Welcome to the digital edition of the April 2016 issue of CERN Courier.

The issue went to print while the LHC resumed operation after the technical stop that started in December 2015. At the same time, in another accelerator, SuperKEKB in Japan, beams have completed their first turns. However, the spotlight these days is not so much on accelerator physics as on the discovery of gravitational waves by the LIGO interferometers in the US, which is gaining the interest of the whole scientific community. The interview with Barry Barish, one of the founding fathers of LIGO, proves just how hard scientific endeavours can sometimes be. Hard, but also extremely rewarding. Coming back to closer universes, this issue also features articles about CERN’s neutron facility, ALICE’s new TPC, and science carried out with a PET cyclotron. Last but not least, Interactions & Crossroads brings you information about interesting conferences in physics and related fields around the world.

To sign up to the new issue alert, please visit: http://cerncourier.com/cws/sign-up.

To subscribe to the magazine, the e-mail new-issue alert, please visit: http://cerncourier.com/cws/how-to-subscribe.
A New Generation of Power Supplies

A completely new generation of power converters with outstanding performances

Bipolar or Unipolar output
Current and Voltage control
Digital control loop
Multiple Fast Interfaces (10/100/1000 Ethernet, SFP)
Linux OS embedded
EPICS IOC included

New Tools for your Experiments

Advanced and improved solutions for beam detection and experimental setups

ELM, photodiodes, ion chambers, diamond detector readout
Configurable full-scale range and bandwidth
Complete beam stabilization systems on photon detectors and encoders
Ready-to-use software packages
Dedicated applications for machine diagnostics and protection
EPICS IOC included

SOFTWARE and DRIVERS

Dedicated software applications
EPICS IOC Drivers

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

CERN/CMS/ATLAS is an experiment at the Large Hadron Collider (LHC) at CERN, the European particle physics laboratory. It is designed to study the properties of the Standard Model of particle physics and search for new physics beyond the Standard Model. The LHC is the world’s largest and most powerful particle collider, capable of accelerating protons and antiprotons to an energy of 13 teraelectronvolts (TeV) per particle.

Editorial and Production

Editor in Chief
Mark S. Wells
Assistant Editor
David B. Pearson
Production Editor
Sue Curtis
Managing Editor
Geraint Tilstone

Advertising

Head of B2B & Marketing
Angela Gage
Marketing & Circulation
Jo Allen

Contents

5

VIEWPOINT

7

NEWS

• The LHC is restarting • Searches with boosted topologies at Run 2 • Astroparticle flow in Run 2 • CMS hunts for supersymmetry in uncharted territory • LHCdata awards physics prizes for its Kaggle competition • Another important step for the AKEW experiment • HiESSI makes first direct measurement of the A, at threshold • First turn for SuperKEKB • EPS exceeds design goal of 500mA stored current • DZERO discovers new four-flavour particle • Testing of DUNE tech begins

15

SCIENCEWATCH

17

ASTROWATCH

18

FEATURES

U10G: a strong belief
Twenty years of hard work with a strong belief that the endeavour would lead to a historic breakthrough.

21

Science with a medical PET cyclotron
Medical PET cyclotrons can be used for multidisciplinary research.

23

ALICE selects gas electron multipliers for its new TPC
The experiment plans a major upgrade for its TPC.

25

Neutrons in full flight at CERN’s nSTAR facility
The facility features two beamlines and two experimental halls.

33

INTERACTIONS & CROSSROADS

39

FACES & PLACES

52

RECRUITMENT

92

BOOKSHELF

94

ARCHIVE

WWW.

106

CERN Courier

April 2016

CERN Courier

April 2016

www.caenels.com

© 2016 CERN/ISSN 0234-0984

On the cover: Artwork showing how our Sun and Earth warp space and time. Geosynchronous orbits are illustrated when charged particles accelerate through space and time. (Image credit: 1 PixelChinese/MIT/LIGO Lab)
Hot or cold
Luvata is the industry leader in providing the best in both superconductors and hollow conductors. We’re helping create magnetic fields for industry and science around the world.

www.luvata.com
www.luvata.com/hollow-conductors
www.luvata.com/superconductors

CERN is the industry leader in superconductors and hollow conductors. We’re helping create the best in both superconductors and hollow conductors. We’re helping create magnetic fields for industry and science around the world.

www.luvata.com

CERN effect
Viewpoint
The CERN effect
Transferring innovation and knowledge so that cutting-edge research can benefit society.

By Sijbrand de Jong
Interest in CERN has evolved over the years. At its inception, the Organization’s founding member states clearly saw the new institution’s potential as a centre of excellence for basic research, a driver of innovation, a provider of first-class education and a catalyst for peace. After several decades of business as usual, CERN is again on the radar of its member-state governments. This is spurred partly by the public interest that has made CERN something of a household name. But whether in the public spotlight or not, it is incumbent on CERN to spell out to all of its stakeholders why it represents such good value for money today, just as it did 60 years ago. Even though the reasons may be familiar to those working at CERN, they are not always so clear to government officials and policy makers, and it’s worth setting them out in detail.

