WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the January/February 2016 issue of *CERN Courier*.

Featuring a beautiful cover image taken by one of the 200 photographers who participated in the 2015 edition of the Particle Physics Photowalk, this issue invites the reader to discover what's in store for CAST, and how XENON is preparing to become the most sensitive experiment for direct dark-matter searches. In parallel, we take you on a trip into the future at the ATLAS and CMS experiments, which are already working hard to get ready for the High-Luminosity phase of the LHC (HL-LHC). Back to the present, we feature a story on the recent record broken by the LHC in its configuration as a lead-ion collider, and an article about the innovative extraction system successfully tested at the PS. Last but not least, the feature about hadrontherapy confirms how particles are effectively helping us to fight cancer.

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EDITOR: ANTONELLA DEL ROSSO, CERN
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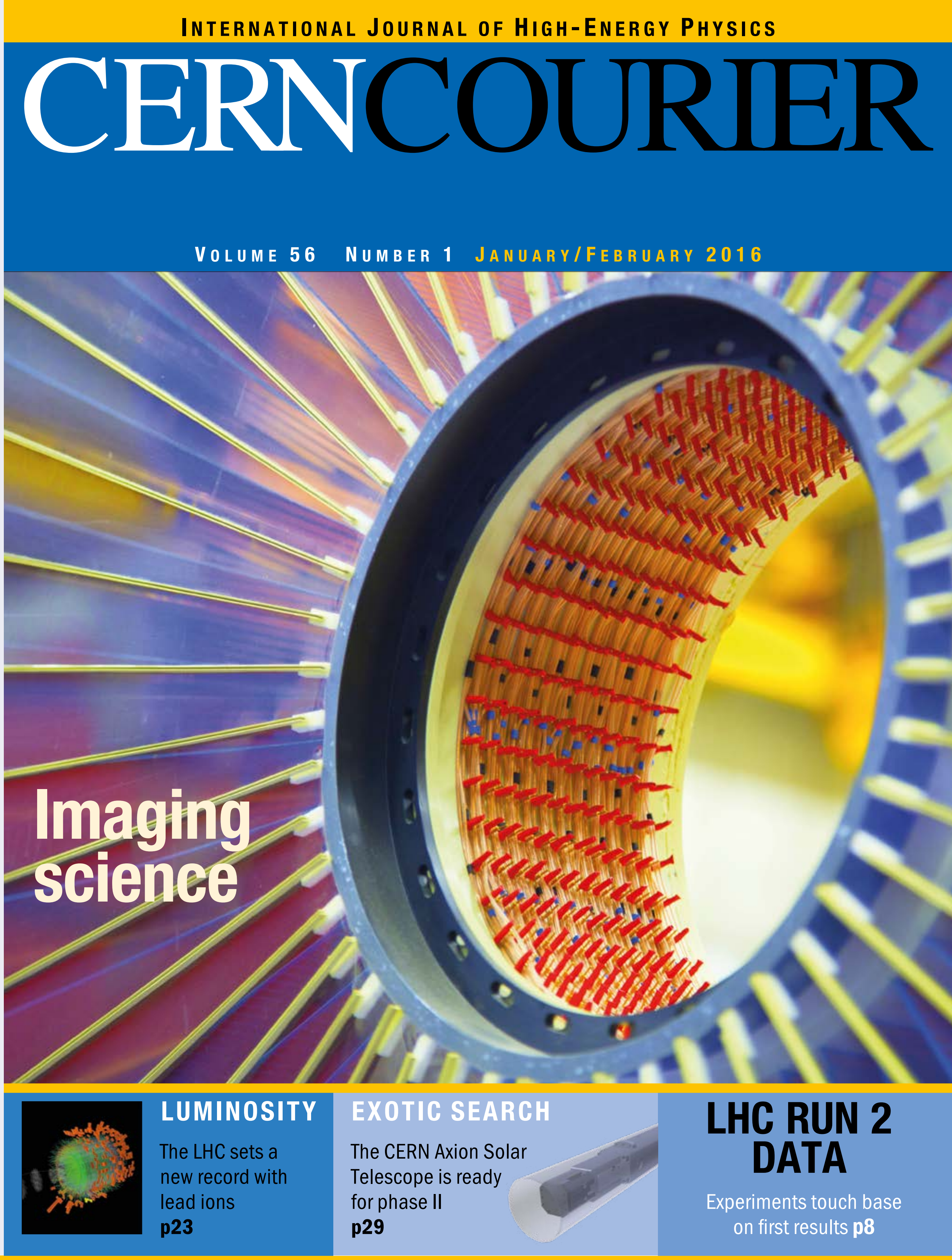

Contents

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

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Editor Antonella Del Rosso
Books editor Virginia Greco
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 76 69070
Web cerncourier.com

Advisory board Luis Alvarez-Gaume, Peter Jenni, Christine Sutton, Claude Amsler, Roger Bailey, Philippe Bloch, Roger Forty

Laboratory correspondents:
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IOP Publishing Ltd, Temple Circus, Temple Way, Bristol BS1 6HG, UK
Tel +44 (0)117 929 7481

Publisher Susan Curtis
Production editor Lisa Gibson
Technical illustrator Alison Tovey
Group advertising manager Chris Thomas
Advertisement production Katie Graham
Marketing & Circulation Angela Gage

Head of B2B & Marketing Jo Allen
Art director Andrew Giaquinto

Advertising
Tel +44 (0)117 930 1026 (for UK/Europe display advertising)
or +44 (0)117 930 1164 (for recruitment advertising);
E-mail: sales@cerncourier.com; fax +44 (0)117 930 1178

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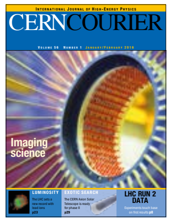


On the cover: Detail of the forward radial wire chamber forming part of the H1 detector that took data at the HERA collider at DESY (Deutsches Elektronen-Synchrotron) from 1992 to 2007. (Image credit: Rosemary Wilson.)

Viewpoint

Science: a model for collaboration?

Two events in November featured CERN as a possible model for building trust across frontiers.

Maurizio Bona/CERN

CERN's seat at the United Nations General Assembly. CERN was granted the status of Observer in 2012.

By Maurizio Bona, CERN, Michel Spiro, CNRS and former president of CERN Council, and Herwig Schopper, WAAS and former CERN Director-General

Today, science, technology and innovation are among the most powerful forces driving social change and development. However, what is the actual role that a fundamental science laboratory like CERN can have when it comes to designing creative strategies to strengthen public goods in society?

With a view to contribute to the realisation of the 2030 Agenda for Sustainable Development, which was approved in September by the United Nations Member States, the United Nations Office at Geneva (UNOG) hosted a one-day symposium organised in collaboration with CERN and with the support of Switzerland and France, in their capacity as CERN host states.

Air, water, biodiversity, education, knowledge, access to the Internet, peace and welfare: these public goods can be preserved only with the involvement of all stakeholders. At the event, policy makers, diplomats, ambassadors, scientists, intellectuals, epistemic associations, representatives of international governmental and non-governmental organisations, and civil-society representatives explored the value of CERN as a model for co-operation.

CERN is a recognised example of peaceful international collaboration based on transparency, openness and inclusion. The invention of the World Wide Web is emblematic of the spirit that drives advances in basic science, which enable open innovation and education, and connect the worldwide community through shared values. A typical scientific community is self-organised and able to share the infrastructure needed by all. The centrality of knowledge (scientific arguments in global policy), long-term thinking, agile project and risk management, even under harsh conditions of unpredictability, smart governance and social networking, big data, considering alternative scenarios – these are all features and "goods" that belong to the scientific world but that also play a role in different contexts.

Necessary compromises

The UN world has an impressive infrastructure that ensures global governance, including the UN Secretariat, the General Assembly and the Economic and Social Council. These structures permitted a global consultation process that led to the formulation and adoption of the 2030 agenda, with its 17 sustainable-development goals and 169 targets. The complexity of the governance of such an important process is the result of necessary compromises. It is everybody's duty to make it efficient and capable of addressing the difficult global challenges the world is now facing. CERN can contribute by explaining its functioning model and by providing, when needed, direct input on science, technology and education.

About one week after the symposium at UNOG, CERN and the World Academy of Arts and Sciences (WAAS) hosted another one-day conference to discuss the topic of "Science, technology, innovation and social responsibility". The event was organised under the auspices of UNOG and saw the participation of the EPS and some Geneva-based international organisations, including the International Labour Office (ILO), World Health Organization (WHO), United Nations Institute for Training and Research (UNITAR), World Meteorological Organization (WMO), International Organization for Standardization (ISO) and World Intellectual Property Organization (WIPO). The specific objective was to survey the potential impact of scientific and technological innovation in different fields on the progress of humanity, independent of political boundaries or limits, whether spiritual or physical.

Lively discussions took place around the topic of social responsibility that comes with self-governance of the scientific community. Obviously, this is of particular relevance when it comes to dealing with health-related issues. In particular, fighting certain types of disease requires a strong collaboration between the scientific community, governments and companies producing vaccines. But scientific and technological developments also have a huge impact on the labour market. In this respect, science and society are not sufficiently synchronised, and future planning needs to be better co-ordinated. In fields such as meteorology, scientific co-operation is accepted as essential, because without it every country would lose: predictions and warnings are possible only with global exchange of data.

All of these initiatives show the importance of keeping the dialogue between scientists, diplomats, policy makers, business experts and the public at large constantly alive. Since the very beginning of the scientific venture that gave birth to CERN, people from different cultures, religions and political opinions could speak the common language of science. In this scenario, peace appears as a natural consequence and becomes an attitude. More than 60 years of peaceful and fruitful collaboration are the tangible result that science can indeed serve as a successful model to follow.

A video recording of "The CERN model, United Nations and Global Public Goods: addressing global challenges" is available at webtv.un.org/watch/panel-1-the-cern-model-science-education-and-global-public-good-cern-unog-symposium-2015/4590293913001. A video recording of the "Science, technology, innovation and social responsibility" conference is available at cds.cern.ch/record/2103652.

News

LHC

A year of challenges and successes

CERN

LHC Page 1 gives live information on the activity at the LHC. The beam operation for 2015 finished on 14 December and it is scheduled to restart in April 2016.

2015 was a tough year for CERN's accelerator sector. Besides assuring delivery of beam to the extensive non-LHC facilities such as the AD, ISOLDE, nTOF and the North Area, many teams also had to work hard to bring the LHC back into business after the far-reaching efforts of the long shutdown.

At the end of 2014 and start of 2015, the LHC was cooled down sector by sector and all magnet circuits were put through a campaign of powering tests to fully re-qualify everything. The six-month-long programme of rigorous tests involved the quench-protection system, power converters, energy extraction, UPS, interlocks, electrical quality assurance and magnet-quench behaviour. The powering-test phase eventually left all magnetic circuits fully qualified for 6.5 TeV.

Some understandable delay was incurred during this period and three things can be highlighted. First was the decision to perform *in situ* tests of the consolidated splices – the so called Copper Stabilizer Continuity Measurement (CSCM) campaign. These were a success and provided confirmation of the quality work done during the shutdown.

Second, dipole-quench re-training took some time – in particular, the dipoles of sector 45 proved a little recalcitrant and reached the target 11,080 A after some 51 training quenches.

Third, after an impressive team effort co-ordinated by the machine-protection team to conceive, prototype, test and deploy the system, a small piece of metallic debris that was causing an earth fault in a dipole in sector 34 was successfully burnt away on the afternoon of Tuesday 31 March.

First beam 2015 went around the LHC on Easter Sunday, 5 April. Initial commissioning delivered first beam at 6.5 TeV after five days and first "stable beams" after two months of careful set up and validation.

Ramp up

Two scrubbing runs delivered good beam conditions for around 1500 bunches per beam, after a concerted campaign to re-condition the beam vacuum. However, the electron cloud, anticipated to be more of a problem with the nominal 25 ns bunch-spacing beam, was still significant at the end of the scrubbing campaign.

The initial 50 ns and 25 ns intensity ramp-up phase was tough going and had to contend with a number of issues, including earth faults, unidentified falling objects (UFOs), an unidentified aperture restriction in a main dipole, and radiation affecting specific electronic components in the tunnel. Although operating the machine in these conditions was challenging, the teams succeeded in colliding beams with 460 bunches and delivered some luminosity to the experiments, albeit with poor efficiency.

The second phase of the ramp-up following the technical stop at the start of September was dominated by the electron cloud and the heat load that it generates in the beam screens of the magnets in the cold sectors. The challenge was then for cryogenics, which had to wrestle with transients and operation close to the cooling-power limits. The ramp-up in number of bunches was consequently slow but steady, culminating in a final figure for the year of 2244 bunches per beam.

Importantly, the electron cloud generated during physics runs at 6.5 TeV serves to slowly condition the surface of the beam screen and so reduce the heat load at a given intensity. As time passed, this effect opened up a margin for the use of more bunches. Cryogenics operations were therefore kept ▷

Sommaire en français

close to the acceptable maximum heat load, and at the same time in the most effective scrubbing regime.

The overall machine availability is a critical factor in integrated-luminosity delivery, and remained respectable with around 32% of the scheduled time spent in stable beams during the final period of proton–proton physics from September to November. By the end of the 2015 proton run, 2244 bunches per beam were giving peak luminosities of $5.2\times10^{33}\,cm^{-2}s^{-1}$ in ATLAS and CMS, with both being delivered an integrated luminosity of around $4\,fb^{-1}$ for the year. Levelled luminosity of $3\times10^{32}\,cm^{-2}s^{-1}$ in LHCb and $5\times10^{30}\,cm^{-2}s^{-1}$ in ALICE was provided throughout the run.

Also of note were dedicated runs at high β* for TOTEM and ALFA. These provided important data on elastic and diffractive scattering at 6.5 TeV, and interestingly a first test of the CMS-TOTEM Precision Proton Spectrometer (CT-PPS), which aims to probe double-pomeron exchange.

As is now traditional, the final four weeks of operations in 2015 were devoted to the heavy-ion programme. To make things more challenging, it was decided to include a five-day proton–proton reference run in this period. The proton–proton run was performed at a centre-of-mass energy of 5.02 TeV, giving the same nucleon–nucleon collision energy as that of both the following lead–lead run and the proton–lead run that took place at the start of 2013.

Good intensities

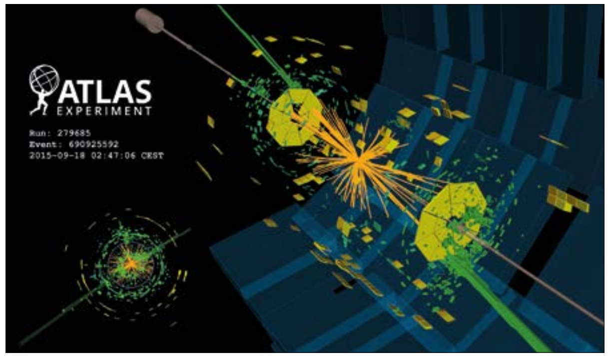
Both the proton reference run and ion run demanded re-set-up and validation of the machine at new energies. Despite the time pressure, both runs went well and were counted a success. Performance with ions is strongly dependent on the beam from the injectors (source, Linac3, LEIR, PS and SPS), and extensive preparation allowed the delivery of good intensities, which open the way for delivery of a levelled design luminosity of $1\times10^{27}\,cm^{-2}s^{-1}$ to ALICE and more than $3\times10^{27}\,cm^{-2}s^{-1}$ to ATLAS and CMS. For the first time in an ion–ion run, LHCb also took data following participation in the proton–lead run. Dedicated ion machine development included crystal collimation and quench-level tests, the latter providing important input to future ion operation in the HL-LHC era.

The travails of 2015 have opened the way for a full production run in 2016. Following initial commissioning, a short scrubbing run should re-establish the electron cloud conditions of 2015, allowing operation with 2000 bunches and more. This figure can then be incrementally increased to the nominal 2700 as conditioning progresses. Following extensive machine development campaigns in 2015, the β* will be reduced to 50 cm for the 2016 run. Nominal bunch intensity and emittance will bring the design peak luminosity of $1\times10^{34}\,cm^{-2}s^{-1}$ within reach. Reasonable machine availability and around 150 days of 13 TeV proton–proton physics should allow the $23\,fb^{-1}$ total delivered to ATLAS and CMS in 2012 to be exceeded.

LHC EXPERIMENTS

Latest ATLAS results with 13 TeV proton–proton collisions at the LHC

Since the first ATLAS results from LHC Run 2 were presented at this summer's conferences (EPS-HEP 2015 and LHCP 2015) with an amount of data corresponding to an integrated luminosity of approximately $80\,pb^{-1}$, the LHC has continued to ramp up in luminosity. The maximum instantaneous luminosity for 2015 was $5\times10^{33}\,cm^{-2}s^{-1}$, which already approaches the Run 1 record of $7\times10^{33}\,cm^{-2}s^{-1}$. ATLAS recorded more than $4\,fb^{-1}$ in 2015, with different physics analyses using from 3.32 to $3.60\,fb^{-1}$, depending on the parts of the detector required to be fully operational with good data quality.



A high-mass dijet event collected by ATLAS in September. The two central high-p_T jets have an invariant mass of 8.8 TeV, the highest-p_T jet has a p_T of 810 GeV, and the leading jet has a p_T of 750 GeV. The missing transverse energy for this event is 60 GeV.

The main goal of the early measurements presented this summer was to study in detail the performance of the detector, to characterise the main Standard Model processes at 13 TeV, and to perform the first searches for phenomena beyond the Standard Model at Run 2. These early searches focused on processes such as high-mass quantum and rotating black-hole production in dijet, multijet and lepton-jet event topologies, for which the higher centre-of-mass energy provided an immediate improvement in sensitivity beyond the reach of the Run 1 data.

The recently completed 2015 data set corresponds to more than 30 times that of this summer. With these data, the full programme of measurements and searches at Run 2 has started, and the first results were presented by the collaboration at a joint ATLAS and CMS seminar on 15 December 2015 during CERN Council week.

These new results benefitted from the first calibration of electron, muon and jet reconstruction and trigger algorithms, *in situ* using the data. The new insertable B layer of pixel detectors significantly improves the precision of the track measurements near the interaction region and is therefore crucial for tagging jets containing heavy quarks.

First measurements include the ZZ cross-section and single top quark, and the Wt production channels at 13 TeV. Top-quark pair production has also been investigated in measurements where the top-quark pair is produced in association with additional jets. These measurements are crucial to provide further checks of the modelling implemented in state-of-the-art generators used to simulate these processes at NLO QCD precision. These measurements can also subsequently be used to further constrain physics beyond the Standard Model that would alter these production modes.

The new data also allowed the first measurements of the Higgs boson production cross-section at 13 TeV, inclusively in the diphoton and ZZ decay channels.

With the increased centre-of-mass energy, and the availability of significantly more data than in the summer, new-particle search results were awaited with much anticipation. A large number of searches for new phenomena motivated by theories beyond the Standard Model in dijet, multijets, photon jets, diphoton, dilepton, single lepton and missing transverse energy channels were completed. Searches for vector-boson pair (VV) and Higgs and vector-boson (VH) topologies with boosted jets have also been completed. Searches for strongly produced supersymmetry (SUSY) that made use of signatures with 0 or 1 lepton, or a Z boson, jets and missing transverse energy and also topologies with B jets, have improved sensitivity from Run 1. Finally, searches for Higgs bosons from extended electroweak symmetry-breaking sectors in final states with a pair of tau leptons, and in pairs of vector bosons, have been performed.

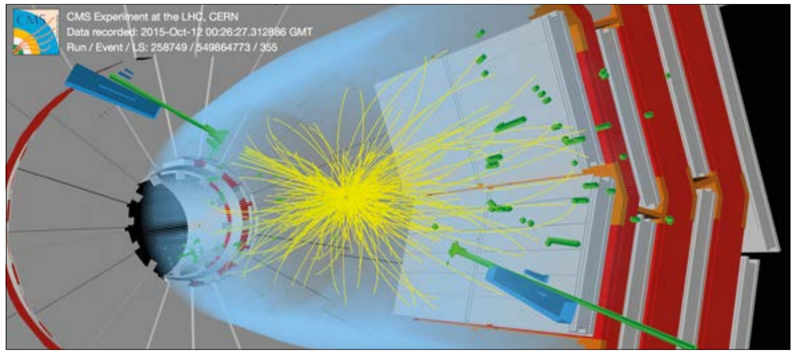
So far, no definitive observation of new physics has been observed in the data, although two excesses have been observed. The first, with a significance of 2.2 standard deviations, was seen in the search for SUSY with gluino production with subsequent decays into a Z boson and missing energy; a 3 standard-deviation excess was observed in this channel in Run 1. The second excess was observed in the search for diphoton resonances where a peak is seen at 750 GeV with a local significance of 3.6 standard deviations, corresponding to a global significance of 2.0 standard deviations. More data will be needed to probe the nature of these excesses.

Limits on a large variety of theories beyond the Standard Model have been derived. The ATLAS experiment is completing its measurements and search programme on the data collected in 2015, and is preparing for the data to come in 2016.

● For more details on the ATLAS results presented at the seminar, see https://twiki.cern.ch/twiki/bin/view/AtlasPublic/December2015-13TeV.

CMS presents new 13 TeV results at end-of-year jamboree

The first phase of collisions after the LHC restart earlier this year provided CMS with data at the novel energy of 13 TeV, enabling CMS to explore uncharted domains of physics. At the end of this exciting year, CMS and ATLAS presented comprehensive overviews of their latest results from analyses performed on the collected data. Here we highlight only a few of the key CMS results – refer to the further reading (below) for more.



The event with the largest-mass jet pair fulfilling all analysis requirements, observed so far with the CMS detector, in data collected in 2015. The mass of the dijet system is 6.14 TeV, exceeding the highest dijet mass of about 5 TeV observed by CMS during LHC Run 1. Both jets are reconstructed in the barrel region of the detector and have transverse momenta of about 3 TeV.

Before exploring the "unknown", CMS first strove to rediscover the "known", as a means to validate the excellent performance of the detector after emerging from the consolidation and upgrade period of Long Shutdown 1. Convincing performance studies as well as early measurements had already been presented at this year's summer conferences. Meanwhile, the studies and physics measurements continued as the size of the data sample increased over the course of the autumn. In total, CMS approved 33 new public results for the end-of-year jamboree, capping off a successful period of commissioning, data collection and analysis. In contrast to the studies performed for other Standard Model particles, CMS preferred to remain blinded for studies involving the LHC's most famous particle, the Higgs boson discovered in 2012, because the collected data sample was not large enough for a Higgs boson signal to be detectable.

However, it was the anticipation of results on searches for new phenomena that filled CERN's main auditorium beyond capacity. The CMS focus was on searches that would already be sensitive to new physics with the small data sample collected in 2015.

Hadron jets play a crucial role in searches for exotic particles such as excited quarks, whose observation would demonstrate that quarks are not elementary particles but rather composite objects, and for heavier cousins of the W boson. These new particles would demonstrate their presence by transforming into two particle jets (a "dijet"). The highest-mass dijet event observed by CMS is shown in the figure. In carrying out this study, CMS searches for bumps in the mass distribution of the dijet system. Seeing no significant excess over the background, a new CMS publication based on the 13 TeV data imposes limits on the masses of these hypothetical particles ranging from 2.6 TeV to 7 TeV, depending on the new-physics model.

CMS also searched for the presence of heavy particles such as a Z′ (Z-prime) boson in the dilepton spectrum, in which unstable exotic particles would transform into pairs of electrons or muons. While CMS observed high-mass events, with dielectrons up to a mass of 2.9 TeV and dimuons up to 2.4 TeV, the data are compatible with the Standard Model and do not provide evidence for new physics.

Finally, CMS observed a slight excess in events with two photons at a diphoton mass around 760 GeV. However, small fluctuations such as this have been observed regularly in the past, including at LHC Run 1, and often disappear as more data is collected. Therefore we are still far from the threshold associated with a new discovery, but the stage is set for great excitement and anticipation in the upcoming 2016 run of the LHC.

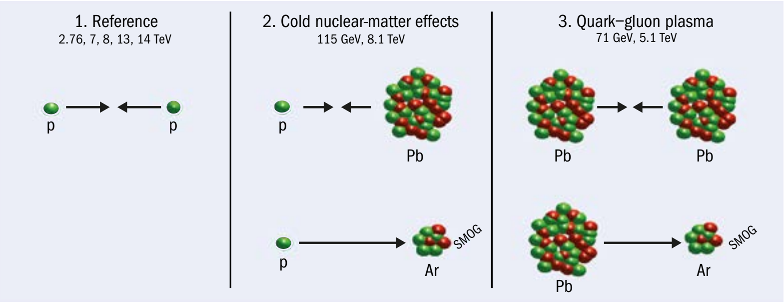
● **Further reading**

For all of the CMS results from the CERN seminar, see cern.ch/cms-results/public-results/preliminary-results/LHC-Jamboree-2015.html.

