatorship that lasted from 1926 to 1974. He was the founder and the present president of the Laboratory for Instrumentation and Experimental Particle Physics (LIP), and was instrumental in Portugal's becoming a member state of CERN.

Mariano Gago studied electrical engineering at the Instituto Superior Técnico (IST) in Lisbon, where he was also involved in continuous political activity, as president of the Students' Association. He went on to study for a PhD in particle physics at the École Polytechnique and the Université Pierre et Marie Curie, his thesis being on the "Production de Ξ^-, de Ω^- et des resonances Ξ^* dans les interactions K^--proton à 14.3 GeV/*c*" in an experiment at CERN. He became professor at IST in 1978, continuing his involvement with experiments at CERN, to where he regularly returned.

It was at this time that he began to prepare the accession of Portugal to CERN as a full member state. This was finally achieved in 1985. LIP was created some months later, as an institute to bring together a small community of physics researchers coming from different universities. At the same time, he was appointed president of the Portuguese funding agency for science, the Junta Nacional de Investigação Científica e Tecnológica (JNICT). This laid the foundations of an impressive career devoted to the reconstruction and strengthening of the whole of science and technology research in Portugal, which lasted for 30 years

As president of the funding agency, and later as minister, Mariano Gago opened the way to a gigantic increase in the number of people working in science in Portugal. In 25 years, the number of PhD holders increased by a factor of eight. He also imposed new peer-evaluation rules for institutions, fellowships and project grants, opening the way for a new generation of people to take leading roles in all areas of science. Thanks to the help of the European Union (EU), which he knew how to make use of in an extremely efficient way, Portuguese science not only increased in size but also improved in quality, and became fully competitive on an international level in many fields.


José Mariano Gago. (Image credit: Luisa Ferreira.)

Mariano Gago believed deeply that science and technology should belong to people in general. During his tenure as minister of science and technology in the years 1995–2002, he created Ciência Viva, a large network of public centres for the popularization of science, extending throughout the country. At the same time, he connected all public schools to the internet, in a pioneering programme. From 2005 to 2011, he was again minister, this time of science, technology and higher education. At IST, as a physics professor, he organized nightly particle-physics seminars for all students in the late 1970s, and promoted experimental-physics laboratories for all of the engineering courses in the 1990s.

During the Portuguese EU presidencies, in 2000, Mariano Gago worked with the European Commission to develop the Lisbon Strategy for the European Research Area and the Information Society and, in 2007, he promoted a strategy for the modernization of EU universities. He chaired the Initiative for Science in Europe, and campaigned for the creation of the European Research Council. He also chaired the High Level Group on Human Resources for Science and Technology, and co-ordinated the European report *Europe Needs More Scientists*, published in 2004.

He also worked with UNESCO to create Ciência Global, a new initiative for the advanced training of scientists from developing countries. He strongly supported the creation of SESAME – the Synchrotron-light for Experimental Science and Applications in the Middle East – which is bringing together all of the countries in this region, from Israel to Iran, and he ensured that Portugal became an official observer.

Mariano Gago always regarded and quoted CERN as an example of international co-operation and peace, maintaining a constant strong connection with the organization. Many people remember his speech at the inauguration of the LHC, and he wrote recently on his "Thoughts on CERN's future", in the context of the 60th-anniversary celebrations (*CERN Courier* October 2014 p78). He was personally involved in other international scientific organizations, being a special adviser to the director-general of the European Space Agency, and a policy adviser to the European Cancer Organization. He was also a member of the Board of the French National Institute of Health and Medical Research, and was the first president of the International Risk Governance Council in Geneva. He helped to create the Cyprus Institute at Nicosia, and served as a member of its Board of Trustees. He was a member of the Portuguese Academy of Sciences and of the Portuguese Academy of Engineering, as well as of the Academia Europaea.

José Mariano Gago will be remembered for his achievements in many fields, as a particle physicist, a science policy maker, a professor, a dear colleague and, without doubt, a scientist who shaped the scientific culture in his country and internationally.

● *Gaspar Barreira, LIP.*

David Fiander 1931–2015

Dave Fiander, who made important contributions to the accelerator complex at CERN, passed away on 29 March. Born in 1931, Dave studied engineering at Imperial College. After graduation he joined the United Kingdom Atomic Energy

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Authority, where he worked on the production of enriched-uranium fuel rods for nuclear power stations. In 1963 he was offered a job at CERN, and joined a group headed by Fred Asner in the PS Division responsible for injection and ejection systems.

The Proton Synchrotron (PS) had recently been completed, accelerating protons to 28 GeV. Once accelerated, the 20 bunches of particles circulated every 110 ns. They were extracted to strike a fixed target from whence a few secondary particles went on to feed a bubble chamber at the far end of the South Hall. The bubble chamber required a very short pulse commensurate with the sensitive time of the chamber, but other experiments in the South Hall used scintillation counters, which needed several 100 ms of resonantly extracted beam spill.

