WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the June 2016 issue of *CERN Courier*.

As the LHC experiments are again collecting data for physics, we touch base on the challenges that high-energy collisions and very intense beams represent for computing. The challenge extends far beyond the lifetime of the LHC if we look at data preservation, which must define winning strategies and permanent solutions to the problem. This month, we also feature CERN's unique kaon factory and CMS's powerful algorithm, which aims to identify and reconstruct individually all of the particles produced in a collision. The cover goes to AugerPrime in the Argentinian Pampas: the challenges that lie ahead here will involve a large community of scientists and innovative hardware solutions. News from CERN, BEPCII and HESS (the latter in Astrowatch) also features in the June issue. Last but not least, after a short but intense "*intermezzo*", Antonella Del Rosso steps down and leaves the floor to the new editor, Matthew Chalmers.

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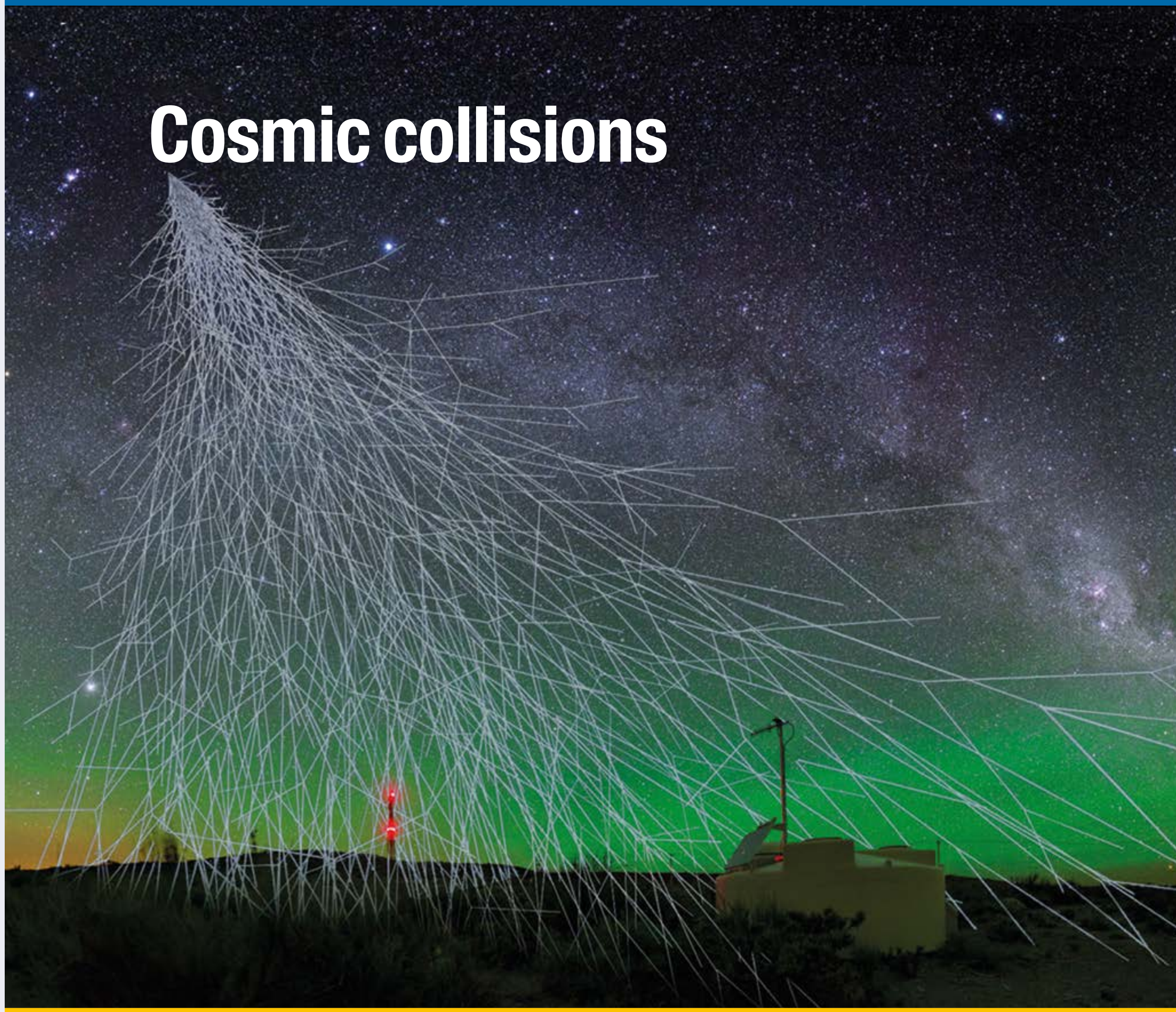
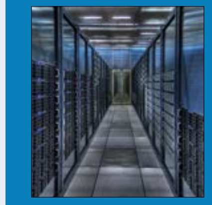
DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS
CERNCOURIER
VOLUME 56 NUMBER 5 JUNE 2016



Cosmic collisions



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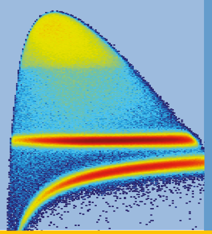

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CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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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);
E-mail: sales@cerncourier.com; fax +44 (0)117 930 1178

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:
China Ya'ou Jiang, Institute of High Energy Physics,
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

CERNCOURIER

VOLUME 56 NUMBER 5 JUNE 2016

On the cover: Artist's rendering of a cosmic-ray air shower with a surface detector of the Pierre Auger Observatory in Argentina. (Image credit: Montage: Helmholtz Alliance for Astroparticle Physics /A Chantelauze; Photo: University of Adelaide/S Saffi; Cosmic Shower: ASPERA/Novapix/L Bret.)

Viewpoint

A global lab with a global mission

It's a dynamic mix of co-operation and competition that drives particle physics forward.

Image credits: CERN

Hosting thousands of physicists from all across the world, building 40 is one of the symbols of CERN's global mission.

By Charlotte Warakaulle

Our world has been transformed almost beyond recognition since CERN was founded in 1954. Particle physics has evolved to become a field that is increasingly planned and co-ordinated around the world. Collaboration across regions is growing. New players are emerging.

CERN is now a global lab, with a European core. This was recognised by CERN member states with the adoption, in 2010, of the geographical enlargement policy that opens up for greater participation from countries outside of Europe. Since then, we have welcomed Israel as a new member state. Romania and Serbia are entering the final stages of accession to membership, and Cyprus has just joined as an associate member in the pre-stage to membership. Since 2015, Pakistan and Turkey have been part of the wider CERN family as associate members, and several more states are applicants for associate membership.

Yet, the changes go much further than our scientific field and the inclusion of new members in our particle-physics family. Global governance is more complex than ever, with overlapping challenges and a greater number of interlocutors. Public opinion is being formed in new ways, driven by technological advances and political change. Global economic changes, with emerging countries gaining influence and clout, shape policy priorities in new ways – also in the scientific field. Support for fundamental science must be constantly nurtured, and partnerships are more necessary than ever.

It is a highly complex and fast-moving global policy space. CERN – and indeed all large labs and research infrastructures – needs to react to and act within this evolving context. The challenge for all of us is to advance in a globally co-ordinated manner, so as to be able to carry out as many exciting and complementary projects as possible, while ensuring long-term support for fundamental science as the competition for resources becomes ever fiercer on all levels.

Global impact

It is against this background that the Director-General of CERN has now, for the first time, established an International Relations (IR) sector. The sector brings together entities within the Organization that are working on different aspects of our international engagement, and it provides a unique opportunity for CERN to strengthen the global dimension of its work.

The IR sector has three overarching objectives. First, to help strengthen CERN's position as a global centre of excellence in science and research through sustained support from all stakeholders. Second, to contribute to shaping a global policy agenda that supports fundamental research, and includes science perspectives more generally. And third, connecting CERN with people across the world to inspire scientific curiosity and understanding.

The immediate priorities for the sector include reinforcing dialogue with our member states, setting future directions for geographical enlargement, and strengthening CERN's voice in global policy debates.

Let me share a couple of the initiatives that are under way.

We have already expanded the interaction with member states with the establishment of thematic forums that enable better dialogue, and new forums will be created in the coming months. We have also begun reflecting on how to focus geographical enlargement in a way that fully supports and reinforces our long-term scientific aspirations. It is critical that enlargement is not seen as an end in itself; it is intended to underpin CERN's scientific objectives through a broader and more diverse support base to strengthen our core scientific work.

Fundamental science

Direct engagement with people across the world is a key aspect of our work. With a newly integrated Education, Communications and Outreach group, we will be able to reach out in a more co-ordinated manner – to stimulate interest in and support for fundamental science, among teachers, students, global science policy makers and the many others around the globe who follow our work. For those of us who work with fundamental science every day, the value and impact seem obvious. But it isn't always that obvious beyond our own corridors. We need to get better at demonstrating how scientific advances impact on the lives of people across the world, every single day, often in surprising but deeply profound ways.

While the IR sector as an institutional construct is new, we are building on a proud, long-standing tradition of inclusive international collaboration in pursuit of a common goal: expanding our collective knowledge. Exploring the frontiers of knowledge has always thrived on ideas, input and initiatives from across the world.

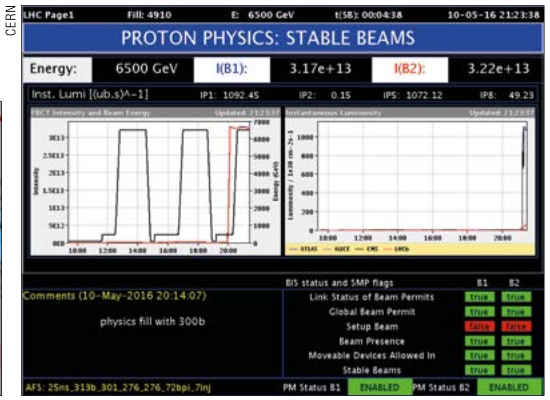
It is truly a privilege to be part of the collective effort that is the CERN IR sector, to take that work forward.

Charlotte Lindberg Warakaulle has served as CERN's director for International Relations since January 2016. From 2001 and until joining CERN, she held a variety of posts at the United Nations, from associate speechwriter to chief of the Political Affairs and Partnerships Section of the United Nations Office at Geneva.

News

THE LHC

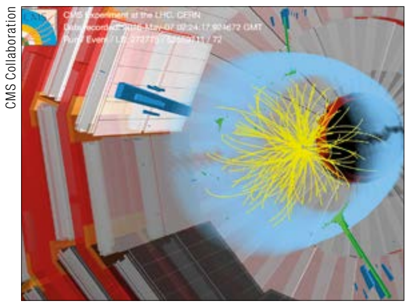
Data to physics



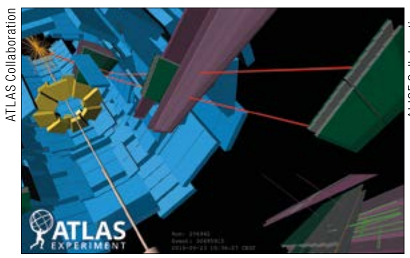
CERN

Left: The LHC Page 1 screen displays "Stable Beams" for the first time in 2016.

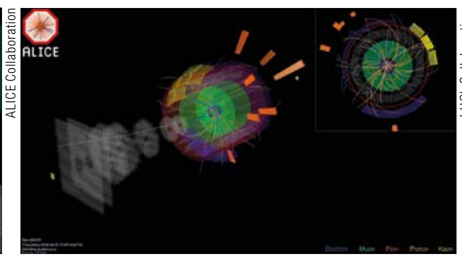
CMS Collaboration



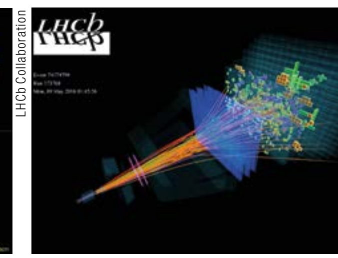
ATLAS Collaboration



ALICE Collaboration



LHCb Collaboration



Anticlockwise from top left: First physics events recorded by the four large LHC experiments at the beginning of May. With the 2016 data, the experiments will be able to perform improved measurements of the Higgs boson and other known particles and phenomena, and look for new physics with increased discovery potential.

At the beginning of May, the LHC declared the start of a new physics season for its experiments. The "Stable Beams" visible on the LHC Page 1 screen (see image above) is the "go ahead" for all the experiments to start taking data for physics.

Since 25 March, when the LHC was switched back on after its winter break, the accelerator complex and experiments have been fine-tuned using low-intensity beams and pilot proton collisions, and now the LHC and the experiments are taking an abundance of data.

The short circuit that occurred at the end of April, caused by a small beech marten that had found its way onto a large, open-air electrical transformer situated above ground, resulted in a delay of only a few days in the LHC running schedule. The relevant part of the LHC stopped immediately and safely after the short circuit, and the entire machine remained in standby mode for a few days.

Now, the four largest LHC experiment collaborations, ALICE, ATLAS, CMS and LHCb, have started to collect and analyse the 2016 data (see images above). Last year, operators increased the number of proton bunches to 2244 per beam, spaced at intervals of 25 ns. These enabled the ATLAS and CMS collaborations to study data from about 400 million million proton–proton collisions. In 2016, operators will increase the number of particles circulating in the machine and the squeezing of the beams in the collision regions. The LHC will generate up to one-billion collisions per second in the experiments.

The physics run with protons will last six months. The machine will then be set up for a four-week run colliding protons with lead ions.

Short but intense...

After a short, but intense, "*intermezzo*" as editor of the *CERN Courier*, I'm stepping down as I head off to new challenges. I would like to thank the *CERN Courier* Advisory Board and the many contributors who are the backbone of the magazine. I would also like to thank Lisa Gibson, the production editor at IOP Publishing. Most importantly, I would like to say that the magazine would not be what it is without its faithful readership, whose feedback I have appreciated greatly during these months. I'm sure that they will continue to provide their support to the new editor, Matthew Chalmers. *Antonella Del Rosso, CERN.*

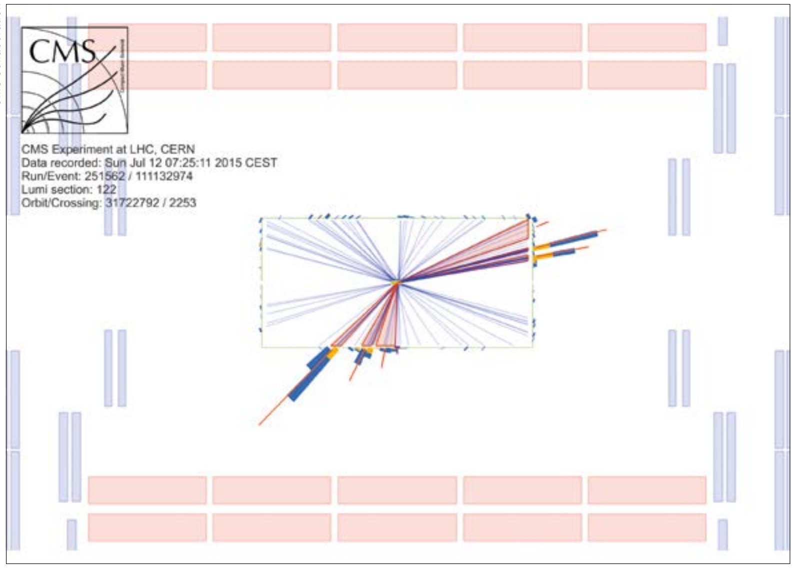
Sommaire en français

LHC EXPERIMENTS

CMS benefits from higher boosts for improved search potential in Run 2

With the increase in the centre-of-mass energy provided by the Run 2 LHC collisions, the production cross-sections of many new-physics processes are predicted to rise dramatically compared with Run 1, in contrast to those of the background processes. However, this increase in the cross-section is not the only way to enhance search sensitivities in Run 2. The higher energy leads to particle production that is more highly boosted. The large boosts result in the collimation of the decay products of the boosted object, which therefore overlap in the detector. For example, a Z boson that decays to a quark and an antiquark will normally produce two jets if it has a low boost. The same decay of a highly boosted Z boson will – in contrast – produce a single massive jet, because the decay products of the quark and antiquark will merge. Using jet-substructure observables, such as the jet mass or the so-called N-subjettiness, the search sensitivity for boosted objects like boosted top (t) quarks or W, Z and Higgs bosons can be enhanced.

CMS Collaboration



Event display of two boosted top-quark candidates, each with the expected three distinct subjets.

CMS has retuned and optimised these techniques for Run 2 analyses, implementing the latest ideas and algorithms from the realm of QCD and jet-substructure phenomenology. It has been a collaboration-wide effort to commission these tools for analysis use, relying on experts in jet reconstruction and bottom-quark tagging, and on data-analysis techniques from many groups in CMS. These new algorithms significantly improve the identification efficiency of boosted objects compared with Run 1.

Several Run 2 CMS studies probing the boosted regime have already appeared, using the 2015 data set. While searches for boosted entities are pursued by many CMS analysis groups, the Beyond 2 Generations (B2G) group focuses specifically on final states composed of one or more boosted objects. Signal processes of interest in the B2G group include W′ → tb and diboson (VV/VH/HH) resonances, where W′ represents a new heavy W boson, "V" a W or Z boson, and H a Higgs boson. Other B2G studies focus on searches for pair- or singly produced vector-like quarks T and B through the decays T → Wb and B → tW. The search range for these novel particles generally lies between 700 GeV and 4 TeV, yielding many boosted objects when these particles decay.

Another study in the B2G group is the search for a more massive version (Z′) of the elementary Z boson, decaying to a top-quark pair (Z′ → tt). This search is performed in the semileptonic decay channel, for which the final state consists of a boosted top-quark candidate, a lepton, missing transverse momentum, and a tagged bottom-quark jet. Here, the boosted topology not only affects the reconstruction of the top-quark candidate, but also the lepton, whose isolation can be spoiled by the nearby bottom-quark jet. Again, special identification criteria are implemented to maintain a high signal acceptance. This analysis excludes Z′ masses up to 3.4 (4.0) TeV for signal widths equal to 10% (30%) of the Z′ mass, already eclipsing Run 1 limits. A complementary analysis, in the all-hadronic topology, is now under way – an event display showing two boosted top-quark candidates is shown in the figure. The three-subjet topology seen for each boosted top-quark candidate is as expected for such decays.

With these new boosted-object reconstruction techniques now implemented and commissioned for Run 2, CMS anxiously awaits possible discoveries with the 2016 LHC data set.

Further reading

Browse all public B2G results at https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G.
Browse boosted object studies at https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsJME.

Les physiciens des particules du monde entier sont invités à apporter leurs contributions au CERN Courier, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse cern.courier@cern.ch.

CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send proposals to the editor at cern.courier@cern.ch.

Theatre of Dreams: LHCb looks to the future

Eighty physicists gathered in Manchester on 6 and 7 April to discuss the future of the LHCb experiment. The LHCb collaboration is currently constructing a significant upgrade to its detector, which will be installed in 2019/2020. The Manchester workshop, entitled Theatre of Dreams: Beyond the LHCb Phase-I Upgrade, explored the longer-term future of the experiment in the second-half of the coming decade, and thereafter.

Sam Tygier

Workshop participants at the University of Manchester museum.

In the mid-2020s, the LHC and the ATLAS and CMS experiments will be upgraded for high-luminosity LHC operation. These activities will necessitate a long shutdown of at least 2.5 years. The Manchester meeting discussed enhancements to the LHCb experiment, dubbed a "Phase-Ib upgrade", which could be installed at this time. Although relatively modest, these improvements could bring significant physics benefits to the experiment. Possibilities discussed included an addition to the particle-identification system using an innovative Cherenkov light-based time-of-flight system; placing detector chambers along the sides of the LHCb dipole to extend the physics reach by reconstructing lower-momentum particles; and replacing the inner region of the electromagnetic calorimeter with new technology, therefore extending the experiment's measurement programme with photons, neutral pions and electrons.

Around 2030, the upgraded LHCb experiment that is currently under construction will reach the end of its foreseen physics programme. At this time, a Phase-II upgrade of the experiment may therefore be envisaged. During the meeting, the experimental-physics programme, the heavy-flavour-physics theory perspectives, and the anticipated reach of Belle II and the other LHC experiments were considered. The goal would be to collect an integrated luminosity of at least 300 fb^{-1}, with an instantaneous luminosity a factor 10 above the first upgrade. Promising high-luminosity scenarios for LHCb from the LHC machine perspective were shown that would potentially allow this goal to be reached, and first thoughts were presented on how the experiment might be modified to operate in this new environment.