Fixed-target and heavy-ion physics with LHCb

Beyond its rich programme in flavour physics based on proton–proton collisions, LHCb opened the door in 2015 to a new domain of physics exploration related to cosmic-ray and heavy-ion physics. Due to its forward coverage, the detector has access to a unique kinematic range in colliding-beam physics. In addition, using a system developed for precise luminosity measurements based on the beam-gas imaging method, neon, helium and argon gas has been injected during some periods into the interaction region to exploit the LHC proton and ion beams for fixed-target physics at the highest available energies.

The measurement of proton–helium collisions has been motivated by recent results from AMS and other space detectors, which suggest that the antiproton yield in cosmic rays may exceed the expected value from secondary production in the interstellar medium. The accuracy of such predictions is limited by the poor knowledge of the proton–helium cross-section for proton energies at the TeV scale. By measuring proton–helium collisions, LHCb mimics the conditions for secondary production, and has the potential to help in the interpretation of these exciting results.



The various beam configurations and the physics that can be explored. SMOG stands for System for Measuring the Overlap with Gas

In proton–argon collisions, a nucleon–nucleon centre-of-mass energy of 110 GeV is generated, which is in between those achieved in experiments at the SPS in the 1980s and 1990s and those probed at RHIC more recently. While the produced energy densities are too low to create quark–gluon plasma (QGP), they allow the study of cold-nuclear-matter (CNM) effects, which are crucial to determine QGP formation.

During the last weeks of the LHC physics programme of 2015, the LHCb collaboration also participated in the heavy-ion run, taking data in both fixed-target mode by recording lead–argon collisions at a centre of mass energy of 69 GeV, and in colliding-beam mode, collecting lead–lead collisions at 5 TeV. In both modes, the energy densities are large enough to create a QGP, however lead–argon collisions have lower multiplicities than lead–lead collisions, and are therefore easier to analyse. The experiment is able to reconstruct lead–lead collisions up to a centrality of about 50%. The rapidity coverage by the LHCb detector in fixed-target mode in the nucleon–nucleon centre-of-mass frame is about $-3 < y < 1$; in colliding-beam mode, the range between $2 < y < 5$ is covered. The experiment has precise tracking, vertexing, calorimetry and powerful particle identification over the full detector acceptance.

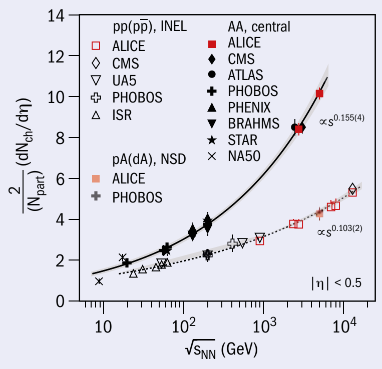
Comparison of collisions in the various configurations allows QGP effects to be disentangled from CNM effects. The various beam configurations are summarised in the diagram.

The focus of LHCb measurements will, on the one hand, be on hard probes such as open heavy-flavour states and quarkonia, which can be carried out down to very low p_T. On the other hand, open questions in the soft sector of QCD can be addressed, which cannot be treated perturbatively. LHCb is looking forward to exciting measurements in a variety of beam configurations in the years ahead.

A new chapter opens with more Pb–Pb collisions for a precision study of hot and dense QCD matter

After the restart of the LHC physics programme in June 2015 with world-record proton–proton collisions at $\sqrt{s} = 13$ TeV, nuclear beams reappeared in the LHC tunnel in November 2015 with subsequent first collisions between ^{208}Pb ions. With unprecedented centre-of-mass energy values of 5.02 TeV in the nucleon–nucleon system, collection of these data marks the beginning of a new chapter in the precision study of properties of hot and dense hadronic matter, and the quest to understand QCD confinement.

Measurement of the inclusive production of charged hadrons in high-energy nucleus–nucleus reactions is a key observable to characterise the global properties of the collision, in particular, whenever the collision energy increases significantly (almost a factor of two with respect to the LHC Run 1). Particle production at collider energies originates from the interplay of perturbative (hard) and non-perturbative (soft) QCD processes. Soft scattering processes and parton hadronisation dominate the bulk of particle production at low transverse momenta, and can only be modelled phenomenologically. On the other hand, with an increase in collision energy, the role of hard processes – parton scatterings with large momentum transfer – increases. Such measurements, which contribute essential information to estimate the initial energy density leading to the formation and evolution of the quark–gluon plasma and its relation to the collision geometry, also provide valuable insight into the initial-state partonic structure of the colliding nuclei.



A compilation of results on mid-rapidity charged-particle density for most central nucleus–nucleus collisions and elementary proton–proton and proton(deuteron)–nucleus collisions.

The ALICE experiment has measured the centrality-dependence of the inclusive charged-particle density ($dN_{ch}/d\eta$) at mid-rapidity ($|\eta| < 0.5$) in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. For an event sample corresponding to the most central 5% of the hadronic cross-section, the pseudorapidity density of primary charged particles at midrapidity is 1943±54, which corresponds to 10.2±0.3 per participating nucleon pair. This represents an increase of a factor of about 2.4 relative to p–Pb collisions at the same collision energy, and a factor of about 1.2 to central Pb–Pb collisions at 2.76 TeV. Previous measurements were performed by ALICE, ATLAS and CMS at the LHC at $\sqrt{s_{NN}} = 2.76$ TeV, and also at lower energies in the range $\sqrt{s_{NN}} = 17–200$ GeV with SPS and RHIC experiments. The figure shows a compilation of results on mid-rapidity charged-particle density for most central nucleus–nucleus collisions and elementary proton–proton and proton(deuteron)–nucleus collisions. Particle production in nucleus–nucleus collisions increases more rapidly with the centre-of-mass energy (per nucleon pair) than in proton–proton and proton(deuteron)–nucleus collisions, in agreement with expectations from the power-law extrapolation of lower-energy results. The characteristics of the centrality dependence of $dN_{ch}/d\eta$ and comparison with several phenomenological models is reported in a recent publication by the ALICE collaboration.

● **Further reading**
arxiv.org/abs/1512.06104

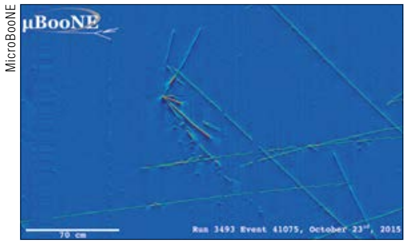
NEUTRINO PHYSICS

MicroBooNE records first neutrino events

MicroBooNE, an experiment designed to measure neutrinos and antineutrinos generated by Fermilab's Booster accelerator (*CERN Courier* September 2014 p8), has recorded its first neutrino events. MicroBooNE is the first of three neutrino detectors of the lab's new short-baseline neutrino (SBN) programme, recommended by the 2014 report of the US Particle Physics Project Prioritization Panel (P5). The ICARUS detector (being refurbished at CERN) as far detector, MicroBooNE as intermediate detector and SBND as near detector will compose the SBN project.

Designed to search for sterile neutrinos and other new physics phenomena in low-energy neutrino oscillations, the SBN programme aims to confirm or refute the hints of a fourth type of neutrino first reported by the LSND collaboration at Los Alamos National Laboratory, and resolve the origin of a mysterious low-energy excess of particle events seen by the MiniBooNE experiment, which used the same short-baseline neutrino beam line at Fermilab.

MicroBooNE uses a 10.4 m-long liquid-argon time-projection chamber (TPC) filled with 170 tonnes of liquid argon.



Top: A neutrino event recorded by the wire planes inside the MicroBooNE detector at Fermilab. Above: Members of the MicroBooNE collaboration pose in front of the Liquid-Argon Test Facility at Fermilab, home of the experiment.

The TPC probes neutrino oscillations by reconstructing particle tracks as finely detailed 3D images. When a neutrino hits the nucleus of an argon atom, its collision creates a spray of subatomic particles. Tracking and identifying those particles allows scientists to reveal the type and properties of the neutrino that produced them.

The MicroBooNE time-projection chamber is the largest ever built in the US and is equipped with 8256 delicate gold-plated wires. The three layers of wires capture pictures of particle interactions at different points in space and time. The superb resolution of the time-projection chamber will allow scientists to check whether the excess of MiniBooNE events—recorded with a Cherenkov detector filled with mineral oil – is due to photons or electrons.

MicroBooNE will collect data for several years, and computers will sift through thousands of neutrino interactions recorded every day. It will be the first liquid-argon detector to measure neutrino interactions from a neutrino beam with particle energies of less than 800 MeV.

Construction is under way for the two buildings that will house the other detectors of the SBN programme: the new 260 tonne Short-Baseline Near Detector (110 m from the neutrino production target) and the 760 tonne ICARUS detector (600 m) that took data at the Gran Sasso National Laboratory in Italy from 2009 to 2012. Like MicroBooNE (470 m from the target), they are both liquid-argon TPCs.

The MicroBooNE collaboration comprises 138 scientists from 28 institutions, while more than 200 scientists from 45 institutions are collaborating on the SBN programme. The experience and knowledge they will gain is relevant for the forthcoming Deep Underground Neutrino Experiment (DUNE), which will use four 10,000 tonne liquid-argon TPCs to examine neutrino oscillations over a much longer distance (1300 km) and a much higher and broader energy range (0.5–10 GeV).

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

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

Sciencewatch

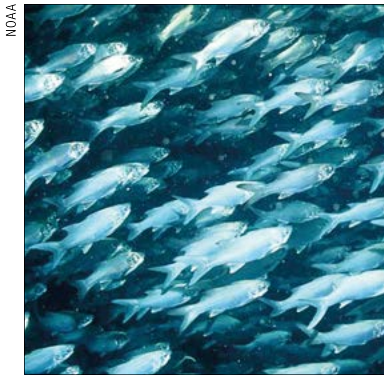
Compiled by John Swain, Northeastern University

How do fish hide?

Many fish have metallic-looking reflective scales due to plates of guanine, and it had been thought that the mirror-like finish was all there was to their camouflage, but it turns out that they work more subtly. Parrish C Brady of the University of Texas at Austin and colleagues studied more than 1500 video-polarimetry measurements from live fish in distinct habitats and under different viewing conditions, and the researchers have shown that the fish adjust the reflection to take into account the highly variable degree of light polarisation in the open ocean, with optimal camouflage at angles associated with predator detection and pursuit.

Further reading
P C Brady *et al.* 2015 *Science* **350** 965.

NOAA



Fish use light reflection to hide.

Worms that heal

A carcinogenic parasitic worm could do a lot of good one day. Michael J Smout of James Cook University in Queensland, Australia, and colleagues were looking at the oriental liver fluke *Opisthorchis viverrini*, which infects around 10 million people in Thailand and Laos who pick it up from eating contaminated raw fish. The parasitic worm can stay in the host's liver for decades, eating the liver but, it seems, patching it up with growth-factor Ov-GRN-1, which it secretes as it goes along. This keeps the host alive until the cumulative damage and inflammation causes bile-duct cancer, resulting in 26,000 deaths per year. The upside is that Ov-GNR-1 accelerates healing and blood-vessel growth in mice, and holds promise for helping the impaired healing of diabetic and elderly patients. Understanding it may also lead to a vaccine for people who have the parasite.

Further reading
M J Smout *et al.* 2015 *PLOS Pathogens* dx.doi.org/10.1371/journal.ppat.1005209.

Fröhlich state finally seen

In 1968, Herbert Fröhlich predicted an analogue of Bose–Einstein condensation in biological macromolecules with a range of vibrational frequencies, which could lead to a macroscopic condensation of energy into the lowest-frequency mode. This would be remarkable not only for its appearing in a biological context, but also for not requiring low temperatures. Now, Gergely Katona of the University of Gothenburg in Sweden and colleagues have finally shown this condensation in a crystallised egg protein (lysozyme) subjected to 0.4 THz radiation. X-ray crystallography shows a non-thermal change in electron density with a micro- to millisecond thermalisation timescale, which can only be explained by Fröhlich condensation. This is the first experimental confirmation of the effect, and may have far-reaching implications for biology.

Further reading
I V Lundholm *et al.* 2015 *Struct. Dyn.* **2** 054702.

How the Moon got its tilt

The origin of the Moon has long been a matter of speculation, with the prevailing idea being that a Mars-sized planet hit the Earth and ejected the material that formed the Moon. The trouble is that models suggest that the Moon should not be tilted more than about 1° from the plane of the Earth's orbit around the Sun. It's actually about 5°, and would have been twice that 4.5 billion years ago.

Now, Kaveh Pahlevan and Alessandro Morbidelli of the Université Côte d'Azur in Nice, France, have pointed out that if there were a direct hit of the kind described, one might expect a lot of near misses with significant gravitational interactions. Starting with an early solar system made of lots of miniplanets between 0.1 and 1 lunar mass (a popular model), a 10° tilt or more comes out as quite reasonable. The theory would also explain why we have so many heavy metals such as gold close to the surface (not having fallen into the molten core), because smaller objects hitting the Earth could deliver them, so this would solve a second mystery at the same time.

Further reading
K Pahlevan and A Morbidelli 2015 *Nature* **527** 492.

Eyes in the armour

Chitons – *Acanthopleura granulate* – are marine molluscs with hard shells. Remarkably, they also have up to 1000 eyes, each a little smaller than a printed period, but there had been doubts as to their degree of functionality. Christine Ortiz of MIT, US, and colleagues demonstrated that they can indeed form images and have photosensitive cells below them forming a sort of retina. They also found that the lenses are made of large crystallographically aligned grains of the same material that makes up their armour: aragonite, a form of calcium carbonate (the other natural form being calcite).

Further reading
L Li *et al.* 2015 *Science* **350** 952.

Cooler distillation

A breakthrough in distillation uses light to heat an ethanol and water mixture far more efficiently. Naomi J Halas and colleagues at Rice University in Houston put gold–silica nanoparticles into the mixture and shone laser light from above – a sharp break from the usual technique, which heats from below (which, once it's been said, makes one wonder why this wasn't thought of earlier!). Local heating drives off the ethanol preferentially with less heat wasted. There's a nice plus, which is that optical distillation avoids getting stuck with an azeotropic mixture, which normally limits alcohol concentration to 95%, and 99% can be easily achieved.

Further reading
O Neumann *et al.* 2015 *Nano Lett.* dx.doi.org/10.1021/acs.nanolett.5b02804.

Astrowatch

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

Nearby supernova accounts for cosmic-ray 'anomalies'

The observed spectrum of cosmic rays has several puzzling features. For instance, the Alpha Magnetic Spectrometer (AMS) measured an excess of positrons and antiprotons at around 100 GeV. While it is tantalising to interpret such discrepancies as dark-matter signatures, a new study shows that they could simply be due to the injection of cosmic rays by a nearby supernova, which exploded two-million years ago.

The composition and spectral properties of cosmic rays are studied with unprecedented accuracy by the AMS-02 experiment (*CERN Courier* October 2013 p23). Mounted on the International Space Station since May 2011, it has already detected and characterised close to 100 thousand million cosmic rays from outer space. This wealth of data constrains extremely precisely the spectral properties of electrons, positrons, protons and antiprotons, as well as of helium and heavier nuclei.

Rather than disproving earlier results by the Payload for Antimatter Matter Exploration and Light nuclei Astrophysics (PAMELA) (*CERN Courier* September 2011 p34), the AMS measurements confirm several cosmic-ray "anomalies". Indeed, the observations do not follow the expected trend for galactic cosmic rays. The main differences are a softer spectral slope of protons as compared with heavier nuclei in the TeV–PeV energy range, and an excess of positrons and antiprotons above ~30 GeV.

According to a small group of astrophysicists, these puzzling discrepancies could simply be due to an additional source of cosmic rays from a nearby supernova. Led by Michael Kachelrieß from the Norwegian University of Science and Technology in Trondheim, the team demonstrates in a recent paper that this is a valid explanation. The researchers get a good match with the observations for a source injecting $\sim 10^{43}$ J in cosmic rays with energies up to at least 30 TeV. The researchers derive this by using a code that follows the trajectories of individual cosmic rays through the galactic magnetic field (GMF) after an instantaneous injection.

They further obtain that the supernova should have been roughly aligned with the local GMF direction at a distance of several-hundred light-years and must have exploded about two-million years ago. A rough estimate based on the size of the Milky Way and the rate of about two supernovas per century (*CERN Courier* January/February 2006 p10), shows that there is a good chance that one has indeed exploded at the inferred distance from the Sun during the last few-million years. Interestingly, independent evidence for such a nearby supernova explosion was already derived from a deposition of the iron isotope ^{60}Fe in a million-year-old layer of the ocean crust.

The authors suggest further possible tests of the nearby supernova interpretation, such as the measure of the Beryllium isotopic ratio ^{10}Be/^{9}Be, because ^{10}Be has a radioactive lifetime of about one-million years. If the idea withstands further data from AMS-02, this would rule out the hopes that the cosmic ray "anomalies" would be a signature of something more fundamental, like dark-matter annihilation or decay.

NASA, ESA, Hubble Heritage Team

This false-colour image by the Hubble Space Telescope shows a small section of the Veil Nebula, a part of the Cygnus Loop supernova remanent. Compared with the supernova described here, it exploded only some 8000 years ago, but at a greater distance of 2100 light-years.

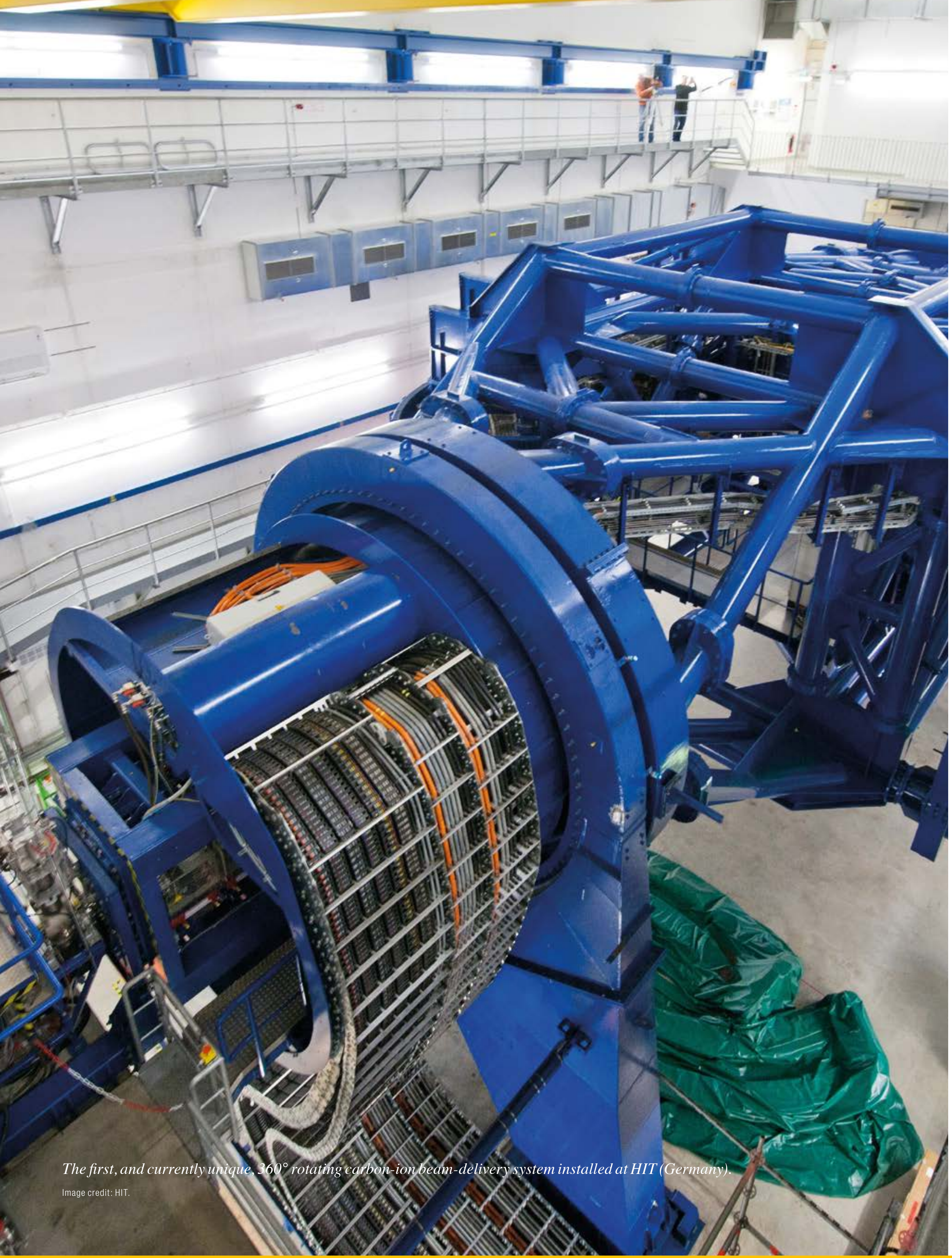
Further reading

M Kachelrieß *et al.* 2015 *Phys. Rev. Lett.* **115** 181103.

Picture of the month

This gently smiling cosmic face was released in November 2015 to celebrate the 100th anniversary of Albert Einstein's theory of general relativity. It is a composite image of a cluster of galaxies seen in visible light by the Hubble Space Telescope and in X-rays (purple) by NASA's Chandra X-ray Observatory. The cluster has been nicknamed the "Cheshire Cat" because of its resemblance to a smiling feline. Some of the arched features are actually distant galaxies whose light has been stretched and bent via the distortion of space–time by the cluster's mass, which is mostly in the form of dark matter. This so-called strong-gravitational-lensing effect was predicted by Einstein, but he thought it would never be observable. Astronomers estimate that the two "eyes" of the cat will merge in about one-billion years, leaving one giant elliptical galaxy at the centre. The cat will then become a smiling Cyclops.

X-ray: NASA/CXC/UA/J Irwin et al.; Optical: NASA/STScI



The first, and currently unique, 360° rotating carbon-ion beam-delivery system installed at HIT (Germany).

Image credit: HIT.

Networking against cancer with ENLIGHT

Hadrontherapy uses beams of protons and other ions to treat cancer. This cutting-edge technology is the epitome of a multidisciplinary and transnational venture.

Manuela Cirilli, CERN, and **Manjit Dosanjh**, ENLIGHT co-ordinator.

Since the establishment of the first hospital-based proton-treatment centres in the 1990s, hadrontherapy has continued to progress in Europe and worldwide. In particular, during the last decade there has been exponential growth in the number of facilities, accompanied by a rapid increment in the number of patients treated, an expanded list of medical indications, and increasing interest in other types of ions, especially carbon. Harnessing the full potential of hadrontherapy requires the expertise and ability of physicists, physicians, radiobiologists, engineers, and information-technology experts, as well as collaboration between academic, research and industrial partners. Thirteen years ago, the necessity to catalyse efforts and co-operation among these disciplines led to the establishment of the European Network for Light Ion Hadron-therapy (ENLIGHT). Its recent annual meeting, held in Cracow in September, offered an ample overview of the current status and challenges of hadrontherapy, as well as stimulating discussion on the future organisation of the community.

Networking is key

ENLIGHT was launched in 2002 (*CERN Courier* May 2002 p29) with an ambitious, visionary and multifaceted plan to steer European research efforts in using ion beams for radiation therapy. ENLIGHT was envisaged not only as a common multidisciplinary platform, where participants could share knowledge and best practice, but also as a provider of training and education, and as an instrument to lobby for funding in critical research and innovation areas. During the years, the network has evolved, adapting its structure and goals to emerging scientific needs (*CERN Courier* June 2006 p27).

The annual ENLIGHT meeting has always played a defining role in this evolutionary process. This year, new and long-time members were challenged to an open discussion on the future of the network, after a day and a half of inspiring talks on various aspects of hadrontherapy.

Challenges ahead

Emerging topics in all forms of radiation therapy are the collection, transfer and sharing of medical data, and the implementation of big data-analytics tools to inspect them. These tools will be crucial in implementing decision support systems, allowing treatment to be tailored to each individual patient. The flow of information in healthcare, and in particular in radiation therapy, is overwhelming not only in terms of data volume but also in terms of the diversity of data types involved. Indeed, experts need to analyse patient and tumour data, as well as complex physical dose arrays, and to correlate these with clinical outcomes that also have genetic determinants.

Hadrontherapy is facing a dilemma when it comes to designing clinical trials. In fact, from a clinical standpoint, the ever increasing number of hadrontherapy patients would allow randomised trials to be performed – that is, systematic clinical studies in which patients are treated with comparative methods to determine which is the most effective curative protocol.