Dave's challenge was to invent a pulsed high-voltage magnet that operated inside the accelerator's vacuum chamber, with an aperture big enough for the beam to pass at injection and a field strong enough to kick the 28-GeV bunches. A septum magnet would then steer the kicked beam out of the machine. This "full-aperture kicker magnet" needed 60 kV to provide the power. A length of high-quality coaxial line, charged to this voltage, produced a pulse of tens of kiloamps when a spark gap (later a thyratron switch) was fired. The pulse was fed into the matched impedance of the ferrite-cored magnet. The rise time of the pulse had to be less than the 100 ns between bunches, and the pulse had to be rigorously flat with an equally rapid fall time.

David Fiander. (Image credit: Fiander family.)

Dave's inventive imagination was equal to that of any of the great accelerator engineers who made CERN possible. He led a small team to complete the device, and founded a generation of many fast-switching magnets to direct CERN's beams of particles from the Booster to the PS to the Super Proton Synchrotron and, nowadays, to the LHC. All of this was done with characteristic precision and reliability, for a misdirected bunch train might bore a hole in the vacuum system or even one of the LHC's superconducting magnets.

Dave's team grew in size to become the Beam Transfer Group in the PS Division. He recruited nationals of many countries, from a variety of engineering backgrounds, leading them to achieve results that none, as individuals, could have hoped for. His secret for gaining their respect was a firm, fair and humane style of management, encouraging new ideas that enabled many advanced pulsed systems to be developed under his leadership.

His most productive years were spent working for Roy Billinge and Eifion Jones as they put together the Antiproton Accumulator. This needed many pulsed devices – for which Dave built the power supply – for a magnetic horn and the lithium lens. The latter, originally from Novosibirsk, combined high voltages and current to send the most intense and concentrated beam of protons CERN could then make through a rod of lithium, which the slightest leak of the water cooling system would have set on fire. In Dave's safe hands this was just another "no problem".

His last project before taking early retirement in 1993 was the pulsed high-voltage supply for the ISOLDE radioactive-beam target station. Yet even in the month he died, Dave was very proud of the first full-aperture kicker, which is still pulsing away after 40 years and is set to do so as long as the PS drives the CERN complex.

We share our sorrow with his family and we convey our deepest condolences and sympathy to Brenda, Susan, Keith, Ian and families.

● *His colleagues and friends.*

Till Moritz Karbach 1979–2015

Till Moritz Karbach, a 35-year-old physicist on the LHCb experiment, suffered a fatal fall on 9 April while rock climbing near the city of Pegnitz in southern Germany.

Moritz joined LHCb in the summer of 2009. At this time he was a postdoc in the Dortmund group, where he had also been a student on the BaBar experiment. In July 2012, he began a CERN research fellowship.

Moritz's contributions to LHCb were wide-ranging. He had particular interest in the measurement of the CP-violating phase γ, and in 2014 was appointed as co-convener of the working group responsible for these studies. He was a world authority on how the results of such measurements should be combined to achieve optimal precision for γ itself. His insight benefitted many other areas of LHCb physics, and in recent months he provided invaluable input to a paper reporting the measurement of the CKM matrix-element V_{ub}, the first such analysis to be performed at a hadron collider.

Moritz Karbach. (Image credit: Karbach family.)