Many interesting ideas were exchanged at the workshop and these will be followed up in the forthcoming months to identify the requirements and R&D programmes needed to bring these concepts to reality.

The meeting was sponsored by the Science and Technology Facilities Council, the Institute of Physics, the Institute for Particle Physics Phenomenology and the University of Manchester.

ATLAS explores the dark side of matter

ATLAS Collaboration

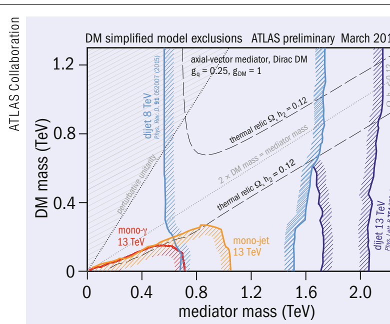


Fig. 1. Exclusion contours on the production of a Z′-like boson coupling to Standard Model quarks and Dirac fermion dark-matter particles. Results from the mono-jet and mono-photon final states at 13 TeV centre-of-mass energy, and the dijet final state, are also given.

Astrophysics and cosmology have established that about 80% of the mass in the universe consists of dark matter. Dark matter and normal matter interact gravitationally, and they may also interact weakly, raising the possibility that collisions at the LHC may produce pairs of dark-matter particles.

With low interaction strength, dark-matter particles would escape the LHC detectors unseen, accompanied by Standard Model particles. These particles, such as single jets, photons, or W, Z or Higgs bosons, could either be produced in the interaction with the dark matter or radiated from the colliding partons. One result would be "mono-X" signals, named because the Standard Model particle, X, would appear alone, without other visible particles balancing their momentum in the transverse plane of the detector.

During Run 1 of the LHC, ATLAS developed a broad programme of searches for mono-X signals. Now, new results from the ATLAS collaboration in the mono-jet and mono-photon channels are the first of these searches in the proton–proton collision data collected in 2015 after increasing the LHC collision energy to 13 TeV. With only 3.2 fb^{-1} of collisions, six times fewer than studied in Run 1, these first Run 2 results already achieve comparable sensitivity to beyond-the-Standard-Model phenomena. In each search, the data with large missing transverse momentum are compared with data-driven estimates of Standard Model backgrounds. As an example, the background to the mono-jet search is known to 4–12%, an estimate nearly as precise as that obtained in the final Run 1 analysis. ATLAS has also released preliminary Run 2 results in the mono-Z, mono-W and mono-H channels.

If dark-matter production is observed, ATLAS has the potential to characterise the interaction itself. To produce dark matter in LHC collisions, the interaction must involve the constituent partons within the proton. If the interaction is mediated by s-channel exchange of a new boson, a decay back to the Standard Model partons could also occur. The ATLAS collaboration has also released new results from the dijet search channel, where new phenomena could modify the smooth dijet invariant mass ▷

CERN COURIER
Volume 56 Number 5 June 2016
IOP Publishing

distribution. With 3.6 fb^{-1} of data, the search already surpasses the sensitivity of Run 1 dijet searches for many kinds of signals. The dijet results are presented on a simplified model of dark-matter production, where the dark boson has axial-vector couplings to quarks and Dirac dark matter.

The results of the mono-photon, mono-jet and dijet searches are shown in figure 1, assuming a version of the axial-vector dark boson whose couplings to dark matter are four times stronger than those to Standard Model quarks. In this scenario, ATLAS dijet results exclude the existence of mediating particles with masses from about 600 GeV to 2 TeV. The mono-jet and mono-photon channels exclude the parameter space at lower mediator and dark-matter masses. For even larger ratios of the dark-matter-to-quark coupling values, dijet constraints quickly weaken, and mono-X searches play a more powerful role.

On the verge of new data-taking in 2016, with the LHC expected to deliver an order of magnitude more luminosity, mono-X and direct mediator searches at ATLAS are set to probe this and other models with unprecedented sensitivity.

Further reading

ATLAS Collaboration 2016 arXiv:1604.01306 [hep-ex].
ATLAS Collaboration 2016 arXiv:1512.01530 [hep-ex].

ALICE probes small-system dynamics with charm production at the LHC

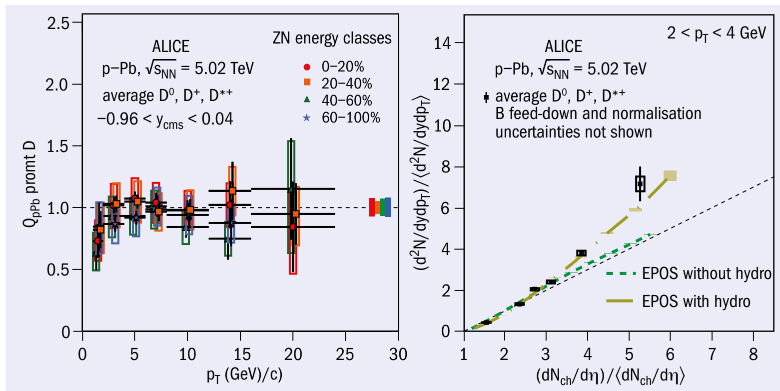


Fig. 1. Left: Average D^0, D^+ and D^{*+} nuclear modification factor as a function of transverse momentum, classified in percentiles of the ZNA energy at very large rapidity (Pb-going direction). Right: Self-normalised average D^0, D^+ and D^{*+} yields for $2 < p_T < 4$ GeV/c as a function of the relative charged-particle multiplicity at central rapidity.

The first p–Pb data-taking campaign at the LHC was undertaken as a test of the initial state of heavy-ion collisions (*CERN Courier* March 2014 p17 and *CERN Courier* October 2013 p17), and surprisingly revealed an enhancement of (identified) particle pairs with small relative azimuthal angle (*CERN Courier* January/February 2013 p9 and *CERN Courier* March 2013 p6) similar to that observed in Pb–Pb collisions where these results are associated with collective effects, such as elliptic flow. A deeper insight into the dynamics of p–Pb collisions is expected to come from measurements classifying events according to the collision centrality.

Hadrons carrying heavy flavour (charm or beauty quarks) are produced in initial hard scatterings and their production rates in the absence of nuclear effects can be calculated using perturbative QCD. Therefore, they are well-calibrated probes that provide information on the nuclear effects at play in the initial and final state of the collision, such as the modification of the parton-distribution functions in nuclei or the energy loss from rescattering between the produced particles, as well as into the dynamics of the heavy-ion collision.

The centrality dependence of prompt D-meson production in p–Pb collisions was studied by the ALICE collaboration by comparing their yields in p–Pb collisions for various centrality classes with those of binary scaled pp collisions at the same centre-of-mass energy via the nuclear modification factor, Q_{pPb}, evaluated as the ratio of these quantities. Q_{pPb} is equal to unity in the absence of nuclear effects. The D-meson Q_{pPb} in collisions classified in percentiles of the energy of slow neutrons detected by the ZNA calorimeter at very large rapidity in the Pb-going direction (figure 1, left) are consistent within uncertainties with unity, i.e. with binary collision scaling of the yield in pp collisions, independent of the geometry of the collision. There is no evidence for a modification of the spectrum shape for $p_T \geq 3$ GeV/c in the initial or final state of p–Pb collisions.

The D-meson yields in p–Pb collisions were also studied as a function of the relative charged-particle multiplicity at mid-rapidity and at large rapidity (Pb-going direction), by evaluating the yields in multiplicity intervals with respect to the multiplicity integrated ones, Y/⟨Y⟩. While with Q_{pPb}, particle production was examined in samples of 20% of the analysed events, this observable explores events from low to extremely high multiplicities corresponding to only 5% (1%) of the analysed events in p–Pb (pp) collisions. These measurements are sensitive to the contribution of multiple-parton interactions in pp and p–Pb collisions. The D-meson yield (figure 1, right) increases with a faster-than-linear trend as a function of the charged-particle multiplicity at mid-rapidity. This behaviour is similar to that of the measurements in pp collisions at 7 TeV. By contrast, the increase of the D-meson yields as a function of charged-particle multiplicity in the Pb-going direction is consistent with linear growth as a function of multiplicity. EPOS3 calculations describe the p–Pb results within uncertainties. The results at high multiplicity are better reproduced by the calculation including a viscous hydrodynamical evolution of the collision.

Charmed-meson measurements in p–Pb collisions have revealed intriguing features. The ALICE collaboration is looking forward to the higher-statistics p–Pb data sample to be collected by the end of 2016, which will allow for higher-precision measurements, bring information on the initial state of heavy-ion collisions and provide further constraints to small-system dynamics.

Further reading

ALICE Collaboration 2014 *Phys. Rev. Lett.* **113** 232301.
ALICE Collaboration 2016 arXiv:1602.07240 (CERN-EP-2016-034), submitted to *JHEP*.

MoEDAL releases new mass limits for the production of monopoles

In April, the MoEDAL collaboration submitted its first physics-research publication on the search for magnetic monopoles utilising a 160 kg prototype MoEDAL trapping detector exposed to 0.75 fb^{-1} of 8 TeV pp collisions, which was subsequently removed and monitored by a SQUID magnetometer located at ETH Zurich. This is the first time that a dedicated scalable and reusable trapping array has been deployed at an accelerator facility.

The innovative MoEDAL detector (*CERN Courier* May 2010 p19) employs unconventional methodologies designed to search for highly ionising messengers of new physics such as magnetic monopoles or massive (pseudo-)stable electrically charged particles from a number of beyond-the-Standard-Model scenarios. The largely passive MoEDAL detector is deployed at point 8 on the LHC ring, sharing the intersection region with LHCb. It employs three separate detector systems. The first is comprised of nuclear track detectors (NTDs) sensitive only to new physics. Second, it is uniquely able to trap particle messengers of physics from beyond the Standard Model, for further study in the laboratory. Third, MoEDAL's radiation environment is monitored by a TimePix pixel-detector array.

Clearly, a unique property of the magnetic monopole is that it has magnetic charge. Imagine that a magnetic monopole traverses the superconducting wire coil of a superconducting quantum interference device (SQUID). As the monopole approaches the coil, its magnetic charge drives an electrical current within the superconducting coil. The current continues to flow in the coil after the monopole has passed because the wire is superconducting, without electrical resistance. The induced current depends only on the magnetic charge and is independent of the monopole's speed and mass.

In the early 1980s, Blas Cabrera was the first to deploy a SQUID device (*CERN Courier* April 2001 p12) in an experiment to directly detect magnetic monopoles from the cosmos. The MoEDAL detector can also directly detect magnetic charge using SQUID technology, but in a different way. Rather than the monopole being directly detected in the SQUID coil *à la Cabrera*, MoEDAL captures the monopoles – in this case produced in LHC collisions – in aluminium trapping volumes that are subsequently monitored by a single SQUID magnetometer.

No evidence for trapped monopoles was seen in data analysed for MoEDAL's first physics publication described here. The resulting mass limit for monopole production with a single Dirac (magnetic) charge ($1g_D$) is roughly half that of the recent ATLAS 8 TeV result. However, mass limits for the production of monopoles with the higher charges $2g_D$ and $3g_D$ are the LHC's first to date, and superior to those from previous collider experiments. Figure 1 shows the cross-section upper limits for the production of spin-1/2 monopoles by the Drell–Yan (DY) mechanism with charges up to $4g_D$. Additionally, a model-independent 95% CL upper limit was obtained for monopole charge up to $6g_D$ and mass reaching 3.5 TeV, again demonstrating MoEDAL's superior acceptance of higher charges.

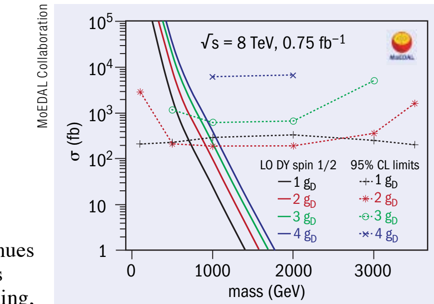


Fig. 1. Cross-section upper limits at 95% confidence level for DY monopole production as a function of mass for spin-1/2. The various line styles correspond to different monopole charges. The solid lines are DY cross-section calculations at leading order.

Despite a relatively small solid-angle coverage and modest integrated luminosity, MoEDAL's prototype monopole trapping detector probed ranges of charge, mass and energy inaccessible to the other LHC experiments. The full detector system containing 0.8 tonnes of aluminium trapping detector volumes and around 100 m^2 of plastic NTDs was installed late in 2014 for the LHC start-up at 13 TeV in 2015. The MoEDAL collaboration is now working on the analysis of data obtained from pp and heavy-ion running in 2015, with the exciting possibility of revolutionary discoveries to come.

Further reading

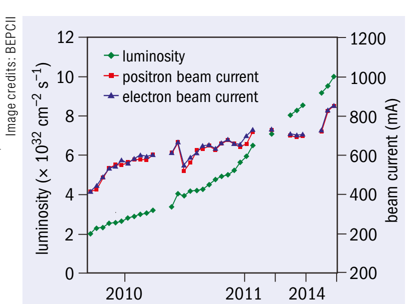
B Acharya *et al.* MoEDAL Collaboration, arXiv to be determined, submitted to *JHEP* April 2016.

Accelerators

BEPCII reaches its design luminosity

A new luminosity record at the charm-tau energy region was recently broken again by the Beijing Electron–Positron Collider (BEPCII). The new record, 1×10^{33} $cm^{-2}s^{-1}$ at 1.89 GeV beam energy, is also the design luminosity for this collider at its design beam energy.

BEPCII, the upgrade project of BEPC (*CERN Courier* September 2008 p7), is a double-ring collider working at 1–2.3 GeV beam energy with a design luminosity of 1×10^{33} $cm^{-2}s^{-1}$ at an optimised beam energy of 1.89 GeV. Because of its performance, ▷



Left: Fig. 1. Luminosity evolution at BEPCII during recent years. Above: Fig. 2. A screenshot of the new record for BEPCII.

BEPCII can be seen as a charm-tau factory. The same as BEPC, BEPCII is characterised as "one machine, two purposes". Indeed, the machine not only provides beam for high-energy physics experiments, it also provides synchrotron-radiation (SR) light to users in parasitic and dedicated modes.

BEPCII is installed in the tunnel that hosted its predecessor, BEPC. Its electron and positron rings, called BER and BPR, respectively, have a circumference of 237.5 m. BER and BPR run in parallel and have a crossing angle of 22 mrad at their interaction point (IP). On the opposite point to the IP, BER and BPR cross with a vertical bump created for each beam by local correctors as its original design. The third ring, BSR, resulting from the connection of the two half rings of BER and BPR, has a circumference of 241.1 m and can be run as a dedicated synchrotron light source at 2.5 GeV energy and a maximum beam current of 250 mA.

Installation of BEPCII was completed in 2006. Since then, the machine has passed the national check and other tests, together with its new detector, BESIII. In mid-July 2009, the luminosity reached $3.2\times10^{32}\,cm^{-2}s^{-1}$. The data-taking for high-energy physics started in August 2009. Besides running at 1.89 GeV design energy from 2010 to 2011, BEPCII has been run at other beam energies, from 1 GeV to 2.3 GeV, for different high-energy physics experiments.

Enhancing measures

In the past seven years, some measures have been taken to enhance the peak and integrated luminosity:

- A longitudinal feedback system was installed to suppress the longitudinal multibunch instability in 2010. During the high-energy-physics data-taking, the horizontal betatron tunes of two rings were moved to very close to half integers – 0.504 or 0.505. The luminosity at the design energy reached $5.21\times10^{32}\,cm^{-2}s^{-1}$ in 2010, and $6.49\times10^{32}\,cm^{-2}s^{-1}$ in 2011 with 720 mA/88 bunches/beam.
- In 2011, the vacuum chambers and eight magnets near the north crossing point were moved by 15 cm to mitigate the parasitic beam–beam interaction. The movement changed the layout of the machine and the beam separation from vertical to horizontal.
- The betatron tunes were changed from the region of (6.5, 5.5) to (7.5, 5.5), reducing the momentum compaction and shortening the bunch length. A luminosity of $7.08\times10^{32}\,cm^{-2}s^{-1}$ with 735 mA/130 bunches/beam was achieved in 2013.
- The emittance was increased from 100 nm•rad to 128 nm•rad to increase the single-bunch current. The luminosity reached $8.53\times10^{32}\,cm^{-2}s^{-1}$ with 700 mA/92 bunches/beam in late 2014.

High beam current is the main feature of this type of collider, which is also a big challenge for BEPCII. The direct feedback of the radiofrequency system was turned on, which helps higher beam current to be more stable. The transverse-feedback system was another big challenge. Beam collision helps to suppress the multibunch instability in the positron ring. The bunch pattern was optimised carefully to increase the luminosity. Finally, thanks to the efforts of all of the accelerator team of BEPCII, the design luminosity, $1\times10^{33}\,cm^{-2}s^{-1}$ with 850 mA/120 bunches/beam at its design energy, which is 100 times higher than the luminosity of BEPC at the same beam energy, was reached at 22.29 p.m. on 5 April 2016. The breakthrough from BEPC to BEPCII is now completed.

Compiled by John Swain, Northeastern University

Humans beat computers at quantum mechanics

Quantum mechanics is usually considered to be counter-intuitive for humans but, remarkably, video games, which correspond to quantum problems, show that we actually do very well. Jacob F Sherson and colleagues at the University of Aarhus in Denmark took a quantum-computer architecture using neutral atoms moved by lasers and turned it into a video game. Players visualise the wave function of a particle as a sloshy liquid and try to pick up an atom from a potential well, move it somewhere else, then bring it back as quickly as they can. Crowdsourced humans succeeded where numerical optimisation failed. Analysis of their moves allowed the team to develop a heuristic optimisation method that outperforms established numerical methods. It's nice to have a human help a computer to calculate, for a change, rather than the other way around.


Merrill College of Journalism

Machines do not surpass humans when quantum mechanics is at stake.

● **Further reading**
J J W H Sørensen *et al.* 2016 *Nature* **532** 210.

ν_e appears in NOvA

The NOvA collaboration has measured the oscillation probability of muon neutrinos into electron neutrinos at the first oscillation maximum. The probability is proportional to $\sin^2(2\theta_{13})$, which has been well measured by reactor experiments. In an exposure equivalent to 2.74×10^{20} protons on target in the upgraded NuMI beam at Fermilab, the researches find a 3.3σ excess of events, disfavouring $0.1\pi<\delta_{CP}<0.5\pi$ in the inverted mass hierarchy at the 90% C.L. – a valuable addition to what we know about the yet poorly measured neutrino-mixing matrix.

● **Further reading**
P Adamson *et al.* (NOvA Collaboration) 2016 *Phys. Rev. Lett.* **116** 151806.

An oxygen white dwarf

A typical white dwarf has a helium and hydrogen outer layer covering a core of carbon and oxygen produced from burning helium. Now, S O Kepler of the Universidade Federal do Rio Grande do Sul in Porto Alegre, Brazil, and colleagues have found a white dwarf with an almost pure oxygen outer layer. The next most abundant elements are neon and magnesium at concentrations that are 25 or more times smaller. Remarkably, no hydrogen or helium are detected. Its mass is also the average mass for a neutron star, making it hard to think of it as coming from carbon burning, which should make it heavier. The discovery challenges conventional thinking and opens the door to a much better understanding of both white dwarfs and stellar evolution.

● **Further reading**
S O Kepler *et al.* 2016 *Science* **352** 6281.

Bleeding nectar

Some plants exude a sweet nectar when their leaves are wounded, and now we know why. Anke Steppuhn of the Free University of Berlin and collaborators studied injuries to the bittersweet nightshade (*Solanum dulcamara*) and found that the nectar attracts ants, which defend it from slugs and flea-beetle larvae, which feed on the plant. Other plants make nectar in specialised organs called nectaries, and the realisation that this plant can do without them could lead to a better understanding of the evolution of these organs.

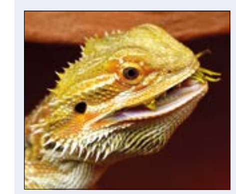
● **Further reading**
T Lortzing *et al.* 2016 *Nature Plants* doi:10.1038/NPLANTS.2016.56.

Seismic gravitational-wave detection

A novel approach to detecting low-frequency gravitational waves in the 0.1–10 Hz band uses the entire Earth as a detector. Francesco Mulgaria and Alexander Kamenshchik of the University of Bologna, Italy, calculate that the more than 20 years of recorded data from thousands of digital seismometers of seismic global networks as a single phased array could – with the use of enormous computational resources – detect absolute strains less than 10^{-17} for bursts and 10^{-21} for periodic signals in the frequency range not well covered by current advanced LIGO and future eLISA.