However, several considerations add layers of complexity to the clinical-trials landscape: the need to compare standard photon radiotherapy not only with protons but also with carbon ions; the positive results of hadrontherapy treatments for main indications; and the non-negligible fact that most of the patients who contact a hadrontherapy centre are well informed about the technique, and will not accept being treated with conventional radiotherapy. Nevertheless, progress on clinical trials is being made. At the ENLIGHT meeting in Cracow, the two dual-ion (proton and carbon) centres in Europe – HIT, in Heidelberg (Germany) and CNAO, in Pavia (Italy) – presented patient numbers and dose-distribution studies carried out at their facilities. The data were collected mainly in cohort studies carried out within a single institution, and the results often highlighted the need for larger statistics and a unified database. More data from patients treated with carbon ions will soon become available, with the opening in 2016 of the MedAustron hadrontherapy centre in Wiener Neustadt (Austria). Clinical trials are also a major focus outside of Europe: in the US, several randomised and non-randomised trials have been set up to compare protons with photons, and to investigate either the survival improvement (for glioblastoma, non-small cell lung cancer, hepatocellular carcinoma, and oesophageal cancer) or the decrease of adverse effects (low-grade glioma, oropharyngeal cancer, nasopharyngeal cancer, prostate cancer and post-mastectomy radiotherapy in breast cancer). Recently, the National Cancer Institute in the US funded a trial comparing conventional radiation therapy ▷

CERNCOURIER

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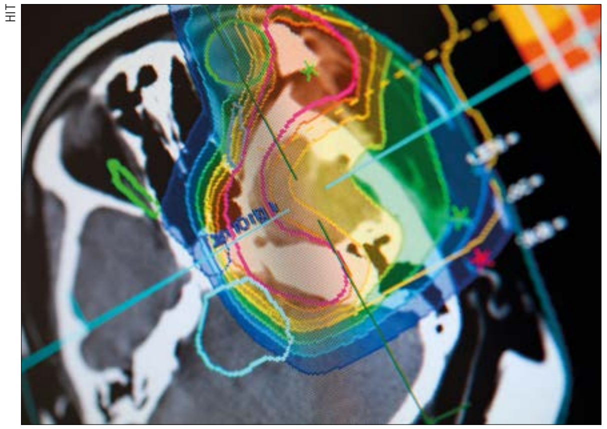
ENLIGHT

ENLIGHT *members attending the annual meeting in Cracow.*

HIT



Simulation of hadron dose deposition in human tissue.

ICTR-PHE

The third edition of the International Conference on Translational Research in Radio-Oncology | Physics for Health in Europe will be held in Geneva from 15 to 19 February. This unique conference gathers scientists from a variety of fields, including detector physicists, radiochemists, nuclear-medicine physicians and other physicists, biologists, software developers, accelerator experts and oncologists.

ICTR-PHE is a biennial event, co-organised by CERN, where the main aim is to foster multidisciplinary research by positioning itself at the intersection of physics, medicine and biology. At ICTR-PHE, physicists, engineers and computer scientists share their knowledge and technologies, while doctors and biologists present their needs and vision for the medical tools of the future, therefore triggering breakthrough ideas and technological developments in specific areas.

The high standards set by the ICTR-PHE conferences have garnered not only an impressive scientific community, but also ever-increasing interest and participation from industry. ICTR-PHE 2016 is also an opportunity for companies to exhibit their products and services at the technical exhibition included in the programme.

and carbon ions for pancreatic cancer.

Besides clinical trials, personalised treatments are holding centre stage in the scientific debate on hadrontherapy. Technology is not dormant: developments are crucial to reduce the costs, to provide treatments tailored to each specific case, and to reach the necessary level of sophistication in beam delivery to treat complex cases such as tumours inside, or close to, moving organs. In this context, imaging is key. Today, it is becoming obvious that the optimal imaging tool will necessarily have to combine different imaging modalities, for example PET and prompt photons. PET is of course a mainstay for dose imaging, but a well-known issue in its application to in-beam real-time monitoring for hadrontherapy comes from having to allow room for the beam nozzle: partial-ring PET scanners cannot provide full angular sampling, therefore introducing artefacts in the reconstructed images. The time-of-flight (TOF) technique is often used to improve the image-reconstruction process. An innovative concept, called a J-PET scanner, detects back-to-back photons in plastic scintillators, and applies compressive sensing theory to obtain a better signal normalisation, and therefore improve the TOF resolution.

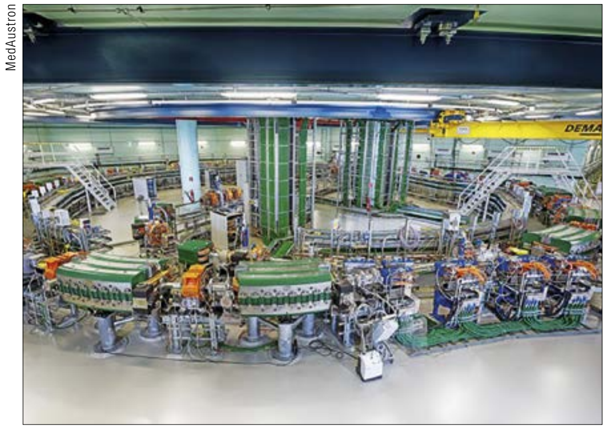
A subject of broad and current interest within the hadrontherapy community is radiobiology. There has been great progress in the comprehension of molecular tumour response to irradiation with both ions and photons, and of the biological consequences of the complex, less repairable DNA damage caused specifically by ions. Understanding the cell signalling mechanisms affected by hadrontherapy will lead to improvements in therapeutic efficacy. A particularly thorny issue is the relative biological effectiveness (RBE) of protons and carbon with respect to photons. More extensive and systematic radiobiology studies with different ions, under standardised dosimetry and laboratory conditions, are needed to clarify this and other open issues: these could be carried out at existing and future beamlines at HIT, CNAO and MedAustron, as well as at the proposed CERN OpenMED facility.

The future of ENLIGHT

Since the annual meeting in Summer 2014, the ENLIGHT community has started to discuss the future of the network, both in terms of structure and scientific priorities. It is clear that the focus of R&D for hadrontherapy has shifted since the birth of ENLIGHT, if only for the simple reason that the number of clinical centres (in particular for protons) has dramatically increased. Also, while technology developments are still needed to ensure optimal and more cost-effective treatment, proton therapy is now solidly in the hands of industry. The advent of single-room facilities will bring proton therapy, albeit with some restrictions, to smaller hospitals and clinical centres.

From a clinical standpoint, the major challenge for ENLIGHT in the coming years will be to catalyse collaborative efforts in defining a road map for randomised trials and in studying the issue of RBE in detail. Concerning technology developments,

MedAustron



The accelerator complex in MedAustron (Austria).

efforts will continue on quality assurance through imaging and on the design of compact accelerators and gantries for ions heavier than protons. Information technologies will take centre stage, because data sharing, data analytics, and decision support systems will be key topics.

Training will be a major focus in the coming years, as the growing number of facilities require more and more trained personnel: the aim will be to train professionals who are highly skilled in their speciality but at the same time are familiar with the multidisciplinary aspects of hadrontherapy.

Over the years, the ENLIGHT community has shown a remarkable ability to reinvent itself, while maintaining its cornerstones of multidisciplinarity, integration, openness, and attention to future generations. The new list of priorities will allow the network to tackle the latest challenges of a frontier discipline such as hadrontherapy in the most effective way.

Résumé

ENLIGHT : un réseau pour lutter contre le cancer

L'hadronthérapie utilise des faisceaux de protons ou d'autres ions pour traiter le cancer. Cette technologie de pointe est le fruit d'une aventure multidisciplinaire et transnationale. Il y a treize ans, la nécessité de stimuler les travaux à la frontière entre ces disciplines a mené à la création du Réseau européen de recherche sur l'hadronthérapie par les ions légers (ENLIGHT). Lors de la récente réunion annuelle du réseau, les participants ont évoqué la future organisation de la communauté et défini une nouvelle liste de priorités en vue de relever les nouveaux défis.

CNAO

One of the treatment rooms at CNAO (Italy).

XENON opens a new era for dark-matter searches

Fig. 1. Members of the XENON1T collaboration at LNGS during the assembly of the TPC.

The recently inaugurated XENON1T detector is designed to be the most sensitive experiment for the direct search of WIMPs.

XENON Collaboration.

In recent years, evidence for the existence of dark matter from astrophysical observations has become indisputable. Although the nature of dark matter remains unknown, many theoretically motivated candidates have been proposed. Among them, the most popular ones are Weakly Interacting Massive Particles (WIMPs) with predicted masses in the range from a few GeV/c^2 to TeV/c^2 and with interaction strengths roughly on the weak scale.

WIMPs are being searched for using three complementary techniques: indirectly, by detecting the secondary products of WIMP annihilation or decay in celestial bodies; by producing WIMPs at colliders, foremost the LHC; and by direct detection, by measuring the energy of recoiling nuclei produced by collisions with WIMPs in low-background detectors.

On 11 November 2015, the most sensitive detector for the direct detection of WIMPs, XENON1T, was inaugurated at the Italian Laboratori Nazionali del Gran Sasso (LNGS) – the largest underground laboratory in the world. XENON1T, led by Elena Aprile of Columbia University, was built and is operated by a collaboration of 21 research groups from France, Germany, Italy, Israel, the Netherlands, Portugal, Sweden, Switzerland, the United Arabic Emirates and the US. In total, about 130 physicists are involved.

XENON1T is the current culmination of the XENON programme of dark matter direct-detection experiments. Starting with the 25 kg XENON10 detector about 10 years ago, the second phase of the experiment, XENON100 (*CERN Courier* October 2013 p13) with 161 kg, has been tremendously successful: in the summer of 2012, the XENON collaboration published results from a search for spin-independent WIMP–nucleon interactions that provided the most stringent constraints on WIMP dark matter, until superseded by the LUX experiment (*CERN Courier* December 2013 p8) with a larger target.

XENON100 has since then also provided a series of other important results, such as constraints on the spin-dependent WIMP nucleon cross-section, constraints on solar axions and galactic axion-like particles and, more recently, searches for annual rate

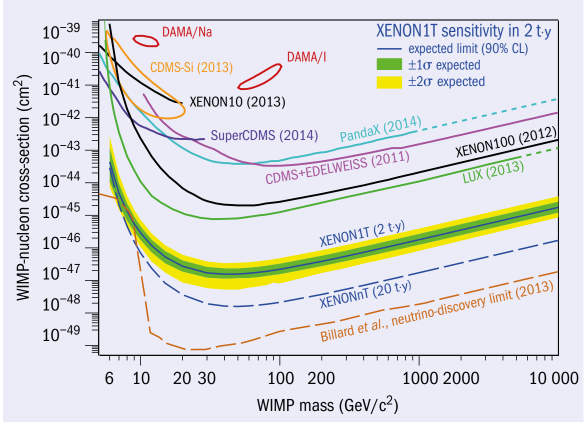


Fig. 2. Predicted sensitivity of XENON1T including all known backgrounds. Results of other experiments are also shown.

modulations, which exclude WIMP–electron scattering that could have provided a dark-matter explanation of the signal observed by DAMA/LIBRA (*CERN Courier* November 2015 p10).

Low background is key

The new XENON1T detector has an estimated sensitivity that is a factor of 100 better than XENON100. This will be reached after about two years of data taking. With only one week of data-taking, XENON1T will be able to reach the current LUX limit, opening up a new phase in the search for dark matter in early 2016.

The XENON detectors are dual-phase time-projection chambers (TPCs) filled with liquid xenon (LXe) as the target material. Interactions of particles in the liquefied xenon give rise to prompt scintillation light and ionisation. The ionised electrons are drifted in a strong electric field and extracted into the gas above the liquid where a secondary scintillation signal is produced. Both scintillation signals are read out by arrays of photomultiplier tubes (PMTs) placed above and below the target volume. The position of the interaction vertex can be reconstructed in 3D by using the hit pattern on the upper PMT array and the time delay between the prompt and secondary scintillation signal. The position reconstruction facilitates self-shielding by only selecting events that interact with the inner "fiducial" volume of the detector. Because of their small cross-section, WIMPs will interact only once in the detector, so the background (e.g. from neutrons) can be reduced further by selecting single-scatter interactions. Beta ▷

Fig. 3. The XENON1T detector. Left: The water Cherenkov veto with cladding, showing the cryostat and its support structure inside. Right: the service building with cryogenics, purification, storage and recovery systems, as well data acquisition and slow control.

and gamma backgrounds are reduced by selecting events with a ratio of secondary-to-prompt signal that is typical for nuclear recoils.

The XENON1T detector is filled with about 3.5 tonnes of liquid xenon in total. Its TPC – 1 m high and 1 m in diameter in a cylindrical shape, laterally defined by highly reflective Teflon – is the largest liquid-xenon TPC ever built. Specially designed copper field-shaping electrodes ensure the uniformity of the drift field for the desired field strength of 1 kV/cm. The TPC's active volume contains 2 tonnes of LXe viewed by two arrays of 3 inch PMTs – 121 at the bottom immersed in LXe and 127 on the top in the gaseous phase. The xenon gas is liquefied and kept at a temperature of about –95 °C by a system of pulse-tube refrigerators. The xenon gas is stored and can be recovered in liquid phase in a custom-designed stainless-steel sphere that can hold up to 7.6 tonnes of xenon in high-purity conditions. Figure 3 shows the XENON1T detector and service building situated in Hall B at LNGS. Figure 1 shows XENON collaborators active in assembling the TPC in a clean room above ground at LNGS.

The expected WIMP–nucleon interaction rate is less than 10 events in 1 tonne of xenon per year. Background rejection is therefore the key to success for direct-detection experiments. Externally induced backgrounds can be minimised by exploiting the self-shielding capabilities. In addition, the detector is surrounded by a cylindrical water vessel 10 m high and 9.6 m in diameter. It is equipped with PMTs to tag muons that could induce neutrons, with an efficiency of 99.9%.

For a detector the size of XENON1T, radioactive impurities in the detector materials and the xenon itself become the biggest challenge for background reduction. Extensive radiation-screening campaigns, using some of the world's most sensitive germanium detectors, have been conducted, and high-purity PMTs have been specially developed by Hamamatsu in co-operation with the collaboration. Contamination of the xenon by radioactive radon (mainly ^{222}Rn) and krypton (^{85}Kr), which dominate the target-intrinsic background, led to the development of cryogenic-distillation techniques to suppress the abundance of these isotopes to unprecedented low levels.

The best scenario

After about two years of data taking, XENON1T will be able to probe spin-independent WIMP–nucleon cross-sections of 1.6×10^{-47} cm² (at a WIMP mass of 50 GeV/c²), see figure 2. In popular scenarios involving supersymmetry, XENON1T will either discover WIMPs or will exclude most of the theoretically relevant parameter space. Following the inauguration, the first physics run is envisaged to start early this year.

Most of the infrastructure, for example the outer cryostat, the Cherenkov muon veto, the xenon cryogenics, the purification and storage systems and the data-acquisition system, has been dimensioned for a larger experiment, named XENONnT, which is designed to contain more than 7 tonnes of LXe. A new TPC, about 40% larger in diameter and height and equipped with about 400 PMTs, will replace the XENON1T TPC. The goal for XENONnT is to achieve another order of magnitude improvement in sensitivity within a few years of data taking. XENONnT is scheduled to start data taking in 2018.

● For further details, see www.xenon1t.org/.

Résumé

XENON ouvre une nouvelle ère pour les recherches sur la matière noire

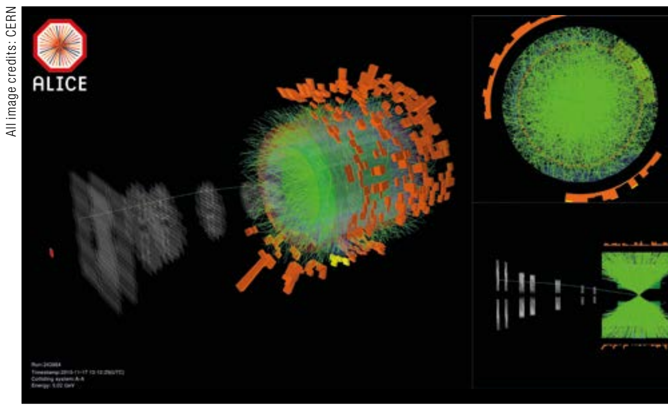
Le détecteur XENON1T est conçu pour être l'expérience la plus sensible pour la recherche directe des particules WIMP. Après environ deux ans de prise de données, XENON1T sera en mesure d'explorer les sections efficaces d'interactions WIMP-nucléon de $1{,}6 \times 10^{-47}$ cm² (à une masse de WIMP de 50 GeV/c²). Dans les scénarios les plus souvent retenus, qui font entrer en jeu la supersymétrie, XENON1T sera amené, soit à découvrir des WIMP, soit à exclure l'essentiel de l'espace de paramètres pertinent du point de vue de la théorie. À la suite de l'inauguration, la première exploitation pour la physique est attendue pour début 2016.

LHC surpasses design luminosity with heavy ions

The LHC has finished 2015 with a successful heavy-ion run. For the first time, the lead nuclei have collided with an average centre-of-mass energy per pair of nucleons of 5.02 TeV.

John Jowett, CERN.

All image credits: CERN



One of the first events recorded by the ALICE experiment during the 2015 LHC run with heavy ions.

The extensive modifications made to the LHC during its first long shutdown allowed the energy of the proton beams to be increased from 4 TeV in 2012 to 6.5 TeV, enabling proton–proton collisions at a centre-of-mass energy of 13 TeV, in 2015. As usual, a one-month heavy-ion run was scheduled at the end of the year. With lead nuclei colliding, the same fields in the LHC's bending magnets would have allowed 5.13 TeV per colliding nucleon pair. However, it was decided to forego the last whisker of this increase to match the equivalent energy of the proton–lead collisions that took place in 2013, namely 5.02 TeV. Furthermore, the first week of the run was devoted to colliding protons at 2.51 TeV per beam. This will allow the LHC experiments to make precise comparisons of three different combinations of colliding particles, p–p, p–Pb and Pb–Pb, at the same effective energy of 5.02 TeV. This is crucial to disentangling the ascending complexity of the observed phenomena (*CERN Courier* March 2014 p17).

The first (and last, until 2018) Pb–Pb operation close to the full energy of the LHC was also the opportunity to finally assess some of its ultimate performance limits as a heavy-ion collider. A carefully targeted set of accelerator-physics studies also had to be scheduled within the tight time frame.

Delivering luminosity

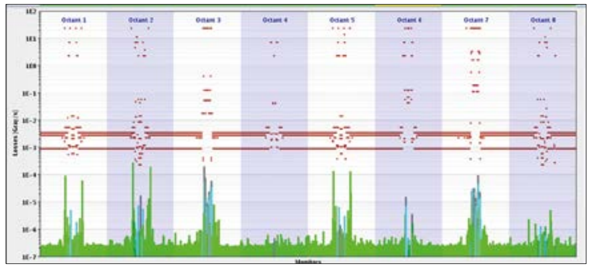
The chain of specialised heavy-ion injectors, comprising the electron cyclotron resonance ion source, Linac3 and the LEIR ring, with its elaborate bunch-forming and cooling, were recommissioned to provide intense and dense lead bunches in the weeks preceding the run. Through a series of elaborate RF gymnastics, the PS and SPS assemble these into 24-bunch trains for injection into the LHC. The beam intensity delivered by the injectors is a crucial determinant of the luminosity of the collider.

Planning for the recommissioning of the LHC to run in two different operational conditions after the November technical stop resembled a temporal jigsaw puzzle, with alternating phases of proton and heavy-ion set-up (the latter using proton beams at first) continually readapted to the manifold constraints imposed by other activities in the injector complex, the strictures of machine protection, and the unexpected. For Pb–Pb operation, a new heavy-ion magnetic cycle was implemented in the LHC, including a squeeze to $\beta^* = 0.8$ m, together with manipulations of the crossing angle and interaction-point position at the ALICE experiment. First test collisions occurred early in the morning of 17 November, some 10 hours after first injection of lead.

The new Pb–Pb energy was almost twice that of the previous Pb–Pb run in 2011, and some 25 times that of RHIC at Brookhaven, extending the study of the quark–gluon plasma to still-higher energy density and temperature. Although the energy per colliding nucleon pair characterises the physical processes, it is worth noting that the total energy packed into a volume on the few-fm scale exceeded 1 PeV for the first time in the laboratory.

The new Pb–Pb energy was almost twice that of the previous Pb–Pb run in 2011.

After the successful collection of the required number of p–p reference collisions, the ▷



Beam-loss monitor signals (on a logarithmic scale) around the whole LHC ring while Pb beams collide. Large peaks due to the BFPP process can be seen on each side of the experiments. Further peaks due to beam cleaning in the collimation insertions IR7 and IR3 are also clearly visible.

Pb–Pb configuration was validated through an extensive series of aperture measurements and collimation-loss maps. Only then could "stable beams" for physics be declared at 10.59 a.m. on 25 November, and spectacular event displays started to flow from the experiments.

In the next few days, the number of colliding bunches in each beam was stepped up to the anticipated value of 426 and the intensity delivered by the injectors was boosted to its highest-ever values. The LHC passed a historic milestone by exceeding the luminosity of 10^{27} cm^{-2} s^{-1}, the value advertised in its official design report in 2004.

This allowed the ALICE experiment to run in its long-awaited saturated mode with the luminosity levelled at this value for the first few hours of each fill.

Soon afterwards, an unexpected bonus came from the SPS injection team, who pulled off the feat of shortening the rise time of the SPS injection kicker array, first to 175 ns then to 150 ns, allowing 474, then 518, bunches to be stored in the LHC. The ATLAS and CMS experiments were able to benefit from luminosities over three times the design value. A small fraction of the luminosity in this run was delivered to the LHCb experiment, a newcomer to Pb–Pb collisions.

Nuclear beam physics

The electromagnetic fields surrounding highly charged ultrarelativistic nuclei are strongly Lorentz-contracted into a flat "pancake". According to the original insight of Fermi, Weizsäcker and Williams, these fields can be represented as a flash of quasi-real photons. At LHC energies, their spectrum extends up to hundreds of GeV. In a very real sense, the LHC is a photon–photon and photon–nucleus collider (*CERN Courier* November 2012 p9). The study of such ultraperipheral (or "near-miss") interactions, in which the two nuclei do not overlap, is an important subfield of the LHC experimental programme, alongside its main focus on the study of truly nuclear collisions.

From the point of view of accelerator physics, the ultraperipheral interactions with their much higher cross-sections loom still larger in importance. They dominate the luminosity "burn-off", or rate at which particles are removed from colliding beams, leading to short beam and luminosity lifetimes. Furthermore, they do so in a way that is qualitatively different from the spray of a few watts of "luminosity debris" by hadronic interactions. Rather, the removed nuclei are slightly modified in charge and/or mass, and emerge as new, well-focussed, secondary beams. These travel along the interaction region just like the main beam but, as soon as they encounter the bending magnets of the dispersion-suppressor section, their trajectories deviate, as in a spectrometer.

The largest contribution to the burn-off cross-section comes from the so-called bound-free pair-production (BFPP) in which the colliding photons create electron–positron pairs with the electron in a bound-state of one nucleus. A beam of these one-electron ions, carrying a power of some tens of watts, emerges from the interaction point and is eventually lost on the outer side of the beam pipe.

Controlled quench

The LHC operators have become used to holding their breath as the BFPP loss peaks on the beam-loss monitors rise towards the threshold for dumping the beams (figure). There has long been a concern that the energy deposited into superconducting magnet coils may cause them to quench, bringing the run to an immediate halt and imposing a limit on luminosity. In line with recent re-evaluations of the magnet-quench limits, this did not happen during physics operation in 2015 but may happen in future operation at still-higher luminosity. During this run, mitigation strategies to move the losses out of the magnets were successfully implemented. Later, in a special experiment, one of these bumps was removed and the luminosity slowly increased. This led to the first controlled steady-state quench of an LHC dipole magnet with beam, providing long-sought data on their propensity to quench. On the last night of the run, another magnet quench was deliberately induced by exciting the beam to create losses on the primary collimators.

Photonuclear interactions also occur at comparable rates in the collisions and in the interactions with the graphite of the LHC collimator jaws. Nuclei of ^{207}Pb, created by the electromagnetic dissociation of a neutron from the original ^{208}Pb at the primary collimators, were identified as a source of background after traversing more than a quarter of the ring to the tertiary collimators near ALICE.

These, and other phenomena peculiar to heavy-ion operation, must be tackled in the quest for still-higher performance in future years.

Résumé

Le LHC dépasse la luminosité nominale pour les ions lourds

Le LHC a terminé l'année 2015 par une exploitation avec des ions lourds. Pour la première fois, la moyenne de l'énergie dans le centre de masse obtenue lors des collisions de noyaux de plomb a atteint 5,02 TeV par paire de nucléons. Cette énergie, inédite pour les collisions plomb-plomb, est presque deux fois supérieure à celle de l'exploitation plomb-plomb précédente, en 2011, et représente quelque 25 fois celle atteinte au RHIC, à Brookhaven ; cette prouesse permet d'élargir l'étude du plasma quarks-gluons à des densités et des températures encore plus élevées.

ATLAS and CMS upgrade proceeds to the next stage

The High-Luminosity LHC project will bring unprecedented collision rates to the experiments, but with some technical challenges.

Didier Contardo, CMS experiment, and **Pippa Wells**, ATLAS experiment.

At the end of the third operational period in 2023, the LHC will have delivered 300 fb^{-1}, and the final focussing magnets, installed at the collision points at each of four interaction regions in the LHC, will need to be replaced. By redesigning these magnets and improving the beam optics, the luminosity can be greatly increased. The High Luminosity LHC (HL-LHC) project aims to deliver 10 times the original design integrated luminosity (number of collisions) of the LHC (*CERN Courier* December 2015 p7). This will extend the physics programme and open a new window of discovery. But key components of the experiments will also have to be replaced to cope with the pile-up of 140–200 proton–proton interactions occurring, on average, per bunch crossing of the beams. In October 2015, the ATLAS and CMS collaborations met a major milestone in preparing these so-called Phase II detector upgrades for operation at the HL-LHC, when it was agreed at the CERN Resource Review Board that they proceed to prepare Technical Designs Reports.