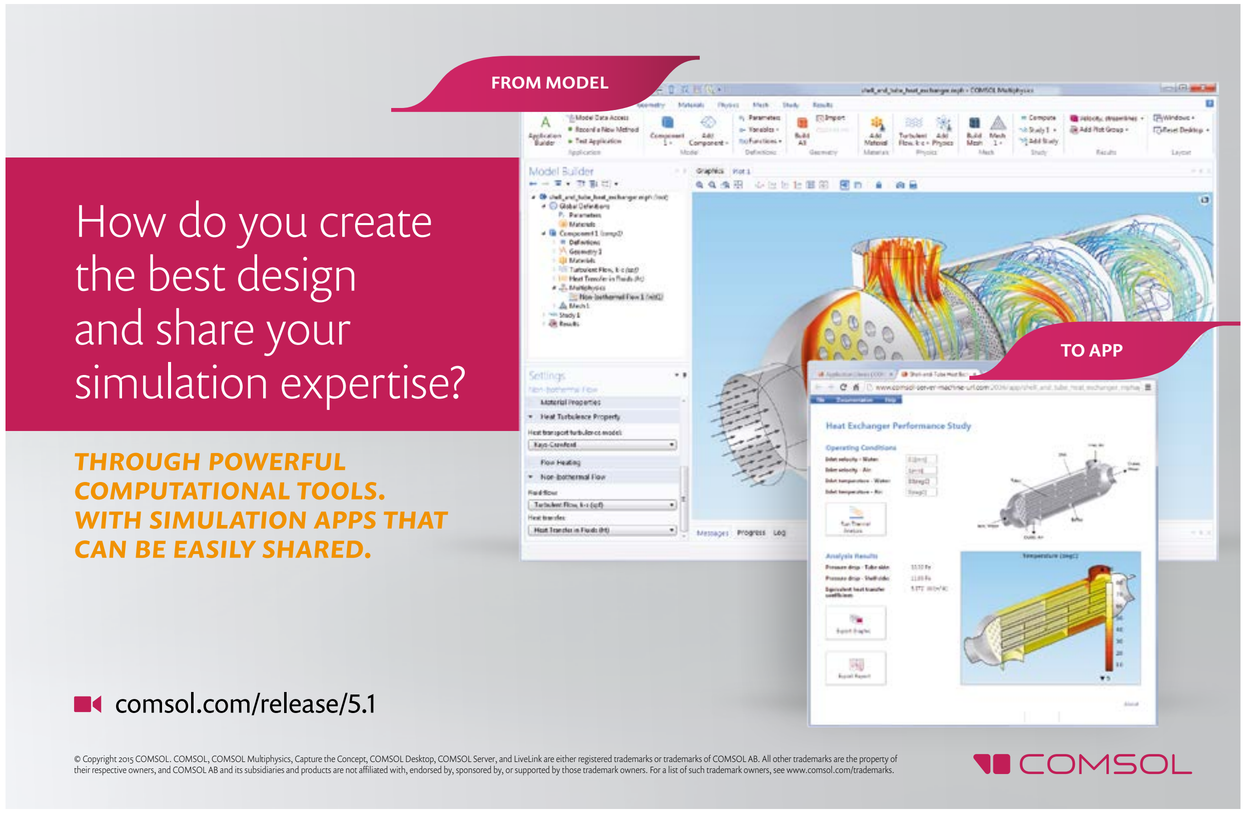
In addition to his analysis activities, Moritz was a talented and committed detector physicist. He was deputy project leader of LHCb's outer tracker and had on-site responsibility for this sub-detector for much of Run 1 of the LHC. Recently, he had started to contribute strongly to research and development activities on the scintillating-fibre tracker, a detector foreseen for the LHCb upgrade.

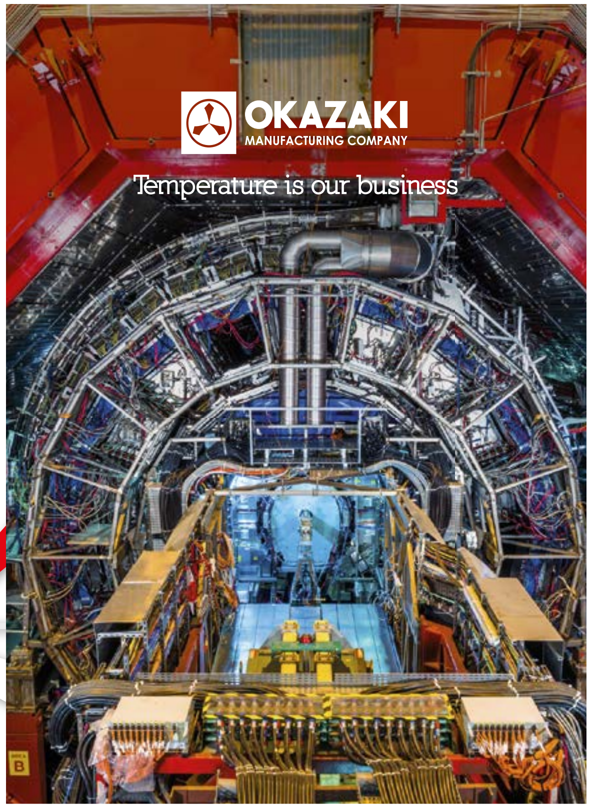
Moritz believed strongly that it is the duty of physicists to explain their work to the outside world. He was involved heavily in the Masterclass programme, which is directed at explaining the process of particle-physics measurements to high-school pupils.

Away from his work, Moritz had a passion for rock climbing and the mountains. While a student, he climbed frequently at Yosemite, and continued these activities in the Alps, having moved to Geneva.

His loss is felt deeply by his parents, brother and sister-in-law, and other close family members. His many friends and LHCb colleagues mourn his passing.