● **Further reading**
F Mulgaria and A Kamenshchik 2016 *Phys. Lett. A* **380** 1503.

Sleeping dragon


The Australian dragon shows sleeping phases much like humans do.

Many animals are known to sleep in some form or another. The brain activities during sleep such as slow-wave (SW) or rapid-eye movement (REM) had, however, only been seen in birds and mammals, suggesting that perhaps only they have brains that sleep the way humans think of it. Enter Mark Shein-Idelson and colleagues at the Max Planck Institut in Frankfurt, Germany, who report that a lizard – the Australian dragon *Pogona vitticeps* – shows SW and REM over 6 to 8 h with a period of about 80 s. Apparently lizards sleep much like we do.

● **Further reading**
M Shein-Idelson *et al.* 2016 *Science* **352** 590.

Lifetime batteries

Tired of poor battery life? May Le Thai and colleagues of the University of Irvine in California have good news. Nanowire capacitors made from manganese-dioxide nanowires coated with a PMMA gel electrolyte can bend to store energy reversibly, without failure, 200,000 times with 94–96% Coulombic efficiency at 1.2 V. You may never need a replacement.

● **Further reading**
M L Thai *et al.* 2016 *ACS Energy Lett.* **1** 57.

CERNCOURIER
Volume 56 Number 5 June 2016
IOP Publishing

Astrowatch

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

Protons accelerated to PeV energies

The High Energy Stereoscopic System (HESS) – an array of Cherenkov telescopes in Namibia – has detected gamma-ray emission from the central region of the Milky Way at energies never reached before. The likely source of this diffuse emission is the supermassive black hole at the centre of our Galaxy, which would have accelerated protons to peta-electron-volt (PeV) energies.

The Earth is constantly bombarded by high-energy particles (protons, electrons and atomic nuclei). Being electrically charged, these cosmic rays are randomly deflected by the turbulent magnetic field pervading our Galaxy. This makes it impossible to directly identify their source, and led to a century-long mystery as to their origin (*CERN Courier* July/August 2012 p14). A way to overcome this limitation is to look at gamma rays produced by the interaction of cosmic rays with light and gas in the neighbourhood of their source. These gamma rays travel in straight lines, undeflected by magnetic fields, and can therefore be traced back to their origin.

When a very-high-energy gamma ray reaches the Earth, it interacts with a molecule in the upper atmosphere, producing a shower of secondary particles that emit a short pulse of Cherenkov light. By detecting these flashes of light using telescopes equipped with large mirrors, sensitive photodetectors, and fast electronics, more than 100 sources of very-high-energy gamma rays have been identified over the past three decades. HESS is the only state-of-the-art array of Cherenkov telescopes that is located in the southern hemisphere – a perfect viewpoint for the centre of the Milky Way (*CERN Courier* January/February 2005 p30).

Dr Mark A Garlick/HESS Collaboration

Artist's impression of the giant molecular clouds surrounding the galactic centre, bombarded by very-high-energy protons accelerated in the vicinity of the central black hole and subsequently shining in gamma rays.

Earlier observations have shown that cosmic rays with energies up to approximately 100 tera-electron-volts (TeV) are produced by supernova remnants and pulsar-wind nebulae. Although theoretical arguments and direct measurements of cosmic rays suggest a galactic origin of particles up to PeV energies, the search for such a "Pevatron" accelerator has been unsuccessful, so far.

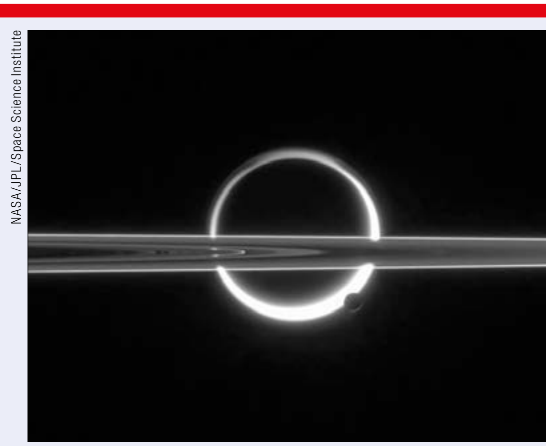
The HESS collaboration has now found evidence that there is a "Pevatron" in the central 33 light-years of the Galaxy. This result, published in *Nature*, is based on deep observations – obtained between 2004 and 2013 – of the surrounding giant molecular cloud extending approximately 500 light-years. The production of PeV protons is deduced from the obtained spectrum of gamma rays, which is a power law extending to multi-TeV energies without showing a high-energy cut-off. The spatial localisation comes from the observation that the cosmic-ray density decreases with a 1/r relation, where r is the distance from the galactic centre. The 1/r profile indicates a quasi-continuous central injection of protons during at least about 1000 years.

Given these properties, the most plausible source of PeV protons is Sagittarius A*, the supermassive black hole at the centre of our Galaxy. According to the authors, the acceleration could originate in the accretion flow in the immediate vicinity of the black hole or further away, where a fraction of the material falling towards the black hole is ejected back into the environment. However, to account for the bulk of PeV cosmic rays detected on Earth, the currently quiet supermassive black hole would have had to be much more active in the past million years. If true, this finding would dramatically influence the century-old debate concerning the origin of these enigmatic particles.

Further reading

HESS Collaboration 2016 *Nature* **531** 476.

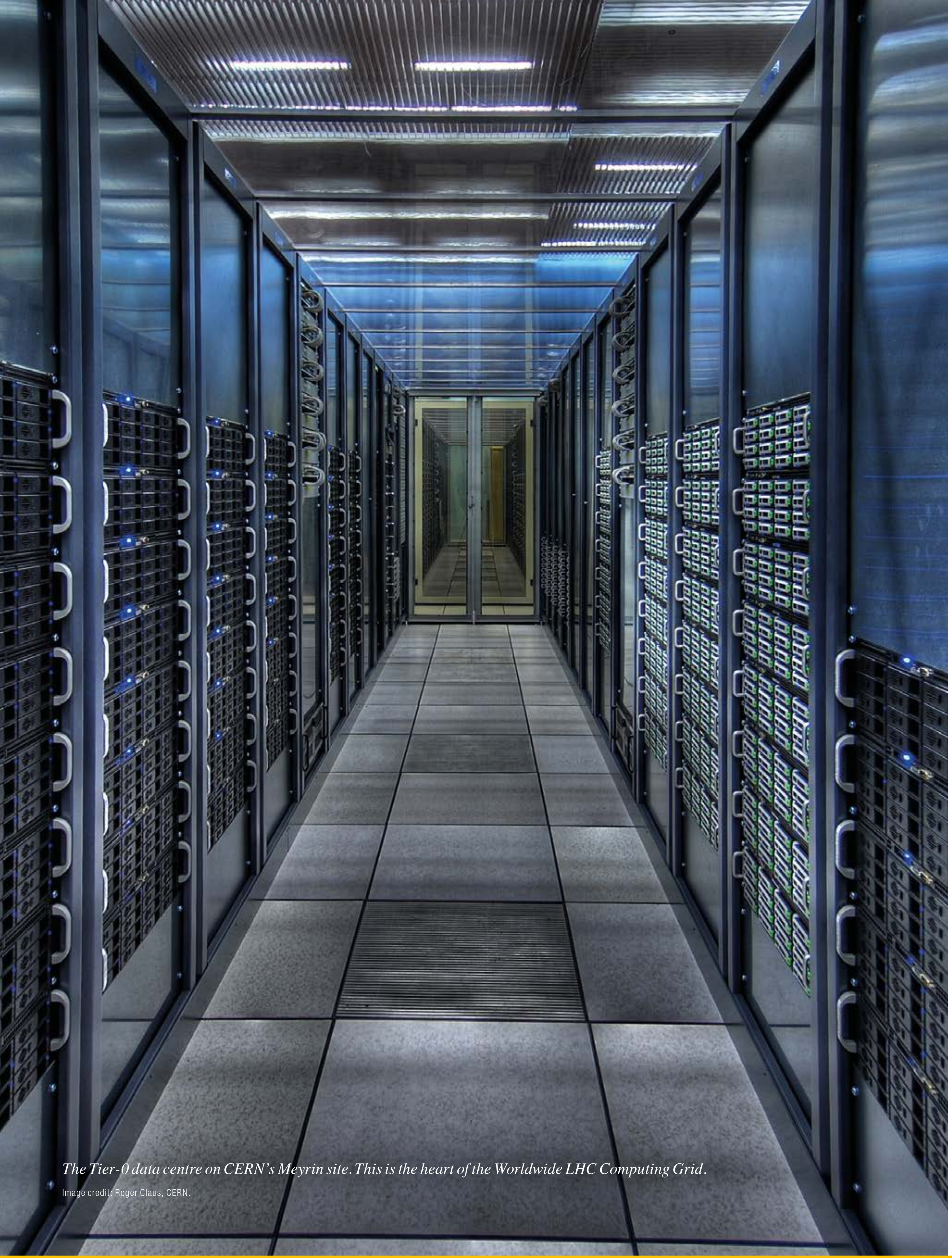
Picture of the month



NASA/JPL/Space Science Institute

This artistic backlit image of the rings of Saturn and two of its moons was recently featured by ESA, although it was taken some 10 years ago by NASA's Cassini spacecraft (*CERN Courier* September 2004 p13). The two moons are Titan (5150 km across) and the 10 times smaller Enceladus – two of the most fascinating moons of Saturn, among more than 60. Titan is seen as a ring – slightly occulted by Enceladus – because light from the distant Sun is being refracted through the Moon's dense atmosphere. Somewhere on Titan's surface rests ESA's Huygens probe, which separated from the Cassini mothership on 25 December 2004 and parachuted down onto the surface of Titan to return the first pictures of this alien landscape. The restless interior of Enceladus produces water geysers at its south pole, which have been pictured by Cassini. After 12 years exploring Saturn's system, the Cassini mission is nearing a dramatic end, with a guided plunge – planned for 15 September 2017 – into the atmosphere of this giant planet.

CERN's IT gears up to face the challenges of LHC Run 2



The Tier-0 data centre on CERN's Meyrin site. This is the heart of the Worldwide LHC Computing Grid.

Image credit: Roger Claus, CERN.

In 2016, the LHC will provide up to one billion collisions per second to its experiments at 13 TeV energy and with increased beam intensity. In such conditions, collision events are more complex to reconstruct and analyse, and computing requirements become tougher.

Phoebe Baldwin and **Mélissa Gaillard**, CERN, with special thanks to all of the contributors.

2015 saw the start of Run 2 for the LHC, where the machine reached a proton–proton collision energy of 13 TeV – the highest ever reached by a particle accelerator. Beam intensity also increased and, by the end of 2015, 2240 proton bunches per beam were being collided. This year, in Run 2 the LHC will continue to open the path for new discoveries by providing up to one billion collisions per second to ATLAS and CMS. At higher energy and intensity, collision events are more complex to reconstruct and analyse, therefore computing requirements must increase accordingly. Run 2 is anticipated to yield twice the data produced in the first run, about 50 petabytes (PB) per year. So it is an opportune time to look at the LHC's computing, to see what was achieved during Long Shutdown 1 (LS1), to keep up with the collision rate and luminosity increases of Run 2, how it is performing now and what is foreseen for the future.

LS1 upgrades and Run 2

The Worldwide LHC Computing Grid (WLCG) collaboration, the LHC experiment teams and the CERN IT department were kept busy as the accelerator complex entered LS1, not only with analysis of the large amount of data already collected at the LHC but also with preparations for the higher flow of data during Run 2. The latter entailed major upgrades of the computing infrastructure and services, lasting the entire duration of LS1.

Consolidation of the CERN data centre and inauguration of its extension in Budapest were two major milestones in the upgrade plan achieved in 2013. The main objective of the consolidation and upgrade of the Meyrin data centre was to secure critical information-technology systems. Such services can now keep running, even in the event of a major power cut affecting CERN. The consolidation also ensured important redundancy and increased the overall computing-power capacity of the IT centre from 2.9 MW to 3.5 MW. Additionally, on 13 June 2013, CERN and the Wigner Research Centre for Physics in Budapest inaugurated the Hungarian data centre, which hosts the extension of the CERN Tier-0 data centre, adding up to 2.7 MW capacity to the Meyrin-site facility. This substantially extended the capabilities of the Tier-0 activities of WLCG, which include running the first-pass event reconstruction and producing, among other things, the event-summary data for analysis.

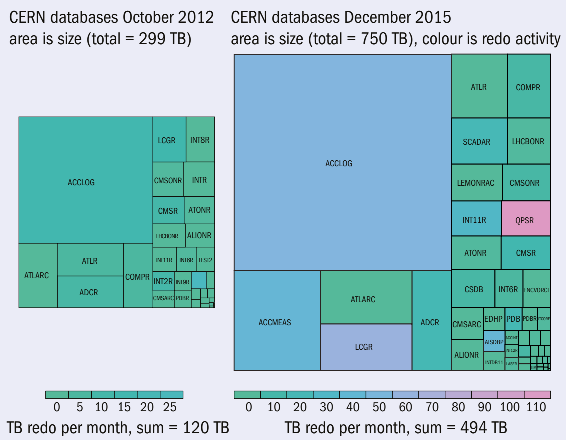
Building a CERN private cloud (cerncourier.com/cws/article/cnl/38515) was required to remotely manage the capacity hosted at Wigner, enable efficient management of the increased computing capacity installed for Run 2, and to provide the computing infrastructure powering most of the LHC grid services. To deliver a scalable cloud operating system, CERN IT started using OpenStack. This open-source project now plays a vital role in enabling CERN to tailor its computing resources in a flexible way and has been running in production since July 2013. Multiple OpenStack clouds at CERN successfully run simulation and analysis for the CERN user community. To support the growth of capacity needed for Run 2, the compute capacity of the CERN private cloud has nearly doubled during 2015, now providing more than 150,000 computing cores. CMS, ATLAS and ALICE have also deployed OpenStack on their high-level trigger farms, providing a further 45,000 cores for use in certain conditions when the accelerator isn't running. Through various collaborations, such as with BARC (Mumbai, India) and between CERN openlab (see the text box, overleaf) and Rackspace, CERN has contributed more than 90 improvements in the latest OpenStack release.

As surprising as it may seem, LS1 was also a very busy period with regards to storage. Both the CERN Advanced STORage manager (CASTOR) and EOS, an open-source distributed disk storage system developed at CERN and in production since 2011, went through either major migration or deployment. CASTOR relies on a tape-based back end for permanent data archiving, and LS1 offered an ideal opportunity to migrate the archived data from legacy cartridges and formats to higher-density ones. This involved migrating around 85 PB of data, and was carried out in two phases during 2014 and 2015. As an overall result, no less than 30,000 tape-cartridge slots were released to store more data. The EOS 2015 deployment brought storage at CERN to a new scale and enables the research community to make use of 100 PB of disk storage in a distributed environment using tens of thousands of ▷

R&D collaboration with CERN openlab

CERN openlab is a unique public–private partnership that has accelerated the development of cutting-edge solutions for the worldwide LHC community and wider scientific research since 2001. Through CERN openlab, CERN collaborates with leading ICT companies and research institutes. Testing in CERN's demanding environment provides the partners with valuable feedback on their products, while allowing CERN to assess the merits of new technologies in their early stages of development for possible future use. In January 2015, CERN openlab entered its fifth three-year phase.

The topics addressed in CERN openlab's fifth phase were defined through discussion and collaborative analysis of requirements. This involved CERN openlab industrial collaborators, representatives of CERN, members of the LHC experiment collaborations, and delegates from other international research organisations. The topics include next-generation data-acquisition systems, optimised hardware- and software-based computing platforms for simulation and analysis, scalable and interoperable data storage and management, cloud-computing operations and procurement, and data-analytics platforms and applications.



Evolution of CERN databases before and after LS1. Size represents the size on disk in TB. Colour represents writing activity in TB/month. The activity is more than four times higher after LS1 than before LS1, with the new quench-protection system real application clusters (QPSR) having an activity of 115 TB/month.

heterogeneous hard drives, with minimal data movements and dynamic reconfiguration. It currently stores 45 PB of data with an installed capacity of 135 PB. Data preservation is essential, and more can be read on this aspect in "Data preservation is a journey", p21 of this issue.

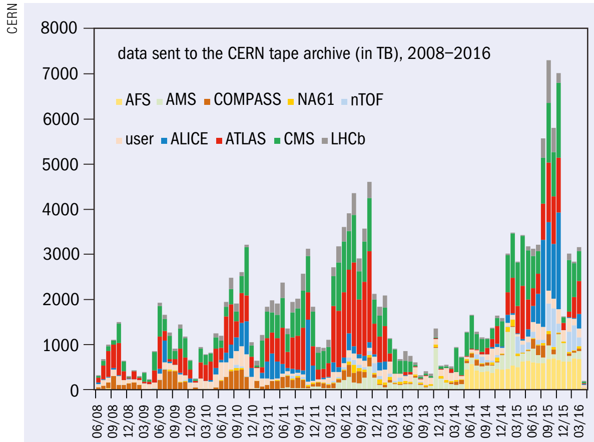
Databases play a significant role with regards to storage, accelerator operations and physics. A great number of upgrades were performed, both in terms of software and hardware, to rejuvenate platforms, accompany the CERN IT computing-infrastructure's transformation and the needs of the accelerators and experiments. The control applications of the LHC migrated from a file-based archiver to a centralised infrastructure based on Oracle databases. The evolution of the database technologies deployed for WLCG database services improved the availability, performance and robustness of the replication service. New services have also been implemented. The databases for archiving the controls' data are now able to handle, at peak, one million changes per second, compared with the previous 150,000 changes per second. This also positively impacts on the controls of the quench-protection system of the LHC magnets, which has been modernised to safely operate the machine at 13 TeV energy. These upgrades and changes, which in some cases have built on the work accomplished as part of CERN openlab projects, have a strong impact on the increasing size and scope of the databases, as can be seen in the CERN databases diagram (above right).

To optimise computing and storage resources in Run 2, the experiments have adopted new computing models. These models move away from the strict hierarchical roles of the tiered centres described in the original WLCG models, to a peer site model, and make more effective use of the capabilities of all sites. This is coupled with significant changes in data-management strategies, away from explicit placement of data sets globally to a much more dynamic system that replicates data only when necessary. Remote access to data is now also allowed under certain conditions. These "data federations", which optimise the use of expensive disk space, are possible because of the greatly improved networking capabilities made available to WLCG over the past few years. The experiment collaborations also invested significant effort during LS1 to improve the performance and efficiency of their core software, with extensive work to validate the new software and frameworks in readiness for the expected increase in data. Thanks to those successful results, a doubling of the CPU and storage capacity was needed to manage the increased data rate and complexity of Run 2 – without such gains, a much greater capacity would have been required.

Despite the upgrades and development mentioned, additional computing resources are always needed, notably for simulations of physics events, or accelerator and detector upgrades. In recent years, volunteer computing has played an increasing role in this domain. The volunteer capacity now corresponds to about half the capacity of the CERN batch system. Since 2011, thanks to virtualisation, the use of LHC@home has been greatly extended, with about 2.7 trillion events being simulated. Following this success, ATLAS became the first experiment to join, with volunteers steadily ramping up for the last 18 months and a production rate now equivalent to that of a WLCG Tier-2 site.

In terms of network activities, LS1 gave the opportunity to perform bandwidth increases and redundancy improvements at various levels. The data-transfer rates have been increased between some of the detectors (ATLAS, ALICE) and the Meyrin data centre by a factor of two and four. A third circuit has been ordered in addition to the two dedicated and redundant 100 Gbit/s circuits that were already connecting the CERN Meyrin site and the Wigner site since 2013. The LHC Optical Private Network (LHCOPN) and the LHC Open Network Environment (LHCONE) have evolved to serve the networking requirements of the new computing models for Run 2. LHCOPN, reserved for LHC data transfers and analysis and connecting the Tier-0 and Tier-1 sites, benefitted from bandwidth increases from 10 Gbps to 20 and 40 Gbps. LHCONE has been deployed to meet the requirements of the new computing model of the LHC experiments, which demands the transfer of data among any pair of Tier-1, Tier-2 and Tier-3 sites. As of the start of Run 2, LHCONE's traffic represents no less than one third of the European research traffic. Transatlantic connections improved steadily, with ESnet setting up three 100 Gbps links extending to CERN through Europe, replacing the five 10 Gbps links used during Run 1.