First and foremost, CERN has made major contributions to how we understand the world that we live in. In the discovery and detailed study of weak vector bosons in the 1980s and 1990s, and the recent discovery of the Higgs boson, messenger of the Brout–Englert–Higgs mechanism, have contributed much to our understanding of nature at the level of the fundamental particles and their interactions; now rightfully called the Standard Model of particle physics. This on its own is a major cultural achievement, and it has taught us much about how we have arrived at this point in history. From moment it all began, 13.6 billion years ago. Appreciation of this cultural contribution has never been higher than today. More than 100,000 people visit CERN every year, including hundreds of journalists reaching millions of people. None leave CERN unimpressed, and all are, without a doubt, culturally enriched by their experience.

Educating and innovating
CERN’s second major area of impact is education, having educated many generations of top-level physicists, engineers and technicians. Some have remained at CERN, while others have gone on to pursue careers in basic research at universities and institutes elsewhere, therefore contributing to top-level education and multiplying the effect of their own experience at CERN. Many more, however, have made their way into industry, fulfilling an important mission for CERN—that of providing skilled people to advance the economies of our member states and collaborating nations. More than 500 doctoral degrees are awarded annually on the basis of work carried out at CERN experiments and accelerators. In 2015, more than 400 doctoral, technical and administrative students were welcomed by CERN, usually staying for between several months and a year. The CERN summer-student and teacher programmes, which provide short stints of intensive education, also welcome hundreds of students and high-school teachers every year.

A third important contribution of CERN is the innovation that results from research that requires technology at levels and in areas where no one has gone before. The best-known example of CERN technology is the World Wide Web, which has profoundly changed the way that our society works worldwide. But the web is just the tip of the iceberg. Advances in fields such as magnet technology, cryogenics, electronics, detector technology and statistical methods have also made their way into society in ways that are equally impactful, although less obviously evident. While the societal benefits of techniques such as advanced photon and lepton detection may not seem immediately relevant beyond the realms of research, the impact they have had in medical imaging, for instance, is profound.

Often not very visible, but no less effective in contributing to our prosperity and well-being, developments such as this are a vital part of the research cycle. CERN is increasingly taking a proactive approach towards transferring its innovation, knowledge and skills to those who can make these count for society as a whole, and this is generally well appreciated. Recent initiatives include public–private partnerships such as OpenLab, Medipix and IdeaSquare, which provide low-entry-threshold mechanisms for companies to engage with CERN technology. In return, CERN benefits through stimulating the kind of industrial innovation that enables next-generation accelerators and detectors.

The recent Viewpoint by CERN Director-General, Fabiola Gianotti (CERN Courier, March 2016 p7) gives a superb outline of the opportunities and challenges for particle physics during the coming years. Clearly it will require great dexterity to juggle the continuation of a state-of-the-art research programme at the LHC and a diverse range of other facilities, with greater engagement with important activities beyond CERN, such as the US neutrino programme, while at the same time preparing for future accelerators and detectors. This will stretch CERN’s capabilities to the limit. But it is precisely this challenge that will motivate the Organization to do better and innovate in all areas, with inevitable benefits for society. Scientific culture and societal impacts advancing hand-in-hand through cutting-edge research: it is this that makes CERN worthy of the support it receives from governments worldwide.

The CERN effect
Transferring innovation and knowledge so that cutting-edge research can benefit society.

By Sijbrand de Jong
Interest in CERN has evolved over the years. At its inception, the Organization’s founding member states clearly saw the new institution’s potential as a centre of excellence for basic research, a driver of innovation, a provider of first-class education and a catalyst for peace. After several decades of business as usual, CERN is again on the radar of its member-state governments. This is spurred partly by the public interest that has made CERN something of a household name. But whether in the public spotlight or not, it is incumbent on CERN to spell out to all of its stakeholders why it represents such good value for money today, just as it did 60 years ago. Even though the reasons may be familiar to those working at CERN, they are not always so clear to government officials and policy makers, and it’s worth setting them out in detail.

First and foremost, CERN has made major contributions to how we understand the world that we live in. In the discovery and detailed study of weak vector bosons in the 1980s and 1990s, and the recent discovery of the Higgs boson, messenger of the Brout–Englert–Higgs mechanism, have contributed much to our understanding of nature at the level of the fundamental particles and their interactions; now rightfully called the Standard Model of particle physics. This on its own is a major cultural achievement, and it has taught us much about how we have arrived at this point in history. From moment it all began, 13.6 billion years ago. Appreciation of this cultural contribution has never been higher than today. More than 100,000 people visit CERN every year, including hundreds of journalists reaching millions of people. None leave CERN unimpressed, and all are, without a doubt, culturally enriched by their experience.

Educating and innovating
CERN’s second major area of impact is education, having educated many generations of top-level physicists, engineers and technicians. Some have remained at CERN, while others have gone on to pursue careers in basic research at universities and institutes elsewhere, therefore contributing to top-level education and multiplying the effect of their own experience at CERN. Many more, however, have made their way into industry, fulfilling an important mission for CERN—that of providing skilled people to advance the economies of our member states and collaborating nations. More than 500 doctoral degrees are awarded annually on the basis of work carried out at CERN experiments and accelerators. In 2015, more than 400 doctoral, technical and administrative students were welcomed by CERN, usually staying for between several months and a year. The CERN summer-student and teacher programmes, which provide short stints of intensive education, also welcome hundreds of students and high-school teachers every year.

A third important contribution of CERN is the innovation that results from research that requires technology at levels and in areas where no one has gone before. The best-known example of CERN technology is the World Wide Web, which has profoundly changed the way that our society works worldwide. But the web is just the tip of the iceberg. Advances in fields such as magnet technology, cryogenics, electronics, detector technology and statistical methods have also made their way into society in ways that are equally impactful, although less obviously evident. While the societal benefits of techniques such as advanced photon and lepton detection may not seem immediately relevant beyond the realms of research, the impact they have had in medical imaging, for instance, is profound.