● *His colleagues and friends.*





Recruitment

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Fermilab

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The Peoples Fellowship at Fermilab seeks applications from newly minted Ph.Ds. (degree conferred within the past three years) in the following disciplines: Accelerator Physics; Accelerator-Related Technology; Particle Physics and Cosmology or related field. Post-doctoral experience is not required but may be advantageous for candidates applying from the field of particle physics and cosmology or a related field.

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This exciting opportunity offers extraordinary latitude in research activities selection. Current areas of research that are of interest at FNAL include (but are not limited to): single particle and collective nonlinear dynamics of intense beams, microwave/optical stochastic and electron cooling of phase-space, high intensity proton beams, high intensity neutrino sources, high-field superconducting magnets, superconducting radio-frequency science and technology, high luminosity and high energy 1-100 TeV class future colliders for leptons and hadrons, novel accelerator concepts, accelerator controls and feedback, and computational physics, simulations and modeling.

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Qualifications and Essential Job Functions

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The application deadline is June 30, 2015.

Questions may be submitted via email to peoplesfellowship@fnal.gov and/or **swapan@fnal.gov**. **Attention: Prof. Swapan Chattopadhyay, Chair, Peoples Fellowship Committee**
There is no legal requirement that Fermilab sponsor an employee for U.S. permanent residence. As a result, Fermilab will make the decision to sponsor an employee on a case-by-case basis. Fermilab will consider the following factors, among others, when determining whether to sponsor an employee for U.S. permanent residence: performance, length of service, long-term need for the position, and cost.

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Applications will be accepted until the positions are filled. Nominations for this position are also encouraged. For more information about the CAPP and its goals, as well as how to apply, see **capp.ibs.re.kr**.
Nominations and questions should be addressed to the director of the center, **Professor Yannis K. Semertzidis**, at **yannis@ibs.re.kr**.

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Institut für Kernphysik, Wilhelm-Klemm-Str. 9, D-48149 Münster
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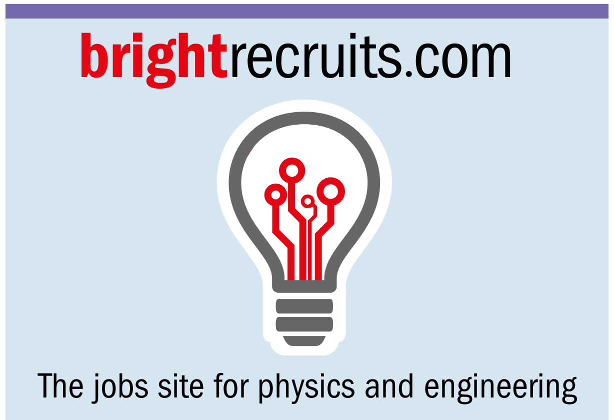

IFIN-HH

Senior and Junior Researchers, Postdoctoral research assistants, PhD students, Engineers, Physicists and Technicians at
Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

eli Nuclear Physics

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) will be a new Center for Scientific Research to be built by the National Institute of Physics and Nuclear Engineering (IFIN-HH) in Bucharest-Magurele, Romania.

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The jobs description, the Candidate's profiles and the Rules of Procedures of Selection can be found at http://www.eli-np.ro/jobs.php.

The applications shall be accompanied by the documents required in the Rules and Procedures of Selection for these positions

The applications shall be sent to the Human Resources Department at human.resources@eli-np.ro.

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The candidate is required to have at least five years of experience after his doctoral degree.

Each candidate should also indicate the names and e-mail addresses of not less than 3 renowned physicists. These physicists will receive an e-mail message from us with instructions on how to submit a recommendation letter on the candidate's behalf.

The decisions will be announced in October 2015 and the selected candidates are expected to start their activities at IIP between January 1st and February 1st, although a different arrangement can also be agreed upon.