With the start of Run 2, supported by these upgrades and improvements of the computing infrastructure, new data-taking records were achieved: 40 PB of data were successfully written on tape at CERN in 2015; out of the 30 PB from the LHC experiments, a record-breaking 7.3 PB were collected in October; and up to 0.5 PB of data were written to tape each day during the heavy-ion run. By way of comparison, CERN's tape-based archive system collected in the region of 70 PB of data in total during the first run of the LHC, as shown in the plot (right). In total, today, WLCG has access to some 600,000 cores and 500 PB of storage, provided by the 170 collaborating sites in 42 countries, which enabled the Grid to set a new record in October 2015 by running a total of 51.1 million jobs.



This plot represents the amount of data, in TB, being sent to the CERN archive between 2008 and 2016. The yearly amount of LHC data has gradually increased since 2010 (Run 1, 2010: 12.5 PB, 2011: 19.1 PB, 2012: 27 PB) and during Run 2 (31.5 PB).

Looking into the future

With the LHC's computing now well on track with Run 2 needs, the WLCG collaboration is looking further into the future, already focusing on the two phases of upgrades planned for the LHC. The first phase (2019–2020) will see major upgrades of ALICE and LHCb, as well as increased luminosity of the LHC. The second phase – the High Luminosity LHC project (HL-LHC), in 2024–2025 – will upgrade the LHC to a much higher luminosity and increase the precision of the substantially improved ATLAS and CMS detectors.

The requirements for data and computing will grow dramatically during this time, with rates of 500 PB/year expected for the HL-LHC. The needs for processing are expected to increase more than 10 times over and above what technology evolution will provide. As a consequence, partnerships such as those with CERN openlab and other programmes of R&D are essential to investigate how the computing models could evolve to address these needs. They will focus on applying more intelligence into filtering and selecting data as early as possible. Investigating the distributed infrastructure itself (the grid) and how one can best make use of available technologies and opportunistic resources (grid, cloud, HPC, volunteer, etc), improving software performance to optimise the overall system.

Building on many initiatives that have used large-scale commercial cloud resources for similar cases, the Helix Nebula the Science Cloud (HNSciCloud) pre-commercial procurement (PCP) project may bring interesting solutions. The project, which is led by CERN, started in January 2016, and is co-funded by the European Commission. HNSciCloud pulls together commercial cloud-service providers, publicly funded e-infrastructures and a group of 10 buyers' in-house resources to build a hybrid cloud platform, on top of which a competitive marketplace of European cloud players can develop their own services for a wider range of users. It aims at bringing Europe's technical development, policy and procurement activities together to remove fragmentation and maximise exploitation. The alignment of commercial and public (regional, national and European) strategies will increase the rate of innovation.

To improve software performance, the High Energy Physics (HEP) Software Foundation, a major new long-term activity, has been initiated. This seeks to address the optimal use of modern CPU architectures and encourage more commonality in key software libraries. The initiative will provide underlying support for the significant re-engineering of experiment core software that will be necessary in the coming years.

In addition, there is a great deal of interest in investigating new ways of data analysis: global queries, machine learning and many more. These are all significant and exciting challenges, but it is clear that the LHC's computing will continue to evolve, and that in 10 years it will look very different, while still retaining the features that enable global collaboration.

Résumé

L'informatique du CERN prête à relever les défis de l'Exploitation 2 du LHC

Pour l'Exploitation 2, le LHC va continuer à ouvrir la voie à de nouvelles découvertes en fournissant aux expériences jusqu'à un milliard de collisions par seconde. À plus haute énergie et intensité, les collisions sont plus complexes à reconstruire et analyser ; les besoins en capacité de calcul sont par conséquent plus élevés. La deuxième période d'exploitation doit fournir deux fois plus de données que la première, soit environ 50 Po par an. Le moment est donc propice pour faire le point sur l'informatique du LHC afin de voir ce qui a été fait durant le premier long arrêt (LS1) en prévision de l'augmentation du taux de collision et de la luminosité lors de la deuxième période d'exploitation, ce qu'il est possible de réaliser aujourd'hui, et ce qui est prévu pour l'avenir.

Data preservation is a journey

CERN, like other scientific organisations, faces the challenge of preserving its "digital memory". Data formats and tools to access it change constantly, and constant effort is required to tackle the issue.

Jamie Shiers, CERN IT Department.

As an organisation with more than 60 years of history, CERN has created large volumes of "data" of many different types. This involves not only scientific data – by far the largest in terms of volume – but also many other types (photographs, videos, minutes, memoranda, web pages and so forth). Sadly, some of this information from as recently as the 1990s, such as the first CERN web pages, has been lost, as well as more notably much of the data from numerous pre-LEP experiments. Today, things look rather different, with concerted efforts across the laboratory to preserve its "digital memory". This concerns not only "born-digital" material but also what is still available from the pre-digital era. Whereas the latter often existed (and luckily often still exists) in multiple physical copies, the fate of digital data can be more precarious. This led Vint Cerf, vice-president of Google and an early internet pioneer, to declare in February 2015: "We are nonchalantly throwing all of our data into what could become an information black hole without realising it." This is a situation that we have to avoid for all CERN data – it's our legacy.

Interestingly, many of the tools that are relevant for preserving data from the LHC and other experiments are also suitable for other types of data. Furthermore, there are models that are widely accepted across numerous disciplines for how data preservation should be approached and how success against agreed metrics can be demonstrated.

Success, however, is far from guaranteed: the tools involved have had a lifetime that is much shorter than the desired retention period of the current data, and so constant effort is required. Data preservation is a journey, not a destination.

The basic model that more or less all data-preservation efforts worldwide adhere to – or at least refer to – is the Open Archival Information System (OAIS) model, for which there is an ISO standard (ISO 14721:2012). Related to this are a number of procedures for auditing and certifying "trusted digital repositories", including another ISO standard – ISO 16363.

This certification requires, first and foremost, a commitment by "the repository" (CERN in this case) to "the long-term retention of, management of, and access to digital information".

In conjunction with numerous more technical criteria, certification is therefore a way of demonstrating that specific goals regarding data preservation are being, and will be, met. For example, will we still be able to access and use data from LEP in 2030? Will we be able to reproduce analyses on LHC data up until the "FCC era"?

In the context of the Worldwide LHC Computing Grid (WLCG), self-certification of, initially, the Tier0 site, is currently under way. This is a first step prior to possible formal certification, certification of other WLCG sites (e.g. the Tier1s), and even certification of CERN as a whole. This could cover not only current and future experiments but also the "digital memory" of non-experiment data.

What would this involve and what consequences would it have? Fortunately, many of the metrics that make up ISO 16363 are part of CERN's current practices. To pass an audit, quite a few of these would have to be formalised into official documents (stored in a certified digital repository with a digital object identifier): there are ▷

Image credits: CERN

Top: The tape-unit reel-display system (RDS) shown mounted over tape units in the 6600 computing complex, in 1965. Above: More recently, an automated magnetic-tape vault at the CERN Computer Centre, in 2008.

Computing challenges

no technical difficulties here but it would require effort and commitment to complete. In addition, it is likely that the ongoing self-certification will uncover some weak areas. Addressing these can be expected to help ensure that all of our data remains accessible, interpretable and usable for long periods of time: several decades and perhaps even longer. Increasingly, funding agencies are requiring not only the preservation of data generated by projects that they fund, but also details of how reproducibility of results will be addressed and how data will be shared beyond the initial community that generated it. Therefore, these are issues that we need to address, in any event.

A reasonable target by which certification could be achieved would be prior to the next update of the European Strategy for Particle Physics (ESPP), and further updates of this strategy would offer a suitable frequency of checking that the policies and procedures were still effective.

The current status of scientific data preservation in high-energy physics owes much to the Study Group that was initiated at DESY in late 2008/early 2009. This group published a "Blueprint document" in May 2012, and a summary of this was input to the 2012 ESPP update process. Since that time, effort has continued worldwide, with a new status report published at the end of 2015.

In 2016, we will profit from the first ever international data-preservation conference to be held in Switzerland (iPRES, Bern, 3–6 October) to discuss our status and plans with the wider data-preservation community. Not only do we have services, tools and experiences to offer, but we also have much to gain, as witnessed by the work on OAIS, developed in the space community, and related standards and practices.

High-energy physics is recognised as a leader in the open-access movement, and the tools in use for this, based on Invenio Digital Library software, have been key to our success. They also underpin more recent offerings, such as the CERN Open Data and Analysis Portals. We are also recognised as world leaders in "bit preservation", where the 100+PB of LHC (and other) data are proactively curated with increasing reliability (or decreasing occurrences of rare but inevitable loss of data), despite ever-growing data volumes. Finally, CERN's work on virtualisation and versioning file-systems through CernVM and CernVM-FS has already demonstrated great potential for the highly complex task of "software preservation".

● For further reading, visit arxiv.org/pdf/1205.4667 and dx.doi.org/10.5281/zenodo.46158.

Résumé
Le défi de la préservation des données

Le CERN, comme toute organisation scientifique, doit préserver sa « mémoire numérique ». Le Laboratoire est reconnu comme étant le leader mondial de la préservation des données : les plus de 100 Po de données du LHC, entre autres, sont conservées proactivement avec une fiabilité croissante, malgré des volumes de données en augmentation constante. La nouvelle norme ISO 16363 exige, en premier lieu, que le « dépositaire » (le CERN en l'occurrence) s'engage à garantir « la conservation et la gestion des données numériques, ainsi que leur accès, sur le long terme ». Couplée à de nombreux autres critères techniques, la certification garantit la réalisation d'objectifs spécifiques en matière de préservation de données.

NA62: CERN's kaon factory

Fig. 1. The NA62 experiment at CERN. Protons from the SPS hit a target upstream (top of the page, target not visible). The kaons produced in the interaction fly all the way through the experiment's detectors, shown in this photograph.

Image credit: CERN.

CERN has a long tradition in kaon physics, which is currently the focus of the NA62 experiment. With the commissioning phase completed in 2015, the experiment is fully in the data-taking period, which should continue until 2018.

NA62 Collaboration.

CERN's long tradition in kaon physics started in the 1960s with experiments at the Proton Synchrotron conducted by, among others, Jack Steinberger and Carlo Rubbia. It continued with NA31, CPLEAR, NA48 and its follow-ups. Next in line and currently active is NA62 – the high-intensity facility designed to study rare kaon decays, in particular those where the mother particle decays into a pion and two neutrinos. The nominal performance of the detector in terms of data quality and quantity is so good that the experiment can undeniably play the role of a kaon factory.

Using its unique set-up, NA62 will address with sufficient statistics and precision a basic question: does the Standard Model also work in the most suppressed corner of flavour-changing neutral currents (FCNCs)? According to theory, these processes are suppressed by the unitarity of the quark-mixing Cabibbo–Kobayashi–Maskawa matrix and by the Glashow–Iliopoulos–Maiani mechanism. What makes the kaons special is that some of these FCNCs are not affected by large hadronic matrix-element uncertainties because they can be normalised to a semi-leptonic mode described by the same form factor, which therefore drops out in the ratio. The poster child of these reactions is the $K \to \pi\nu\bar{\nu}$. By measuring the decay rate, it will be possible to determine a combination of Cabibbo–Kobayashi–Maskawa matrix elements independently of B decays. Discrepancies compared with expectations might be a signature of new physics.

Testing Standard Model theoretical predictions is not easy, because the decay under study is predicted to occur with a probability of less than one part in 10 billion. Therefore, the first experimental challenge is to collect a sufficient number of kaon decays. To do so, in 2012, an intense secondary beam from the Super Proton Synchrotron (SPS), called K12, had to be completely rebuilt. Today, NA62 is exploiting this intense secondary beam, which has an instantaneous rate approaching 1 GHz. Although we know that approximately only 6% of the beam particles are kaons, each single particle sent by the SPS accelerator has to be identified before entering the experiment's decay region. At the heart of the tracking system is the gigatracker (GTK), which is able to measure the impact position of the incoming particle and its arrival time. This information is used to associate the incoming particle with the event observed downstream, and to reconstruct its kinematics. To do so with the required sensitivity, 200 picoseconds time-resolution in the gigatracker is required.

The GTK consists of a matrix of 200 columns by 90 rows of hybrid silicon pixels. To affect the trajectory of the particles as little as possible, the sensors are 200 μm thick and the pixel chip is 100 μm thick. The GTK is placed in a vacuum and operated at a temperature of –20 °C to reduce radiation-induced performance degradation. The NA62 collaboration has developed innovative ways to ensure effective cooling, using light materials to minimise their effect on particle trajectory.

In addition to measuring the direction and the momentum of each particle, the identity of the particle needs to be determined before it enters the decay tank. This is done using a differential Cherenkov counter (CEDAR) equipped with state-of-the-art optics and electronics to cope with the large particle rate.

Final-pion identification

There is a continuous struggle between particle physicists, who want to keep the amount of material in the tracking detectors to a minimum, and engineers, who need to ensure safety and prevent the explosion of pressurised devices operated inside the vacuum tank, such as the NA62 straw tracker made of more than 7000 thin tubes. In addition, the beam specialists would even prefer to have no detector at all. Any amount of material in the beam leads to scattering of particles into the detectors placed downstream, leading to potential backgrounds and unwanted additional counting rates. In NA62, the accepted signal is a single pion π^+ and nothing else, so every trick in the book of experimental particle physics is used to determine the identity of the final pion, including a ring imaging Cherenkov (RICH) counter for pion/muon separation up to about 40 GeV/c.

Augusto Ceccucci

Fig. 2. Members of the NA62 collaboration in the experiment's control room.

Perhaps the most striking ▷

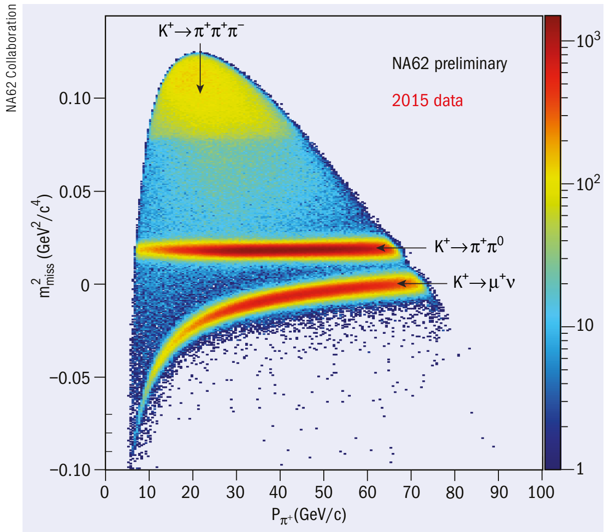


Fig. 3. The squared missing mass, reconstructed under the hypothesis that the charged track is a pion, versus the track momentum for decays of particles tagged to be kaons.

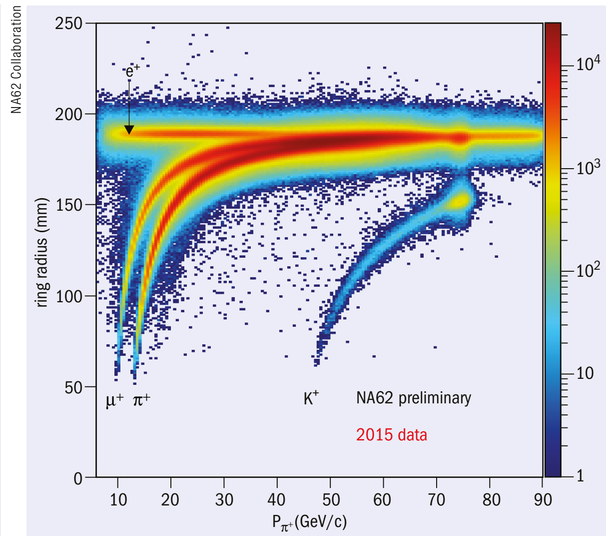


Fig. 4. The particle identification of the combined tracking and RICH spectrometers.

feature of NA62 is the complex of electromagnetic calorimeters deployed along and downstream of the vacuum tank: 12 stations of lead-glass rings (using crystals refurbished from the OPAL barrel at LEP), of which 11 operate inside the vacuum tank; a liquid-krypton calorimeter, a legacy of NA48 but upgraded with new electronics, and smaller detectors complementing the acceptance. These calorimeters form the NA62 army deployed to suppress the background originating from $K^+\to\pi^+\pi^0$ decays when both photons from the π^0 decay are lost: only one π^0 out of 10^7 remains undetected. As you have probably realised by now, NA62 is not a small experiment; a picture of the detector is shown in figure 1.

Even with a 65 m-long fiducial region, only 10% of the kaons decay usefully, so only six in 1000 of the incoming particles measured by the GTK actually end up being used to study kaon decays in NA62 – a big upfront price to pay. On the positive side, the advantage is the possibility to have full control of the initial and final states because the particles don't cross any material apart from the trackers, and the kinematics of the decays can be reconstructed with great precision. To demonstrate the quality of the NA62 data, figure 3 shows events selected with a single track for incoming particles tagged as kaons and figure 4 shows the particle-identification capability.

In addition to suppressing the π^0, NA62 has to suppress the background from muons. Most of the single rate in the large detectors is due to these particles, either from the more frequent pion and kaon decay ($\pi^+\to\mu^+\nu$ and $K^+\to\mu^+\nu$) or originating from the dump of the primary proton beam. In addition to the already mentioned RICH, NA62 is equipped with hadron calorimeters and a fast muon detector at the end of the hall to deal with the muons. A powerful and innovative trigger-and-data-acquisition system is a crucial ingredient for the success of NA62, together with the commitment and dedication of each collaborator (see figure 2).

NA62 was commissioned in 2014 and 2015, and it is now in the middle of a first long phase of data-taking, which should last until the accelerator's Long Shutdown 2 in 2018. The data collected so far indicate a detector performance in line with expectations, and preliminary results based on these data were shown at the Rencontres de Moriond Electroweak conference in La Thuile, Italy, in March. A big effort was invested to build this new experiment, and the collaboration is eager to exploit its physics potential to the full.

Having designed NA62 to address with precision the $K^+\to\pi^+\nu\bar{\nu}$ decay means that several other physics opportunities can be studied with the same detector. They range from the study of lepton universality to radiative decays. The improved apparatus with respect to NA48 should also allow measurements of $\pi\pi$ scattering and semi-leptonic decays to be improved on, and possible low-mass long-lived particles to be looked for.

The quality of the detector, the possibility to use both charged and neutral secondary beams, and the foreseen availability of the SPS extracted beams for the duration of exploitation of the LHC make NA62 a bona-fide kaon factory.

Résumé

NA62 : l'usine à kaons du CERN

Le CERN est fort d'une longue tradition en physique des kaons, tradition perpétuée aujourd'hui par l'expérience NA62. La phase de mise en service a cédé la place en 2015 à la phase d'acquisition de données, qui devrait se poursuivre jusqu'en 2018. NA62 est conçue pour étudier avec précision la désintégration $K^+\to\pi^+\nu\bar{\nu}$, mais elle est aussi utile pour examiner d'autres aspects, notamment l'universalité des leptons et les désintégrations radiatives. La qualité du détecteur, la possibilité d'utiliser des faisceaux secondaires aussi bien chargés que neutres, et la disponibilité prévue des faisceaux extraits du SPS pour la durée de l'exploitation du LHC font de NA62 une véritable usine à kaons.

Particle flow in CMS

The CMS particle-flow algorithm aims to identify and reconstruct individually all of the particles produced in a collision, through an optimal combination of the information from the entire detector. These particles are then used to build higher-level physics objects, such as jets, and the missing transverse momentum, with superior resolution.

M Bachtis, P Janot and **J Steggemann**, CERN, and **C Bernet**, IPNL, Université Claude Bernard Lyon1, CNRS/IN2P3.

In hadron-collider experiments, jets are traditionally reconstructed by clustering photon and hadron energy deposits in the calorimeters. As the information from the inner tracking system is completely ignored in the reconstruction of jet momentum, the performance of such calorimeter-based reconstruction algorithms is seriously limited. In particular, the energy deposits of all jet particles are clustered together, and the jet energy resolution is driven by the calorimeter resolution for hadrons – typically 100%/$\sqrt{E}$ in CMS – and by the non-linear calorimeter response. Also, because the trajectories of low-energy charged hadrons are bent away from the jet axis in the 3.8 T field of the CMS magnet, their energy deposits in the calorimeters are often not clustered into the jets. Finally, low-energy hadrons may even be invisible if their energies lie below the calorimeter detection thresholds.