Often not very visible, but no less effective in contributing to our prosperity and well-being, developments such as this are a vital part of the research cycle. CERN is increasingly taking a proactive approach towards transferring its innovation, knowledge and skills to those who can make these count for society as a whole, and this is generally well appreciated. Recent initiatives include public–private partnerships such as OpenLab, Medipix and IdeaSquare, which provide low-entry-threshold mechanisms for companies to engage with CERN technology. In return, CERN benefits through stimulating the kind of industrial innovation that enables next-generation accelerators and detectors.

The recent Viewpoint by CERN Director-General, Fabiola Gianotti (CERN Courier, March 2016 p7) gives a superb outline of the opportunities and challenges for particle physics during the coming years. Clearly it will require great dexterity to juggle the continuation of a state-of-the-art research programme at the LHC and a diverse range of other facilities, with greater engagement with important activities beyond CERN, such as the US neutrino programme, while at the same time preparing for future accelerators and detectors. This will stretch CERN’s capabilities to the limit. But it is precisely this challenge that will motivate the Organization to do better and innovate in all areas, with inevitable benefits for society. Scientific culture and societal impacts advancing hand-in-hand through cutting-edge research: it is this that makes CERN worthy of the support it receives from governments worldwide.
The LHC is restarting

The LHC, last among all of CERN’s accelerators, is resuming operation with beam while this issue goes to press. The year-end technical stop (YETS) started on 14 December 2015. During the 11 weeks of scheduled maintenance activities, several interventions have taken place in all of the accelerators and beamlines. They included the maintenance of the cryogenic system at several points; the replacement of 18 magnets in the Super Proton Synchrotron (SPS); an extensive campaign to identify and remove thousands of obsolete cables; the replacement of the LHC beam absorbers for injection (TDIs) that are used to absorb the SPS beam if a problem occurs; providing vital protection for the LHC; and 12 LHC collimators have been dismantled and reinstalled after modification of the vacuum chambers, which restricted their movement.

The YETS also gave the experiments the opportunity to carry out repairs and maintenance work in their detectors. In particular, this included fitting the ATLAS vacuum-chamber bellow and cleaning the cold box at CMS, which had caused problems for the experiment’s magnet during 2015. Bringing beams back into the machine after a technical stop of a few weeks is no trivial matter. The Electrical Quality Assurance (ELQA) team needs to test the electrical circuits of the superconducting magnets, certifying their readiness for operation. After that, the powering tests can start, and this means about 7000 tests in 12 days – a critical task for all of the teams involved, which rely on the availability of all of the sectors. About four weeks after the start of commissioning, the LHC is ready to receive first beams and for them to circulate for several hours in the machine (stable beams).

The goal of this second part of Run 2 is to reach 2700 bunches per beam at 6.5 TeV and with nominal 25 ns spacing. In 2015, the machine reached a record of 2244 bunches in each beam, just before the beginning of the YETS. In 2016, the focus of the operators will be on ensuring maximum availability of the machine. For this, pipe scrubbing will be performed several times to keep the electron cloud effects under control. Thanks to the experience acquired in 2015, the operators will be able to improve the injection process and to perform ramping and squeezing at the same time, therefore reducing the time needed between two successive injections.

In addition to several weeks of steady standard 13 TeV operation with 2500 bunches per beam and β*=40 cm, the accelerator schedule for 2016 includes a high β* (~2.5 km) running period for TOTEM/ALFA dedicated to the measurement of the elastic proton–proton scattering in the Coulomb–nuclear interference region. The schedule also includes one month of heavy-ion run. Although various configurations (Pb–Pb, p–Pb) are still under consideration, the period – November – has already been decided. As usual, the heavy-ion run will conclude the 2016 operation of the LHC, while the extended year-end technical stop (EYETS) will start in December and will last about five months, until April 2017.

Several upgrades are already planned by the experiments during the EYETS, including installation of the new pixel system at CMS. The goal for the second part of Run 2 is to reach 1.5 × 10^34 cm–2 s–1 of luminosity, which with about 2700 bunches and 25 ns spacing is estimated to produce a pile-up of 40 events per bunch crossing. This should give an integrated luminosity of about 25 fb–1 in 2016, which should ensure a total of 100 fb–1 for Run 2 – planned to end in 2018.

High Precision UHV

Chambers delivered on time

Customise & Build your own vacuum chamber - use our Free online Chamber Builder™ Service

- Highly skilled in-house technicians
- 100% Quality Faroarm® Inspection
- Optional Bake out with RGA
- 316LN Flanges & Materials in Stock
- Unique Hydra–Cool™ water cooling technology - unrivalled performance, low cost
- Contact us for a Chamber Enquiry Today!

www.lesker.com | Enabling Technology for a Better World
Anisotropic flow in Run 2

Exploiting the data collected during November 2015 with Pb–Pb collisions at the record-breaking energy of √sNN = 5.02 TeV, ALICE measured for the first time the anisotropic flow of charged particles at this energy. Relativistic heavy-ion collisions are the tool of choice to investigate quark–gluon plasma (QGP), a state of matter where quarks and gluons move freely over distances that are large in comparison to the typical size of a hadron. Anisotropic flow, which measures the momentum anisotropy of final-state particles, is sensitive on the one hand to the initial density and to the initial geometry fluctuations of the overlap region, and on the other hand to the transport properties of the QGP. Flow is quantified by the Fourier coefficients, v_n, of the azimuthal distribution of the final-state charged particles. The dominant flow coefficient, v_2, referred to an elliptic flow, is related to the initial geometric anisotropy. Higher coefficients, such as triangular flow (v_3) and quadrangular flow (v_4), can be related primarily to the response of the produced QGP to fluctuations of the initial energy density profile of the participating nucleons.