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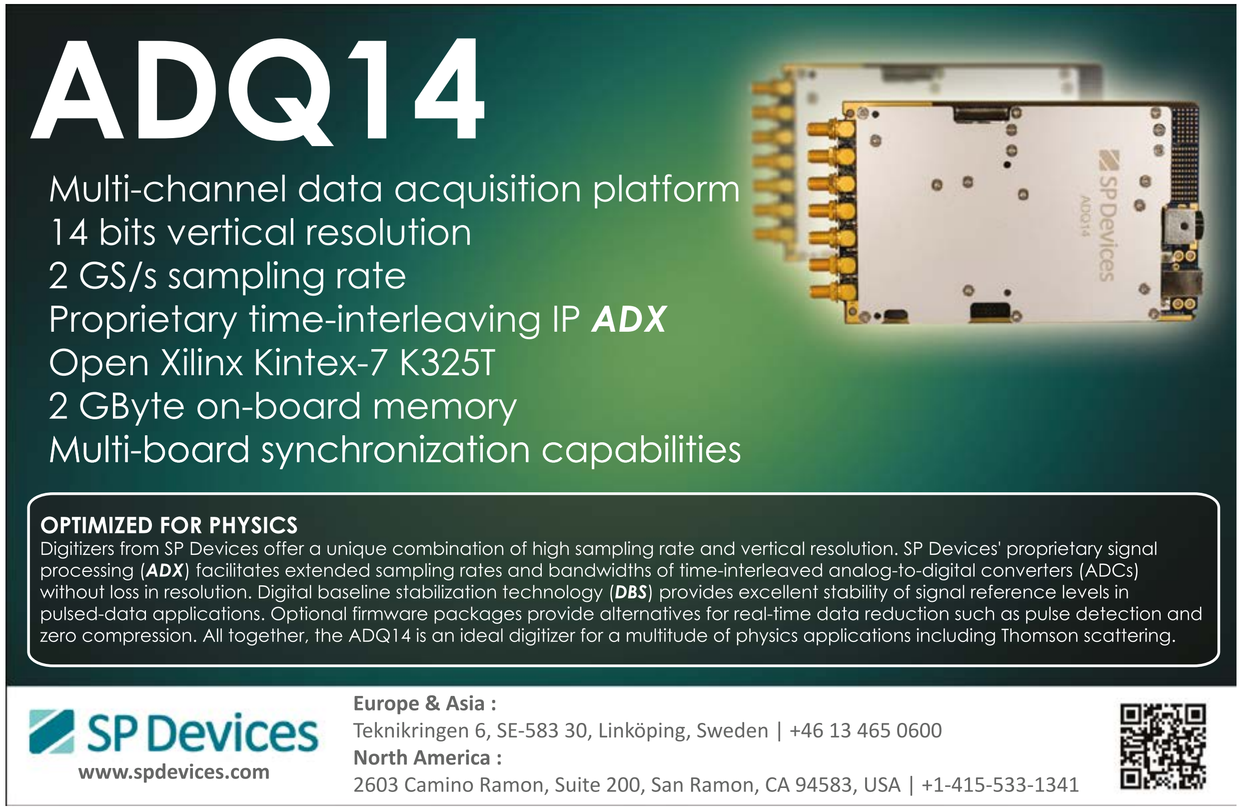
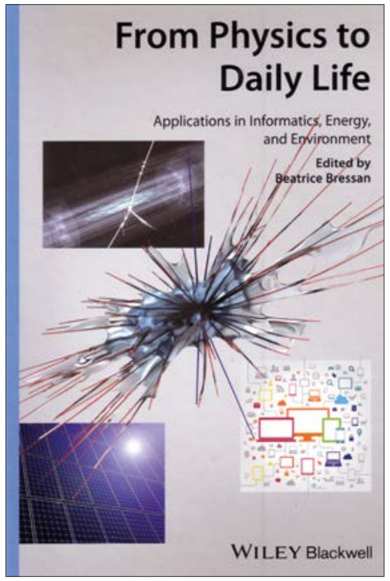


Bookshelf

From Physics to Daily Life: Applications in Informatics, Energy, and Environment
and
From Physics to Daily Life: Applications in Biology, Medicine and Healthcare
By Beatrice Bressan (ed.)
Wiley-Blackwell
Hardback: £60 €75
E-book: £54.99 €66.99
(The prices are for each book separately)



The old adage that "necessity is the mother of invention" explains, in a nutshell, why an institution like CERN is such a prolific source of new technologies. The extreme requirements of the LHC and its antecedents have driven researchers to make a host of inventions, many of which are detailed in these informative volumes that cover two broad areas of applications.

Eclectic is the word that comes to mind reading through the chapters of the two tomes that are all linked, in one way or another, to CERN. The editor, Beatrice Bressan, has done a valiant job of weaving together different styles and voices, from technical academic treatise to colourful first-hand account. For example, in one of his many insightful asides in a chapter entitled "WWW and More", Robert Cailliau, a key contributor to the development of the World Wide Web, muses wryly that even after a 30-year career at CERN, it was not always clear to him what "CERN" meant.

Indeed, as the reader is reminded throughout these two books, CERN is the convenient shorthand for several closely connected organizations and networks, each with its own innovation potential. There's the institution in Geneva whose staff consist primarily of engineers, technicians and administrators who run the facility. Then there's the much more numerous global community of researchers that develop and manage giant experiments such as ATLAS. And underpinning all of this is the vast range of industrial suppliers, which provide most of the technology used at CERN, often through a joint R&D process with staff at CERN and its partner institutions.

From a purely utilitarian perspective, the justification for CERN surely lies in the contracts it provides to European industry. Without the billions of euros that have been cycled through European firms to build the LHC, there would be little political appetite for such a massive project. As explained in the introductory chapter by Bressan and Daan Boom – reproduced in both volumes, together with a chapter on Swiss spin-off – there has been a great deal of knowledge transfer thanks to these industrial contracts. Indeed, this more mundane part of CERN's industrial impact may well dwarf many of the more visible examples of innovation illustrated in subsequent chapters.