In contrast, in lepton-collider experiments, particles are identified individually through their characteristic interaction pattern in all detector layers, which allows the reconstruction of their properties (energy, direction, origin) in an optimal manner, even in highly boosted jets at the TeV scale. This approach was first introduced at LEP with great success, before being adopted as the baseline for the design of future detectors for the ILC, CLIC and the FCC-ee. The same ambitious approach has been adopted by the CMS experiment, for the first time at a hadron collider. For example, the presence of a charged hadron is signalled by a track connected to calorimeter energy deposits. The direction of the particle is indicated by the track before any deviation in the field, and its energy is calculated as a weighted average of the track momentum and the associated calorimeter energy. These particles, which typically carry about 65% of the energy of a jet, are therefore reconstructed with the best possible energy resolution.

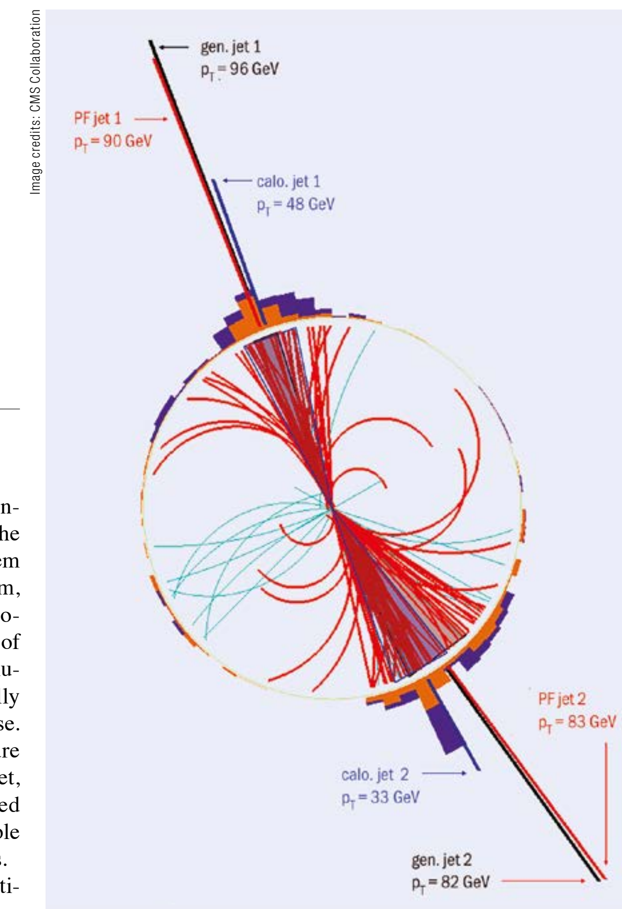


Fig. 1. Jet reconstruction in a simulated dijet event. The reconstructed particles clustered in the two jets are displayed with thicker lines. For clarity, unclustered particles with $p_T < 1$ GeV are not shown. The particle-flow jet transverse momentum, indicated as a radial line, is compared to the momenta of the corresponding generated and calorimeter jets.

Calorimeter energy deposits not connected to a track are either identified as a photon or as a neutral hadron. Photons, which represent typically 25% of the jet energy, are reconstructed with the excellent energy resolution of the CMS electromagnetic calorimeter. Consequently, only 10% of the jet energy – the average fraction carried by neutral hadrons – needs to be reconstructed solely using the hadron calorimeter, with its 100%/$\sqrt{E}$ resolution. In ▷

addition to these types of particles, the algorithm identifies and reconstructs leptons with improved efficiency and purity, especially in the busy jet environment.

Key ingredients for the success of particle flow are excellent tracking efficiency and purity, the ability to resolve the calorimeter energy deposits of neighbouring particles, and unambiguous matching of charged-particle tracks to calorimeter deposits. The CMS detector, while not designed for this purpose, turned out to be well-suited for particle flow. Charged-particle tracks are reconstructed with efficiency greater than 90% and a rate of false track reconstruction at the per cent level down to a transverse momentum of 500 MeV. Excellent separation of charged hadron and photon energy deposits is provided by the granular electromagnetic calorimeter and large magnetic-field strength. Finally, the two calorimeters are placed inside of the magnet coil, which minimises the probability for a charged particle to generate a shower before reaching the calorimeters, and therefore facilitates the matching between tracks and calorimeter deposits.

After particle flow, the list of reconstructed particles resembles that provided by an event generator. It can be used directly to reconstruct jets and the missing transverse momentum, to identify hadronic tau decays, and to quantify lepton isolation. Figure 1 illustrates, in a given event, the accuracy of the particle reconstruction by comparing the jets of reconstructed particles to the jets of generated particles. Figure 2 further demonstrates the dramatic improvement in jet-energy resolution with respect to the calorimeter-based measurement. In addition, the particle flow improves the jet angular resolution by a factor of three and reduces the systematic uncertainty in the jet energy scale by a factor of two. The influence of particle flow is, however, far from being restricted to jets with, for example, similar improvements for missing transverse-momentum reconstruction and a tau-identification background rate reduced by a factor three. This new approach to reconstruction also paved the way for particle-level pile-up mitigation methods such as the identification and masking of charged hadrons from pile-up before clustering jets or estimating lepton isolation, and the use of machine learning to estimate the contribution of pile-up to the missing transverse momentum.

The algorithm, optimised before the start of LHC Run I in 2009, remains essentially unchanged for Run II, because the reduced bunch spacing of 25 ns could be accommodated by a simple reduction of the time windows for the detector hits. The future CMS upgrades have been planned towards optimal conditions for particle flow (and therefore physics) performance. In the first phase of the upgrade programme, a new pixel layer will reduce the rate of false charged-particle tracks, while the read-out of multiple layers with low noise photodetectors in the hadron calorimeter will improve the neutral hadron measurement that limits the jet-energy resolution. The second phase includes extended tracking allowing for full particle-flow reconstruction in the forward region, and a new high-granularity endcap calorimeter with extended particle-flow capabilities. The future is therefore bright for the CMS particle-flow reconstruction concept.

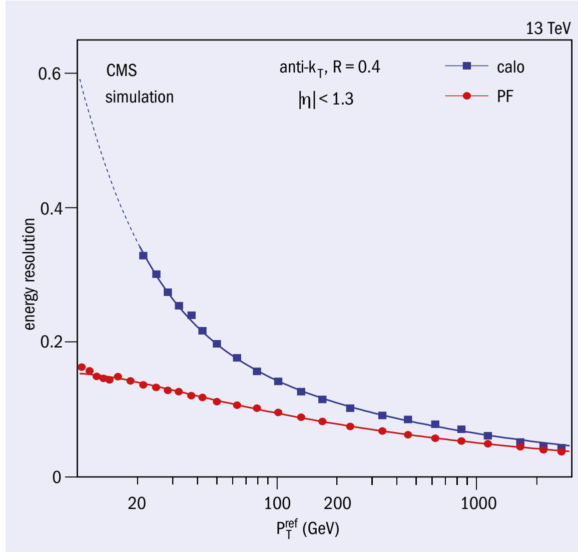


Fig. 2. Jet-energy resolution for calorimeter and particle-flow jets as a function of the jet transverse momentum. The improvement in resolution, of almost a factor of two at low transverse momentum, remains sizable even for jets with very high transverse momentum.

● CMS Collaboration, "Particle flow and global event description in CMS", in preparation.

Résumé

Reconstruction du flux de particules dans CMS

L'algorithme de reconstruction du flux de particules de CMS combine les informations de l'ensemble du détecteur pour identifier et reconstruire les particules de l'état final de manière optimale. Ces particules sont ensuite utilisées pour construire avec une meilleure résolution les objets de physique de haut niveau tels que les jets ou l'impulsion transverse manquante.

An Auger Observatory water-Cherenkov surface detector on the Pampa Amarilla.

AugerPrime looks to the highest energies

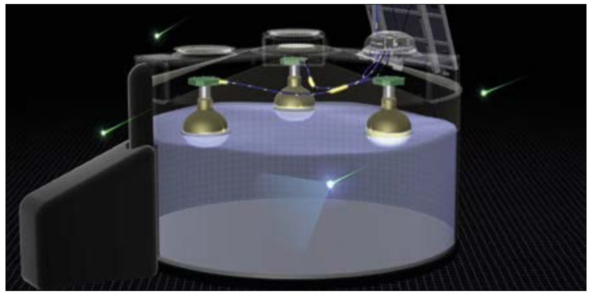
The world's largest cosmic-ray experiment, the Pierre Auger Observatory in Mendoza Province, Argentina, is embarking on its next phase, named AugerPrime.

Gregory Snow, University of Nebraska, US, for the Pierre Auger Collaboration.

Since the start of its operations in 2004, the Auger Observatory has illuminated many of the open questions in cosmic-ray science. For example, it confirmed with high precision the suppression of the primary cosmic-ray energy spectrum for energies exceeding 5×10^{19} eV, as predicted by Kenneth Greisen, Georgiy Zatsepin and Vadim Kuzmin (the "GZK effect"). The collaboration has searched for possible extragalactic point sources of the highest-energy cosmic-ray particles ever observed, as well as for large-scale anisotropy of arrival directions in the sky (*CERN Courier* December 2007 p5). It has also published unexpected results about the specific particle types that reach the Earth from remote galaxies, referred to as the "mass composition" of the primary particles. The observatory has set the world's most stringent upper limits on the flux of neutrinos and photons with EeV energies (1 EeV = 10^{18} eV). Furthermore, it contributes to our understanding of hadronic showers and interactions at centre-of-mass energies well above those accessible at the LHC, such as in its measurement of the proton–proton inelastic cross-section at $\sqrt{s} = 57$ TeV (*CERN Courier* September 2012 p6).

The current Auger Observatory

The Auger Observatory learns about high-energy cosmic rays from the extensive air showers they create in the atmosphere (*CERN Courier* July/August 2006 p12). These showers consist of billions of subatomic particles that rain down on the Earth's surface, spread over a footprint of tens of square kilometres. Each air shower carries information about the primary cosmic-ray particle's arrival direction, energy and particle type. An array of 1600 water-Cherenkov surface detectors, placed on a 1500 m grid covering 3000 km^2, samples some of these particles, while fluorescence detectors around the observatory's perimeter observe the faint ultraviolet light the shower creates by exciting the air molecules it passes through. The surface detectors operate 24 hours a day, and are joined by fluorescence-detector measurements on clear moonless nights. The duty cycle for the fluorescence detectors is about 10% that of the surface detectors. An additional 60 surface detectors in a region with a reduced 750 m spacing, known as the infill array, focus on detecting lower-energy air showers whose footprint is smaller than that of showers at the highest energies. Each surface-detector station (see image above) is self-powered ▷



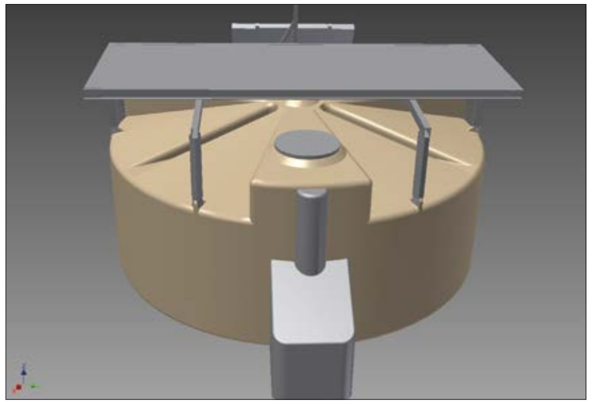
Cherenkov light produced by air-shower particles is detected by three photomultiplier tubes, which view the water volume.

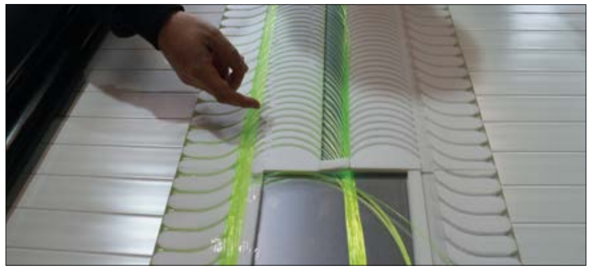
by a solar panel, which charges batteries in a box attached to the tank (at left in the image), enabling the detectors to operate day and night. An array of 153 radio antennas, named AERA and spread over a 17 km^2 area, complements the surface detectors and fluorescence detectors. The antennas are sensitive to coherent radiation emitted in the frequency range 30–80 MHz by air-shower electrons and positrons deflected in the Earth's magnetic field.

The motivation for AugerPrime and its detector upgrades

The primary motivation for the AugerPrime detector upgrades is to understand how the suppressed energy spectrum and the mass composition of the primary cosmic-ray particles at the highest energies are related. Different primary particles, such as γ-rays, neutrinos, protons or heavier nuclei, create air showers with different average characteristics. To date, the observatory has deduced the average primary-particle mass at a given energy from measurements provided by the fluorescence detectors. These detectors are sensitive to the number of air-shower particles versus depth in the atmosphere through the varying intensity of the ultraviolet light emitted along the path of the shower. The atmospheric depth of the shower's maximum number of particles, a quantity known as X_{max}, is deeper in the atmosphere for proton-induced air showers relative to showers induced by heavier nuclei, such as iron, at a given primary energy. Owing to the 10% duty cycle of the fluorescence detectors, the mass-composition measurements using the X_{max} technique do not currently extend into the energy region $E > 5 \times 10^{19}$ eV where the flux suppression is observed. AugerPrime will capitalise on another feature of air showers induced by different primary-mass particles, namely, the different abundances of muons, photons and electrons at the Earth's surface. The main goal of AugerPrime is to measure the relative numbers of these shower particles to obtain a more precise handle on the primary cosmic-ray composition with increased statistics at the highest energies. This knowledge should reveal whether the flux suppression at the highest energies is a result of a GZK-like propagation effect or of astrophysical sources reaching a limit in their ability to accelerate the highest-energy primary particles.

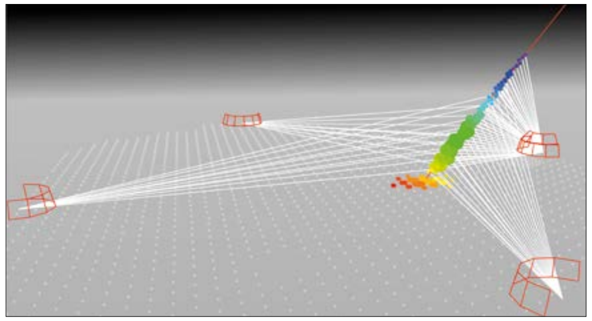
The key to differentiating the ground-level air-shower particles lies in improving the detection capabilities of the surface array. AugerPrime will cover each of the 1660 water-Cherenkov surface detectors with planes of plastic-scintillator detectors measuring 4 m^2. Surface-detector stations with scintillators above the Cherenkov detectors will allow the Auger team to determine the electron/photon versus muon abundances of air showers more precisely compared with using the Cherenkov detectors alone. The scintillator planes will be housed in light-tight, weatherproof enclosures, attached to the existing water tanks with a sturdy support frame, as shown above. The scintillator light will be read out with wavelength-shifting fibres inserted into straight extruded holes in the scintillator planes, which are bundled and attached to photomultiplier tubes. Also above, an image shows how the green wavelength-shifting fibres emerge from the scintillator planes and are grouped into bundles. Because the surface detectors operate 24 hours a day, the AugerPrime upgrade will yield mass-composition information for the full data set collected in the future.





Top: Drawing of an AugerPrime surface-detector station with scintillator planes measuring 4 m^2, housed in a weatherproof enclosure above a water-Cherenkov detector. Above: An AugerPrime scintillator detector with green wavelength-shifting fibres, which carry light to a photomultiplier tube (not shown).

The AugerPrime project also includes other detector improvements. The dynamic range of the Cherenkov detectors will be extended with the addition of a fourth photomultiplier tube. Its gain will be adjusted so that particle densities can be accurately measured close to the core of the highest-energy air showers. New electronics with faster sampling of the photomultiplier-tube signals will better identify the narrow peaks created by muons. New GPS receivers at each surface-detector station will provide better timing accuracy and calibration. A subproject of AugerPrime called AMIGA will consist of scintillator planes buried 1.3 m under the 60 surface detectors of the infill array. The AMIGA detectors are directly sensitive to the muon content of air showers, because the electromagnetic components are largely absorbed by the overburden.



Event display of an ultra-high-energy air shower, showing surface detectors recording hits and light seen by all four fluorescence-detector sites.

The AugerPrime Symposium

In November 2015, the Auger scientists combined their biannual collaboration meeting in Malargüe, Argentina, with a meeting of its International Finance Board and dignitaries from many of its collaborating countries, to begin the new phase of the experiment in an AugerPrime Symposium. The Finance Board endorsed the development and construction of the AugerPrime detector upgrades, and a renewed international agreement was signed in a formal ceremony for continued operation of the experiment for an additional 10 years. The observatory's spokesperson, Karl-Heinz Kampert from the University of Wuppertal, said: "The symposium marks a turning point for the observatory and we look forward to the exciting science that AugerPrime will enable us to pursue."

While continuing to collect extensive air-shower data with its current detector configuration and publishing new results, the Auger Collaboration is focused on finalising the design for the upgraded AugerPrime detectors and making the transition to the construction phase at the many collaborating institutions worldwide. Subsequent installation of the new detector components on the Pampa Amarilla is no small task, with the 1660 surface detectors spread across such a large area. Each station must be accessed with all-terrain vehicles moving carefully on rough desert roads. But the collaboration is up to the challenge, and AugerPrime is foreseen to be completed in 2018 with essentially no interruption to current data-taking operations.

● For more information, see auger.org/augerprime.

Résumé

Lancement d'AugerPrime

Des rayons cosmiques d'ultra-haute énergie en provenance du fin fond de l'Univers seront bientôt observés par un œil plus acéré. L'Observatoire Pierre Auger a en effet mis en route sa prochaine phase, appelée AugerPrime, consacrée à l'amélioration des détecteurs. En novembre 2015, un nouvel accord a été signé pour la poursuite de l'exploitation de l'expérience pour une durée supplémentaire de dix ans. Cette nouvelle phase vise principalement à comprendre le lien entre la partie supprimée du spectre d'énergie et la composition des masses des rayons cosmiques primaires aux plus hautes énergies. Elle devrait prendre fin en 2018, sans interruption des opérations de collecte de données.

Interactions & Crossroads

ASTROPARTICLES

Planning the route for new APPEC road map

Astrid Chantelauze

The astroparticle-physics community gathered in Paris to plan its new road map, to be published later this year.

Where next for European astroparticle physics? It's less than five years since the last road map for astroparticle physics in Europe was published. In that short time, key scientific discoveries have been made, helping to indicate the direction for future research. The discovery of the Higgs boson at CERN, the detailed mapping of the cosmic microwave background by the Planck space telescope, and the recent direct detection of gravitational waves, have all energised the discipline. The Astroparticle Physics European Consortium (APPEC, www.appec.org/) has developed and expanded since the last road map in 2011, and on 6 and 7 April, APPEC convened a meeting in Paris to examine the current state of astroparticle physics, seek input from the community for the new road map, and hear its recommendations for funding agencies, research institutes and universities. The meeting was organised by former APPEC chair Stavros Katsanevas (APC) and his team, and the schedule and slides are available to view online (app2016.in2p3.fr/programme.html). Physicists and astronomers responded to the call enthusiastically and debated the first-draft "Considerations" presented by APPEC and its Scientific Advisory Committee.

More than 200 scientists and invited speakers gathered at the Sorbonne to review the different topics covered in astroparticle physics – a discipline at the intersection of particle physics, astronomy and cosmology – and to weigh up potential recommendations for inclusion in the road map. Those recommendations will look ahead to developments in the fields of multimessenger astronomy, neutrino properties, dark matter and energy, the cosmic microwave background and gravitational waves. While the scope for new discoveries across these fields is almost limitless, APPEC is committed to producing a "resource aware" road map that will respect the impact and constraints of available technology and funding, and also look at the important roles of computing infrastructure, education and outreach.

Joint actions

CERN's Director-General, Fabiola Gianotti, was among the invited speakers at the meeting. She highlighted some of the complementarity between astroparticle-physics and particle-physics work at the LHC. She also laid out opportunities for the astroparticle-physics community – and said that in the future, there was potential for joint actions on detector research and development, technology transfer and infrastructure development. Fabiola Gianotti reminded the group about the opportunities to interact and develop ideas with the International Particle Physics Outreach Group at CERN.