Figure 1 shows the centrality dependence of flow coefficients, both for 2.76 and 5.02 TeV Pb–Pb collisions. Compared with the lower-energy results, the anisotropic flow v_2, v_3 and v_4 increase at the newly measured energy by 3.0(6.0)% (4.3(1.4)% and 10.2(3.8)%, respectively, in the centrality range 0–50%.

The transport properties of the created matter are investigated by comparing the experimental results with hydrodynamic model calculations, where the shear-viscosity to entropy density ratio, η/s, is the dominant parameter. Previou studies demonstrated that anisotropic flow measurements are best described by calculations using a value of η/s close to 1/4π, which corresponds to the lowest limits for a quantum fluid. It is observed in figure 1 that the magnitude and the increase of flow measured at the higher energy remain compatible with hydrodynamic predictions, favouring a constant value for η/s going from v_2=2.7% to 5.02 TeV Pb–Pb collisions.

It is also observed that the results of p_T-differential flow are comparable for both energies. This observation indicates that the increase measured in the integrated flow (figure 1) reflects the increase of the mean transverse momentum. Further comparisons of differential-flow measurements and theoretical calculations will provide a unique opportunity to test the validity of the hydrodynamic picture, and the power to further discriminate between various possibilities for the temperature dependence of the shear-viscosity to entropy density ratio of the produced matter in heavy-ion collisions at highest energies.

Further reading


CMS hunts for supersymmetry in uncharted territory

The CMS collaboration is continuing its hunt for signs of supersymmetry (SUSY), a popular extension to the Standard Model that could provide a weakly interacting massive-particle candidate for dark matter, if the lightest supersymmetric particle (LSP) is stable.

With the increase in the LHC centre-of-mass energy from 8 to 13 TeV, the production cross-section for hypothetical SUSY partners rises; the first searches to benefit are those looking for the strongly coupled SUSY partners of the gluon (gluino) and quarks (squark) that had the most stringent mass limits from Run 1 of the LHC. By decaying to a stable LSP, which does not interact in the detector and instead escapes, squarks and gluinos can leave a characteristic experimental signature of a large imbalance in transverse momentum.

Searches for new physics based on final states with jets (a bundle of particles) and large transverse-momentum imbalance are sensitive to broad classes of new-physics models, including supersymmetry. CMS has searched for SUSY in this final state using a variable called the “transverse mass”, MT2, to measure the transverse-momentum imbalance, which strongly suppresses fake quark flavour, extending our Run 1 limits by more than 300 GeV. We are also sensitive to squarks, with our constraints summarised in figure 1. We set limits on bottom–squark masses up to 880 GeV, top squarks up to 800 GeV, and light-flavour squarks up to 600–1200 GeV, depending on how many states are degenerate in mass.

Even though SUSY was not waiting for us around the corner at 13 TeV, we look forward to the 2016 run, where a large increase in luminosity gives us another chance at discovery.

Further reading

SUS-15-003, 0-lep (MT2).

LHCb awards physics prizes for its Kaggle competition

Machine learning, also known as physics circles as multivariate analysis, is used more and more in high-energy physics, mostly in data analysis but also in other applications such as trigger and reconstruction. The community of machine learning data scientists organises “Kaggle” competitions to solve difficult and interesting challenges in different fields.

With the aim being to develop interactions with the machine-learning community, LHCb organised such a competition, featuring the search for the lepton-flavour violating decay, 

Further reading

CEB-EP-2016-057.

Anisotropic flow in Run 2

Exploiting the data collected during November 2015 with Pb–Pb collisions at the record-breaking energy of √sNN = 5.02 TeV, ALICE measured for the first time the anisotropic flow of charged particles at this energy. Relativistic heavy-ion collisions are the tool of choice to investigate quark–gluon plasma (QGP), a state of matter where quarks and gluons move freely over distances that are large in comparison to the typical size of a hadron. Anisotropic flow, which measures the momentum anisotropy of final-state particles, is sensitive on the one hand to the initial density and to the initial geometry fluctuations of the overlap region, and on the other hand to the transport properties of the QGP. Flow is quantified by the Fourier coefficients, v_n, of the azimuthal distribution of the final-state charged particles. The dominant flow coefficient, v_2, referred to an elliptic flow, is related to the initial geometric anisotropy. Higher coefficients, such as triangular flow (v_3) and quadrangular flow (v_4), can be related primarily to the response of the produced QGP to fluctuations of the initial energy density profile of the participating nucleons.

Figure 1 shows the centrality dependence of flow coefficients, both for 2.76 and 5.02 TeV Pb–Pb collisions. Compared with the lower-energy results, the anisotropic flow v_2, v_3 and v_4 increase at the newly measured energy by 3.0(6.0)% (4.3(1.4)% and 10.2(3.8)%, respectively, in the centrality range 0–50%).