Still, as several examples in these two volumes illustrate, there is no doubt that CERN can also generate the sort of "disruptive technologies" that shape our modern world. The web is the most stunning example, but major advances in particle accelerators and radiation sensors have had amazing knock-on effects on industry and society, too, as chapters by famous pioneers such as Ugo Amaldo and David Townsend illustrate clearly.

The question that journalists and other casual observers never cease to ask, though, is why has Europe not benefitted more directly from such breakthroughs? Why did touch screens, developed for the Super Proton Synchrotron control room, not lead to a slew of European high-tech companies? Why was it Silicon Valley and not some valley in Europe that reaped most of the direct commercial benefits of the web? Where are all of the digital start-ups that the hundreds of millions of euros invested in Grid technology were expected to generate?

Chapters on each of these technologies provide some clues to what the real challenge is. As Cailliau remarks wistfully, "WWW is an excellent example of a missed opportunity, but not by CERN." In other words, to be successful, invention needs not only a scientific mother, it requires an entrepreneurial midwife, too. That is an area where Europe has been sorely lacking.

The only omission in these otherwise wide-ranging and well-researched books, in my opinion, is the lack of discussion on the central role of openness in CERN's innovation strategy. Open science and open innovation are umbrella terms mentioned enthusiastically in the introductory chapter by Sergio Bertolucci, CERN's director for research and computing. But there are no chapters dealing specifically with how open-access publication or open-source software and hardware – areas where CERN has for years been a global pioneer – have impacted knowledge transfer and innovation. Perhaps that is a topic broad enough for a third volume.

That said, there is, in these two volumes, already ample food for more thoughtful debate about successful knowledge management and technology transfer in and around European research organizations like CERN. If these books provoke such debate, and that debate leads to progress in Europe's ability to transform innovations sparked by fundamental physics into applications that improve daily life, they will have made an important contribution.

● *Francois Grey, University of Geneva.*

● For the colloquium held at CERN featuring talks by contributors to these two books, visit https://indico.cern.ch/event/331449/.

Inside Story

Flying over ALICE

A drone video underlines the importance of social media in science communication today.

I am deeply struck by the reaction of people when they visit CERN installations. Even if most visitors already have a vague expectation, nothing can replace the direct experience of being in front of the most complex machines ever built by mankind. CERN is the home of the LHC – the biggest and most powerful accelerator in the world. If the LHC ring, with its 27-km circumference, were installed on the Earth's surface instead of being 100 m underground, it would be one of the human artefacts potentially visible from spacecraft in lower orbits. The drawback of such magnitude is that one cannot really embrace the LHC from the ground: it's just too big.

So the ultimate breathtaking visitor experience really comes from descending into the caverns hosting the giant detectors that operate on the accelerator itself. Hence, the LHC long shutdown after its first operational phase provided a unique chance to see the underground installations. In fact, more than 70,000 people visited CERN during the Open Days in 2013, and about 4000 came to visit ALICE. Before guiding the visitors down to the cavern, we usually show introductory slides describing the scientific mission and the complexity of the ALICE detector, and we tell the audience about its many highlights. We show axonometric drawings and quote physical dimensions: 16-m high, 25-m long, 10,000 tonnes in weight, and so on. However, such numbers don't really stick in people's minds until they are able to see with their own eyes the cyclopic iron doors of the solenoid magnet, the multiple layers of sensitive detector elements packed together and densely instrumented with electronics boards, the intricate networks of data and power cables, the cooling pipes, and the innervating support structures.

Unfortunately, not everyone can come to CERN and take such a visit into the LHC detectors. Moreover, the maintenance period is now completed. For more than three years the underground areas will be mostly inaccessible, and I realized that many would miss a unique opportunity. So when I found out that my colleague at INFN Francesco Sborzacchi, together with Benedikt Langhans, had operated a drone for an evacuation exercise at the LHCb experiment, I asked if they would be willing to fly their drone in ALICE. Shooting an aerial video sequence seemed the perfect way to convey a true "CERN experience".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Now you can see the world of #CERN....by drone! - bbc.in/1wTeghS