Projects across the next decade will help to reveal some secrets about physics, and perhaps address questions where the Standard Model does not hold all of the answers with some "new physics". The CERN community can look forward to complementary particle-physics observations from the Pierre Auger Observatory – looking at natural particle accelerators and the potential of proton astronomy. Speakers from several countries highlighted the impetus that the direct discovery of gravitational waves has given to gravitational-wave research, and Advanced Virgo will allow Europe to become part of the global network of gravitational-wave detection and move towards the era of gravitational-wave astronomy. Observations of the high-energy universe such as those to be conducted by the Cherenkov Telescope Array and KM3NeT will also be important – these projects feature in the ESFRI road map and will certainly be included in the APPEC one. International collaboration will be vital for scientific advances, and co-ordination and ambition at a European level will help to boost worldwide experiments.

Speaking at the close of the meeting, APPEC chair Frank Linde (Nikhef) said that he believed there was room for developing greater ties with CERN, as well as uniting the community for APPEC common calls and European funding applications. He pointed out that astroparticle physics covers excellent and appealing science, incredible experiments, and a distributed but united community of researchers. APPEC will publish its road map later this year.

Future accelerators

FCC Week 2016 showcases progress and challenges

INFN

FCC Week 2016 – a major gathering for high-energy experts from Europe and beyond.

From 11 to 15 April, more than 450 participants from all over the world met in Rome to discuss the progress achieved in the Future Circular Collider (FCC) study, and the challenges that lie ahead.

The future of high-energy physics in the timescale of the 21st century hinges on designing and building future colliders that could take an order of magnitude beyond the present energy and intensity frontiers. Reaching this goal in an efficient way calls for a large circular collider, and the FCC study explores different options.

The FCC study develops concepts for post-LHC circular colliders. The emphasis of the study is on a 100 TeV hadron collider, while an electron–positron collider is considered as a potential first step. A hadron–electron scenario is also examined, testifying to the rich programme of such a large-scale infrastructure. It was launched in 2014 as a direct response to the European Strategy for Particle Physics, and today embraces more than 70 institutes from 26 countries (*CERN Courier* April 2014 p16).

The second FCC Week showed that CERN and the worldwide physics community must now come together to prepare for the future. The full exploitation of the LHC, including its high-luminosity phase (HL-LHC), sets a timescale of 20 years (*CERN Courier* May 2016 p5). This timescale, along with the complexity of the FCC project and the desire to profit from other international studies for future accelerators, makes the FCC study a timely effort.

The physics potential for each of the FCC-study scenarios (proton–proton, electron–positron or electron–proton) was reviewed during the meeting. Each has its specific virtues, although there is also strong complementarity while they set certain challenges for the design of the machine and the experiments. Detector-design concepts for all three scenarios were also presented, while areas where further theoretical or experimental input is needed were identified. Technologies that need to be developed for the detectors (including electronics, trigger, and data links) were discussed, while a detailed report on physics at 100 TeV was presented in Rome and will soon be available online. The FCC physics programme shows that this infrastructure is not a mere follow-up on the past, but involves machines that could open new horizons in our quest to understand nature.

The meeting showcased the copious R&D efforts to push key technologies to meet the requirements of the FCC. Physicists, engineers and representatives from industry discussed the present challenges and opportunities in different areas, including: the development of superconducting materials; the 16 T superconducting magnets programme; the new superconducting radiofrequency cavities; and innovative vacuum systems and efficient cryogenics.

Finally, substantial progress has been made on infrastructure and operation studies. This includes the civil-engineering studies for a 90–100 km tunnel in the Geneva area that fits with the geographical conditions. Operational aspects also become crucial when thinking about such a machine – controls and machine protection, as well as energy-consumption, reliability and safety, were some of the topics covered during the meeting.

The FCC Week also featured the work of younger researchers: more than 100 presented their latest research in the poster sessions. Three of them received the FCC Innovation Award, which distinguishes early-stage researchers or engineers for outstanding work carried out within the scope of the study.

The efforts presented during the 2016 FCC Week will culminate in a Conceptual Design Report by 2019. This will serve as a decision aid for a future particle-research infrastructure.

Finally, a public event, "Discovery Machines", was organised during the FCC Week. Physicists and experts from economics met to discuss intriguing questions in modern physics and the societal impact of large-scale research infrastructures, including the development of new technologies, the training of young researchers, and cultural and major scientific breakthroughs.

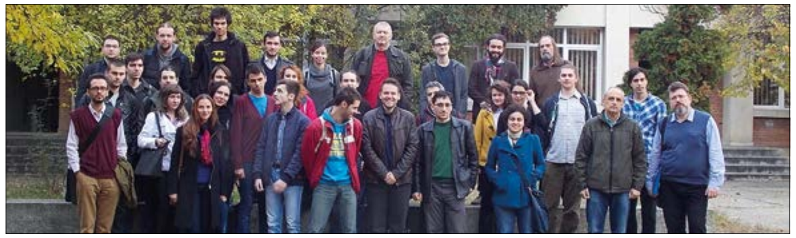
The next FCC Week will take place in Berlin from 27 May to 2 June 2017. This meeting will mark a major review of the study, and will be an important step in launching the preparation of the FCC Conceptual Design Report.

● For more information, visit fccw2016.web.cern.ch/fccw2016/.

Training programmes

A successful year for SEENET-MTP

SEENET



Lecturers and students at the SEENET-MTP school in Bucharest.

The Southeastern European Network in Mathematical and Theoretical Physics (SEENET-MTP) was founded in 2003 to organise scientific and research activities in the Balkan region, to promote the exchange of students and encourage communication between them, and to build institutional capacity in physics and mathematics The programme is a tool to provide an exciting working atmosphere for students from different centres and countries, who often share a feeling of isolation during their PhD studies (*CERN Courier* December 2013 p21).

In January 2015, with the support of the CERN Theory Department, the network launched a joint PhD training programme aimed at students from southeastern European countries. The main part of the programme was designed to be a series of intense, one-week schools for PhD students, advanced masters students, and young postdocs who study high-energy physics and related fields. Each school included lectures followed by appropriate exercises.

The first school was organised in 2015 in Belgrade (Serbia), on 21–27 June. The main topic of the seminar was supergravity, which was covered by the two guest lecturers, Leonardo Castellani (INFN Torino) and Hagen Triendl (CERN). The seminar was organised by the Faculty of Physics of the University of Belgrade, whose scientists also gave lectures and prepared exercises to test the students' learning achievements. In total, 15 participants from six countries attended the seminar.

The second school was held later in the year in Bucharest (Romania) on 8–14 November. The title of the seminar was Modern Aspects of Quantum Field Theory. This event was mainly intended for PhD students who study high-energy physics and related fields. The topics of the school covered modern aspects of quantum field theory and applications. There were several guest lectures: Hubert Spiesberger (University of Mainz) gave a lecture on "Path integral formalism in QFT", and Nikolaos Tetradis (University of Athens and CERN) gave a talk entitled "Field theory, renormalization and cosmology". The programme was completed by Ciprian Acatrinei (Department of Theoretical Physics, IFIN-HH, Bucharest), who presented the challenges of "QFT in strong backgrounds – applications for ELI-NP" . The talk was followed by a colloquium on "Tachyon field theory and inflation" given by Goran Djordjevic (University of Niš, Serbia). The tutorial exercises were given by Nikolaos Brouzakis (University of Athens) and other scientists from Bucharest.

In total, 31 participants from seven countries attended this second school organised by SEENET-MTP. We are very much indebted to the local organising team at Horia Hulubei National Institute and the Faculty of Physics, Bucharest.

The SEENET-MTP activities, including the very successful PhD programme, are possible thanks to the support of the 14 full members of the network and, in particular the main local organisers. Importantly, most of the travel and local expenses were covered through a CERN grant transferred to the local organising institutions.

The SEENET-MTP network, expressing its thanks for support of the programme, gave awards of merit to Sergio Bertolucci, director of Research and Scientific Computing at CERN (2009–2015), and Wolfgang Lerche, head of the CERN TH Group (2013–2015). Ignatios Antoniadis's support of the programme, in its initial phase, and that of Luis Alvarez-Gaume during the whole period, is warmly acknowledged.

It is expected that new schools will be organised in the framework of the SEENET-MTP PhD training programme in 2016.

● For more information, see phd.seenet-mtp.info and www.seenet-mtp.info.

Events calendar

3–10 August
ICHEP 2016
Chicago, US
At ICHEP, physicists from around the world gather to share the latest advancements in particle physics, astrophysics/cosmology and accelerator science, and to discuss plans for major future facilities.
www.ichep2016.org

6–9 September
High Precision for Hard Processes (HP2)
Buenos Aires, Argentina
This sixth workshop of the series is devoted to high-precision studies of hard-scattering processes at hadron colliders. The main themes include recent developments and new results on theory and phenomenology of hard-scattering processes within the Standard Model and its extensions.
www.icas.unsam.edu.ar/deflo/hp2.html

29 October–6 November
NSS/MIC
Strasbourg, France
This conference brings together engineers and scientists from around the world to share their knowledge and to gain insight and inspiration from others in the field of nuclear and medical instrumentation. The conference will include a distinguished series of short courses, relevant refresher courses, and workshops that will address areas of particular interest.
2016.nss-mic.org/

Faces & Places

CELEBRATION

The Joint Institute for Nuclear Research turns 60

All image credits: JINR

Spectacular fireworks concluded the celebratory events for the 60th anniversary of JINR .

A festive event to celebrate the 60th anniversary of the Joint Institute for Nuclear Research (JINR) (*CERN Courier* March 2006 p15) was held in the evening of 26 March in the "Mir" cultural centre. The event was attended by members of the directorate and personnel of the laboratory, as well as Dubna City mayor Vyacheslav Mukhin, the head and representatives of the City Administration, leaders of firms and organisations, deputies, and representatives of public associations. In his speech, JINR director and academician of the Russian Academy of Sciences, Victor Matveev, recalled the main phases and activities in the history of the institute. He spoke about each research laboratory individually, as well as about the people who made JINR's history and contributed to the construction of the key facilities. On this occasion, the Ministry of Education and Science of the Russian Federation awarded three JINR scientists – A V Efremov, V K Lukianov and M G Itkis – with the title "Honorary Worker of Science and Technology". During the ceremony, Matveev also presented grants and congratulatory certificates to Dubna teachers. At the end of his speech, on behalf of the JINR directorate and the JINR Scientific Council, Matveev congratulated staff members and veterans of JINR, and all those who attended the event.

The festivities for the anniversary had been preceded on 25 March by the laying of the first stone of the Complex of Superconducting Rings for Heavy Ion Colliding Beams (the NICA complex, nica.jinr.ru/), and continued with a special session of the JINR Committee of Plenipotentiaries that was held on 4–5 April. A concluding ceremony featured ballet dancers of the Bolshoi Theatre, who performed classical *pas-de-deux* and *adagio* from famous ballets including *Giselle*, *The Nutcracker* and *Swan Lake*. After the *entr'acte*, the Orpheus Radio Symphony Orchestra played famous waltzes from ballets and operas, such as *Tales from the Vienna Woods*, *On the Beautiful Blue Danube* and *Voices of Spring Waltz*. Later in the evening, in the Molodezhnaya grassy glade near to the "Mir" cultural centre, a colourful show and fireworks closed the celebrations. Representatives of the Russian Federation and the Moscow region administrations, international organisations such as the UN, UNESCO, the EU, the IAEA, and leaders of scientific centres – JINR international co-operation partners – were invited to take part in the event. Among them was CERN's Director-General Fabiola Gianotti, who congratulated JINR scientists on the 60th anniversary of the institute.

On the same occasion, the Press Office of JINR, in collaboration with INTERGRAFIKA, organised a full-scale poster and multimedia exhibition. The colourful poster exhibition, "JINR – 60", consisted of 30 posters highlighting the achievements of the institute, its future plans and the wide international co-operation that the laboratory enjoys. In addition, an exhibition of 80 photographs taken by JINR photographers presented portraits of famous scientists, JINR staff members and guests, events and working moments. They provided an impressive picture of the unique atmosphere of research at JINR.

Top: At midday, Moscow time, members of the JINR directorate, plenipotentiaries and representatives of the JINR Association of Young Scientists and Specialists let 60 white-dove balloons into the sky to mark the opening of the CP session. Middle: The festive concert at the "Mir" culture centre. Above: The ceremony laying the first stone for the construction of the NICA collider, at the VBLHEP site.

Appointments

Federico Antinori elected as the new ALICE spokesperson

On 8 April, the ALICE collaboration Board elected Federico Antinori from INFN Padova (Italy) as the new ALICE spokesperson. During his three-year mandate, starting in January 2017, Antinori will lead a collaboration of more than 1500 people from 154 physics institutes worldwide.

Antinori has been a member of the collaboration since it was created, and he has already held many senior leadership positions. Currently, he is the experiment's physics co-ordinator, with responsibility for overseeing the whole sector of physics analysis. During this time, ALICE has produced many of its most prominent results. Before that, he was the co-ordinator of the Heavy Ion First Physics Task Force, charged with analysis of the first Pb–Pb data samples. In 2007 and 2008, Antinori served as ALICE deputy spokesperson. He was also the first ALICE trigger co-ordinator, having a central role in defining the experiment's trigger menus from the first run in 2009 until the end of his mandate in 2011. He also played an important role in commissioning the experiment before the start of its operation.

Antinori feels honoured to be entrusted by the collaboration with its leadership: "ALICE is a unique scientific instrument, built with years of dedication and the labour of hundreds of colleagues. We have practically only begun to exploit its possibilities. As spokesperson, I can play a key role in making ALICE ever more efficient and successful, and this is a truly exciting prospect for me."


CERN

Federico Antinori will start his mandate in January 2017.

Awards

The first Guido Altarelli Award

The 24th International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS2016) was held in April at DESY, Hamburg, during which the first Guido Altarelli Award was presented. The award honours the memory of the late Guido Altarelli, a pioneer in unravelling the structure of the proton and developing the theory of the strong force, and a mentor and supporter of promising young scientists. The two recipients were selected from 24 outstanding young scientists, nominated by distinguished scientists from all over the world by a selection committee composed of members of the DIS workshop series International Advisory Committee. Two exceptional candidates were selected, who have made outstanding contributions to topics close to the subjects of the DIS16 Workshop – Fabrizio Caola, a theorist from CERN, and Jan Kretzschmar, an experimental physicist from the ATLAS collaboration, Liverpool, UK.

Fabrizio Caola is widely recognised for his pioneering work on high-precision physics for the LHC. He combines formidable technical skills with a deep understanding of the physics of QCD processes. After graduating in Milan with a thesis on QCD resummation, he contributed to NNLO QCD corrections to 2→2 processes at hadron colliders, and was one of the theorists who suggested to constrain the decay width of the Higgs particle using the ZZ decay at large invariant masses with data from the LHC experiments.

Jan Kretzschmar undertook his PhD at DESY, Zeuthen, and graduated from the Humboldt University in Berlin with a thesis on determination of the structure functions F_2 and F_L with data from the H1 experiment at HERA. He has continued his outstanding work on proton structure functions at the LHC, leading the measurement of the W and Z cross-sections with data from the ATLAS experiment and using the results to improve the knowledge of the proton structure function. He is currently convener of the ATLAS collaboration's Standard Model analysis group.

This year, the award was kindly sponsored by *Nuclear Physics B* and the Association of Sponsors and Friends of DESY.

● For more information about DIS16, visit https://dis2016.desy.de/.


Marta Mayer, DESY

Left to right: Aharon Levy (chair of the DIS workshops IAC), Fabrizio Caola (CERN), Massimo Altarelli (XFEL), Monica Pepe-Altarelli (CERN), Jan Kretzschmar (ATLAS collaboration) and Olaf Behnke (DESY, local chair of the DIS16 Hamburg workshop).

Philippe Lebrun receives Mendelssohn Award

The International Cryogenic Engineering Committee recently awarded CERN's Philippe Lebrun for the outstanding contribution by the CERN cryogenics group to the design, construction and operation of high-energy accelerators and associated large detectors using cryogenics and superconductivity.

Lebrun conducted the R&D on the superfluid helium cryogenic system for the LHC. He then led CERN's Accelerator Technology Department during the construction of the machine, and played a major role during the construction of the cryogenic high-field magnets.

The award, established in 1986 in memory of Kurt Mendelssohn (1906–1982), the founder of the ICEC Committee, was bestowed during the 26th International Cryogenic Engineering Conference held in New Delhi, India, in March. Lebrun was invited to give an award lecture entitled "Cryogenics for high-energy accelerators: highlights from the first 50 years."

In his lecture, Lebrun discussed the development of cryogenics over the past half-century and presented its outlook in future large projects, with reference to the main engineering domains of cryostat design and heat loads, cooling schemes, efficient power refrigeration and cryogenic fluid management.

● For further information, see icec26-icmc2016.org/The%20ICEC%20Mendelssohn%20Award%C2%9D.php.


Laurent Tavian

Philippe Lebrun during his award lectures at the recent ICEC conference.

Accelerators

Five years of synchrotron light in ALBA

At 3.45 p.m. on 16 March 2011, a group of scientists and technicians of the ALBA Synchrotron in Barcelona were celebrating with cava. Eight years after the project's approval, the facility's accelerator complex had produced its first synchrotron light – and the first synchrotron light in Spain. A year later, the first experiments started .

To mark the 5th anniversary of this successful commissioning, a celebration was held at ALBA on 16 March this year for all of the staff, together with Dieter Einfeld, the former head of the Accelerators Division, who gave a presentation about the events that led up to the exciting first observation of synchrotron light. The anniversary celebration finished with a toast by all the attendees. In addition, a commemorative video had been made to explain the atmosphere of the historic moment, with several anecdotal accounts.

Today, ALBA's accelerator complex (*CERN Courier* November 2008 p31) works for about 6000 hours a year with an availability above 97%. Improvements have been made since commissioning, such as working in top-up mode and the use of a new fast orbit-feedback system to increase beam stability. ALBA operates with seven beamlines available for experiments and each year hosts more than 1000 researchers. At the end of 2016, an eighth beamline will come into operation, devoted to infrared microspectroscopy, and in 2018 and 2020, two more new beamlines will begin operation.

● For the commemoration video, see https://youtu.be/Rv0H_D-mrBI.

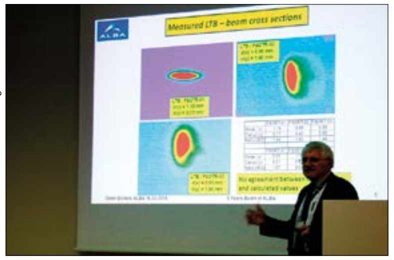


Image credits: ALBA

Above: Dieter Einfeld gives his presentation. Top right: Scientists and technicians of the ALBA Synchrotron in Barcelona enjoying the celebration.

CERN

Globe of Science and Innovation reopens

The globe is made almost entirely out of wood (2000 m³ in total) from Swiss forests, which replenish themselves at a rate of 700 m³ per hour.

After about a year of renovation work, one of the best-known symbols of CERN has recently reopened its doors. Visitors to the laboratory will now be able to see the free and permanent "Universe of Particles" exhibition installed in the ground floor of the Globe of Science and Innovation. This new exhibition sits alongside the recently revamped, interactive "Microcosm" exhibition (*CERN Courier* March 2016 p45). Both exhibitions take visitors on a journey deep into the world of particles and back to the Big Bang, showcasing the full scale and wonder of CERN's monumental experiments, such as the LHC, and the people behind them.

Designed by Geneva architects T Büchi and H Dessimoz, the globe was initially built to house the Swiss national "Expo.02" exhibition in Neuchâtel. The Swiss Confederation donated the globe to CERN in June 2003 and, in 2004, the building hosted the official celebrations marking the 50th anniversary of the laboratory.

At 27 m high and 40 m in diameter, the building is about the size of the dome of Saint Peter's cathedral in Rome, therefore any renovation project had to be ambitious.

After more than 10 years' faithful service, certain components that were initially designed to last only for the months of the Neuchâtel exhibition needed to be replaced to extend the globe's lifetime. The 18 outer cylindrical arcs, each measuring 32 m in length, have been replaced by new ones of identical appearance but made from a hardier type of wood. In addition to this, the external ramps, disabled-access facilities, staircases and lighting system have been replaced. The globe is now set to host new cultural events, lectures and exhibitions.