The transport properties of the created matter are investigated by comparing the experimental results with hydrodynamic model calculations, where the shear-viscosity to entropy density ratio, η/s, is the dominant parameter. Previous studies demonstrated that anisotropic flow measurements are best described by calculations using a value of η/s close to 1/4π, which corresponds to the lowest limits for a quantum fluid. It is observed in figure 1 that the magnitude and the increase of flow measured at the higher energy remain compatible with hydrodynamic predictions, favouring a constant value for η/s going from v_2=2.7% to 5.02 TeV Pb–Pb collisions.

It is also observed that the results of p_T-differential flow are comparable for both energies. This observation indicates that the increase measured in the integrated flow (figure 1) reflects the increase of the mean transverse momentum. Further comparisons of differential-flow measurements and theoretical calculations will provide a unique opportunity to test the validity of the hydrodynamic picture, and the power to further discriminate between various possibilities for the temperature dependence of the shear-viscosity to entropy density ratio of the produced matter in heavy-ion collisions at highest energies.

Further reading

Further reading:

- "First turns" for SuperKEKB
- "The three middle “spikes” are signals from CLAWS, a subsystem of the BEAST II detector triggered by the SuperKEKB injection signal."
- "Belle II is designed to have the world’s highest luminosity — a factor of 40 higher than the earlier KEKB machine, which holds many records for accelerator performance. SuperKEKB will therefore be the leading accelerator on the “luminosity frontier.”"
- "The BEAST II detector will collect data in the unique environment produced by SuperKEKB’s first beams, allowing Belle II to safely roll into the beam in 2017.

For more information, visit:

- 
- 
- 
- 

The three middle “spikes” are signals from CLAWS, a subsystem of the BEAST II detector triggered by the SuperKEKB injection signal. Belle II is designed to have the world’s highest luminosity — a factor of 40 higher than the earlier KEKB machine, which holds many records for accelerator performance. SuperKEKB will therefore be the leading accelerator on the “luminosity frontier.” The BEAST II detector at SuperKEKB was designed and built by an international collaboration of more than 600 physicists from 23 countries. This collaboration is working to build an accelerator expert to optimise the machine. At the same time as first turns were achieved, the BEAST II in its cave at Tsukuba Hall was being assembled into its slumber. The BEAST II detector is a system of detectors designed to measure the beam backgrounds of the SuperKEKB project. The parasitic radiation produced by electromagnetic showers when the beam collides with the walls of the vacuum pipe not only obscures the signals that we wish to observe, but can also damage the detector. Therefore, when operating the new accelerator, these beam backgrounds must be well understood.

The BEAST II detector will collect data in the unique environment produced by SuperKEKB’s first beams, allowing Belle II to safely roll into the beam in 2017.

For more information, visit:

- 
- 
- 
-
**News**

**Light source**

TPS exceeds design goal of 500 mA stored current

In December last year, the 3 GeV Taiwan Photon Source (TPS) of the National Synchrotron Radiation Research Center (NSRRC) stored 520 mA of electron current in its storage ring, and gave the world a bright synchrotron light as the International Year of Light 2015 came to an end. This is the second phase of commissioning conducted after the five-month preparation work set to bring the electron current of TPS to its design value of 500 mA (CERN Courier June 2010 p16 and April 2015 p22).

After the first light of TPS shone on December 31, 2014, the beam injection stored an electron current greater than 100 mA with the efficiency of the booster to storage ring exceeding 75% using Petra cavities. To overcome the instability of the electron beam, high chromaticity and a vertical feedback system were applied to damp the vertical instability at a high current, in this case close to 100 mA, whereas the longitudinal instability appeared when the beam current reached around 85 mA. Subsequently, the dynamic pressure of the vacuum conditioning reached 10$^{-10}$ Pa at 100 mA after feeding 35 ams-per-hour beam dose. At this stage, the TPS was ready for the upgrade implementation scheduled for the remainder of 2015.

Several new components were installed during this phase, including new undulators and superconducting cavities, while the cryogenic and control systems were completed.

The upgrade activities also involved the injection system and the transfer line between booster and storage, to improve the injection efficiency and the stability of the system. In addition, 96 fast-feedback corrector magnets were placed at both ends of the straight sections, as well as upstream of the dipole magnets.

After several test runs in the fourth quarter of 2015, an unusual and unfamiliar phenomenon began to emerge, preventing the electron current from progressing beyond 230 mA. The pressure of the vacuum chamber located in the first dipole of the second arc section in the storage ring repeatedly surged to more than 300 times the normal Under 10$^{-10}$ Pa when the beam current increased to 190 mA. A small metal–plastic pellet that contaminated the vacuum environment was removed and the staff performed flange welding on the spot.

After the vacuum problem had been solved, commissioning of TPS went smoothly, ramping from 0 to 520 mA in 11 minutes on December 12.

While the TPS was ramping up its stored-current target value, two beamlines—the protein microcrystallography beamline (TPS-05) and the temporally coherent X-ray diffraction beamline (TPS-09)—were in the commissioning phase. The TPS beamlines will be open for use in 2016.

**New particles**

DZero discovers new four-flavour particle

Scientists from the DZero collaboration at the US Department of Energy’s Fermilab have discovered a new particle—the latest member to be added to the exotic species of particles known as tetraquarks. In 2003, scientists from the Belle experiment in Japan reported the first evidence of quarks hanging out as a foursome, forming a tetraquark. Since then, physicists have glimpsed a handful of different tetraquark candidates, including now the recent discovery by DZero—the first observed to contain four different quark flavours.