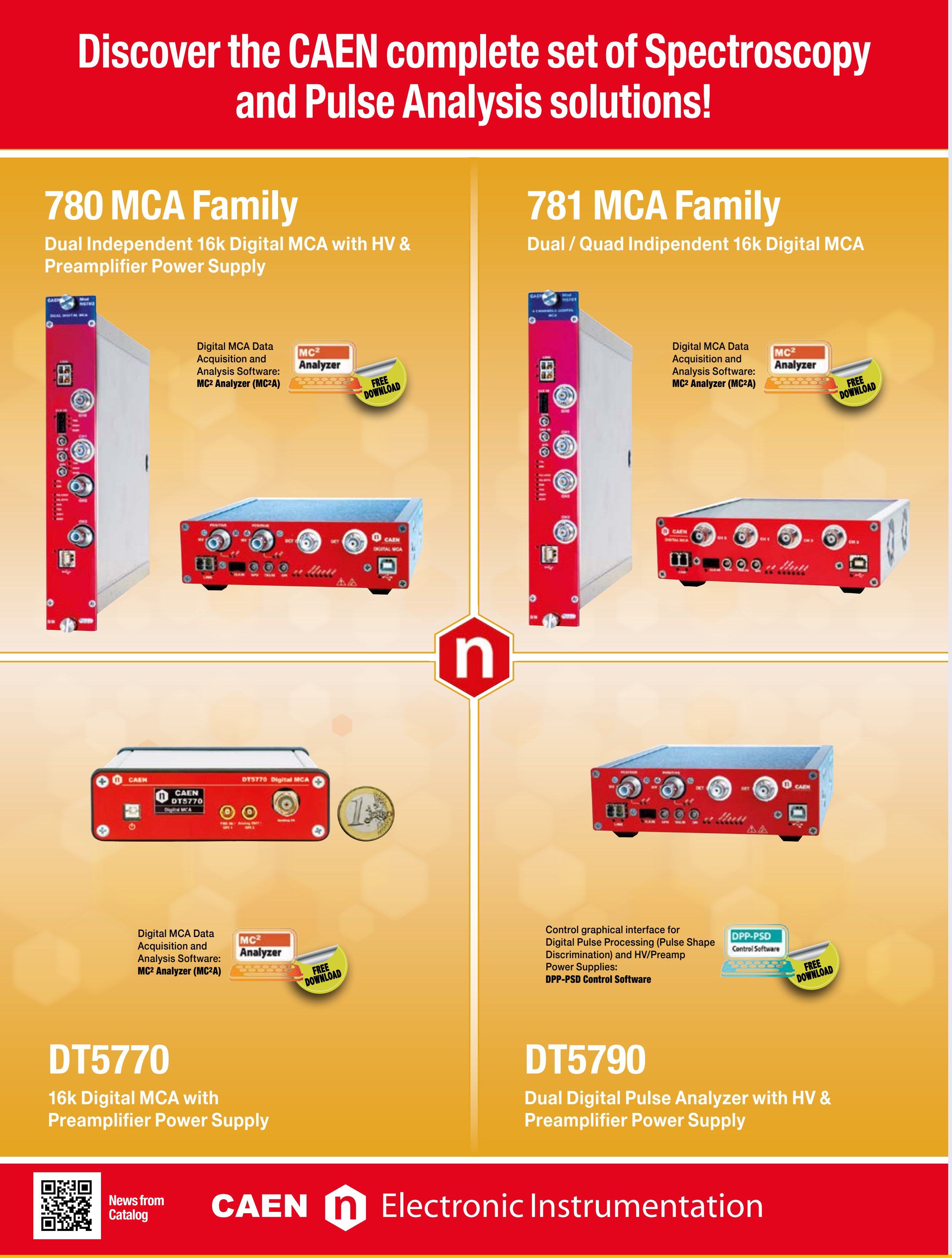
The tweet by BBC Click. (Image credit: BBC.)

The idea was to fly the drone over the ALICE site, down to the shaft, in front of the ALICE solenoid, over the beam pipe, and finally to hover it on the central barrel and near to the muon spectrometer. The concept for the video was precise: a three-minute clip, with dynamic scene changes, no voice-over, but short captions with simple yet informative content. We wanted the viewer to survey the whole ALICE site, peek into our new, state-of-the art control room, jump into the shaft and "inspect" the detector as close as possible, at times "sticking their nose inside it". The sequences with the time-lapse of the magnet-door closure and the scenes with the collision-event examples were added to explain the status of readiness and the ALICE scientific mission, respectively.

After several iterations, the footage became the video *Flying over ALICE* – the result of much co-operative work – and was published on the CERN and ALICE social-media channels, such as Twitter and Facebook. As of today, the overall score of the original video on YouTube and Facebook has reached almost 80,000 hits, and is still being viewed. It is worth noting that many news sites provided their own streaming, which means that the effective number of viewers is larger than the YouTube count. After going on the social networks, major news websites such as NBC News, Discovery News and CNET picked up the footage instantly. After a few days, bookkeeping the list of sites that linked to the ALICE video became too difficult because it went all over the world, being re-launched by multi-million-follower Twitter accounts such as BBC-Click in the UK, and nationwide news sites in Germany, Italy, the Netherlands, Spain, Portugal, Singapore, Sierra Leone and South Africa.