Obituaries

Valerio Gracco 1940–2015

Valerio Gracco.

Valerio Gracco, a passionate enthusiast of physics, passed away on 24 October 2015, in Geneva.

Born in Torino (Italy) on 23 December 1940, Valerio obtained his degree in physics in December 1963. His thesis was on the interaction of 14 MeV neutrons with nuclei.

Valerio spent his first years after university at LAL-Orsay (France), where he continued to study nuclear-physics interactions and photodisintegrations of deuterons from 140 to 400 MeV. He also went on to explore strong interactions and vector meson dominance (VMD) with electron–positron annihilations at the Anneau de Collisions d'Orsay (ACO).

At the end of the 1960s, Valerio became a fellow of CERN. At the CERN PS, he participated in the S91 experiment under the guidance of Arne Lundby. The experiment studied the elastic scattering of protons, pions and kaons on 5 GeV and 10 GeV/c protons, and was then extended under the name S120 to also encompass studies on a few inelastic channels (two-body production of a hypercharge state).

In 1976, while he was a research associate in the INFN group of Sergio Ferroni in Genova (Italy), Valerio and Lundby proposed the WA7 experiment, which used large proportional chambers (3 × 3 m²) built at the Ponte Carrega Laboratory (Genova). WA7 ran in CERN's West Area and used a beam of 20 and 30 GeV to study pion and proton large-angle elastic scattering on protons.

In 1978, he was appointed a full professor and, in the same year, he also became director of the INFN Section in Genova. In 1980, Valerio started a two-year mandate as a member of the INFN Executive Board ("*Giunta*") and vice-president of the INFN Council. These years were marked by the hard R&D work and important progress made on the development of instrumentation for experiments at CERN. This success was made possible by Valerio's collaboration with excellent technicians, but it was also due to his dedication in teaching experimental laboratory classes and detector techniques with a modern outlook and spirit.

In 1980, Valerio joined the group at CERN who proposed to study charmonium spectroscopy by using antiproton annihilations on protons from a hydrogen-gas jet target. That target demanded an important technological development that was mainly provided by the Genova INFN and GNSM teams that worked closely with the ISR staff.

By 1983, the jet target was installed in one of the ISR rings and the experiment R704 could take data until the closure of the ISR machine in June 1984.

After 1982, Valerio started to moderate his heavy involvement with the INFN organisation and management, and went on to think of the best way to involve the Genova team with the LEP experiments. He initially joined the OPAL collaboration, but then decided to move to COLLEPS (later called DELPHI) led by Ugo Amaldi. He suggested that Ansaldo (an industry based in Genova) build the superconducting solenoid for the experiment, and even obtained the necessary funds. However, the collaboration decided to build it with other partners. Valerio stayed in the collaboration and participated in work for the technical proposal published in 1983. DELPHI was built between 1983 and 1988, and operated up to the end of 2000. The Genova team built nearly half of the DELPHI electromagnetic calorimeter (HPC), and a large number of physicists collaborated in the hardware and software development, and data analysis. Within the collaboration, Valerio had several prestigious roles, including physics co-ordinator and project leader of the RICH group and of the HPC.

In the second half of the 1990s, while continuing to be involved in high-energy particle-physics projects, his interests also turned to cosmic-radiation physics, with the aim of consolidating participation of the Genova team in this field of physics. He led the participation of the group in the AirWatch/EUSO enterprise to build an Earth-orbiting observatory watching from space the extensive air showers produced by cosmic radiation in the atmosphere. He contributed personally to the important role of the group in the project design.

In parallel, approaching the LHC era, he also led the participation of the Genova team in LHCb, where the group contributed substantially to the mechanics, electronics and controls of the RICH detectors.

Valerio also devoted a lot of his time to teaching, ranging from experimental laboratory physics to general physics and astroparticle physics. He was an excellent and demanding teacher, while also keeping himself up-to-date.

His knowledge of and enthusiasm for physics was huge. He was a hard worker, always available whenever needed, either to be on call or participating in a test beam. He was demanding to his collaborators, but no more than he was with himself.

We remember the past, the work he accomplished, and the many physics achievements of Valerio Gracco. All of this remains, and gives strength to our community and, we hope, to his wife, Maja. To her, we express our warmest sympathy.

● *His friends and colleagues.*

Berend Kuiper 1930–2016

Berend Kuiper arrived at CERN at the beginning of 1956, having graduated as an engineer from the prestigious Technical University of Delft in the Netherlands.

At the time, the team led by John Adams and tasked with the construction of the PS was still housed in the barracks next to the Physics Institute of the University of Geneva, only later moving to Meyrin. ▷

Berend was assigned to the Magnet Group, directed by Colin Ramm, and here he joined colleagues Bas de Raad, Renzo Resegotti, Simon van der Meer and, a few months later, Günther Plass.

The project was destined to build the first synchrotron using the alternating-gradient principle. One of its challenges was to produce a magnetic field that was extremely uniform over the entire 628 m circumference of the PS.

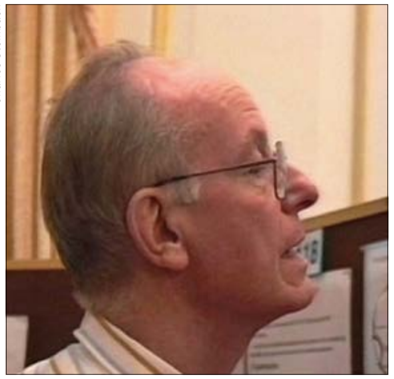
It was therefore the principal task of the group to produce a series of 100 magnets with extreme precision. Berend and his colleagues proceeded to make magnetic measurements.

Today, almost 60 years later, the same magnets are still being used to produce the protons that feed the LHC.

A few years later, with his colleague Günther Plass, Berend constructed the first fast-extraction system for the PS beam.

That was the prelude for construction of the fast-ejection system for the Soviet synchrotron at Serpukhov near Moscow, which at the time was the most powerful machine in the world.

Berend, heading a team of some 40 engineers and technicians from CERN, some accompanied by family members, left for nearly six months in Russia to install this extraction system designed and built at CERN. Taking into account the context of the period, it was a rather exceptional enterprise, because all of the components and tools had to be shipped – from the tiniest screw to the smallest screwdriver.



Charles Steinbach

Berend Kuiper.

The complex, including a beam-transport system and a radiofrequency separator, was CERN's contribution that allowed European physicists to use a machine that did not have an equivalent in the scientific world.

Back at CERN, Berend was one of a handful of staff who contributed to the start of a new European scientific organisation – ESO.

He participated in the project for the first big telescope to be installed in Chile.

At the start of the 1970s, he was put in charge of renovating the PS control system, which had evolved into a heterogeneous assembly of disparate elements (linear accelerators, injectors, main ring, etc) but needed to become the injector for the SPS to-be.

Berend was a polyvalent engineer, and although *a priori* he was not a specialist in these techniques, he built a coherent system with great adaptive potential. The system was capable of integrating the needs of the SPS, followed by the production and accumulation of antiprotons, then LEP and finally the LHC.

In 1985, he launched the International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS), to bring together all high-energy physics labs for discussions on controls.

These conferences have become the touchstone in the area of controls, and Berend was the guest of honour at the 10th conference, held in Geneva in 2005 (the 15th took place in Melbourne in 2015).

With his big lanky silhouette and unshakable optimism, Berend leaves us with the memory of a great engineer, rigorous but always inspiring his collaborators in the face of external constraints, and able to reach set goals under difficult circumstances.

It is with people like him that CERN achieved the scientific successes that put Europe at the forefront of world science.

● *His friends and colleagues.*

David C Rahm 1927–2016

Dave Rahm was an experimental physicist who spent almost his entire career at Brookhaven National Laboratory (BNL), and a significant part of his research was carried out at CERN. He passed away on 20 March.

Dave was fortunate to work with many great scientists. In 1956, he worked on the first bubble chambers for his PhD with Donald Glaser at the University of Michigan. Glaser won the 1960 Nobel Prize in Physics for their work. Dave started working at BNL in 1954. He took leave from BNL in 1960–1961 to work at Saclay in France on bubble chambers with Bernard Gregory, who later became Director-General at CERN. Dave continued contributing to bubble chambers at BNL, for example on the experiment that used the 80" chamber to discovery the Ω^-. He was a visiting scientist at CERN in 1968 and 1969, and worked with Nobel laureate Georges Charpak and Herb Steiner during the development of multiwire proportional chambers (MPCs).

Joseph Rubino, BNL

Dave Rahm.

In the mid-1970s, Dave started working as a member of the Omega Group with Bill Willis and Veljko Radeka on a liquid-argon (LAr) electromagnetic (EM) calorimeter and a lithium-foil radiator (TRD) Xe-proportional wire-chamber transition radiation detector for ISR experiments 806, 807 and 808. Dave also worked with Bob Palmer on superconducting magnets for Isabelle.

In the 1990s, he worked on the RD3 accordion EM LAr calorimeter with Daniel Fournier of Orsay. Dave also worked on the calorimeters of the NA34 and NA44 experiments. In the same years, he also took part in the GEM experiment at the SSC, and carried out a beam test of a liquid-krypton EM calorimeter at CERN. From 1994 until his retirement in 2001, he worked on the ATLAS LAr calorimeters and cathode strip muon chambers.

Dave was an expert in many aspects of detectors, and was very gregarious. We all very much miss the opportunity to consult with him on many subjects.

● *His colleagues at BNL.*

Bruno Zotter 1932–2015

Bruno Zotter passed away on 22 December 2015. He was one of the leading theoretical accelerator physicists who made essential contributions in the recent period of development of particle accelerators after single-particle stability became well understood, and after which the interaction of beams of increasing intensity with themselves and their environment moved into focus.

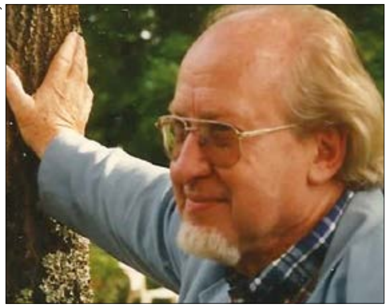
Bruno was the right man at the right time for this. His thesis at the Technische Hochschule in Vienna dealt with the calculation of electromagnetic fields in high-frequency cavities, one of the topics that accompanied him for the rest of his professional career, which after a short stint at the International Patent Office in The Hague, started with work on low-noise travelling-wave tubes in a US government laboratory in New Jersey.

The predictable decline of this line of research due to the emergence of semiconductor applications led him to move into the related particle-accelerator field at CERN's ISR, where the importance of high-intensity beam phenomena had already been realised during the construction phase.

Bruno refined existing models and developed new ones, favouring an analytical approach in his many contributions that laid the foundations for the steady increase in circulating proton-beam current up to 40 A, typically.

He had a propensity for theory and mathematics. A sign of this is his work on the summation of infinite algebraic and Fourier series, but he also participated in experimental work in parallel to advancing theoretical understanding. This included topics as diverse as space-charge phenomena, beam–beam effects, and definition and determination of the accelerator coupling impedance characterising the potential of the adverse interaction of a vacuum chamber with the beam, depending on the frequency spectrum of the latter. He also applied his insight when the Super Proton Synchrotron became affected by high-intensity effects after the running-in phase, and he actively participated in CERN's studies of the options for a post-ISR accelerator at the high-energy frontier, the most prominent examples being LEP, the LHC and CLIC.

LEP offered an ideal playground for Bruno, in particular, the interaction of the very short, intense electron bunches with the vacuum enclosure and the long array of RF cavities. An impressive set of publications illustrates his tenacious investment, where he put the enormous increase in computer power to good use to refine the comprehensive simulations of collective effects. Although an appreciated lecturer at accelerator schools and workshops, he also found time to summarise the main part of his work in the book *Impedances and Wakes in High-Energy Accelerators*, written with his friend Sam Kheifets from SLAC.



Zotter family

Bruno Zotter.

His competence, steady focus on high-level electrodynamics-related accelerator physics, and an extraordinary gift for tutoring, attracted an amazing number of students and visitors to work with him. Many visitors from abroad remember with gratitude his generous help in overcoming bureaucratic hurdles and getting around in the Geneva area. His colleagues remember him as an open but independently minded, often sarcastic, discussion partner. He was known for perseveringly pondering over problems seemingly too difficult or tedious for the rest of us, but tricky and, therefore, interesting enough to be worth his investment. After some gestation, he would discreetly put his solution on the table. He stayed active in the field, even after his retirement in 1997, remaining a valued tutor, discussion partner and co-author, with a vivid interest in the latest developments and measurement results obtained in the CERN accelerators continuously being pushed for higher performance.

Having enjoyed over the years his competence and his benevolent, unassuming attitude, we are proud to have had the chance to work with him, be it as colleague, visitor or student.

● *His friends and colleagues.*

Recruitment

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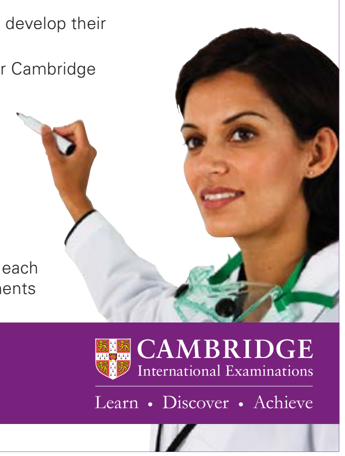

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Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

eli Nuclear Physics

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ELI-NP is a complex facility which will host two state-of-the-art machines of high performances:

- A very high intensity laser with two 10 PW lasers;
- A very high intensity laser with two 10 PW lasers; A very intense, brilliant γ beam, very low bandwidth, with E γ until 19 MeV, which is obtained by incoherent Compton back scattering of a laser light off an intense electron beam (Ee> 700 MeV) produced by a warm LINAC.

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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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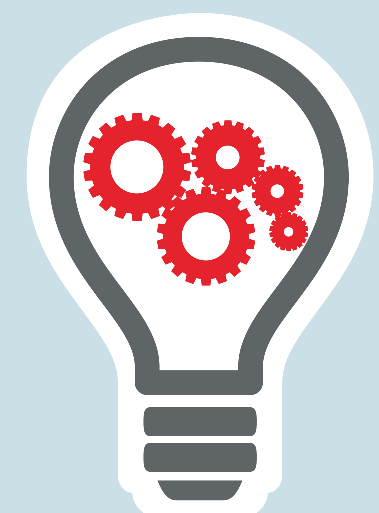
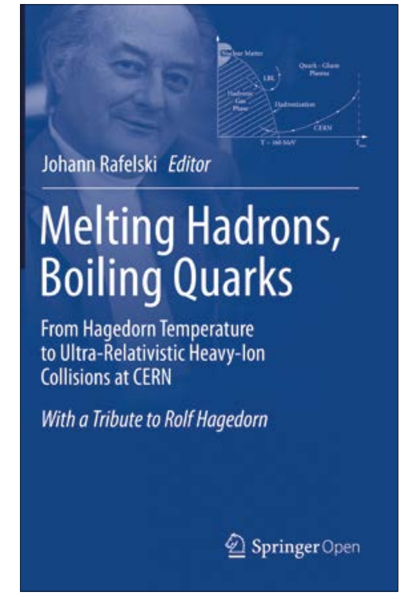


The jobs site for physics and engineering

Bookshelf

Compiled by Virginia Greco, CERN

Melting Hadrons, Boiling Quarks: From Hagedorn Temperature to Ultra-Relativistic Heavy-Ion Collisions at CERN. With a Tribute to Rolf Hagedorn
By Johann Rafelski (ed.)
Springer
Also available at the CERN bookshop



The statistical bootstrap model (SBM), the exponential rise of the hadron spectrum, and the existence of a limiting temperature as the ultimate indicator for the end of ordinary hadron physics, will always be associated with the name of Rolf Hagedorn. He showed that hadron physics contains its own limit, and we know today that this limit signals quark deconfinement and the start of a new regime of strong-interaction physics.

This book is edited by Johann Rafelski, who was a long-time collaborator with Hagedorn and took part in many of the early conceptual developments of the SBM. It may perhaps be best characterised by pointing out what it is not. It is not a collection of review articles on the physics of the SBM and related topics, which could be given to newcomers as an introduction to the field. It is not a collection of reprints to summarise the well-known work of Hagedorn on the SBM, and it is also not a review of the history of this theory. Actually, in this thoughtfully composed volume, aspects of all of the above can be found. However, it goes beyond all of them.

Including a collection of earlier articles on Hagedorn's work, as well as new invited articles by a number of authors, and original work by Hagedorn himself, along with comments and reprinted material of Rafelski, the book clearly gains its value through the unexpected. It provides an English translation of an early overview article by Hagedorn written in German, as well as unpublished material that may even be new to well-informed practitioners in the field. As such, it presents the transcript of the draft minutes of the 1982 CERN Scientific Policy Committee (SPC) Meeting, at which Maurice Jacob, then head of the CERN Theory Division, reported about the 1982 Bielefeld workshop on the planned experimental exploration of ultra-relativistic heavy-ion collisions, setting the scene for the forthcoming experimental programme at CERN's SPS.

The book is split into three parts.

Part I, "Reminiscences: Rolf Hagedorn and Relativistic Heavy Ion Research", contains a collection of 15 invited articles from colleagues of Hagedorn who witnessed the initial stages of his work, leading to formulation of the SBM theory in the early 1960s, and its decisive contribution in expressing the need for an experimental research programme in the early 1980s: Johann Rafelski, Torleif Ericson, Maurice Jacob, Luigi Sertorio, István Montvay and Tamás Biro, Krzysztof Redlich and Helmut Satz, Gabriele Veneziano, Igor Dremin, Ludwik Turko, Marek Gaździcki and Mark Gorenstein, Grażyna Odyniec, Hans Gutbrod, Berndt Müller, and Emanuele Quercigh. These contributions draw a lively picture of Hagedorn, both as a scientist and as a man, with a wide range of interests spanning high-energy physics to music. They also illustrate the impact of Hagedorn's work on other areas of physics.

Part II, "The Hagedorn Temperature", contains a collection of original work by Hagedorn. In this section, the scientist's seminal publication that appeared in 1964 in *Nuovo Cimento* is deliberately not included; however, publications that emphasise the hurdles that had to be overcome to get to the SBM, and the interpretation Hagedorn offered on his own work in later years, are presented. This is undoubtedly of great interest to those familiar with the physicist's work but also curious about its creation and growth.

Part III, "Melting Hadrons, Boiling Quarks: Heavy Ion Path to Quark–Gluon Plasma", puts the work of Hagedorn into the context of the discussion of a possible relativistic heavy-ion programme at CERN that took place in the early 1980s. It starts with his thoughts about a possible programme of this kind, presented at the workshop on future relativistic heavy-ion experiments, held at the Gesellschaft fuer Schwerionenforschung (GSI). It also includes the draft minutes of the 1982 CERN SPC meeting, and some early works on strangeness production as an indicator for quark–gluon plasma formation, as put forward after many years by Rafelski.

The book is undoubtedly an ideal companion to all those who wish to recall the birth of one of the main areas of today's concepts in high-energy physics, and it is definitely a well-deserved credit to one of the great pioneers in their development.

● *Frithjof Karsch, Bielefeld University, Germany.*

Unifying Physics of Accelerators, Lasers and Plasmas
By Andrei Seryi
CRC Press

Particle accelerators have led to remarkable discoveries and enabled scientists to develop and test the Standard Model of particle physics. On a different scale, accelerators have many applications in technology, materials science, biology, medicine (including cancer therapy), fusion research, and industry. These machines are used to accelerate electrons, positrons or ions to energies in the range of 10 s of MeV to 10 s of GeV. Electron beams are employed in generating intense X-rays in either synchrotrons or free-electron lasers, such as the Linear Collider Light Source at Stanford or the XFEL in Hamburg, for a range of applications.

Particle accelerators developed over the last century are now approaching the energy frontier. Today, at the terascale, the machines needed are extremely large and costly. The size of a conventional accelerator is determined by the technology used and final energy required. In conventional accelerators, radiofrequency microwave cavities support the electric fields responsible for accelerating charged particles. Plasma-based particle accelerators, driven by either lasers or particle beams, are showing great promise as future replacements, primarily due to the extremely large accelerating electric fields they can support, leading to the possibility of compact structures. These fields are supported by the collective motion of plasma electrons, forming a space-charge disturbance moving at a speed slightly ▷

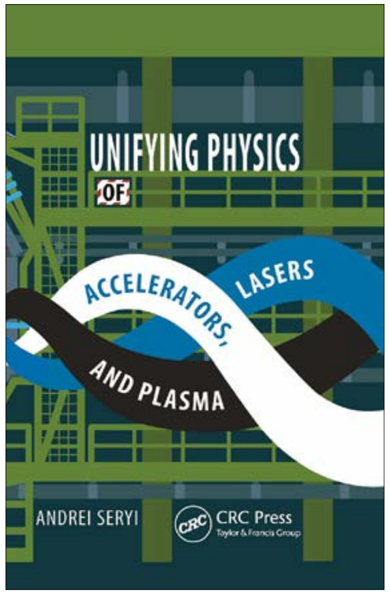
below the speed of light in a vacuum. This method is commonly known as plasma wakefield particle acceleration.