New physics at the HL-LHC

The headline result of the first operation period of the LHC was the observation of a new boson in 2012. With the present data set, this boson is fully consistent with being the Higgs boson of the Standard Model of particle physics. Its couplings (interaction strengths) with other particles in the dominant decay modes are measured with an uncertainty of 15–30% by each experiment, and scale with mass as predicted (see figure 1). With the full 3000 fb^{-1} of the HL-LHC, the dominant couplings can be measured with a precision of 2–5%; this potential improvement is also shown in figure 1. What's more, rare production processes and decay modes can be observed. Of particular interest is to find evidence for the production of a pair of Higgs bosons, which depends on the strength of the interaction between the Higgs bosons themselves. This will be complemented by precise measurements of other Standard Model processes and any deviations

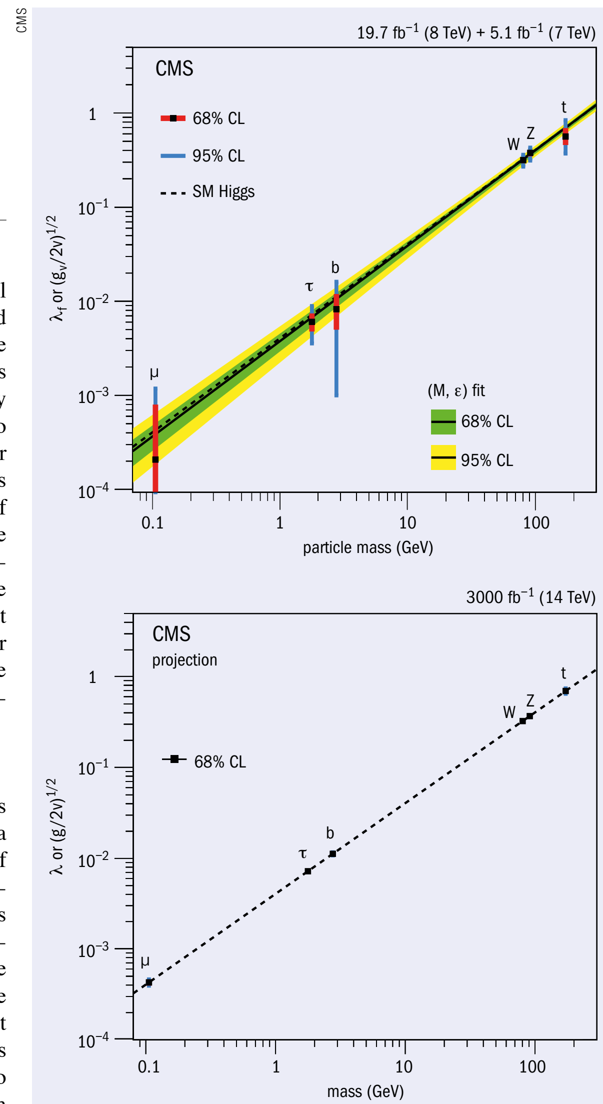


Fig. 1. The Higgs boson couplings precision measured with the current data (top) and their projection at the end of the HL-LHC programme (bottom).

from the theoretical predictions will be indirect evidence for a new type of physics.

In parallel, the direct search for physics beyond the Standard Model will continue. The theory of supersymmetry (SUSY) introduces a heavy partner for each ordinary particle. This is very attractive in that it solves the problem of how the Higgs boson can remain relatively light, with a mass of 125 GeV, despite its interactions with heavy particles; in particular, SUSY can cancel the large corrections to the Higgs mass from the 173 GeV top quark. According to SUSY, the contributions from ordinary particles are cancelled by the contributions from the supersymmetric partners. The presence of the lightest SUSY particle can also explain the dark matter in the universe. Figure 2 compares the results achievable at the LHC and HL-LHC in a search for electroweak SUSY particles. Electroweak SUSY production has a relatively low rate, and benefits from the factor 10 increase in luminosity. Particles decaying via a W boson and a Z boson give final states with three leptons and missing transverse momentum.

Other "exotic" models will also be accessible, including those that introduce extra dimensions to explain why gravity is so weak compared with the other fundamental forces.

If a signal for new particles or new interactions begins to emerge – and this might happen in the second ongoing period of the LHC operation, which is running at higher energy compared with the first period – the experiments will have to be able to measure them precisely at the HL-LHC to distinguish between different theoretical explanations.

Experimental challenges

To achieve the physics goals, ATLAS and CMS must continue to be able to reconstruct all of the final-state particles with high efficiency and low fake rates, and to identify which ones come from the collision of interest and which come from the 140–200 additional events in the same bunch crossing. Along with this greatly increased event complexity, at the HL-LHC the detectors will suffer from unprecedented instantaneous particle flows and integrated radiation doses.

Detailed simulations of these effects were carried out to identify the sub-systems that will either not survive the high luminosity environment or not function efficiently because of the increased data rates. Entirely new tracking systems to measure charged particles will be required at the centre of the detectors, and the energy-measuring calorimeters will also need partial replacement, in the endcap region for CMS and possibly in the more forward region for ATLAS.

The possibility of efficiently selecting good events and the ability to record higher rates of data demand new triggering and data-acquisition capabilities. The main innovation will be to implement tracking information at the hardware level of the trigger decision, to provide sufficient rejection of the background signals. The new tracking devices will use silicon-sensor technology, with strips at the outer radii and pixels closer to the interaction point. The crucial role of the tracker systems in matching signals to the different collisions is illustrated in figure 3, where the event display shows the reconstruction of an interaction producing a pair of top quarks among 200 other collisions. The

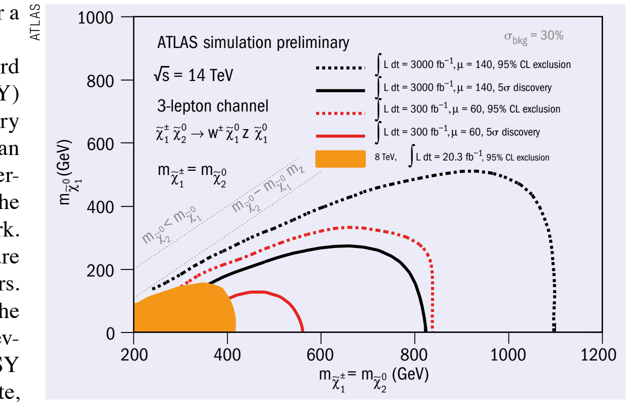


Fig. 2. The extension in discovery potential and search reach from the LHC to the HL-LHC for direct pair production of a chargino and a neutralino.

granularity will be increased by about a factor of five to produce a similar level of occupancies as with the current detectors and operating conditions. With reduced pixel sizes and strip pitches, the detector resolution will be improved. New thinner sensor techniques and deeper submicron technologies for the front-end read-out chips will be used to sustain the high radiation doses. And to further improve the measurements, the quantity and mass of the materials will be substantially reduced by employing lighter mechanical structures and materials, as well as new techniques for the cooling and powering schemes. The forward regions of the experiments suffer most from the high pile-up of collisions, and the tracker coverage will therefore be extended to better match the calorimetry measurements. Associating energy deposits in the calorimeters with the charged tracks over the full coverage will substantially improve jet identification and missing transverse energy measurements. The event display in figure 4 shows the example of a Higgs boson produced by the vector boson fusion (VBF) process and decaying to a pair of τ leptons.

The calorimeters in ATLAS and CMS use different technologies and require different upgrades. ATLAS is considering replacing the liquid-argon forward calorimeter with a similar detector, but with higher granularity. For further mitigation of pile-up effects, a high-granularity timing detector with a precision of a few tens of picoseconds may be added in front of the endcap LAr calorimeters. In CMS, a new high-granularity endcap calorimeter will be implemented. The detector will comprise 40 layers of silicon-pad sensors interleaved with W/Cu and brass or steel absorber to form the electromagnetic and hadronic sections, respectively. The hadronic-energy measurement will be completed with a scintillating tile section similar to the current detector. This high-granularity design introduces shower-pointing ability and high timing precision. Additionally, CMS is investigating the potential benefits of a system that is able to measure precisely the arrival time of minimum ionising particles to further improve the vertex identification for all physics objects.

The muon detectors in ATLAS and CMS are expected to survive the full HL-LHC period; however, new chambers and ▷

ATLAS

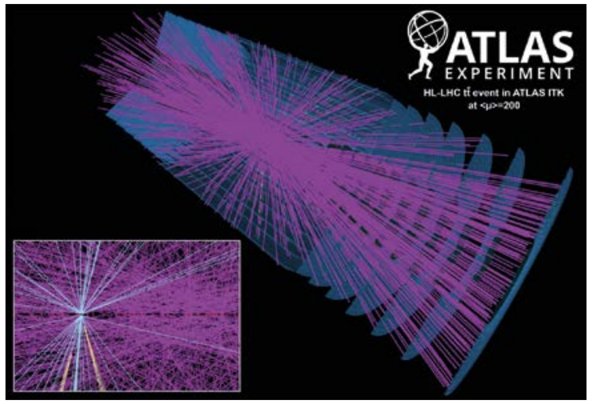


Fig. 3. Event display of a top–antitop event with 200 pile-up events in the ATLAS Phase-II tracker. The zoom bottom left shows the collision region, stretched to be 9 cm long and 11 mm tall. The tracks from the top quarks are highlighted. They all come from the same interaction, and the displaced vertices from b-hadron decays have been reconstructed.

CMS

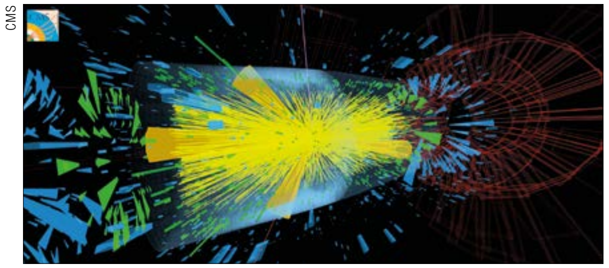


Fig. 4. The display of an event with a Higgs boson produced in the VBF process on top of 200 pile-up collisions. The efficient identification of the forward jets accompanying this process requires association of the calorimeter energy deposits with charged tracks.

read-out electronics will be added to improve the trigger capabilities and to increase the robustness of the existing systems. ATLAS will add new resistive plate chambers (RPC) and small monitored drift tube chambers to the innermost layer of the barrel. The endcap trigger chambers will be replaced with small-strip thin gap chambers. CMS will complete the coverage of the current RPCs in the endcaps with high-rate capability chambers in gas electron multipliers in the front stations and RPCs in the last ones. Both experiments will install a muon tagger to benefit from the extended tracker coverage.

The trigger systems will require increased latency to allow sufficient time for the hardware track reconstruction and will also have larger throughput capability. This will require the replacement of front-end and back-end electronics for several of the calorimeter and/or muon systems that will otherwise not be replaced. Additionally, these upgrades will allow the full granularity of the detector information to be exploited at the first stage of the event selection.

Towards Technical Design Reports

To reach the first milestone in the approval process agreed with the CERN scientific committees, ATLAS and CMS prepared detailed documentation describing the entire Phase II "reference" upgrade scope and the preliminary planning and cost evaluations. This documentation includes scientific motivations for the upgrades, demonstrated through studies of the performance reach for several physics benchmarks and examined in 140 and 200 collision pile-up conditions. The performance degradation with two scenarios of reduced cost, where the upgrades are descoped or downgraded, was also investigated. After reviewing this material, the CERN LHC Committee and the Upgrade Cost Group reported to the CERN Research Board and the Resource Review Board, concluding that: "For both experiments, the reference scenario provides well-performing detectors capable of addressing the physics at the HL-LHC."

The success of this first step of the approval process was declared, and the ATLAS and CMS collaborations are now eager to proceed with the necessary R&D and detector designs to prepare Technical Design Reports over the next two years.

● For further details, visit https://cds.cern.ch/record/2055248, https://cds.cern.ch/record/2020886 and https://cds.cern.ch/record/2055167/files/LHCC-G-165.pdf.

Résumé

Le programme d'amélioration pour ATLAS et CMS passe à la phase suivante

Le projet LHC haute luminosité permettra également d'étendre le programme de physique des expériences. Des éléments clés des détecteurs devront être remplacés pour que ces instruments puissent traiter l'empilement d'interactions proton-proton – 140 à 200 en moyenne par croisement de paquets. En octobre 2015, le Comité d'examen des ressources du CERN a confirmé que les collaborations peuvent à présent élaborer des rapports de conception technique (TDR). Le franchissement de cette première étape du processus d'approbation est un grand succès pour les expériences ATLAS et CMS.

Luca Nagel/CAST

Giovanni Cantatore and Marin Karuza in front of the CAST magnet, holding the heart of the KWISP force sensor: nanomembranes to detect the direct coupling of exotic particles to matter.

CAST: enlightening the dark

After sixteen years searching for solar axions, CAST is attracting new collaborators and widening its scientific programme.

K Zioutas, CAST spokesperson, **G Cantatore**, CAST deputy spokesperson, and **M Karuza**, CAST scientist.

Our star has been the target of human investigation since the beginning of science. However, a plethora of observations are not yet understood. A good example is the unnaturally hot solar corona, the temperature of which spans 1–10 MK. This anomaly has been studied since 1939 but, in spite of a tremendous number of observations, no real progress in understanding its origin has been made. We also know that a significant fraction of the Sun's total luminosity, about 4%, can escape as some form of radiation that we do not yet know, without being in conflict with the constraints imposed by the evolution of the Sun. In this framework, physicists have hypothesised the existence of exotic particles, including axions and chameleons. Other particles, such as the celebrated WIMPs, also point to the Sun as a target for relevant investigations. Indeed, over cosmic time periods, WIMPs can be gravitationally trapped inside the solar core. There, they condense, allowing their mutual annihilation into known particles, including escaping high-energy neutrinos.

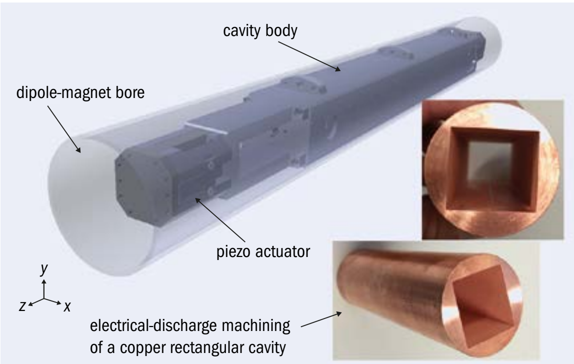
A breakthrough discovery in the so-called "dark sector" could pop up at any time. The question is when this will happen and where: in an Earth-bound laboratory or in a space-bound one. It is worth stressing that it is not at all obvious whether the extreme conditions in the Sun can be completely duplicated on Earth.

Benchmark for axion searches

For many days in recent years, CAST – the CERN Axion Solar Telescope (*CERN Courier* April 2010 p22) – has pointed its antenna towards the Sun for about 100 minutes during sunrise and sunset. Its aim was to detect solar axions through the Primakoff effect (1950), a classic detection scheme from particle physics. This solar-axion search was completed in November 2015 (*CERN Bulletin*, https://cds.cern.ch/journal/CERNBulletin/2015/39/News%20Articles/2053133?ln=en), and even though CAST has not ▷

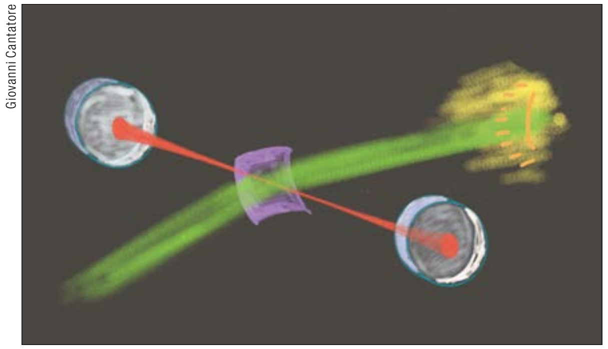
CERN Courier January/February 2016
Exotic particles

CAPP, Korea



Axions from the Big Bang can convert into microwaves inside these resonant cavities, which are inserted into the bores of the CAST magnet and immersed in its 9.6 T dipole field.

Giovanni Cantatore



Artist's view of the KWISP force-sensor principle. An optical Fabry–Pérot resonator senses the movements of a nanomembrane, which like a sail, catches the wind of chameleons from the Sun.

observed an axion signature, it provides world-best limits on the axion interaction strength with normal matter in the form of the magnetic field present inside the CAST magnet bores.

The results of the CAST scientific programme were also achieved thanks to the X-ray telescope (XRT) recovered from the ABRIXAS German space mission and installed downstream on one of the magnet bores. The telescope works as a lens focusing the photon flux onto the detector. Any increase in the signal-to-noise ratio would be a signature of axions. This unique technique, borrowed from astrophysics, allowed the collaboration to simultaneously measure signal and background. Given its success, a second X-ray telescope was added in 2014.

Very accurate tracking of the Sun is crucial to the experiment's data analysis. To provide this, CERN surveyors pinpoint exactly where the telescope lies and where it is pointing to, relative to a reference in time and space. However, to be absolutely certain, twice a year, when the Sun is visible through a window in the CAST experimental hall, the magnet tracks the Sun with a camera mounted and aligned to point exactly along its axis. This process of "Sun filming" has confirmed that CAST is pointing at the centre of the Sun with sufficient precision.

Up to now, CAST has been looking for exotica that the Sun might have produced some 10 minutes earlier. However, thanks to a continuous upgrade programme for the detectors and the development of new ideas, the collaboration is now extending its horizons, back in time closer to the Big Bang and into the dark sector. In its 119th meeting, the CERN SPS and PS experiments Committee (SPSC) recommended the new CAST physics programme for approval, which includes searches for relic axions and chameleons.

Axions from the Big Bang

Due to their extremely long lifetime (longer than the age of the universe), axions produced during the Big Bang could still be detected today. These relic particles have been searched for with instruments using a resonant cavity immersed in a strong magnetic field where axions are expected to convert into photons (with a probability that depends quadratically on the magnetic-field intensity). The signal is further enhanced when the cavity is at resonance with the photon frequency. In particular, the signal strength depends on the cavity "quality factor", defined as the ratio between the cavity fundamental frequency and the resonance line width.

However, the inherent problem of axion searches is the unknown rest mass, although the cosmologically preferred mass range for the so-called cold dark-matter axions lies between μeV/c² and meV/c², with a favoured region around 0.1 meV. The photon energy is equal to the axion rest mass, because its kinetic energy is negligibly small. To scan the regions of interest, the cavity resonant frequency is varied over a certain axion-mass range, basically determined by cavity size and shape.

Dipole magnets, such as the CAST magnet, can be transformed into relic axion antennas by means of new resonant microwave cavities. These cavities, designed and built by the Korean Centre for Axion and Precision Physics (CAPP) in collaboration with CERN, will be inserted inside the dipole magnetic field within the 1.7 K cold bores to search for microwave photons converted from cosmological axions, which would be direct messengers from the Big Bang era. In addition, a second microwave sensor will be inserted in the other bore. With its new set-up currently under construction, CAST should have access to an axion-mass range up to 100 μeV/c². At these relatively high mass values, detection becomes much harder, but the hope is that this region, which is critical for the dark-matter conundrum, will also be explored.

Chameleons come on stage

As may be imagined, detecting chameleons – new scalar particles that are possible candidates for the unknown dark energy – is not a trivial matter. The CAST collaboration plans to do it by exploiting two different couplings: Primakoff coupling to photons and direct coupling to matter.

The expected energy spectrum of solar chameleons has a peak at about 600 eV, making it even harder to detect them through their Primakoff coupling than the axions. Therefore, sub-keV threshold, low-background photon detectors are required. To tackle this problem, the CAST collaboration decided to start with a Silicon Drift Detector (SDD), becoming, with recently published results, the first chameleon helioscope. The new InGRID detector, based on the MicroMegas concept and having on-board read-out electronics, replaced the CCD camera in the XRT focal plane in 2014, improving the overall expected performance of CAST for solar chameleons.

Chameleon particles are theorised to have amazing properties: they can freely traverse thick slabs of dense matter if they impinge on them normally (i.e. perpendicular to), or they can bounce off nanometre-thin membranes, not much denser than ordinary glass, when approaching them at a grazing incidence angle of just a few degrees. In doing so, they exert a minute force, much like grains of sand hitting the palm of a hand. If detected, this tiny force is the signature of the direct interaction of chameleons with matter.

Forces are experienced in everyday life, so there may seem to be nothing special about detecting them. However, sensing exceedingly tiny forces requires advanced skills and techniques. The KWISP opto-mechanical force sensor is able to instantaneously feel forces of 10^{-14} N – that is, the weight of a single bacterium. It uses a Si_3N_4 membrane, just 100 nm thick, to intercept the flux of solar chameleons. Being as elastic as a drumhead, it flexes under their collective force (pressure) by an amount less than the size of an atomic nucleus. The membrane sits inside a Fabry–Pérot optical resonator, made of two high-reflectivity super mirrors facing each other, where a standing wave from an IR laser beam is trapped. As the membrane flexes, the characteristic frequency of this wave changes, generating the signal. The power of the KWISP sensor comes from the combined response of two high-Q resonators, the optical (Fabry–Perot) and the mechanical (membrane).

In addition to KWISP, a further ingredient is necessary in the search for chameleons: a time-dependent amplitude modulation on the chameleon flux in such a way as to beat the drum at its eigenfrequency for maximum effect. To solve this problem, the authors have invented the chameleon chopper, which is basically a rotating optically flat surface, applying the principle of chameleon optics: transmission at normal incidence, reflection at grazing incidence. Surprisingly, phase-locking techniques can also exploit this angular variation to obtain additional information on chameleon physics.

Sensing exceedingly tiny forces requires advanced skills and techniques.

According to theory, the internal surfaces of the ABRIXAS telescope, designed to reflect X-rays impinging at grazing incidence, would also reflect and focus chameleons. This increases their flux by a factor larger than 100, which is further enhanced by the exposure time gained from Sun-tracking. This unplanned ability of the X-ray telescope is one of those lucky events by which nature sometimes smiles at scientists, allowing them to explore its secrets.

Why does the number of Galileo Galilei's dark spots change in an 11 year period?
How does the Sun's clock work?
What is the flare trigger?
What is the origin of the enigmatic hot corona?
What accelerates the solar wind?
Can we reproduce the Sun in a laboratory?
Does the Sun shine dark light? (<4% allowed)

Table 1. Solar mysteries.

The KWISP prototype is currently taking data at INFN Trieste (Italy) and a clone is being commissioned at CERN to take advantage of the CAST infrastructure. As mentioned also by the SPSC referees, with the force-sensor KWISP, it should be possible to address more fundamental physics questions, such as quantum gravity or the validity of Newton's 1/R² law at short distances. We plan, with colleagues from the Technical University in Darmstadt (Germany), Freiburg University (Germany) and CAPP (Korea), to develop an advanced KWISP design, *a*KWISP, and we welcome the interest of additional collaborators.

While it remains one of the lowest-cost astroparticle physics experiments, CAST is preparing to leap further into the dark sector. As history teaches us (see table 1), the Sun may be the key to this, although as our understanding of the Sun deepens, we will most probably uncover more mysteries about the star that gives us life.

● For more information, see https://cds.cern.ch/record/2022893.

Résumé

CAST: éclairer le secteur sombre

Après seize ans passés à chercher des axions solaires, CAST attire de nouveaux collaborateurs et élargit son programme scientifique. Lors de sa 119e réunion, le Comité des expériences SPS et PS du CERN (SPSC) a recommandé l'approbation du nouveau programme de physique de CAST, qui comprend la quête d'axions reliques et de caméléons. La collaboration procède à des améliorations de son installation d'expérimentation, avec de nouvelles cavités résonnantes, de nouveaux détecteurs, et le capteur de force opto-mécanique KWISP, capable de détecter des forces de 10^{-14} N, soit le poids d'une seule bactérie.