DZero scientists first saw hints of the new particle, called X(5568), in July 2015. After performing multiple cross-checks, the collaboration confirmed that the signal could not be explained by backgrounds or known processes, but was evidence of a new particle. And the X(5568) is not just any new tetraquark. While all other observed tetraquarks contain at least two of the same flavour, X(5568) has four different flavours: up, down, strange and bottom.

Four-quark states are rare, and although there is nothing in nature that forbids the formation of a tetraquark, scientists do not understand them nearly as well as they do two- and three-quark states. This latest discovery comes on the heels of the first observation of a pentaquark—a five-quark particle—announced last year by the LHCB experiment at the LHC.

The next step will be for DZero scientists to understand how the four quarks are put together. Indeed, the quarks could be scrunched together in the tight ball, or they might be a pair of tightly bound quarks revolving at some distance from the other pair. Scientists will sharpen the picture of the quark quartet by making measurements of properties such as the way that X(5568) decays or how much it spins on its axis.

As with previous investigations of the tetraquarks, studies of the X(5568) will provide another window into the workings of the strong force that holds these particles together.

Seventy-five institutions from 18 countries collaborated on this result from DZero.

**FURTHER READING**

http://arxiv.org/abs/1602.07588

**Additional reading**

The DUNE 35 tonne prototype, a test version of the future DUNE detector.

DUNE scientists are also paying special attention to the prototype’s wire planes—pieces that hold the thin wires strung across the detector to pick up electrons. To ensure the frames will fit into the narrow mineshaft at SURF and avoid having to stretch the wires across the long DUNE detectors, risking sagging, scientists plan to use a series of independent 6-m-long and 2.3-m-wide frames. These wire planes should measure tracks in the liquid argon, both in front of and behind them, unlike other detectors.

Engineers have also moved some of the detector’s electronic parts inside the cryostat, which holds liquid argon at –0.84°C. Much like the full detectors, development of the components of the 35 tonne prototype depends on teamwork. For the prototype, Brookhaven and SLAC national laboratories in the US provided much of the electronic equipment. Indiana University, Colorado State University, Louisiana State University and Massachusetts Institute of Technology worked on the light detectors; and the universities of Oxford, Sussex and Sheffield helped to make special digital cameras that can survive in liquid argon, and wrote the software to make sense of the data. Fermilab was responsible for the cryostat and cryogenic support systems.

Scientists will use what they learn from this small prototype version to build one of the full-scale modules for a larger, 400 tonne prototype currently under construction at the CERN Neutrino Platform. A second 400 tonne module using dual-phase technology will also be built at CERN. These will be the final tests before installation of the four huge detectors at SURF for the actual experiment, which is scheduled to start in 2021/2022.

**New experiments**

Testing of DUNE tech begins

The planned Deep Underground Neutrino Experiment (DUNE) CERN Courier December 2015 p19 will require for DZero scientists to understand how the quark quartet by making measurements of properties such as the way that X(5568) decays or how much it spins on its axis. As with previous investigations of the tetraquarks, studies of the X(5568) will provide another window into the workings of the strong force that holds these particles together.

Seventy-five institutions from 18 countries collaborated on this result from DZero.

**FURTHER READING**

http://arxiv.org/abs/1602.07588

**Additional reading**

The DUNE 35 tonne prototype, a test version of the future DUNE detector.

DUNE scientists are also paying special attention to the prototype’s wire planes—pieces that hold the thin wires strung across the detector to pick up electrons. To ensure the frames will fit into the narrow mineshaft at SURF and avoid having to stretch the wires across the long DUNE detectors, risking sagging, scientists plan to use a series of independent 6-m-long and 2.3-m-wide frames. These wire planes should measure tracks in the liquid argon, both in front of and behind them, unlike other detectors.

Engineers have also moved some of the detector’s electronic parts inside the cryostat, which holds liquid argon at –0.84°C. Much like the full detectors, development of the components of the 35 tonne prototype depends on teamwork. For the prototype, Brookhaven and SLAC national laboratories in the US provided much of the electronic equipment. Indiana University, Colorado State University, Louisiana State University and Massachusetts Institute of Technology worked on the light detectors; and the universities of Oxford, Sussex and Sheffield helped to make special digital cameras that can survive in liquid argon, and wrote the software to make sense of the data. Fermilab was responsible for the cryostat and cryogenic support systems.

Scientists will use what they learn from this small prototype version to build one of the full-scale modules for a larger, 400 tonne prototype currently under construction at the CERN Neutrino Platform. A second 400 tonne module using dual-phase technology will also be built at CERN. These will be the final tests before installation of the four huge detectors at SURF for the actual experiment, which is scheduled to start in 2021/2022.

**New experiments**

Testing of DUNE tech begins

The planned Deep Underground Neutrino Experiment (DUNE) CERN Courier December 2015 p19 will require for DZero scientists to understand how the quark quartet by making measurements of properties such as the way that X(5568) decays or how much it spins on its axis. As with previous investigations of the tetraquarks, studies of the X(5568) will provide another window into the workings of the strong force that holds these particles together.

Seventy-five institutions from 18 countries collaborated on this result from DZero.

**FURTHER READING**

http://arxiv.org/abs/1602.07588

**Additional reading**

The DUNE 35 tonne prototype, a test version of the future DUNE detector.