Plasma-based accelerators are the brainchild of the late John Dawson and colleagues at the University of California, Los Angeles, and is a topic that is being investigated worldwide with a great deal of success. In the 1980s, John David Lawson asked: "Will they be a serious competitor and displace the conventional 'dinosaur' variety?" This is still a valid question, with plasma accelerators already producing bright X-ray sources through betatron radiation at the lower energy scale, and there are plans to create electron beams that are good enough to drive free-electron lasers and future colliders. The topic and application of these plasma accelerators have seen rapid progress worldwide in the last few years, with the result that research is no longer limited to plasma physicists, but is now seeing accelerator and radiation experts involved in developing the subject.

The book fills a void in the understanding of accelerator physics, radiation physics and plasma accelerators. It is intended to unify the three areas and does an excellent job. It also introduces the reader to the theory of inventive problem solving (TRIZ), proposed by Genrikh Altshuller in the mid 20th century to aid in the development of successful patents. It is argued that plasma accelerators fall into the prescription of TRIZ, however, it could also be argued that knowledge, imagination, creativity and time were all that was needed. The concept of TRIZ is outlined, and it is shown how it can be adopted for scientific and engineering problems.

The book is well organised. First, the fundamental concepts of particle motion in EM fields, common to accelerators and plasmas, are presented. Then, in chapter 3, the basics of synchrotron radiation are introduced. They are discussed again in chapter 7, with a potted history of synchrotrons together with Thomson and Compton scattering. It would make sense to have the history of synchrotrons in the earlier chapter.

The main topic of the book, namely the synergy between accelerators, lasers and plasma, is covered in chapter 4, where a comparison between particle-beam bunch compression and laser-pulse compression is made. Lasers have the additional advantage of being amplified through a non-linear medium amplification using chirped-pulse amplification (CPA). This method, together with optical parametric amplification, can push the laser pulses to even higher intensities.



The basics of plasma accelerators are covered in chapter 6, where simple models of these accelerators are described, including laser- and beam-driven wakefield accelerators. However, only the lepton wakefield drivers, not the proton one used for the AWAKE project at CERN, are discussed. This chapter also describes general laser plasma processes, such as laser ionisation, with an update on the progress in developing laser peak intensity. The application of plasma accelerators as a driver of free-electron lasers is covered in chapter 8, describing the principles in simple terms, with handy formulae that can be easily used. Proton and ion acceleration are covered in chapter 9, where the reader is introduced to Bragg scattering, the DNA response to radiation and proton-therapy devices, ending with a description of different plasma-acceleration schemes for protons and ions. The basic principles of the laser acceleration of protons and ions by sheaths, radiation pressure and shock waves are briefly covered. The penultimate chapter discusses beam and pulse manipulation, bringing together a fairly comprehensive but brief introduction to some of the issues regarding beam quality: beam stability, cooling and phase transfer, among others. Finally, chapter 11 looks at inventions and innovations in science, describing how using TRIZ could help. There is also a discussion on bridging the gap between initial scientific ideas and experimental verification to commercial applications, the so-called "Valley of Death", something that is not discussed in textbooks but is now more relevant than ever.

This book is, to my knowledge, the first to bridge the three disciplines of accelerators, lasers and plasmas. It fills a gap in the market and helps in developing a better understanding of the concepts used in the quest to build compact accelerators. It is an inspiring read that is suitable for both undergraduate and graduate students, as well as researchers in the field of plasma accelerators. The book concentrates on the principles, rather than being heavy on the mathematics, and I like the fact that the pages have wide margins to take notes.

● *Robert Bingham, University of Strathclyde, Glasgow.*

Books received

Principles of Radiation Interaction in Matter and Detection (4th edition)

By C Leroy and P G Rancoita
World Scientific
Also available at the CERN bookshop

Based on a series of lectures given to undergraduate and graduate students over several years, this book provides a comprehensive and clear presentation of the physics principles that underlie radiation detection.

To detect particles and radiation, the effects of their interaction with matter, when passing through it, have to be studied. The development of increasingly sophisticated and precise detectors has made possible many important discoveries and measurements in particle and nuclear physics.

The book, which has reached its 4th edition thanks to its good reception by readers, is organised into two main parts. The first is dedicated to an extensive treatment of the theories of particle interaction, of the physics and properties of semiconductors, as well as of the displacement damage caused in semiconductors by traversing radiation.

The second part focuses on the techniques used to reveal different kinds of particles, and the relative detectors. Detailed examples are presented to illustrate the operation of the various types of detectors. Radiation environments in which these mechanisms of interaction are expected to take place are also described. The last chapter is dedicated to the application of particle detection to medical physics for imaging. Two appendices and a very rich bibliography complete the volume.

This latest edition of the book has been fully revised, and many sections have been extended to give as complete a treatment as possible of this developing field of study and research. Among other things, this edition provides a treatment of Coulomb scattering on screened nuclear potentials resulting from electrons, protons, light ions and heavy ions, which allows the corresponding non-ionising energy-loss (NIEL) doses deposited in any material to be derived.

Physics and Mathematical Tools: Methods and Examples

By A Alastuey, M Clusel, M Magro and P Pujol
World Scientific

This volume presents a set of useful mathematical methods and tools that can be used by physicists and engineers for a wide range of applications. It comprises four chapters, each structured in three parts: first, the general characteristics of the methods are described, then a few examples of applications in different fields are given, and finally a number of exercises are proposed and their solutions sketched.

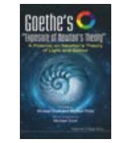
The topics of the chapters are: analytical properties of susceptibilities in linear response theory, static and dynamical Green functions, and the saddle-point method to estimate integrals. The examples and exercises included range from classical mechanics and electromagnetism to quantum mechanics, quantum field theory and statistical physics. In this way, the general mechanisms of each method are seen from different points of view and therefore made clearer.

The authors have chosen to avoid derivations that are too technical, but without sacrificing rigour or omitting the mathematics behind the method applied in each instance. Moreover, three appendices at the end of the book provide a short overview of some important tools, so that the volume can be considered self-contained, at least to a certain extent.

Intended primarily for undergraduate and graduate physics students, the book could also be useful reading for teachers, researchers and engineers.

Goethe's 'Exposure of Newton's Theory': A Polemic On Newton's Theory of Light and Colour

By M Duck and M Petry (translators), with an introduction by M Duck
Imperial College Press



Johann Wolfgang von Goethe is undoubtedly famous for his literary work, however it is not widely known that he was also fond of science and wrote a polemic text on Newton's theory of light and colours, which he did not accept. He tried to reproduce the experiment that Newton used to demonstrate that light is heterogeneous but, according to what Goethe himself wrote, he could not obtain the same results.

The book provides an English translation of Goethe's polemic, completed by an introduction in which a possible justification of this resistance by Goethe to Newton's theory is given. Many suppositions have been offered: maybe he was prevented from reasoning clearly by a psychological refusal, or perhaps he was simply unable to understand Newton's experiments and reproduce them well.

In the introduction to this volume, the editor suggests that the reason for Goethe's stubborn attitude, which made him preserve his belief that light is immutable and that colours result from the interaction of light and darkness, is theological. Goethe believed in the spiritual nature of light, and he could not conceive it as being anything other than simple, immutable and unknowable.

This book, addressed to historians of science, philosophers and scientists, will allow the reader to discover Goethe's polemic against Newton and to obtain new insights into the multifaceted personality of the German poet.

Superconductivity: A New Approach Based on the Bethe–Salpeter Equation in the Mean-Field Approximation

By G P Malik
World Scientific

This specialist book on superconductivity proposes an approach to the topic, based on the Bethe–Salpeter equations, that allows a description of the characteristics of superconductors (SCs) that are considered unconventional.

The basic theory of superconductivity, elaborated in 1957 by Bardee, Cooper and Schrieffer (BCS), which was worth a Nobel prize to its "fathers", proves itself to be inadequate in describing the behaviour of high-temperature superconductors (HTSCs) – materials that have a critical temperature higher than 30 K. In this monographic work, the author shows how a generalisation of the BCS equations enables the superconducting features of non-elemental SCs to be addressed in the manner that elemental SCs are dealt with in the original theory. This generalisation is achieved by adopting the "language" of Bethe–Salpeter.

It was the intention of the author to give an essential treatment of the topic, without including material that is not strictly necessary, and to keep it reasonably simple and accessible. Nevertheless, quantum field theory (QFT) and its finite-temperature version (FTFT) are used to derive some equations in the text, so a basic knowledge of them is needed to follow the dissertation.

The Unknown as an Engine for Science: An Essay on the Definite and the Indefinite

By H J Pirner
Springer

This essay is the result of interdisciplinary research pursued by the author, a theoretical physicist, on the concept of the indefinite and its expression in different fields of human knowledge. Examples are taken from the natural sciences, mathematics, economics, neurophysiology, history, ecology and philosophy.

Physics and mathematics often deal with the indefinite, but they try to reduce it, to reach a theory that would be able to explain everything or to allow reliable predictions. Indefiniteness is strictly connected to uncertainty, which is a component of many analyses of complex processes, so the concept of the indefinite can also be found in economics and risk assessments.

The author explains how uncertainty is present in the humanities. For example, historians might have to work on just a few indeterminate sources and connect the dots to reconstruct a story. Uncertainty is also inherent to our memory – we tend to forget, and lose and confuse details. Psychologists understand that forgetting permits new ideas to form, while strong memories would prevent them from emerging.

The book shows how uncertainty and indefiniteness define the border of our understanding and, at the same time, are engines for research and for continuous attempts to push back that limit.

The first part focuses on information and how it helps to reduce indefiniteness. New elements must be combined with existing parts to be integrated in the knowledge system, so that maximum profit can be taken from the new information. The author tries to quantify the value of information on the basis of its ability to reduce uncertainty.

The second part of the book presents a number of methods that can be used to handle indefiniteness, which come from fuzzy logic, decision theory, hermeneutics, and semiotics. An interdisciplinary approach is promoted because it enables bridges to be built between the different fields among which our knowledge is dispersed.

CERN Courier Archive: 1973

A look back to CERN Courier vol. 13, June 1973, compiled by Peggie Rimmer

Detection techniques

Scanning tables at CERN

All image credits: CERN

Studying bubble-chamber film on one of the MILADY scanning tables, where sufficient information is collected to be able to tell the Hough–Powell Device (HPD) measuring machines where to look. The operator picks out events of interest on the film and records details such as vertex position and a few track co-ordinates on magnetic tape.

An HPD, which carries out precise measurement, automatically without human intervention, on the film previously scanned on a MILADY table. An optical-mechanical spot sweeps over the film and full track co-ordinates are transmitted to a computer.

An LSD (or Spiral Reader) measuring machine, which receives film previously scanned on Shivamatic scanning tables. An operator is involved in the measurement process to set the machine on the vertex of the event to be measured. A slit, moving in a spiral, then searches the film and sends track information to a computer.

A SAAB scanning table, designed to cope with the special film from the heavy liquid bubble chamber, Gargamelle. The chamber volume is covered by separate cameras and separate images can be projected. Measurement is carried out online with a computer.

ERASME, the latest scanning and measuring system at CERN. It combines both stages and allows operator intervention in the measurement process to an extent that has not been possible before. ERASME is designed to handle film from the Big European Bubble Chamber (BEBC).

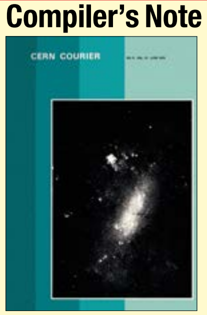
Photographs of tracks made by high-energy charged particles passing through a bubble chamber constitute one of our most direct means to access the sub-nuclear world. No other detection technique gives such a satisfying portrayal of particle interactions.

The full measurement of an "event" – track images recorded on stereoscopic photographs – consists of geometrical and kinematic analyses, determining the number, type, momentum and energy of the particles in the interaction. This involves reconstructing the spatial geometry of the tracks and applying the laws of conservation of energy and momentum to the initial and final particles. First, however, the film needs to be examined (scanned) to see whether any events of interest occurred.

Scanning tables consist, essentially, of an optical-projection system. They allow an operator to select interesting events and to record data (on magnetic tape, for example) to be fed to measuring devices. Scanning can be difficult because what is seen of a track on the film does not often, by itself, identify the particle that caused it, and because uncharged particles leave no tracks and yet can be an essential part of the information required. It is a relatively straightforward operation for a human being. However, it has proved very difficult to implement an exclusively automated process.

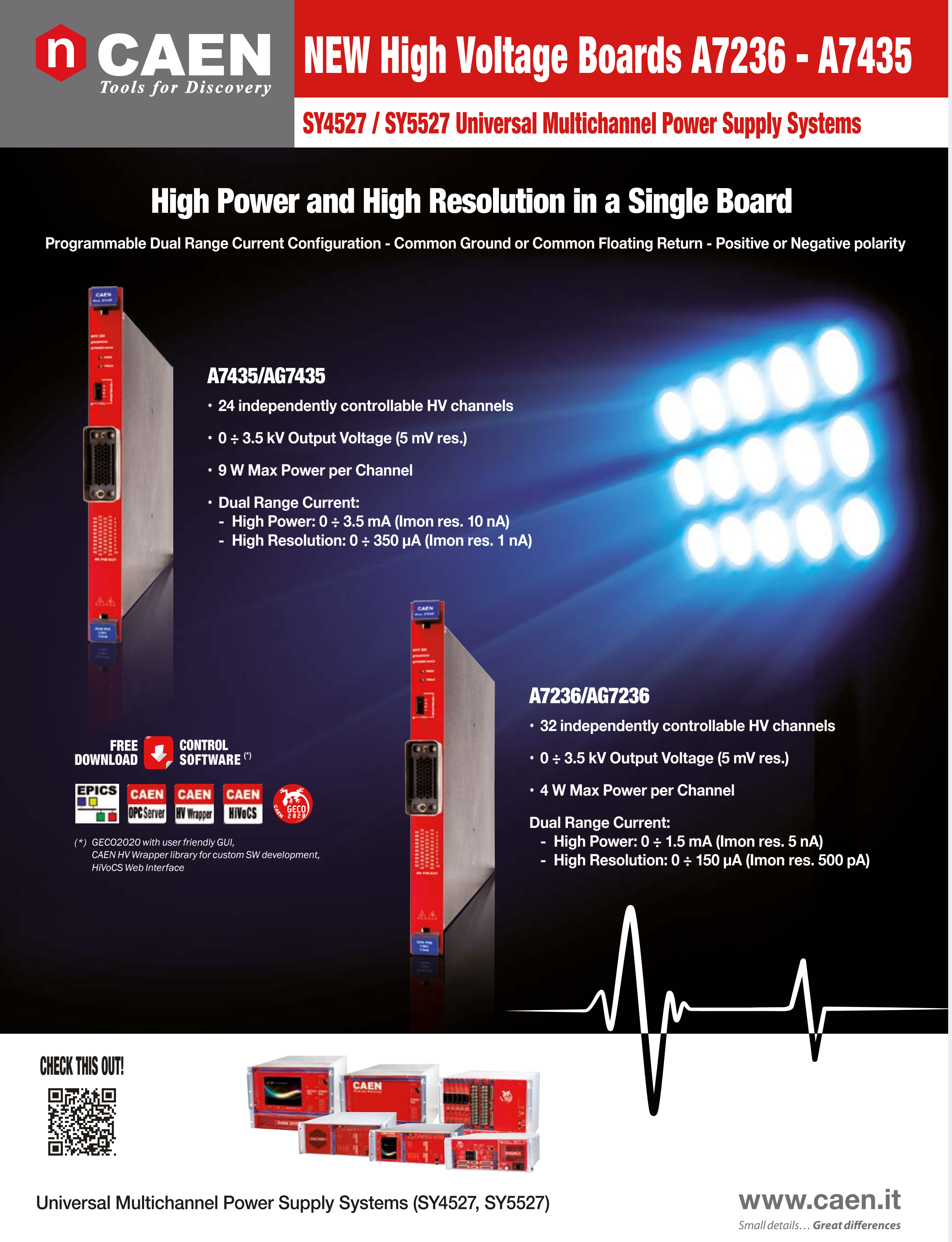
● Compiled from texts on pp186–188.

Compiler's Note



A la recherche du temps perdu!

Mechanical gadgets are intrinsically fascinating – witness the popular appeal of the kinetic art of Swiss sculptor Jean Tinguely – and physicists with an engineering bent, a flair for computing and unbridled ingenuity found the challenge of constructing scanning machines irresistible. Given the dearth of female physicists in labs at the time and the fact that most scanners were "girls", computer-aided data analysis often gave rise to computer-aided dating. Many a romance began in the purlieu of a scanning room, sometimes blossoming into a lifelong relationship, sometimes ending in heartbreak. There must be several senior readers who can confirm this!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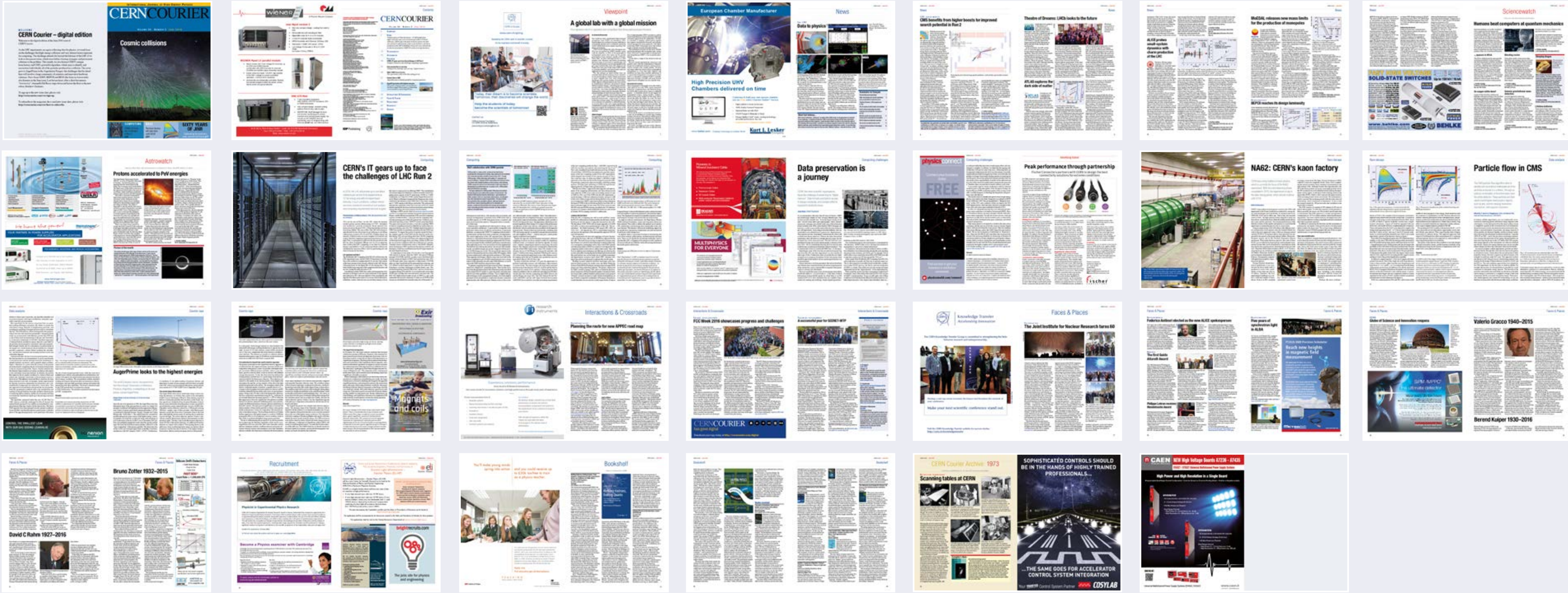

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Volume 56 Number 5 June 2016

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