Imaging science: physics laboratories under the spotlight

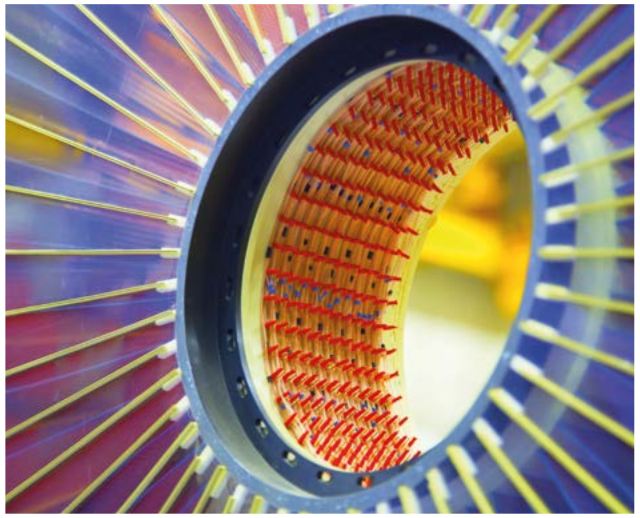
On 25 and 26 September 2015, eight physics laboratories lifted the curtain on their backstage activities for a series of local Photowalk competitions. More than 200 photographers, armed with their best lenses, were invited to CERN (Switzerland), DESY (Germany), Fermilab (US), INFN (Italy), KEK (Japan), SLAC (US), SUPL (Australia) and TRIUMF (Canada) to capture the cutting-edge technologies, feats of engineering and people behind the physics. Following these local events, each laboratory selected three winning photos from the hundreds submitted and put them forward for the international Global Physics Photowalk competition organised by the Interactions collaboration. The images featured here are the six winning entries from the international competition. Three of them were chosen by an international jury made up of artists, photographers and scientists and the other three were chosen by a public vote.

Julie Haffner, CERN.

Above: "Lighting the way for dark-matter detection and future particle-physics research." An electric mining drill deep within the Stawell Gold Mine (SUPL). Awarded 1st people's choice.

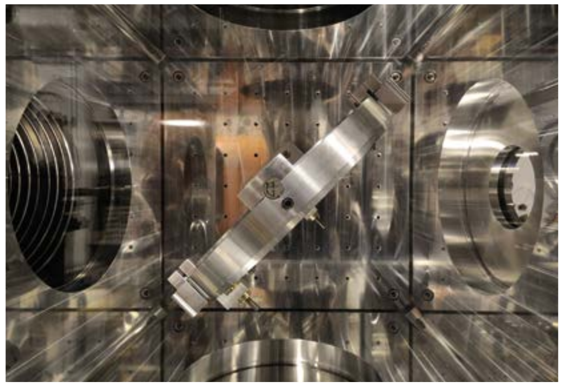
Left: "The Incredibles." This photograph was taken in the CERN restaurant, one of the key meeting points for CERN scientists. The jury noted the humanity behind the image: "There is a need for transferring ideas to make and create the world we live in." Awarded 3rd jury's choice.

Right: Taken in the temporary laboratory set up in the Stawell Gold Mine at SUPL, the image "gives a sense of the work that goes into particle physics long before there are data to analyse". Awarded 2nd jury's choice.



Right: Detail of the forward radial wire chamber forming part of the H1 detector that took data at the HERA collider at DESY from 1992 to 2007. Awarded 3rd people's choice.

Above: From TRIUMF's main control room, operators control the laboratory's main cyclotron and proton beamlines. The jury noted the technical complexity of the science with the emotional component of the human operator. Awarded 1st jury's choice.



Right: A vacuum chamber containing a mirror carrying the FLAME laser beam to the experimental room of the SPARC accelerator at the INFN National Laboratory of Frascati. Awarded 2nd people's choice.

Image credits: (clockwise from top left) Molly Patton/Laboratory: SUPL, Australia; Robert Hradil/Laboratory: CERN, Switzerland; Katy Mackenzie/Laboratory: TRIUMF, Canada; Pietromassimo Pasqui/Laboratory: INFN, Italy; Rosemary Wilson / Laboratory: DESY, Germany; Mark Killmer/Laboratory: SUPL, Australia.

PS beam extraction becomes more efficient

Since September 2015, the proton beam for fixed-target physics at CERN's Super Proton Synchrotron has been generated using a new, more efficient extraction scheme from the Proton Synchrotron.

Simone Gilardoni, **Massimo Giovannozzi**, **Cédric Hernalsteens**, **Alexander Huschauer** and **Guido Sterbini**, CERN, on behalf of the MTE project members and of the OP crew.

First thought of in 2002 with the goal of significantly reducing beam losses that cause high ring activation, the Multi-Turn Extraction (MTE) system (*CERN Courier* March 2009 p29) has, since then, encountered numerous challenges during its implementation in the Proton Synchrotron (PS). Now, the regular MTE operation over the last two months constitutes a crucial milestone for this new beam manipulation, and paves the way for further studies and optimisations.

The lows

In 2010, MTE was the default choice to deliver beam for the Super Proton Synchrotron (SPS) physics run. However, after only a few weeks of operation for the production of neutrinos in the framework of the CNGS programme, the PS extraction mode had to revert back to Continuous-Transfer (CT) extraction, which is associated with high beam losses along the ring circumference. This feature was the reason for studying an alternative extraction mode. In the new scheme, the beam is split horizontally into five beamlets – one in the centre and four in stable islands of the horizontal phase space. Unfortunately, the intensity sharing between the islands and the centre (figure 1) and the extraction trajectories were fluctuating on a cycle-to-cycle basis. This was not only significantly affecting the beam transmission through acceleration in the SPS, but also prevented proper optimisation of the SPS parameters. In addition, activation of the PS extraction region had increased anomalously, although the rest of the ring was profiting from a significant reduction in radiation levels with respect to CT operation.

Intense investigations were undertaken to find the source of the observed variations and to overcome the PS ring activation. The latter problem proved to be much easier to solve than the former. ▷

All image credits CERN

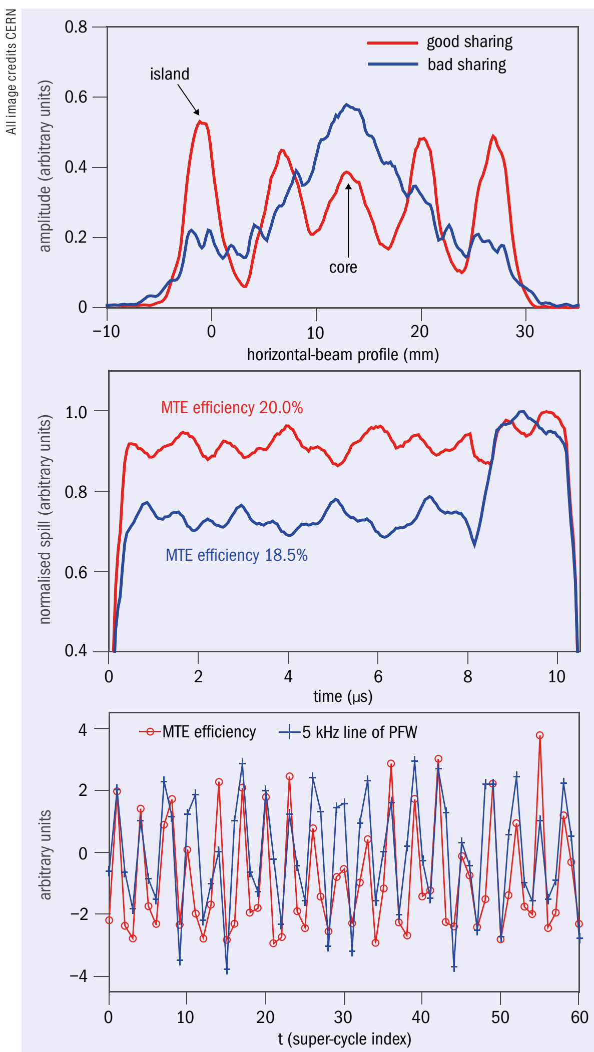


Fig. 1. Measurements of the beam profiles after splitting (top) and the corresponding beam spills after extraction, as measured in the transfer line (centre). The correlation between the oscillations in the MTE efficiency and the 5 kHz line of the PFW current is also shown (bottom).

Accelerator techniques

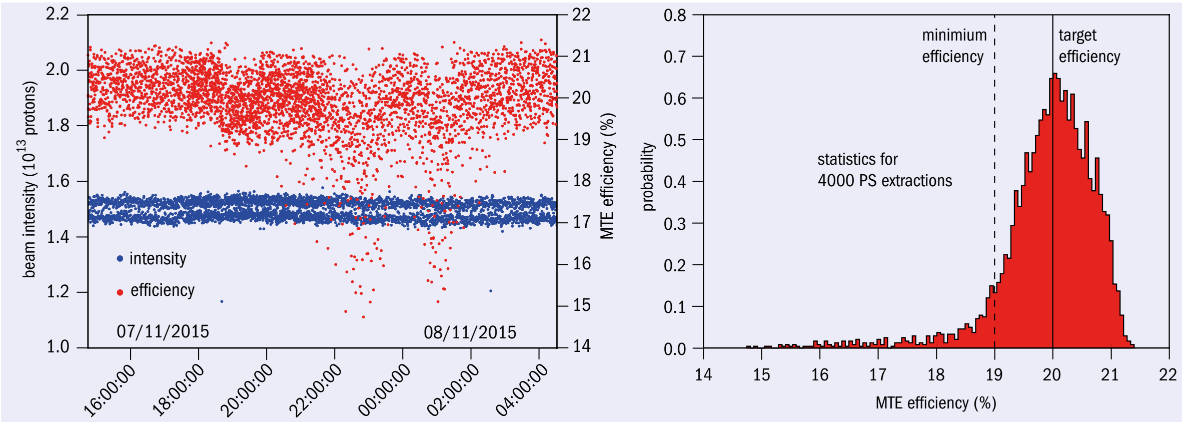


Fig. 2. Time evolution of the MTE efficiency (left) and the resulting distribution (right). The MTE efficiency is defined as the average of the beam intensity of each of the first four extracted turns normalised to the total beam intensity: I_{island}/I_{tot}. Minimum and target efficiencies as requested by the SPS are also shown.

The increased activation was tackled by designing a new piece of hardware, a so-called dummy septum, which is a passive septum with only a copper blade and no coils for generating a guiding magnetic field. The dummy septum is supposed to intercept protons from the de-bunched beam during the extraction-kickers' rise time, therefore preventing them from interacting with the blade of the active extraction septum. This approach, combined with appropriate shielding of the dummy septum, provides a well-localised loss point that is acceptable in terms of overall activation of the PS ring. It is worth noting that the use of a shadowing device for the main extraction septum is a known approach in, for example, the SPS. However, in a small ring like the PS, the two devices cannot easily be located next to each other, which makes the overall configuration more complicated in terms of beam dynamics.

A side effect of the implementation of the dummy-septum solution is that the horizontal aperture of the PS ring is reduced, which calls for a complete review of all PS fast-extraction schemes to make them compatible with the presence of the dummy septum. This additional hurdle was overcome and the proposed solution looked acceptable on paper.

During Long Shutdown 1 (February 2013–May 2014) the design, construction, and installation of the dummy septum was completed, together with some modifications to the powering of the extraction bump. The beam commissioning of the whole system, including the new extractions, was completed successfully by the end of 2014.

To tackle the fluctuations of the extraction trajectories, systematic observations of hardware parameters in the PS ring, such as the currents of the key magnetic elements controlling the machine configuration, were undertaken. The aim was to find a correlation with the changes in intensity sharing between beamlets. Despite the long and detailed observations, no evidence for the guilty element was found, and the sources of fluctuations remained unidentified.

The highs

Activities to track down the origin of the fluctuations in the intensity sharing and of the extraction trajectories of the MTE beam resumed at the beginning of the 2015 physics run. Eventually, it was possible to identify a correlation between these variations and the amplitude of a 5 kHz ripple present on the current of some special circuits located in the PS main magnets (figure 1). The PS ring is made up of 100 combined-function main magnets with additional coils installed on the magnets' poles. These so-called pole-face windings (PFWs) and figure-of-eight loops allow control of the working point in terms of tunes and linear chromaticities, and some higher-order parameters such as the second-order chromaticity. The ensemble of the electrical circuits present in the main magnets and the interaction between the various components is extremely complex; all switching-mode power converters feature a ripple at 5 kHz with a varying phase, which turned out to be the culprit of the observed fluctuations.

This crucial observation guided the power-converter experts to implement mitigation measures (additional inductances to filter the ripple amplitude), and their expected effect was immediately observed as improvement of the stability of the MTE beam parameters (figure 2).

This milestone again opened up the route to transfer to the SPS, and first tests of beam delivery were conducted in the summer of 2015. Their success accelerated the subsequent steps, which culminated in the decision to use MTE for fixed-target physics: after the low of 2010, MTE was back in business.

Of course, this was just the start rather than the end of efforts. The studies, which were conducted on both the PS and SPS rings, continued in view of improving the overall beam quality. The intensity was raised from an initial value of about 1.6×10^{13} protons extracted from the PS to about 2.0×10^{13} protons at the end of the run, with extraction efficiency in the PS around 98% (figure 3).

This milestone again opened up the route to transfer to the SPS.

Accelerator techniques

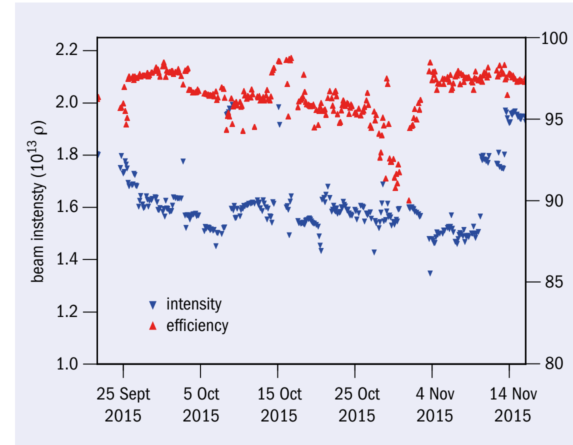


Fig. 3. Variation over time of the beam intensity (blue dots) and of the extraction efficiency (red dots) in the PS.

By the end of the run, the PS Booster joined the challenge, managing to produce brighter beams in the vertical plane to improve SPS transmission, which is plagued by limitation of the vertical aperture. The final touch was the finalisation of the dummy-septum configuration.

Promising future

The progress and future of MTE were discussed in two internal reviews in 2015. Given the overall success of the MTE studies, commissioning and operation during the last part of the physics run, MTE will be the standard extraction mode for the 2016 fixed-target run at the SPS. This is a necessary step to acquire better knowledge of the new beam manipulation, and also understand the limitations coming from the existing hardware. In parallel, studies to probe the beam behaviour for even higher intensities will be carried out. This is important in view of future projects requiring even more intense beams than those delivered today. By the middle of next year, a firm decision concerning the long-term future of MTE and its predecessor CT will be taken.

● For all MTE-related documents (design report, publications and talks), visit ab-project-mte.web.cern.ch/AB-Project-MTE/Documents.html.

Résumé

L'extraction des faisceaux du PS devient plus efficace

Depuis septembre 2015, les faisceaux de protons utilisés pour les expériences de physique avec cible fixe auprès du Supersynchrotron à protons du CERN sont produits par un nouveau système d'extraction à partir du Synchrotron à protons. Ce système, plus efficace, est appelé système d'extraction multitours (MTE). Les tests ayant été probants dans l'ensemble, le MTE sera, en 2016, le mode d'extraction standard pour l'exploitation avec cible fixe auprès du SPS. D'ici le milieu de l'année prochaine, une décision définitive sera prise sur le futur à long terme du MTE.

Interactions & Crossroads

Conferences

Quark Matter goes to Japan

Participants gather in the Kobe Fashion Mart for the 25th Quark Matter conference.

This October, the 25th Quark Matter conference assembled 650 participants in the Japanese city of Kobe. In a week packed with 168 parallel and 33 plenary talks, and two poster sessions, they discussed the latest results of the heavy-ion beam programmes at CERN's Large Hadron Collider (LHC) and at BNL's Relativistic Heavy Ion Collider (RHIC), as well as a broad range of theory highlights.

In a short opening ceremony on Monday morning, the conference chair, Hideki Hamagaki, president of the Japanese Physical Society, Yasuhiko Fujii, vice-president of the Science Council of Japan, Kumie Inose, mayor of Kobe, Kizo Hisamoto, director of the Center for Nuclear Study, the University of Tokyo, Takaharu Otsuka, and director of the RIKEN Nishina Center, Hideto En'yo, gave welcome addresses followed by a message from the Japanese prime minister, Shinzo Abe. In the scientific opening talk, Gordon Baym (University of Illinois) reviewed the key questions that motivated experimentation with relativistic nuclear beams 30 years ago, and discussed how these questions have evolved in the intervening decades.

Ultrarelativistic heavy-ion collisions are known for displaying remarkably strong signatures of collectivity. These support the fluid paradigm, according to which the low-momentum spectra of hadrons result from a fluid dynamical response to the initial pressure gradients present in the high-energy-density medium formed in the collision zone. This is of interest because the propagation of fluid fluctuations depends on the properties of the medium; data therefore constrain the transport properties of dense QCD matter such as shear viscosity, which are calculable from first principles in QCD.

In the previous QM conference in Darmstadt, similar features of collectivity observed in the smaller collision systems studied in the 2013 LHC p+Pb run and in d+Au collisions at RHIC had already been discussed. In Kobe, the ATLAS and CMS collaborations presented new analyses of p+p collisions, including a first glimpse of results from the 13 TeV run.

Events with more than ~100 charged- particle tracks share important commonalities with the signatures of collectivity seen in nucleus–nucleus collisions, and these extrapolate smoothly to smaller event multiplicities, albeit that non-flow effects such as jet-like correlations are more difficult to disentangle in these smaller systems. In the same context, the ALICE collaboration reported characteristic changes in the hadrochemical composition of high-multiplicity p+p collisions – for instance, the ratio Λ/K (also reported by the CMS collaboration) and the production of multi-strange baryons Ξ and Ω relative to pions increase with multiplicity in p+p collisions, in a pattern that resembles those observed in Pb+Pb and p+Pb collisions. In addition, the RHIC experiments contributed to a better understanding of the weak system size and weak energy dependence of the collective effects in small collision systems with first data on p+Au and ^{3}He+Au centre-of-mass energies of 200 GeV per nucleon–nucleon pair.

New analyses

In a special plenary session, "Quark gluon plasma in small systems?", the conference discussed the challenges that small systems pose to a dynamical understanding of collectivity in QCD. This was just one of the highlights for which Kobe will be remembered and that was taken up in several plenary talks.

The conference also covered a broad range of new analyses on high-momentum hadronic processes in nucleus–nucleus collisions that probe the high-density medium through which they propagate. LHC and RHIC experiments featured, for instance, detailed analyses of the jet substructure and of heavy-flavour production aimed at pinning down the properties of partonic energy loss in a dense QCD medium. CMS gave an update of the measurement of the bottomonium family in heavy-ion collisions at the LHC, where different states are sequentially suppressed as a function of their binding energy. ALICE reported a strong enhancement of J/ψ production at low p_T in peripheral collisions, possibly indicating the first observation of electromagnetic production of J/ψ in hadronic collisions.

Beyond Kobe, the field is eagerly awaiting the results from the ongoing Pb+Pb run at the LHC at 5 TeV centre-of-mass energy. This will include qualitatively novel experimental possibilities, because LHCb will be joining in a Pb+Pb run for the first time. In the next five years, the field is also looking forward to the beam-energy scan programme at RHIC. Beyond this period, Quark Matter discussed the sPHENIX project at RHIC that aims at qualitatively improved measurements of hard probes, and that had received first favourable reviews shortly before the conference, as well as physics at the LHC with increased luminosity and experimental performance after Long Shutdown 2. Low-energy programmes at CERN's SPS, at NICA, FAIR and J-PARC were mentioned, and the physics motivations and updated plans for a US-based electron–ion collider were presented. The results from the high-energy heavy-ion runs at the LHC will be the main highlights of the next two Quark Matter editions, in Chicago in 2017 and in Venice in 2018.

TRIUMF's Whistler workshop strengthens the case for future linear colliders

TRIUMF

The attendees of the LCWS2015 linear-colliders workshop, which was hosted by TRIUMF in Whistler, Canada.

In early November 2015, 220 participants from around the world gathered in Whistler, British Columbia, Canada, for the annual International Workshop on Future Linear Colliders (LCWS2015, lcws15.triumf.ca/). Hosted by TRIUMF, the workshop provided the opportunity to continue the study of the physics case for a high-energy linear electron–positron collider – taking into account the recent LHC results – and to review the progress in detector and accelerator designs for both the ILC and CLIC projects.

Continuing developments

LCWS2015 begun with a review of recent linear-collider activities and developments. Sachio Komamiya, a chair of the Linear Collider Board, opened the workshop with a summary of the board's activities and plans. Of the efforts identified, the priorities include continuing accelerator-technology developments, reinforcing political activities to facilitate intergovernmental negotiations, and continuing the development of the physics programme, taking into account LHC results. He also presented the comments from Japanese government studies about hosting the ILC in Japan, revealing that an additional period of approximately two years is needed before the government will arrive at a decision, and that international support for the project is therefore essential.

Linear-collider collaboration chair Lyn Evans summarised the technical progress that has been made over the past few years for both the CLIC and ILC designs, recognising that strong collaborations between many universities and laboratories have helped with the design developments and improvements to the accelerator parameters. Experience with the design and construction of the free-electron lasers, such as XFEL (DESY) and LCLS-II (SLAC), provides important developments related to linear-collider technologies.

KEK director-general Masato Yamauchi summarised the situation in Japan, which is strongly considering hosting the ILC. He underlined the need to share the project costs internationally and to confirm the willingness of each participating country to cover a reasonable fraction of the project expenses.

The review talks also highlighted the status and plans of both the ILC and CLIC projects, recent results from the LHC (including the first 13 TeV analyses) and a review of the field in respect of the areas where linear colliders could make critical contributions, including discoveries in the top-quark sector, precision Higgs studies, searches for dark matter and beyond Standard Model particles and interactions.

During the following three days of the workshop, more than 250 presentations took place, with ample time allowed for discussions at the parallel sessions of multiple working groups. Accelerator physicists discussed beam dynamics, beam delivery systems, machine–detector interfaces, sources, energy efficiency, nanobeams and conventional facilities. There were sessions on Higgs and electroweak, beyond the Standard Model, and top/QCD/loopverein physics. Detector sessions focused on software development, detector performance, machine detector interface, integration and vertex, tracking, calorimetry and muon systems. The CLIC and ILC projects and the detector collaborations also met during the workshop.

An interesting roundtable discussion entitled "How to formulate the case for the ILC – to physicists, to other scientists, and to the public" provided lively presentations, with many questions from the participants.

Future visions

The final day of the workshop concentrated on the summary reports from all working groups, followed by a vision talk on future linear colliders by Hitoshi Murayama. Alberto Ruiz Jimeno concluded LCWS2015 with the announcement that the spring 2016 linear-colliders workshop will be hosted in Cantabria, Spain from 30 May to 5 June. Mark your calendars!

Meetings

SESAME charts shared cultural future for the Middle East

CERN/James Gillies

SESAME beamline scientist Gihan Kamel (left) discusses the laboratory's infrared beamline with prospective users.

The 2015 SESAME Users' Meeting, the 13th in the series, was likely to be the final one before the commissioning of the pioneering regional light source for the Middle East begins in late 2016. The meeting was opened by SESAME director Khaled Toukan, who pointed out that not only will SESAME be the first light source in the region, but also its first intergovernmental centre of scientific excellence. Toukan went on to describe the progress towards commissioning. The first stage of the injector was commissioned in 2012, with the second stage in 2014. In 2015, the first full cell of the 2.5 GeV SESAME ring was commissioned at CERN, and components are now steadily arriving at the laboratory. Eight of the 16 girders that will support the main ring's magnets are at the laboratory, along with half of the dipoles. Almost half of the quadrupoles and sextupoles have arrived at the port of Aqaba and are awaiting transport to the laboratory. The magnets, along with their supporting girders and power supplies, have been provided through the European Commission-funded CESSAMag project coordinated by CERN.

SESAME's scientific director Giorgio Paolucci painted a vibrant picture of the initial science programme at the laboratory's two day-one beamlines, an X-ray absorption fine-structure/X-ray fluorescence (XAFS/XRF) beamline and an infrared beamline. He also pointed out the good progress towards beamlines three and four: a powder-diffraction beamline and a beamline for protein crystallography, both identified as priorities by the SESAME user community.

The XAFS/XRF beamline is built on a donation from a group at the European Synchrotron Radiation Facility (ESRF), and will provide an important tool for materials science, environmental science, life science, archaeology, art, cultural heritage and a broad range of industrial applications. The beamline components are at SESAME, while delivery of the beamline hutches is expected in March 2016. Discussions are underway with Italy's INFN concerning the development of a high-sensitivity silicon drift detector, and all is expected to be ready for beam by late summer 2016.

SESAME's infrared beamline, developed in co-operation with the French SOLEIL light source, is the first completely new beamline for the laboratory. Using an off-line source, it is already being used for research, and is also expected to be ready in the second half of 2016.

Beamline number three, a materials-science beamline based on a wiggler donated by the Swiss Light Source, should be complete by the end of 2017, while a macromolecular crystallography beamline should follow in 2018. This fourth beamline will benefit from a grant of $2 million from the Jordanian Scientific Research Support Fund.

Ready to go

Concluding the presentations from SESAME directors was technical director Erhard Huttel, who reported on the status of the machine. The CESSAMag project, he said, is reaching a conclusion, with all of the magnets and power supplies on their way to SESAME. Each magnet has been tested and shown to perform about a factor of 10 above the specification. At the time of the meeting, the power supplies were due to be delivered to the laboratory in December 2015, while the first batch of vacuum-chamber components had passed their factory acceptance tests. Delivery of the vacuum system is scheduled to be complete by April 2016. The RF system, with an amplifier designed at SOLEIL and cavities being provided by the Italian INFN and Elettra synchrotron in Trieste, is due for delivery starting in February 2016. All this leads to installation from January to October 2016, with commissioning scheduled for the end of the year. By the time of the next users' meeting, concluded Huttel, the SESAME main ring should be closed up and ready to go.