DUNE scientists are also paying special attention to the prototype’s wire planes—pieces that hold the thin wires strung across the detector to pick up electrons. To ensure the frames will fit into the narrow mineshaft at SURF and avoid having to stretch the wires across the long DUNE detectors, risking sagging, scientists plan to use a series of independent 6-m-long and 2.3-m-wide frames. These wire planes should measure tracks in the liquid argon, both in front of and behind them, unlike other detectors.

Engineers have also moved some of the detector’s electronic parts inside the cryostat, which holds liquid argon at –0.84°C. Much like the full detectors, development of the components of the 35 tonne prototype depends on teamwork. For the prototype, Brookhaven and SLAC national laboratories in the US provided much of the electron
Incandescent return

A new approach to incandescent bulbs promises to beat LEDs for efficiency. Ognen Ilic and colleagues at MIT replaced the traditional light bulb filament with a flat tungsten ribbon. They then coated glass sheets with a photonic crystal made of alternating layers of tantalum oxide and silicon dioxide, with thicknesses determined by computer modelling, and sandwiched the tungsten between the two. The photonic crystals are transparent to visible light but reflect infrared photons back onto the filament so that they reheat it instead of being radiated. The efficiency so far is 6.5%, triple that of conventional light bulbs, but 40% may be reachable, which would far outstrip compact fluorescent bulbs (7% to 13%) and LED’s (5% to 15%).

When trees break

Data suggest that trees break at a critical wind speed of about 42 m/s, regardless of the characteristics of any given tree. This has now been explained by Christophe Clanet of LAdHyX, of the Ecole Polytechnique in Palaiseau, France, and colleagues, using Hooke’s law, the Griffiths criterion for cracks, and tree allometry and modelling trees as fragile rods. The maximum wind speeds on Earth are about 50 m/s, so this may be part of why trees are so long-lived.

Back to nine planets?

If you are unhappy about Pluto losing its official status as a planet, the good news is that there may be a 9th one that we’ve missed so far, orbiting out beyond Pluto with a period of 10,000–20,000 years. While not yet seen directly, Konstantin Batygin and Michael E Brown of Caltech argue that just such a planet, with a mass of around 10 Earth masses or more, explains an otherwise mysterious clustering seen in Kuiper-belt objects. It spends much of the time very far from the Sun, so would be hard to see directly, but the Subaru Telescope in Hawaii has a chance, as does the Large Synoptic Survey Telescope in Chile, which should start operating within 10 years.

First castes

Social insects have castes – queens, workers, and soldiers – and the origin of this structure has been tracked back to ancient termites. Michael Engel of the University of Kansas in Lawrence and colleagues found six termite species preserved in amber from Myanmar, showing evidence of castes and dating back 100 million years. The previous oldest caste soldiers were just 17 million years old.

Further reading


Further reading


Further reading


A plant that counts

Remarkably, the Venus flytrap can count to five. Erwin Neher of the Max Planck Institute for Biophysical Chemistry in Göttingen, Germany, and colleagues, recorded electrical impulses from the plant in response to one to 60 touches. Two touches close the trap, but after only five touches the plant starts to make the enzyme that digests its prey, and to increase production of a sodium transporter used to absorb nutrients.

Further reading


Further reading


Further reading


Further reading

O Ilic et al. 2016 Science 351 257.

Further reading

Egami et al. 2016 Science 351 482.

Further reading

M Ossendrijver 2016 Science 351 484.

Further reading

S Dong et al. 2016 Science 351 482.

Further reading


Further reading

M S Engel et al. 2016 Nature 529 484.

Further reading

D Silver et al. 2016 Science 351 482.

Further reading

S Dong et al. 2016 Science 351 257.

Further reading


Further reading


A plant that counts

Remarkably, the Venus flytrap can count to five. Erwin Neher of the Max Planck Institute for Biophysical Chemistry in Göttingen, Germany, and colleagues, recorded electrical impulses from the plant in response to one to 60 touches. Two touches close the trap, but after only five touches the plant starts to make the enzyme that digests its prey, and to increase production of a sodium transporter used to absorb nutrients.

Further reading


Further reading


Further reading


Further reading

O Ilic et al. 2016 Science 351 257.

Further reading

Egami et al. 2016 Science 351 482.

Further reading

M Ossendrijver 2016 Science 351 484.

Further reading

S Dong et al. 2016 Science 351 482.

Further reading


Further reading

M S Engel et al. 2016 Nature 529 484.

Further reading

D Silver et al. 2016 Science 351 482.
Gamma-ray excess is not from dark matter

An excess of gamma rays at energies of a few GeV was found to be a good candidate for a dark-matter signal (CERN Courier April 2014 p33). Two years later, a pair of research articles refute this interpretation by showing that the excess photons detected by the Fermi Gamma-ray Space Telescope are not smoothly distributed as expected for dark-matter annihilation. Their clustering reveals instead a population of unresolved point sources, likely millisecond pulsars.

The Milky Way is thought to be embedded in a dark-matter halo with a density gradient increasing towards the galactic centre. The central region of our Galaxy is therefore a prime target to find an electromagnetic signal from dark-matter annihilation. If dark matter is made of weakly interacting massive particles (WIMPs) heavier than protons, such a signal would naturally be in the GeV energy band. A diffuse gamma-ray emission detected by the Fermi satellite and having properties compatible with a dark-matter origin created hope in recent years of finally detecting this elusive form of matter more directly than only through gravitational effects.