The (partially) unexpected success of the ALICE drone footage underlines the importance of social networks in science communication, because they offer a viable alternative to or complement the "vertical" media channels, such as television, which tend to confine science in a niche or, worse, to distort and dilute its contents. On the other hand, the "horizontal" communication paradigm driving social networks offers to scientific institutions and scientists the opportunity to directly connect to people and media operators, providing first-hand, fresh feedback on the latest achievements of research and, most of all, on its importance and role for today's society. I believe that the interest of the general public for science goes much further than what is commonly imagined by the traditional media operators. The feedback loop of commonplaces demands that people perceive science as abstruse and distant, or worse, "not really useful". This flaw is, for the most part, a consequence of the fact that the media confine science behind a wall of stereotypes and sensationalism. At the same time, we must admit that not many scientists excel in communication skills. In this respect, social networks may provide a sort of "quantum tunnelling" allowing more and more scientists to sneak through these communication barriers.

- *Federico Ronchetti, INFN (Laboratori Nazionali di Frascati) and CERN. Based on an article that first appeared in* ALICE Matters, *alicematters.web.cern.ch.*



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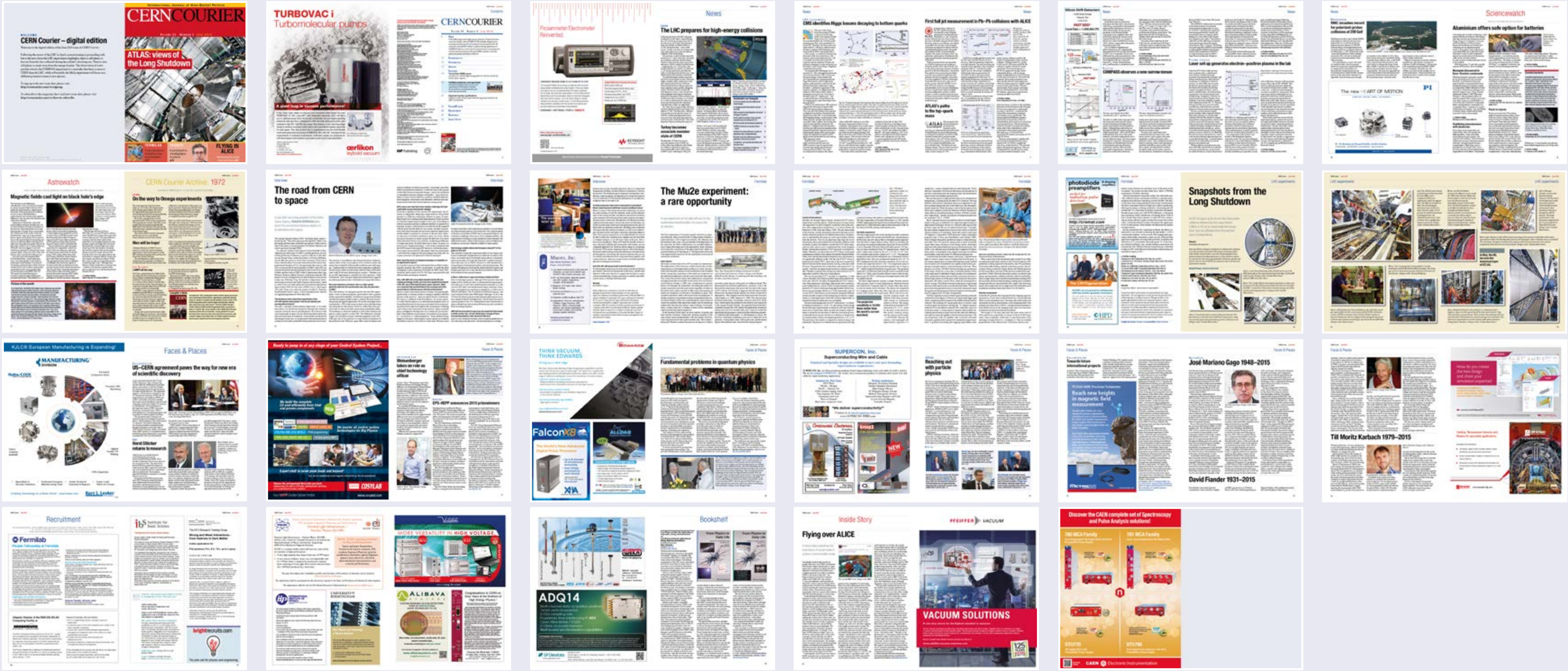

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VOLUME 55 NUMBER 5 JUNE 2015

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