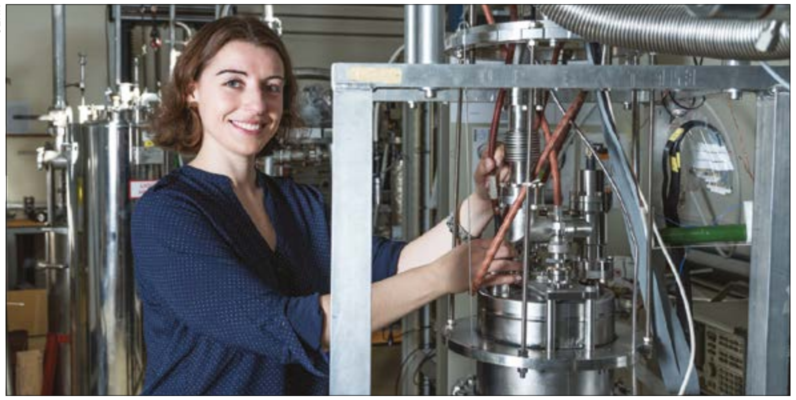
The remainder of the plenary talks mixed science perspectives from SESAME staff and users with inspirational talks from representatives of light sources around the world. Jesper Andersen presented Sweden's Max IV lab, while Marco Stampanoni of the Swiss Light Source discussed the remarkable potential of tomography, including a spectacular demonstration of the reconstruction of old film too fragile to be unrolled. Sarah Elliott of the University of Reading gave a broad overview of archaeological techniques, such as the identification of the earliest instances of animal penning in the Fertile Crescent.

Herman Winick of SLAC, one of the pioneers of SESAME, painted a compelling case for light sources in the developing world. They are capable of world-class research with only moderate outlay, provide training, reverse the brain drain, address regional concerns and promote peaceful collaboration among neighbours. He went on to describe existing facilities in China, Brazil, India, Korea, Taiwan and Thailand that have proven their worth. These are now well established, many are upgrading, and some have stimulated complementary programmes such as the bourgeoning nanotechnology research linked to Brazil's light source.

Among the talks from SESAME users was one by Israeli archaeometrist Jan Gunneweg. After years of scientific work on the Dead Sea Scrolls found at Qumran, Gunneweg issued a call to the SESAME user community to develop proposals to explore their common cultural heritage. He proposed a multidisciplinary approach through which SESAME members would team up to explore the cultural heritage of the region, and went on to give a long list of potential topics, ranging from unravelling the remaining mysteries of the pyramids, to studying the Amarna tablets, the plethora of ancient manuscripts from across the region, or even taking a scientific approach to the story of Noah's ark. Gunneweg's proposal distils the essence of SESAME into a single thought: it is as much about finding a shared cultural future, as it is about investigating.

SRF2015 features latest advances in superconducting RF cavities

CERN



CERN's Sarah Aull, whose presentation "On the understanding of Q slopes on thin niobium films" was awarded the first prize for young researchers oral presentations at SRF2015. The Q slope, i.e. the degradation of Q with accelerating gradient, is currently the main limitation for niobium-film technology. Curing the Q slope of niobium films will make this technology attractive for many future accelerator projects.

Experts working in the field of superconducting radio-frequency (RF) cavities presented their latest results at the SRF2015 conference, which was held in Whistler, British Columbia, Canada, earlier this autumn. From 13 to 18 September, more than 300 experts in the field covered the latest advances in the science, technology, and applications of superconducting RF.

An important aspect of designing future accelerators that will reach higher-energy frontiers is the further improvement of RF cavities, which are used to accelerate charged particles. The study of superconducting radio-frequency (SRF) cavities remains one of the most active fields of research, given the global interest for accelerators capable of accelerating different species of particles with higher efficiency. SRF cavities are also essential for numerous applications that accelerators find in industry, medical imaging and treatment, as well as for future promising applications.

In the past three decades, the development of sophisticated fabrication and preparation methods has led to high-performing SRF cavities and made this technology affordable for many particle accelerators. Key to the concept is the ultra-low surface resistance of the superconductor, which allows storing energy in the cavities with very low losses.

CERN researchers work with different materials that could be used for these cavities. Up to now, superconducting RF cavities have mainly been manufactured using high-purity niobium sheets, and although the properties of the best cavities are excellent, there is still a lack of understanding of loss mechanisms, as well as of the effect of treatments and dynamic effects. In addition, a team of experts is currently exploring different options for superconducting materials that can be used for coating RF cavities and lead to better performance. In the framework of the conceptual study report for the Future Circular Collider, research is currently undertaken in the areas of RF design, SRF materials and coating technology.

At the SRF2015 conference, speakers also covered a number of other topics, including developments for the HIE-ISOLDE upgrade, the high-luminosity upgrade of the LHC, the bulk-niobium high-gradient programme, and fabrication- and preparation-related challenges. The conference included a number of plenary talks, as well as a three-day poster session. Each poster session was followed by a "hot-topic" discussion addressing key questions, while the day before the start of the conference was dedicated to a student poster session. Finally, an industrial exhibit was organised during the conference, giving researchers the opportunity to discuss the latest results with key vendors and envisage new opportunities that might come from the application of future developments in the fields.

All in all, it was a well-attended conference, igniting vibrant discussions in a rapidly developing field. SRF2017 will take place in Lanzhou, China, where further important results are expected to be announced, given the rapid development of the field.

SCHOOLS

CAS course looks at the limitations of particle beams

The CERN Accelerator School (CAS) recently organised a specialised course on Intensity Limitations in Particle Beams at CERN, from 2 to 11 November 2015.

Many accelerators and storage rings, whether intended for particle-physics experiments, synchrotron light sources or industrial applications, require beams of high brightness and the highest possible intensities. A good understanding of the possible limitations is required to achieve the desired performance. This course covered the interaction of beams with their surroundings and with other beams, as well as further collective effects. The lectures on the effects and possible mitigations were complemented by tutorials.

The course was very successful, with 66 students representing 14 nationalities attending. Most participants came from European countries, but also from Armenia, China and Russia. Feedback from the participants was positive, reflecting the standard of the lectures and teaching.

In addition to the academic programme, the participants also had an opportunity to take part in a typical Swiss excursion to Bern and Gruyères, and a short CERN tour, both of which were highly appreciated by all who took part.

Forthcoming CAS courses in 2016 will be: a specialised school on free-electron lasers and energy-recovery linacs (FELs and ERLs) in collaboration with DESY in Hamburg, Germany in June; an introductory school on accelerator physics in Istanbul, Turkey in September; and a specialised school on beam injection, extraction and transfer (location to be decided), in November.

● More information on CAS courses can be found on the CAS website at www.cern.ch/schools/CAS.

WORKSHOP

Frontiers in hadron and nuclear physics with strangeness and charm

J Marton

Participants outside the Villa Tambosi in Trento, Italy, home to ECT.*

Experts and young researchers alike met at the European Centre for Theoretical Studies in Nuclear Physics and Related Areas – ECT* – in Trento, Italy, from 18 to 23 October 2015, at the "Frontiers in hadron and nuclear physics with strangeness and charm" international workshop. They discussed the most recent achievements and future perspectives in hadron and nuclear physics with strangeness and charm, from both theoretical and experimental points of view.

In the strangeness sector, a very intriguing situation is represented by the so-called "deeply bound kaonic nuclei" where, according to some theories, the presence of a strange (anti)quark in the nuclei might bind it by ten(s) of MeV per nucleon. However, in the framework of other theories, the binding energy is much smaller. New results in this sector, obtained by the AMADEUS, FOPI, HADES and E15 collaborations, were discussed, together with future perspectives at DAΦNE and J-PARC.

The kaonic atom studies represent the ideal tool to research the low-energy QCD; the precision measurement of the kaonic deuterium is planned in the framework of the SIDDHARTA-2 at DAΦNE and at J-PARC. When combined with SIDDHARTA's kaonic hydrogen result, this will enable us to determine the isospin-dependent antikaon–nucleon scattering lengths, the fundamental quantities for understanding low-energy QCD in the strangeness sector. The discovery of two solar-mass neutron stars also triggered a vivid discussion about the possible role of strangeness in astrophysics.

In the charm sector, a hot topic of debate was represented by the recently discovered Pc(4450), which is claimed to be a charmed pentaquark but whose interpretation was questioned by some of the speakers.

The workshop was organised by Kai-Thomas Brinkmann (University of Giessen, Germany), Catalina Curceanu (LNF-INFN, Italy), Johann Marton (SMI-Vienna, Austria), Ulf-G Meißner (University of Bonn and FZ Jülich, Germany) and Bing-Song Zou (ITP/CAS, China).

● For full details and presentations, see smifbsd0.smi.oeaw.ac.at/ECT/.

EINN conference celebrates 20 years

EINN

The winners of the best poster award are announced at the evening plenary session.

The Electromagnetic Interactions with Nucleons and Nuclei (EINN) conference, which began in 1995, was held on the Santorini and Milos islands in Greece until it moved to Paphos in Cyprus in 2011. The series covers experimental and theoretical topics in nuclear and hadronic physics. It also serves as a place to make contacts and as a forum for discussions on the current and future developments in the field. The conference has unofficially been a counterpart of the US Gordon Conference on Photonuclear Physics and is held in alternate years, with a traditionally strong US participation. No proceedings are produced, in the tradition of the Gordon and Euroconferences, in order to encourage the frank exchange of even tentative information.

The 11th EINN conference took place in Paphos on 1–7 November, and attracted around 100 participants from 19 countries in Europe, North America and Asia. This year marked 20 years of the successful organisation of the series, and a celebration organised by K de Jager, who was the first chair, took place.

Since 2011, the conference programme has had dedicated sessions for postdoctoral fellows and advanced graduate students, who receive financial support. In 2013 an extra day was added prior to the conference, which included pedagogical lectures to facilitate the understanding by younger physicists of the more technical talks during the conference. This year a two-day pre-conference event on "Frontiers and careers in photonuclear physics" was added. This included skills development and talks for students, and was very well received. As is customary, two topical parallel workshops were organised, one on spectroscopy and the other on the spin structure of nucleons and nuclei, which this year included selected talks from the submitted abstracts as well as invited talks. More than 40 students and postdoctoral fellows participated in the conference by receiving partial support.

A highlight of the conference was the evening plenary poster session, which drew a large attendance with lively discussions. The authors of the three best posters were selected by a secret vote of all attendees. The winners, who were young researchers from the Cyprus Institute, MIT, and Mainz University, were awarded the Feynman lecture series and commemoratory gifts, and presented a talk on the subject of their posters during the plenary session.

The conference covered a wide range of theoretical and experimental developments in hadron physics, including the dipole moments of neutral and charged particles, the proton-radius puzzle, new experimental facilities, dark-matter searches, nuclear astrophysics, lattice QCD, spectroscopy, the spin structure of nucleons, precision electroweak physics and new physics searches. With the study of QCD being a major focus of present activities and future plans in physics research worldwide, the EINN conference will continue to provide an important international forum, particularly for young physicists, for the foreseeable future.

● For more information, see www.cyprusconferences.org/einn2015/ and www.einnconference.org.

Events calendar

6–11 March
LEAP (Low Energy Antiproton Physics) 2016
Kanazawa, Japan
LEAP 2016 will feature discussions in the field of antiproton physics.
leap2016.riken.jp

7–11 March
ICEC 26 – ICMC 2016
New Delhi, India
Biennial international conference on cryogenic engineering and cryogenics materials. The conference will feature ongoing large superconducting and cryogenic projects.
icec26-icmc2016.org

12–26 March
Rencontres de Moriond
La Thuile, Aosta valley, Italy
As is tradition, the event will feature three thematic conferences: electroweak interactions and unified theories; QCD and high-energy interactions; and cosmology.
moriond.in2p3.fr

11–15 April
Annual Meeting of the Future Circular Collider study
Rome, Italy
This second meeting will bring together leading experts in engineering and science to exchange information about the design progress and to set the goals for the coming year. Dedicated technology R&D programmes will also be presented.
fccw2016.web.cern.ch

Faces & Places

Awards

APS announces prizewinners for 2016

From left to right: Jonathan Dorfan, David Hitlin, Fumihiko Takasaki and Stephen L Olsen.

The American Physical Society (APS) has announced many of its awards for 2016, including major prizes in experimental and theoretical nuclear and particle physics.

The major award in experimental particle physics, the W K H Panofsky Prize, recognises and encourages outstanding achievements in the field. For 2016, it goes to Jonathan Dorfan of Okinawa Institute of Science and Technology, David Hitlin of California Institute of Technology, Fumihiko Takasaki of KEK and Stephen Olsen of the Institute for Basic Science. The four physicists are recognised for "leadership in the BaBar and Belle experiments, which established the violation of CP symmetry in B-meson decay, and furthered our understanding of quark mixing and quantum chromodynamics".

The Robert R Wilson Prize for Achievement in the Physics of Particle Accelerators is another award that recognises and encourages outstanding work. Vasili Parkhomchuk of the Budker Institute of Nuclear physics receives the 2016 prize for his "crucial contributions in the proof-of-principle of electron cooling, for leading contribution to the experimental and theoretical development of electron cooling, and for achievement of the planned parameters of coolers for facilities in laboratories around the world".

In the theoretical domain, the J J Sakurai Prize for Theoretical Particle Physics recognises and encourages outstanding achievement in particle theory. The 2016 prize is awarded to Peter Lepage of Cornell University for "inventive applications of quantum field theory to particle physics, particularly in establishing the theory of hadronic exclusive processes, developing non-relativistic effective field theories, and determining Standard Model parameters with lattice gauge theory".

In addition, the Herman Feshbach Prize is for outstanding research in theoretical nuclear physics. Xiangdong Ji of the University of Maryland, College Park, and Shanghai Jiao Tong University, receives the 2016 prize for his "pioneering work in developing tools to characterise the structure of the nucleon within QCD and for showing how its properties can be probed through experiments; this work not only illuminates the nucleon theoretically but also acts as a driver of experimental programmes worldwide".

Gamma-rays and black holes

Also in nuclear physics, the Tom W Bonner Prize is for outstanding experimental research in the field, including the development of a method, technique or device that significantly contributes in a general way to nuclear-physics research. The 2016 prize is awarded to I-yang Lee of Lawrence Berkeley National Laboratory, for "seminal contributions to the field of nuclear structure through the development of advanced gamma-ray detectors as realised in the Gammasphere device, and for pioneering work on gamma-ray energy tracking detectors demonstrated by the Gamma-ray Energy Tracking Array (GRETINA)."

The Dannie Heineman Prize for Mathematical Physics recognises outstanding publications in the field, and for 2016 it goes to two well-known theoreticians from Harvard University. Cumrun Vafa and Andrew Strominger are honoured for "leadership in numerous central developments in string theory, quantum field theory, and quantum geometry; including the interplay between string theory and Calabi-Yau geometry and especially for their elucidation of the origin of black-hole entropy from microscopic states".

Black holes are also cited in the 2016 Maria Goeppert Mayer Award. This award, which is to recognise and enhance outstanding achievement by a woman physicist in the early years of her career, goes to Henriette Elvang of the University of Michigan, for "discovering new types of black holes in higher dimensions, and giving us a deeper understanding of scattering amplitudes in quantum field theory".

In other awards for young people, Stefan Hoeche of SLAC receives the 2016 Henry Primakoff Award for Early-Career Particle Physics for his "innovative techniques of event simulation for high-energy hadron colliders, enabling the comparison of theory and experiment with high precision". The 2016 Dissertation Award in Nuclear Physics, which is to recognise a recent PhD in the field, goes to Chun Shen of McGill University, for his "successful prediction of anisotropic flow in Pb+Pb collisions at the LHC, his elucidation of the 'direct photon flow puzzle', and his contributions to the development of a computational tool of viscous fluid dynamics enabling precision studies of relativistic heavy-ion collisions".

Last but not least, particle physics features in the awarding of the 2016 Prize for a Faculty Member for Research in an Undergraduate Institution. Gregory Adkins of Franklin & Marshall College receives the prize for his "highly significant and sustained contributions to quantum electrodynamics calculations, including the physical properties of positronium, and for tireless and profound commitment to involving undergraduates in theoretical physics research".

● For more details, see www.aps.org/programs/honors/new-recipients.cfm.

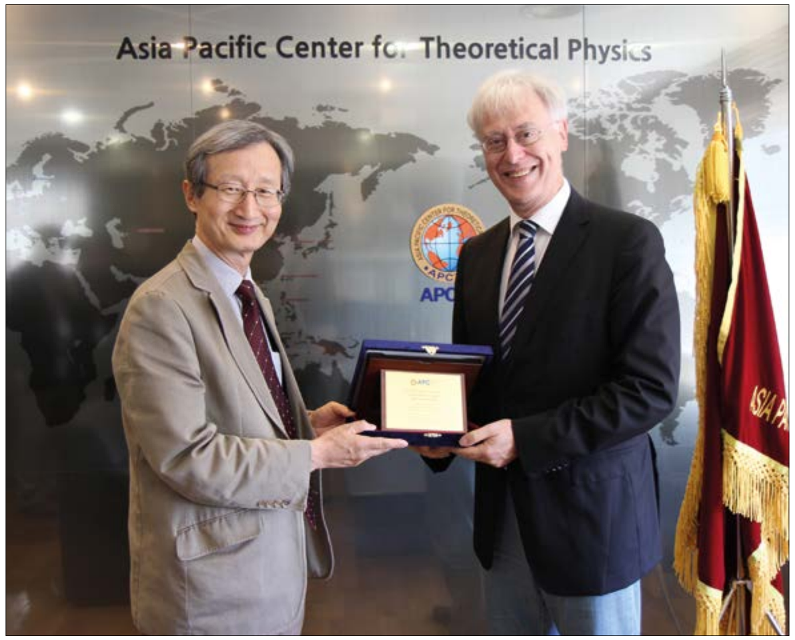
Benjamin Lee professorship award for Karlheinz Langanke

Karlheinz Langanke, scientific director of GSI (Germany), has been awarded the Benjamin Lee professorship. Awarded by the Asian Pacific Center for Theoretical Physics (APCTP) in Korea, the professorship is given to outstanding theoretical physicists for "groundbreaking research in different areas of theoretical physics". Langanke's research focuses on nuclear astrophysics, in particular on nuclear reactions in supernovae and on stellar-element synthesis. Langanke is the first European theorist to receive the professorship.

At the award ceremony organised during the annual conference of the Korean Physical Society, Langanke gave a keynote talk on the unique research opportunities offered by the future accelerator facility FAIR at GSI. He also gave a series of lectures on nuclear astrophysics for students at APCTP.

The professorship is awarded in memory of Benjamin Lee, an outstanding Korean theoretical physicist who died tragically young in 1977 in a car accident. The award has been granted annually since 2012.

GSI



Karlheinz Langanke (right) is awarded the Benjamin Lee professorship.

Breakthrough prize for neutrino oscillations

The 2016 Breakthrough Prize in Fundamental Physics, which recognises major insights into the deepest questions of the universe, has been awarded to five teams of researchers "for the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the Standard Model of particle physics".

The $3 million award will be shared equally among researchers from five collaborations: the Daya Bay reactor neutrino experiment, led by Yifang Wang, Institute of High Energy Physics, Chinese Academy of Sciences, and Kam-Biu Luk, University of California, Berkeley and Lawrence Berkeley National Laboratory; KamLAND, led by Atsuto Suzuki, Iwate Prefectural University; the KEK to Kamioka (K2K) and Tokai to Kamioka (T2K) long-baseline neutrino experiments, led by Koichiro Nishikawa, KEK; Sudbury Neutrino Observatory, led by Arthur McDonald, Queen's University; and Super-Kamiokande, led by Takaaki Kajita, Institute for Cosmic Ray Research and Kavli Institute for the Physics and Mathematics of the Universe, and Yoichiro Suzuki of the Kavli Institute.

The Breakthrough prizes, which include awards in life sciences and mathematics, were founded in 2012 by a group of Silicon Valley innovators to celebrate science and scientists. They were presented at the 3rd Annual Breakthrough Prize Awards Ceremony in Silicon Valley on 8 November, broadcast live on the National Geographic channel.

● For more details, see https://breakthroughprize.org/News/29.

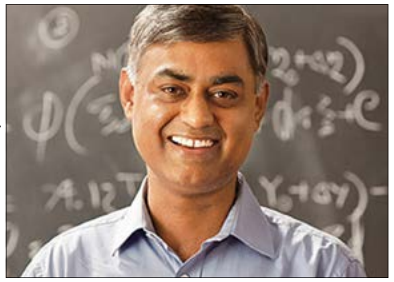
APPOINTMENTS

Sandip Trivedi appointed director of TIFR

Sandip Trivedi became the new director of the Tata Institute of Fundamental Research (TIFR) in July. TIFR is one of the major institutions for basic-science research in India, with activities that span physics, chemistry, biology, mathematics, computer science, interdisciplinary sciences and science education. TIFR scientists are also involved in the CMS experiment at CERN.

Trivedi is a theoretical physicist who has made important contributions to quantum field theory, string theory and cosmology. He has been appointed for a five-year term and succeeds Munstansir Barma.

Infosys Science Foundation



Sandip Trivedi.

CERN Courier January/February 2016

Faces & Places

Krzysztof Kurek appointed new director of NCBJ

Krzysztof Kurek took up the position as the new director-general of the Polish National Centre for Nuclear Research (NCBJ) from 25 October, for a four-year term. His vision for development won the competition that was opened in May by the NCBJ Scientific Council, and he was recommended to the minister of economy as the best candidate.

Kurek graduated from the Technical Physics and Applied Mathematics Faculty of the Warsaw University of Technology in 1980. As associate professor, he worked on the COMPASS experiment at CERN, and since 2013 he has been a member of the Polish team working on the LHCb experiment at the LHC. Kurek is the author or co-author of more than 250 papers published in internationally recognised scientific journals. Before becoming the NCBJ's new director-general, Kurek was the former head of NCBJ's PhD studies and former scientific secretary.

NCBJ

Krzysztof Kurek.

Marcela Carena appointed first Fermilab director of international relations

Marcela Carena has been appointed to the newly created role of director of international relations at Fermilab. Her responsibilities include developing a strategy for international engagement, promoting contact and collaboration with global partners, establishing new ties and strengthening existing ones.

The position reflects the new model and scale for international partnership at the heart of the proposed Long-Baseline Neutrino Facility (LBNF) hosted by Fermilab. Plans for the facility and its Deep Underground Neutrino Experiment (DUNE) incorporate the scientific goals and expertise of the worldwide neutrino-physics community, and the governance model follows the highly successful one adopted by the LHC experiments.

In her new role, Carena, who is head of Fermilab's Theory Department, will interface with CERN as well as with other scientific organisations and governmental agencies around the world.

● For more information, see news.fnal.gov/?p=23958.

Fermilab

Marcela Carena.

EVENTS

International Cosmic Day at DESY in Zeuthen

Thirteen pupils from a secondary school in Berlin attended the International Cosmic Day at the research centre DESY in Zeuthen. The goal for the day was to measure cosmic particles – "messengers from outer space" – and to work as researchers.

First, they learnt about the new topic in a lecture: that cosmic rays interact in the atmosphere to produce secondary particles, and how these particles can be detected at ground level. Then the experimenting began. The students measured the rate and arrival directions of secondary cosmic particles, and soon realised that the rate depends distinctly on the direction, and more specifically on the zenith angle.

After recording these measurements, they discussed possible explanations. In video calls to other participating groups, the young researchers exchanged ideas about their experimental set-ups and measurement results, experiencing the practical use and value of such exchanges and comparisons. Their common task made the students both partners and competitors, and inspired them to produce the best possible result. The atmosphere was soon identified as the origin of the non-uniform distribution of arrival directions of the secondary particles.

At the end of the day, the students compiled a one-page write-up of their results for a booklet summarising the day's achievement of all of the groups.

DESY

Secondary-school students participate in the International Cosmic Day at DESY.

Twenty birthday candles for LHCb

In August 1995, a letter of intent was submitted for LHCb – the world's first dedicated b-physics experiment realised at a hadron collider. On 5 November, the LHCb collaboration marked the 20th anniversary of this event with a special celebratory meeting. Around 200 participants attended and listened to the presentations, which recalled the history of the collaboration, the many challenges that it had to overcome, numerous important achievements and future prospects.

Since the beauty quark b and antiquark b bound-state Υ was discovered in 1977 at Fermilab, many experiments at different accelerators have been carried out to study all of the complex physics processes in which such particles are involved. With the advent of the LHC, it became clear that such a high proton–proton collision energy would give rise to a very high beauty-particle production rate. But how to conduct high-precision experiments in this very difficult environment? At the LHC workshop in Evian in 1992, three b-physics experiments were proposed. In June 1994, the LHC Committee requested that the interested parties form one new collaboration to propose a single new experiment based on the collider mode.

LHCb Collaboration

Members of the LHCb collaboration celebrate the 20th birthday of the experiment in the main auditorium at CERN. Fabiola Gianotti, CERN's Director-General (left, front row), also joined in the celebrations.

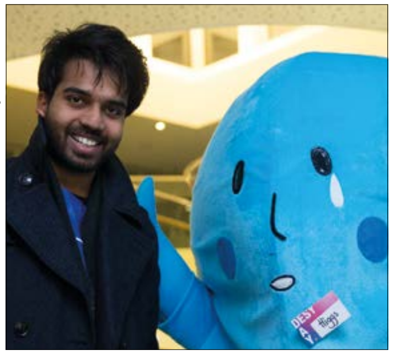
The letter of intent for LHCb was submitted in 1995 and the experiment was approved in 1998. The design of the experiment was re-optimised in 2003, a process in which many important improvements were made.

The ideas imagined 20 years ago have been very successful, even beyond initial expectations, and have allowed excellent physics results to be obtained. Beauty hadrons can be reconstructed with background levels as low as those obtained at e^+e^- colliders, and they are collected at a much higher rate. In addition, the production of all beauty mesons and baryons is observed at LHCb contrary to B-factory experiments, which are limited to studying light beauty meson decays only.

Read more about the history of LHCb, its physics results and prospects for the future, in the LHCb20-fest presentations.

● For more details, see cds.cern.ch/record/290868/files/SC00000024.pdf and https://indico.cern.ch/event/434085.

Evidence of the Higgs at DESY



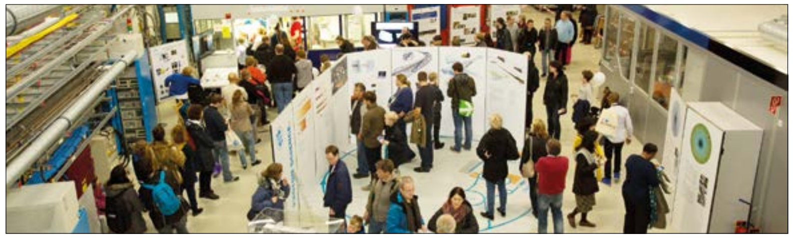
All images: © DESY 2015

In November, the DESY laboratory in Germany opened its doors to the public from noon to midnight. (Left) The Higgs particle, and (right) DESY's Director-General, Helmut Dosch, meet and greet visitors.

More than 18000 visitors, 1200 volunteers, some 120 attractions and activities, 3000 DESY apples, more than 1000 chocolate marshmallows, three accelerator tunnels and one Higgs mascot – these are the vital statistics of "DESY day", the open day at the German research centre. Every other year, coinciding with and forming part of the Hamburg-wide night of the sciences, DESY opens its doors to the public. The event lasts from noon to midnight and turns the sober campus into a lively science funfair family event.

Three accelerator tunnels were open to the public, including that of the European X-ray Free-Electron Laser (XFEL), which is nearing completion. Visitors also flocked to the laboratory's metal, wood and electronics workshops, its many experimental halls, the control rooms of DESY's accelerators and of the ATLAS and CMS experiments, the computer centre and the auditorium. Research partners on the DESY campus like the Centre for Ultrafast Imaging, the European Molecular Biology Lab or the Center for Free-Electron Laser Science also presented their science. Visitors could test their timing in a linear human accelerator, produce their own crystals and watch them grow under the microscope, try their luck with a gantry crane, watch how a chocolate marshmallow behaves in a vacuum, try an ultra-high-speed camera or have a go at extinguishing a fire.

From time to time, a large figure would appear in the crowds: the Higgs particle was on campus! Visitors were quick to take a selfie with it – not only because it is so hard to catch, but also because the best selfie won a prize. The Higgs, an import from the Japanese laboratory KEK, was impersonated by particle-physics students from the ATLAS, CMS and ILC groups at DESY.



DESY's Director-General, Helmut Dosch, also mingled with the crowds, and thanked visitors for their interest in DESY's work: "Events like this one show how fascinated people are with the adventure of research."

Visit

CERN

On 17 November, **HRH Princess Maha Chakri Sirindhorn of Thailand** visited CERN. Princess Sirindhorn was visiting the laboratory for the fifth time, following her last visit in 2010. The princess was accompanied by a delegation that included the director of the Synchrotron Light Research Institute (SLRI) in Thailand, Sarawut Sujitjorn, and a large group of Thailand's diplomatic representatives in Switzerland. Upon her arrival, the princess was welcomed by **Rolf Heuer**, CERN Director-General until the end of 2015, and **Fabiola Gianotti**, CERN Director-General as of January 2016. The princess was given a brief update on the laboratory's activities since her last visit, in April 2010. Later on, she witnessed the signature of the framework collaboration agreement between CERN and the SLRI, represented by Rolf Heuer and Sarawut Sujitjorn, respectively. This co-operation agreement is the latest development in the context of CERN's well-established scientific relations with Thailand. Afterwards, the princess and her delegation met a small group of young Thai scientists working at CERN, before concluding their visit with a guided tour of the ISOLDE facility and the LEIR accelerator.

Outreach

CERN launches 2016 Beamline for Schools competition

CERN is offering high-school students worldwide the chance to create and perform a scientific experiment on a CERN accelerator beamline. Now in its third year, the Beamline for Schools (BL4S) competition is open to teams of at least five students aged 16+ with at least one adult supervisor, or "coach".

Students can find out about the beamline and facilities via the BL4S website (cern.ch/bl4s), then think of a simple, creative experiment. They can register their team to start receiving e-mail updates and submit a written proposal and short video by 31 March. Winners will be announced in June, and will come to CERN, preferably in September. Previous winners have tested webcams and classroom-grown crystals in the beamline, others have studied how particles decay and investigated high-energy gamma rays.

All participants will receive a certificate. Shortlisted teams will win a BL4S t-shirt for each team member, a cosmic-ray detector for the school and, for some, the chance to visit a nearby physics laboratory. For the winning team(s), nine members and up to two adult coaches per team will be invited, all expenses paid, to CERN for 10 days, to carry out the experiments on the beamline.

CERN

Winners from the 2015 competition alongside Italian and South African ambassadors and CERN scientists.

Beamline for Schools is a CERN & Society project, funded in 2016 in part by the Alcoa Foundation; additional contributions are received from National Instruments.

● Spread the word to high schools near you. For more information, see cern.ch/bl4s.

Obituaries

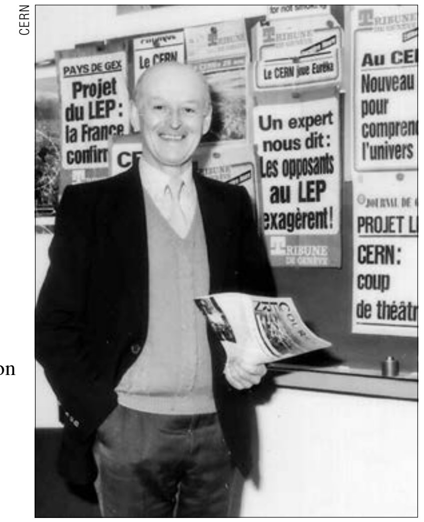
Roger Anthoine 1925–2015

Roger Anthoine, who was involved with public relations at CERN for more than 25 years, passed away on 26 October. The first editor of the *CERN Courier*, he had celebrated his 90th birthday in March (*CERN Courier* April 2015 p41).

A graduate in engineering and journalism, Roger came to CERN from the electrical industry in May 1959. He was hired to start a "house publication" for the laboratory, a role that placed him in the Public Information Office (PIO), which dealt with all of the laboratory's public-relations activities under the direct supervision of the Director-General. In mid-August, the first issue of the publication appeared in two editions – English and French – under the unifying name Roger had proposed: *CERN Courier/Courrier CERN* (*CERN Courier* July/August 2009 p30).

In 1960, following the sudden death of John MacCabe, Roger became head of the PIO, a position that he was to hold until he retired in 1986, dealing with the whole gamut of CERN's public relations – from press releases and relations with journalists to the organisation of visits, including those of important dignitaries. It was within these operations that he introduced the concept of in-house guides to explain the organisation to visitors, at the time mostly on Saturdays. His years as head of the PIO were studded with numerous highlights

CERN



Roger Anthoine.

including, as he was later to recall, the comic strips about CERN's deeds published by *La Tribune de Genève* in the 1970s, the naming of CERN streets, the preservation of Roman vestiges and large "erratic" stones unearthed on the site, the organisation's first films and, last but not least, the coining of the words "Cernois/Cernite". With his new responsibilities, Roger had to pass the *CERN Courier* on to others, and in 1965 he oversaw the birth of CERN's *Weekly Bulletin* for the internal audience, allowing the *Courier* to become more clearly focussed on news in particle physics for the international scientific community.

After retirement, Roger reverted to his first love, aviation, and he remained active for many years in technical writing. A pilot since 1944, he wrote numerous articles and books on the subject in French and English, and often acted as consultant on historical events connected with aviation. Most recently, one book in particular – *Aviateurs-Piétons vers la Suisse 1940-1945* (Editions Sécavia) – led to interviews with Radio Télévision Suisse for its "Living History" series, broadcast, sadly, only after Roger's death.

During his time with the PIO, Roger had developed good contacts with members of CERN Council, management and staff. Often seen at CERN until his last days, he was particularly proud, decades after retirement, to be still addressed by name by former CERN colleagues of all walks of life. No doubt they will continue to notice his presence around the site – and in the continuing legacy of the *Courier* and *Bulletin*. He is survived by his daughter, France, and son Didier.

● *His friends at CERN. This text takes inspiration from an obituary that Roger – ever the professional – prepared himself some years before he died.*

Marcel Froissart 1934–2015

With great sadness, we announce the death of theoretical physicist Marcel Froissart on 21 October, at the age of 81.

Marcel was extremely bright. As a teenager, he won the "concours général", a competition for high-schools students in France. He went on to study at Ecole Polytechnique and Ecole des Mines. I first met him in 1956 when, with Jacques Mandelbrojt, he wrote the notes of the lectures given by Chen Ning Yang in Paris on parity violation. This showed his incredible scientific precocity – he was just 22. Until he became professor at Collège de France in 1974, he was mostly in Saclay, interspersed with periods at CERN, Berkeley and Princeton.

Collège de France

Marcel Froissart.

At CERN, he collaborated with Vladimir Glaser and Wolfgang Pauli, trying to make sense of Heisenberg's non-linear theory and ending up with the conclusion that this was impossible. Back at Saclay, he became interested in the proof of Mandelstam's representation for Yukawa-like potentials. I remember he thought that the proof I proposed with John Bowcock was not rigorous (he was right, although the issues could be fixed). His major contribution then was the discovery, with Raymond Stora (also recently deceased, *CERN Courier* November 2015 p40) of the way a polarised beam can be depolarised in an ▷

accelerator. This work is still being used by accelerator engineers worldwide.

Froissart's greatest period was when he was at Berkeley, where Goeff Chew was preaching the S-matrix theory, as opposed to field theory. In this atmosphere, Froissart tried to produce a non-trivial result, and he succeeded marvellously. At the "La jolla" conference in 1961, he presented what is now known as the "Froissart bound" – that total cross-sections cannot increase faster than the square of the logarithm of the energy. The proof was based on a non-trivial combination of unitarity and analyticity. For analyticity, Froissart used the postulate of Mandelstam representation. I was present and, for me, it was a real turning point in my life. Previously, I had been working mostly on potential scattering, but after that I decided to work on high-energy behaviour of scattering amplitudes. In 1966, I succeeded to prove the Froissart bound without the postulate of Mandelstam representation, and Froissart presented my results very fairly at the 1966 Berkeley conference. It must be said that the "Froissart bound" seems to be qualitatively saturated experimentally. The first indications came from the ISR, and they were confirmed by the Sp$\bar{\text{p}}$S collider and now by the LHC (we are anxiously awaiting the results of the experiments at 13 TeV).

Back at Saclay, Froissart collaborated with Lascoux and Photiadi on attempts to prove Mandelstam representation in perturbation; he also worked on improving numerical programmes because he was impressed by Daniel Bessis's attempts to use Padé approximants to calculate scattering amplitudes. He also spent two years at Princeton, where his great critical sense made Sam Treiman call him "Mr Guillotine". At that point, he decided to leave theoretical physics. His experience in computing turned out to be very useful in 1972 when he became head of Saclay's bubble-chamber group, where big simulations were needed. In 1973, he was ready to accept a chair at Collège de France, where he inherited the directorship of the laboratories of Louis Leprince-Ringuet and Francis Perrin. He retired in 2004.

Marcel Froissart was certainly an excellent laboratory director, but he was above all a great theoretician, to whom, personally, I owe a lot, as I've explained. Besides being a great scientist, Marcel Froissart was a charming person. We shall miss him.

● *André Martin.*

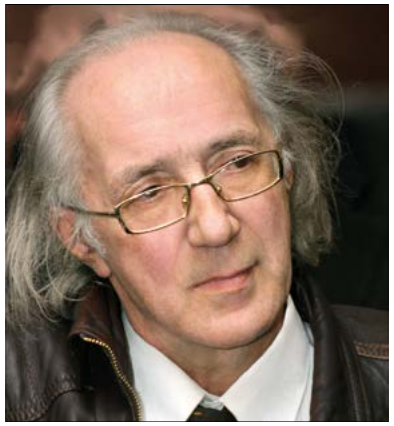
Vadim Kuzmin 1937–2015

Vadim Alekseevich Kuzmin, a prominent Russian theoretician, passed away on 17 September at the age of 78. He will be remembered for groundbreaking contributions to particle physics, cosmic-ray physics, neutrino physics and cosmology.

Vadim Kuzmin was born in Moscow on 16 April 1937. Finishing school in 1955, he began his physics studies at the Moscow State University the same year. He obtained his PhD in physics in 1964 in the Lebedev Physical Institute, where he was employed from 1961 after graduating from the university. From 1971, he worked in the Theory Division of the Institute for Nuclear Research (INR), Moscow. In 2000, he was elected to the Russian Academy of Sciences.

Vadim is possibly best known for the Greisen–Zatsepin–Kuzmin effect. In 1966, he and Georgiy Zatsepin and, independently, Kenneth Greisen, predicted that the spectrum of cosmic rays should be suppressed at the highest energies as a result of scattering off the cosmic microwave background. Observation of this cut-off would imply that the highest-energy cosmic rays originate in the nearby universe, opening up the experimental search for sources, while the absence of the cut-off would signify new physics. Studies of the GZK effect went on to determine the direction of research in cosmic-ray physics for decades, and while the GZK suppression has since been observed, the identification of powerful cosmic accelerators is still a priority in astroparticle physics.

INR



Vadim Kuzmin.

Less well known is that Vadim suggested the gallium–germanium method for detecting solar neutrinos – an ambitious idea that was successfully implemented by the SAGE and GALLEX collaborations. The results played a key role in proving that the solar neutrino puzzle cannot be solved by modifications of the solar model, and pointed instead to the real culprit: neutrino oscillations.

Vadim also made many fundamental contributions to the cosmology of the early universe. In pioneering papers, independently of Andrei Sakharov but at about the same time, he realised that the baryon asymmetry of the universe could be explained by particle physics. He also proposed that the necessary baryon-number non-conservation could be observed in laboratory experiments on neutron–antineutron oscillations. One of his best-known papers, written with Valery Rubakov and Mikhail Shaposhnikov, later pointed out that the necessary condition for baryogenesis – rapid-baryon-number non-conservation – is already satisfied in the Standard Model of elementary particles and does not require any new hypothetical interactions.

In recent years, Vadim worked on the cosmological puzzles of dark matter and dark energy. He suggested that dark matter and baryon asymmetry can appear together, in one process, therefore explaining the balance of dark and visible matter in the universe. Together with Rubakov and Igor Tkachev, he introduced superheavy dark matter, which opens the window to trans-Planckian physics and has deep connections to the inflationary birth of the universe.

Vadim had great sense of humour – his friends loved being victims of his innocent spoofs. He was fond of camping and trout fishing at the lakes of Karelia, and mushroom hunting in the forests near Moscow. He was a spirited painter, and many of his friends possess his artworks, preserving memories of Vadim as he was at the time. Our thoughts go to his family and friends, and the many others who shared important parts of their professional lives with Vadim.

● *His friends and colleagues.*

Lev Okun 1929–2015

Lev Borisovich Okun passed away on 23 November.

His death is a great loss to the global particle-physics community and to Russian science. Okun was one of the world's distinguished theoretical physicists, and a person with genuine passion and drive for science.

He was inseparably linked with the Institute of Theoretical and Experimental Physics (ITEP) where he arrived as a postgraduate student in 1954 and worked there until his last day. He was head of the Theoretical Physics Laboratory at ITEP for 30 years, and also professor at the Moscow Institute for Physics and Technology for many years.

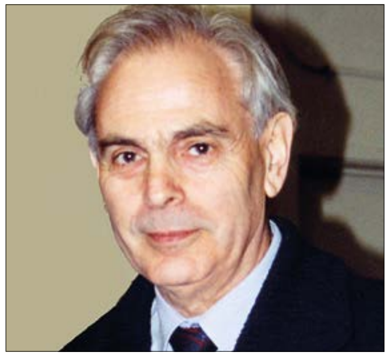
Okun was a student of Pomeranchuk (who was a student of Lev Landau), and Landau once said about him: "He is my grandson."

Okun's contribution to particle physics is remarkable. In the field of strong interactions, the famous Okun–Pomeranchuk theorem on the equality of cross-sections for scattering particles from the same isomultiplet at asymptotically high energies was proved in 1956. A year later, he proposed a composite model, known as the Sakata–Okun model, in which hadrons (the term that Okun had coined) were constructed from "pre-particles", the predecessors of quarks. Within this model, he predicted the new η and η' mesons, which were discovered several years later.

The physics of weak interactions was his favourite subject. His early paper written in collaboration with Ioffe and Rudik in 1957 observed that the P-parity violation in beta decay also means a violation of the C parity. He was the first to understand the important role of CP symmetry in the decays of neutral K mesons, and suggested an experiment to look for CP violation.

Okun also conceived a new field of research at the intersection of particle physics, cosmology and astrophysics. The first paper in this field was written by Lev Borisovich (in collaboration with Zel'dovich and Pikel'ner) in 1965. They developed a method for calculating the relic abundance of elementary particles during the expansion of the universe. They performed a calculation of free-quark concentration. Non-observation of free quarks was one of the arguments for quark confinement. The approach that emerged

CERN



Lev Okun.

from this paper now plays a crucial role in searches for solutions to the origin of dark matter in the universe. In 1964, in a paper written together with Pomeranchuk and Kobzarev, the idea of a "mirror world" came into existence. "Mirror matter" is still a possible candidate for dark matter. Vacuum-domain walls investigated by Okun in 1974 were the first macroscopic objects of QFT that could determine the evolution of the universe. In the same year, Okun, Voloshin and Kobzarev published a pioneering paper on the decay of the false vacuum – a subject that unexpectedly became relevant to the physical vacuum in our universe after the discovery of the Higgs boson with 125 GeV mass.

Okun had an extraordinary pedagogical talent. Due to his deep understanding of physics, he had the unique ability to put even the most intricate theoretical constructions in simple terms. Many generations of physicists studied particle physics with his textbooks *Weak Interactions of Elementary Particles* (1963) and *Leptons and Quarks* (1980, 1990).

He was absolutely devoted to physics and embodied the quest for truth that is at the heart of physics. He attracted young talent and was a founder of one of the world's great schools of particle physics.

Okun was the first Soviet physicist elected to the Scientific Policy Committee of CERN. He was awarded prestigious international prizes.

He was an extraordinary person of outstanding integrity, a friend of great warmth and a source of deep knowledge and wisdom. He will be remembered by his family, friends and colleagues.

● *His friends and colleagues.*

Recruitment

WWW.OEAW.AC.AT/SMI

ÖAW Österreichische Akademie der Wissenschaften

The Stefan Meyer Institute for Subatomic Physics of the Austrian Academy of Sciences in Vienna is devoted to the study of fundamental symmetries and interactions. In its division "Precision experiments at low energies" a new position of

Junior group leader for antihydrogen research

has been opened. The successful candidate is expected to contribute to the existing activities on antihydrogen hyperfine spectroscopy and gravity measurements at the Antiproton Decelerator of CERN which are currently performed within the ASACUSA and AEgIS collaborations.

In addition to the junior group leader position (tenure track, initial appointment 5 years), funding for the equivalent of two Ph.D. positions as well as funds for travel and investment are available. The candidate is expected to obtain additional external funding for his research activities.

Candidates are required to have a Ph.D. in experimental physics and low-energy atomic physics type experiments at particle accelerator laboratories. Previous involvement in antihydrogen experiments, ion or atom trapping, or particle detection will be of advantage. Candidates need to provide a research plan together with the usual documents and submit them to

smi@oeaw.ac.at until March 15, 2016.

More information can be obtained from
http://www.oeaw.ac.at/smi/jobs
or by email from eberhard.widmann@oeaw.ac.at

SMI

FACULTY POSITION IN ACCELERATOR PHYSICS AT MICHIGAN STATE UNIVERSITY

Michigan State University (MSU) is seeking outstanding candidates for a faculty position in accelerator physics and engineering. MSU is establishing the Facility for Rare Isotope Beams (FRIB) as the leading rare isotope scientific user facility for the U.S. Department of Energy Office of Science and is operating the National Superconducting Cyclotron Laboratory (NSCL) as a world-class laboratory for nuclear science with funding from the U.S. National Science Foundation (NSF).

The successful candidate is expected to conduct world-leading research and innovative technology development, and contribute to the strong graduate program in accelerator physics leveraging the opportunities provided by FRIB. Present research at FRIB/NSCL addresses cutting-edge accelerator physics and technology including superconducting radiofrequency (SRF) cavities, large scale cryogenics, advanced beam dynamics, large-scale numerical modeling, integrated controls, diagnostics, and instrumentation. New areas of research include those associated with the FRIB accelerator upgrade and the next generation high intensity and high power accelerators.

Faculty appointments will be in the FRIB/NSCL faculty system at a rank commensurate with experience. FRIB/NSCL faculty members typically have joint appointments in an MSU academic department, such as Physics and Astronomy, or Engineering, where they are expected to teach courses and supervise graduate students. Details about FRIB/NSCL faculty appointments are provided at **www.hr.msu.edu/documents/facacadhandbooks/ NSCLFacPos.htm.**

Applicants must have a Ph.D. or equivalent and are normally expected to have postdoctoral experience. The search committee will begin reviewing applications starting February 1, 2016. Application packets should include a cover letter addressed to the accelerator physics faculty search committee, a CV that includes a list of publications and talks, a research plan of no more than two pages, and the names and email addresses of at least three references. Application materials should be emailed to **careers@frib.msu.edu.**

MICHIGAN STATE UNIVERSITY

MSU is committed to achieving excellence through cultural diversity. The University actively encourages applications and/or nominations of women, persons of color, veterans and persons with disabilities.

MSU is an Affirmative Action, Equal Opportunity Employer.

ULB UNIVERSITÉ LIBRE DE BRUXELLES

Full time academic position in experimental astroparticle physics

The physics department of the Université Libre de Bruxelles (ULB) seeks outstanding candidates in the field of astroparticle physics.

The experimental particle and astroparticle physics group is located within the Inter-university Institute for High Energies (IIHE – ULB/VUB). This research group of 100 people has a long history at the forefront of experimental research with major contributions to detector construction and data analysis in accelerator experiments (Delphi at LEP, H1 at DESY and CMS at LHC), in astroparticles (the large-scale South Pole neutrino observatories AMANDA, IceCube, and ARA), in neutrino oscillation physics (OPERA at Gran Sasso, SoLiD at SCK-CEN), and in R&D on data acquisition systems for deployment at future accelerator and non-accelerator facilities, supported by laboratory workshop facilities and technical personnel. The experimental particle physics group maintains a close collaboration with colleagues in the ULB/VUB theory groups whose research interests include phenomenology, cosmology, astroparticle and astrophysics.

More details may be found on the institute's web page: www.iihe.ac.be.

A successful candidate shall demonstrate a history of outstanding experimental or observational research and leadership in the field. Strong skills in the development of detector instrumentation are an asset.
The candidate is invited to participate in the framework of the existing research projects but is also encouraged to begin new research topics.

The official vacancy can be found on:
http://wwwdev.ulb.ac.be/greffe/files/5034.pdf
Application deadline: 15 Mar 2016

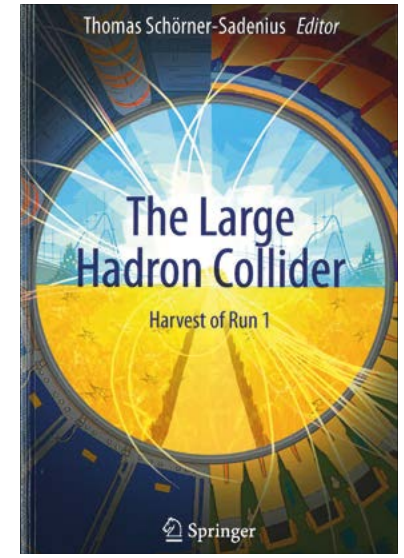
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265.

Bookshelf

Compiled by Virginia Greco, CERN

The Large Hadron Collider: Harvest of Run 1

By Thomas Schörner-Sadenius (ed.)
Springer



On the verge of obtaining new results from the first year of Run 2 of the LHC, a book summarising the results from Run 1 is highly anticipated.

The impressive effort needed to write such an overview must be acknowledged. The LHC experiments (ALICE, ATLAS, CMS, LHCb, and TOTEM) have published more than 1000 results from Run 1, and producing a comprehensive review of them while ensuring that the book remains accessible to young researchers is a demanding task that requires careful editorial work. This seems to have been the intention of the authors, which in my opinion has been accomplished.

Individual chapters are written by teams of well-recognised experts working in each specific field. The book starts with a short historical overview, describing the development of the LHC project – three-decades long – from first ideas to its realisation. The reader will find an interesting summary of the difficult financial situation the LHC had to confront, while receiving harsh competition from similar accelerator projects (UNK, SSC).

Clearly, the legacy of Run 1 is marked by the discovery of the Higgs boson, therefore a long and interesting chapter is dedicated to a description of its discovery and, later on, to the measurement of its properties, but the volume shows the impact of the LHC results on all of the different fronts of high-energy physics. The interplay between recent theory developments and experimental results is clearly presented. Furthermore, each physics chapter is introduced by a short theoretical summary, showing the pedagogical intention of the authors. Results are often contextualised by comparing them with the current status of each topic and by showing perspectives for future improved results.

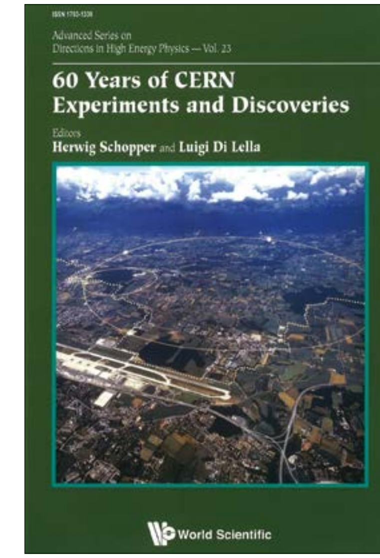
Besides allowing senior researchers to quickly scan through the plethora of LHC results, the book will be particularly useful for young researchers trying to familiarise themselves with certain aspects of LHC physics. It stimulates further reading and gives a long list of references at the end of each chapter – in my opinion, this is a main bonus of the book.

Although the results from Run 1 at the LHC are destined to be quickly outdated by new results from Run 2, I believe that this book could serve for several years as initial reading for any physicist when first confronted with LHC physics, thanks to the historical and pedagogical point of view adopted.

● *Paolo Meridiani, INFN Roma (Italy).*

60 Years of CERN Experiments and Discoveries

By Herwig Schopper and Luigi Di Lella (eds.)
World Scientific
Also available at the CERN bookshop



This book is a treasure trove of particle physics, highly recommended for physics teachers, graduate students and professionals of the field. With 17 chapters, it offers a concise essay of 60 years of particle physics at CERN from the point of view of the people in charge of the different experiments.

The first three chapters cover the present day at CERN: the full LHC programme, from the Higgs boson discovery to Beauty physics and quark–gluon plasma. They draw a relatively synthetic but precise picture of the four major experiments at LHC (ATLAS, CMS, LHCb, ALICE), giving really useful information to the reader.

The surprises, at least for me, come in the chapters that follow. They explain physics that is already in textbooks, but provide a great deal of detail about each specific endeavour – a pleasure to read if you are interested not only in the results but also in the intellectual journey and historical context.

Chapters 4 (number of light neutrinos) and 5 (gauge-coupling-constants precision physics) are dedicated to LEP results, chapter 6 to the discovery of W and Z bosons in the Super Proton Synchrotron (SPS), and chapter 7 to the fundamental neutral current experiment at Gargamelle. Going back in time to Gargamelle, one can appreciate the ingenuity of the physicists' community struggling with the data to get a clearer picture of electroweak physics, at a time when the microelectronics revolution was still far off.

From chapter 8 to the end of the book, the reader picks up little gems. CERN is not only the LHC or LEP, but much more. Chapter 8 tells the story of neutrino physics at the SPS, in particular the precise measurement of the Weinberg angle and how that effort paved the way for actual neutrino-oscillation experiments. Chapters 9 and 10 are dedicated to kaon physics, in particular to the direct measurement of CP violation in kaon decay by the NA31/NA28 collaborations at the SPS, and to discrete symmetry (T, CPT and CP) measurements in the neutral-kaon system using the LEAR antiproton storage ring. Here, the reader discovers that the large volume of statistics on $\pi^+\pi^-$ decays possible at LEAR (now evolved to LEIR) enabled testing of the equivalence principle between particles and antiparticles, as well as of EPR correlations.

Chapter 11 highlights the physics discoveries at the Intersecting Storage Rings (ISR). Remembered as the first hadron collider and a technological feat, it also made an important contribution ▷

Bookshelf

to fundamental physics by discovering the rise of the proton–proton scattering total cross-section. Chapters 12 and 13 discuss topics out of chronological order. Chapter 13 concerns the discovery of partons in hadrons from the ISR to the SPS, with details of the hadron internal structure, revealed by muon scattering in the SPS, given in chapter 12. "Modern" LHC parlance as "gluon colliders" can be traced back to the ISR; jet production, now a workhorse at the LHC programme, was evident from the SPS UA2 experiment. Deep inelastic scattering has been an active field at CERN for more than 35 years, and has had a fundamental impact on the present day understanding of hadronic-matter structure.

But CERN is not only about colliders. Atomic physics is very much alive there, as well as the study of exotic atoms (pionic, muonic, kaonic) and anti-atoms. Chapter 14 traces the history of antimatter–exotic matter at CERN, up to present-day experiments at ALPHA and ATRAP, even for testing the equivalence principle (does antimatter fall down?) with AEgIS or GBAR.

Muon-storage technological challenges and the g-2 measurement at CERN, a hot topic today, come within chapter 15, which contains two special-relativity surprises: a gamma-ray time-of-flight experiment from the Proton Synchrotron (PS) target, demonstrating the independency of c from the source motion, and time dilation in circular orbits for the muon lifetime in flight. Chapter 16 explains the beginning of the accelerator programme at CERN with the physics contribution of the CERN 600 MeV Synchrocyclotron (pi meson decays), in particular the first measurement of the muon anomalous moment.

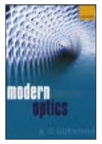
Closing the book, chapter 17 discusses part of the nuclear-physics programme, specifically with ISOLDE – an "alive and kicking" experiment dedicated to the study of radioactive nuclei, mainly nuclear ground-state properties and excited nuclear states populated in radioactive decays, but now also leading the production of medical isotopes for fundamental studies in cancer research.

As a final remark, I enjoyed this book not only for the range of topics and extensive explanations, but also because it is easily readable – not an easy goal when the number of authors is so high. Definitely a must read.

● *Rogelio Palomo, University of Sevilla (Spain).*

Books received

Modern Optics (2nd edition)
By B D Guenther
Oxford University Press



This book is the result of a one-semester course that has been taught by the author to juniors, seniors and first-year graduate students in physics and engineering at Duke University for 13 years.

It gives an overview of the fundamentals in optical science, the principals of which are explained by using a rigorous approach based on Maxwell's equations. Besides the classical topics, the book includes some material not found in more conventional textbooks on the subject: nonlinear optics, guided waves, photonic structures, surface plasmons and more. Anisotropy is also largely discussed, even if it needs the use of tensors, because of its importance in modern optics.

This 2nd edition retains an emphasis on both the fundamental principles of optics and exposure to actual optical-engineering problems and solutions. It introduces a large number of applications such as laser optics, fiber optics and medical imaging, which makes the book appealing to engineering students and professors.

A selection of optional material has also been added in the appendices, adaptable to different interests and to stimulate further reading. Many pictures, tables and diagrams accompany the text, making the exposition clear and complete.

Instantons and Large N: An Introduction to Non-Perturbative Methods in Quantum Field Theory
By Marcos Mariño
Cambridge University Press

Intended to be a fundamental resource for graduate students in particular, theoretical and mathematical physics, the book gives a highly pedagogical introduction to some advanced topics of quantum field theory (QFD).

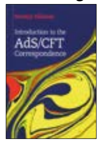
The standard approach to QFD, one of the pillars of modern physics, is the perturbative one. Although successful, it is not sufficient to address many important phenomena. In this book, the author gives an introduction to two methods that go beyond the standard perturbative framework: instantons and large-N expansion.

The first part of the volume offers a detailed exposition of instantons in quantum mechanics, supersymmetric quantum mechanics, the large-order behaviour of perturbation theory, and Yang–Mills theories. In the second part, large-N expansion in QFT is examined.

The topics are presented in a well-organised form, and each subject is explained with detailed mathematical derivations and then illustrated with a model or example in which it is implemented. This enables students to move easily through the text and gain practical experience with the most important tools of the field.

Apart from the basic building blocks in the theory of instantons and of large-N expansion, the choice of topics has been dictated by the author's taste and expertise, as he himself admits. As a consequence, some subjects covered extensively elsewhere in the literature are left aside, while space has been given to topics not commonly treated in textbooks. Moreover, supersymmetry has been avoided as much as possible, by choice.

Introduction to the Ads/CFT Correspondence
By Horaţiu Năstase
Cambridge University Press



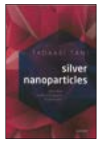
The aim of this book is to give a pedagogical introduction to Anti-de Sitter/Conformal Field Theory, or AdS/CFT, which is the relation between quantum field theory with conformal invariance, living in our flat 4D space, and string theory, which is a quantum theory of gravity and other fields, living in the background solution of AdS$_5 \times S^5$ (5D anti-de Sitter space multiplied by a five-sphere).

Assuming knowledge of only the basics of quantum field theory, the text provides readers with all of the concepts and tools needed to engage with AdS/CFT. In the first part, the author describes some fundamental concepts of general relativity, supersymmetry, supergravity, string theory, conformal field theory and D-branes. He has chosen not to overload the text with too many details about these fields, to keep the reader focused. The second section provides a clear and rigorous dissertation on AdS/CFT correspondence (in the context of its best understood example). Finally, in the third part, more specialised applications are discussed, such as QCD, quark–gluon plasma and condensed matter.

The book is self-contained, introducing all of the necessary basic concepts and most of the AdS/CFT methods and tools, but for an in-depth or exhaustive treatment, the reader is advised to refer to research articles. The many examples and exercises at the end of each chapter reveal the pedagogical vocation of the volume, nevertheless it will also be a useful reference for researchers in the fields of particle, nuclear and condensed-matter physics.

Bookshelf

Silver Nanoparticles: From Silver Halide Photography to Plasmonics
By Tadaaki Tani
Oxford University Press



This book gives a comprehensive review of the synthesis, optical properties and applications of silver nanoparticles and nanomaterials.

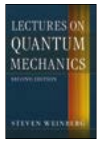
Today, nanoscience, which is the study of extremely small things, plays a fundamental role in technology, and is connected to many scientific fields: physics, chemistry, biology, material science and engineering. Nanoparticles are of great scientific interest because they provide a bridge between bulk materials and atomic or molecular structures. We know that bulk material normally has constant physical properties regardless of its size, whereas size-dependent properties are often observed at the nanoscale.

Researchers are interested in nanoparticles of noble metals, including silver (Ag), because they show high potential for possible future plasmonic devices. On the other hand, nanoparticles of silver and silver halides (AgX) have been extensively studied in silver-halide photography.

The author offers an overview of both the properties of silver nanoparticles and related materials, and know-how in AgX photography. The first part (chapters 1–3) introduces the structure and preparation of nanoparticles of Ag and other noble metals for plasmonics, as well as those of Ag and AgX nanoparticles in photography. Then, in chapter 4, the relevant properties and performance of nanoparticles of Ag and related materials are presented, focusing in particular on light absorption and scattering. In the third part (chapters 5–7), the author discusses the applications of this research in catalysis, photovoltaic effects and plasmonics. New ideas in the field are also presented at the end.

Full of pictures and references, this text represents a synthesis of up-to-date knowledge in the field.

Lectures on Quantum Mechanics (2nd edition)
By Steven Weinberg
Cambridge University Press
Also available at the CERN bookshop



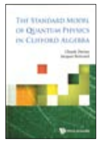
After the great success of the 1st edition, the textbook on modern quantum mechanics by Nobel laurate Steven Weinberg is presented in a fully updated 2nd edition.

Thanks to his profound knowledge and expertise, the author explains in an exceptionally clear and rigorous way the topics of the subject that he considers to be the most important for a one-year graduate course. He begins with an historical review of quantum mechanics and an account of classic solutions to the Schrödinger equation, then goes on to develop quantum mechanics in a modern Hilbert-space approach.

Weinberg gives much greater emphasis than usual to principles of symmetry, and covers subjects that are often omitted in books on quantum mechanics, such as Bloch waves, time-reversal invariance, the Wigner–Eckart theorem, isotopic spin symmetry, Levinson's theorem, etc. This 2nd edition includes major additions to existing chapters and has also been enriched by the addition of six new sections, covering topics such as the rigid rotor and quantum-key distribution.

The author takes care to explain the formalism, to be clear and coherent, and includes numerous examples from elementary particle physics. Problems are also included at the end of each chapter. Well-structured and easily readable, this book is bound to receive the same approval as the 1st edition did.

The Standard Model of Quantum Physics in Clifford Algebra
By C Daviau and J Bertrand
World Scientific



In this book, the authors discuss the Standard Model, drawing upon Clifford algebra (a special case of geometric algebra) of space–time, following the work of Hestenes and other physicists that in the 1980s revisited Dirac theory using Clifford formalism.

After an introduction on the basics of Clifford algebra and the Dirac equation, the authors move on to place Dirac theory in a 3D framework, based on the Clifford algebra Cl_3 of 3D space. They introduce their homogeneous nonlinear equation and explain why, in their opinion, it is better than the Dirac equation, which is its linear approximation.

Several consequences deriving from these novelties are then discussed extensively. In particular, a first attempt to reconcile the quantum world with inertia and gravitation is made.

The book also includes three appendices, reporting demonstrations and calculations related to the concepts explained in the text, and a rich bibliography.

Classical Dynamics: A Modern Perspective (2nd edition)
By E C G Sudarshan and N Mukunda
World Scientific

More than 40 years since the appearance of the first edition, this book in now published in a revised version that is presented with the same passion and dedication as the original. The authors confess that they have always had an "affair of the heart" with classical dynamics, and this remains alive.

In the volume, classical dynamics is treated as a subject in its own right, as well as a research frontier. While presenting all of the essential principles, the authors demonstrate that a number of key results originally considered only in the context of quantum theory and particle physics have their foundations in classical dynamics.

Even if the text is based on what the authors define as "our understanding of quantum mechanics", this new version builds on many suggestions coming from other physicists and continuous dialogue with students using the book as a reference.

Key Nuclear Reaction Experiments: Discoveries and Consequences
By Hans Paetz gen. Schieck
IOP Publishing

Nuclear physics has seen enormous developments in the last century. The study of nuclear reactions has given fundamental insights into the nature of the forces that act within nuclei and on the structure of nuclides.

This book traces the history of the development of nuclear physics by reviewing key experiments that have shaped our understanding of the field. It is interesting to look back to the beginning and discover how crucial results were obtained by very simple means, and how the sophisticated and complex experiments of today came about. Experiments are described in detail and their outcomes are discussed. In some cases, original drawings are included, accompanied by new figures and plots when needed.

The theoretical background to the experiments is also given, but is kept concise. Nevertheless, the reader can refer to the references at the end of each chapter for a more in-depth treatment of individual subjects.

Besides drawing on the history of experiments and related discoveries, the book shows how misinterpretations and prejudices in some cases prevented or delayed fundamental breakthroughs.

CERN Courier Archive: 1973

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

Physics at Laboratory 1

News from Gargamelle

Having obtained evidence for new hadronic constituents [partons] by electromagnetic and strongly interacting probes, the question arises whether they also manifest themselves in weak interactions. Preliminary measurements of the total cross-sections for antineutrinos and neutrinos in the heavy-liquid bubble chamber Gargamelle show both cross-sections rising linearly with energy in the range from 1 to 9 GeV, with the ratio between them of one third. These results agree with models where the partons are quarks, and imply that nucleons consist of three quarks and some quark–antiquark pairs.

However, free quarks have not been found. Why do nucleons exhibit a granular structure but it is not possible to knock out one of these grains? In experiments at the ISR, where quark masses up to 22 GeV could be observed, no particles with the fractional charges predicted for quarks have been seen. Maybe their masses are beyond presently available energies. Or maybe they are just mathematically useful concepts in describing particle behaviour without correspondence in physical reality.

● Compiled from texts on pp3–5.

Above right: An antineutrino interaction recorded in the heavy-liquid bubble chamber Gargamelle. The interaction produced a high-energy muon, which travelled across the chamber, a low-energy negative pion, which stopped in the chamber, and a positive pion, which interacted to give a neutral pion that decayed into gammas, which materialized in electron–positron pairs in the heavy liquid.

At the synchro-cyclotron

During the past year, the physics programme of the 600 MeV synchro-cyclotron (SC) has included 18 experiments (plus those at the isotope separator, ISOLDE) involving scientists from about 30 research centres. The experiments have mainly concerned nuclear physics, but several are studying aspects of particle physics and there is also a modest programme of radiobiology.

At ISOLDE, fed by the SC, short-lived "exotic" nuclei are studied. In the SC experimental areas there are related experiments, such as an Orsay investigation of fragmentation, which provides astrophysics with data on stellar and interstellar interactions, and a Cologne study using targets of lunar-rock composition to estimate the effect of cosmic rays on the surface of the Moon.

The energy of the SC was selected so that it would be capable of copious production of pions, and this has been used in a long sequence of experiments where pions have been fired at nuclei. As well as protons and pions, muons are also available. One of the muon experiments produces muonic atoms, where the muon becomes a satellite of the atom in the same way as an electron. When the muon is in the higher atomic energy levels, it is sensitive to any asymmetry in movement of protons in the nuclear volume and it has been possible to measure the quadrupole moment associated with the rotation of ellipsoidal, or cigar-shaped, nuclei.

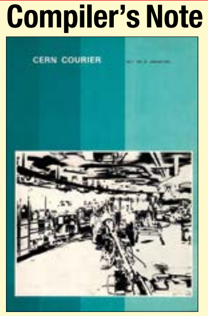
The peak internal beam current is about 1.5 μA. The main aims of the improvement programme are to increase this by a factor of 10 and raise the extraction efficiency well above its present value of around 6%. This will be achieved by replacing several important machine components, including a "hooded-arc" ion source and new central electrodes with an r.f. system capable of providing voltages as high as 30 kV, a frequency modulation from 30 to 16.7 MHz, and an increase the SC pulse repetition rate from 55 to over 500 Hz.

The starting date of the shutdown to carry out these improvements is not yet fixed since the rotary condenser, the mechanical tuning element of the r.f. system, has not been fully tested. The Advisory Panel of physics users strongly recommends bringing the condenser to CERN for completion after a preliminary test at the manufacturers. If this does not reveal any major technical difficulties, the shutdown, expected to last for just under a year, could start before the middle of the year.

● Compiled from texts on pp34–36.

The rotary condenser of the r.f. acceleration system for the SC improvement programme in its vacuum housing, with the end shield removed. The eight symmetrically placed electrodes couple the condenser to the oscillator valve via the coaxial feed (centre).

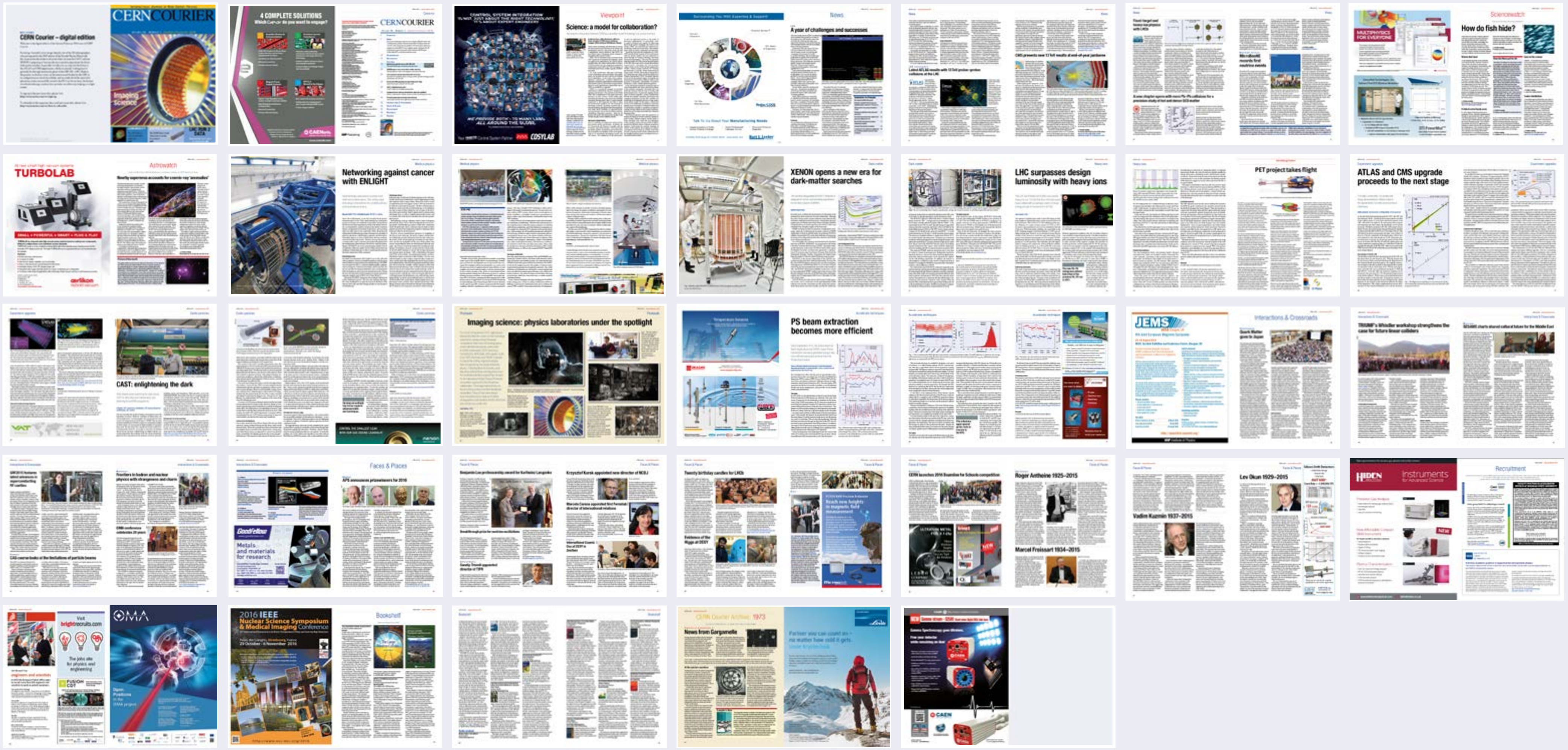
Compiler's Note



The Gargamelle chamber is exhibited in the Microcosm garden at CERN. In 1973/1974, Gargamelle provided existential evidence for Z bosons, neutral partners of the hypothesized charged weak-interaction bosons, W±, and detailed testing of the electroweak Standard Model became top priority, especially at CERN. In 1983, W and Z bosons were created in the proton–antiproton collider, in 1989 experiments at LEP restricted the number of matter "generations" to three, and in 2012 Higgs bosons, the unverified components of the model, were observed at the LHC.

The SC improvement programme was started in July 1973 and completed in January 1975. This versatile and venerable machine, CERN's first accelerator, commissioned in 1957, delivered particle beams until its closure in 1990. It now offers a unique look into CERN's history as part of the visits programme.


CAEN Electronic Instrumentation
NEW Gamma stream - S2580 Stand-alone Digital MCA tube base
Gamma Spectroscopy goes Wireless.
Free your detector while remaining on-line!
• Wireless and wired connectivity via USB, Ethernet, Bluetooth and WiFi
• Internal battery and data-storage
• Embedded GPS(*) for data geolocation
• ARM based CPU for unattended operations
• Specialized for NaI(Tl), LaBr3(Ce), and CeBr3 with standard 14-pin and 10-8 stages PMTs
• Multiple acquisition modes: PHA, PHA with time stamp, MCS(*), SCA(*) and signal inspector
• Gain stabilizer based on natural or calibration radioactivity
• Supported by MC2Analyzer software and GammaTOUCH
GammaTOUCH App for Android
(*) coming soon
CHECK THIS OUT!
MC2Analyzer
GammaTOUCH
Software for Spectroscopy Solutions (Windows® / Android™)
CAEN Tools for Discovery
FREE DOWNLOAD
All Control Software are available for free download on the web site.
www.caen.it
Small details… Great differences
Typical NaI detector with 14-pin PMT.
γstream is plugged on the PMT tube.



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