Two independent studies published in Physical Review Letters are now disproving this interpretation. Using different statistical-analysis methods, the two research teams found that the gamma rays of the excess emission at the galactic centre are not distributed as expected from dark matter. They both find evidence for a population of unresolved point sources instead of a smooth distribution.

The study, led by Richard Bartels of the University of Amsterdam, the Netherlands, uses a wavelet transformation of the Fermi gamma-ray images. The technique consists of a convolution of the photon count map with a wavelet kernel shaped like a Mexican hat, with a width tuned near the Fermi angular resolution of 0.4°. The processing reveals many peaks circled in black. The brightest ones match the sources detected by Fermi (red circles), while the fainter ones suggest a hidden population of unresolved point sources. The colour scale encodes the signal-to-noise ratio.

Picture of the month

This faint dwarf galaxy called IC 1613 was discovered in 1906 in the constellation of Cetus. It is a member of the Local Group of galaxies and lies just over 2.3 million light-years away. The image, captured with the OmegaCAM camera on ESO’s VLT Survey Telescope in Chile, shows many details of this irregular galaxy containing very little cosmic dust. This property allowed astronomers to use it decades ago to study precisely variable stars such as Cepheid and RR Lyrae, which have the special property that their period of brightening and dimming is linked directly to their intrinsic brightness. By measuring the period, astronomers can derive the actual luminosity of the star and hence—using the observed brightness—its distance. It is thanks to such peculiar stars that the cosmic distance ladder could be constructed. The extension of this ladder deeper and deeper into space with the use of new “standard candles” such as Type Ia supernovae led to the Nobel-prize-winning discovery of the accelerating expansion of the universe (CERN Courier November 2011 p5).

Further reading


Gamma-ray map of an area (2° wide) around the galactic centre showing the wavelet transform of the Fermi data. This processing reveals many peaks circled in black. The brightest ones match the sources detected by Fermi (red circles), while the fainter ones suggest a hidden population of unresolved point sources. The colour scale encodes the signal-to-noise ratio.
Two black holes about to merge. On 11 February, the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo collaborations published a historic paper in which they showed a gravitational signal emitted by the merger of two black holes. The signal has been observed with 50 times the sensitivity of the original 40 m prototype.

This result comes after 20 years of hard work by a large collaboration of scientists operating the two LIGO observatories in the US. Barry Barish, Linde professor of physics, emeritus, at the California Institute of Technology and former director of the Global Design Effort for the International Linear Collider (ILC), led the LIGO endeavour from 1994 to 2005. On the day of the official announcement to the scientific community and the public, Barish was at CERN to give a landmark seminar that captivated the whole audience gathered in the packed Main Auditorium.

On 11 February, the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo collaborations published a historic paper in which they showed a gravitational signal emitted by the merger of two black holes. The signal has been observed with 50 times the sensitivity of the original 40 m prototype.

This result comes after 20 years of hard work by a large collaboration of scientists operating the two LIGO observatories in the US. Barry Barish, Linde professor of physics, emeritus, at the California Institute of Technology and former director of the Global Design Effort for the International Linear Collider (ILC), led the LIGO endeavour from 1994 to 2005. On the day of the official announcement to the scientific community and the public, Barish was at CERN to give a landmark seminar that captivated the whole audience gathered in the packed Main Auditorium.

The CERN Courier had the unique opportunity to interview Barish just after the announcement.

Professor Barish, this achievement comes after 20 years of hard work, uncertainties and challenges. This is what research is all about, but what was the greatest challenge you had to overcome during this long period?

It really was to do anything that takes 20 years and still be supported and have the energy to reach completion. We started long before that, but the project itself started in 1994. LIGO is an incredible technical achievement. The idea that you can take on high risk in such a scientific endeavour requires a lot of support, diligence and perseverance. In 1994, we convinced the US National Science Foundation to fund the project, which became the biggest programme to be funded. After that, it took us 10 years to build it and to make it work well, plus 10 years to improve the sensitivity and bring it to the point where we were able to detect the gravitational waves. And along the way no one had done this before.

Indeed, the experimental set-up we used to detect the gravitational signal is an enormous extrapolation from anything that was done before. As a physicist, you learn that extrapolating a factor of two can be within reach, but a factor of 10 sounds already like a dream. If you compare the first 40 m interferometer we built on the CALTECH campus with the two 4000 m interferometers we have now, you already have an idea of the enormous leap we had to make. The leap of 100 m in size involved at least that in complexity and sophistication, eventually achieving more than 10,000 times the sensitivity of the original 40 m prototype.

What were your feelings upon seeing the event on your screen?

When we tracked back the formation of the event data from the two interferometers, and we could see that the signal was recorded within seven milliseconds – exactly the time we expect for the same thing. We had a glimpse of that with the first single event. With just the first glimpse at the universe with gravitational waves, astronomers had never seen stellar black holes of these masses.

What do you think are the most important consequences of the discovery?

The discovery opens two new areas of research for physics. One is on the general-relativity theory itself. Gravitational waves are a powerful way of testing the heart of the theory by investigating the strong-field realm of gravitational physics. Even with just this first event – the merging of two black holes – we have created a true laboratory where you can study all of this, and understanding general relativity at an absolutely fundamental level is now opening up.

The second huge consequence of the discovery is that we can now look at the universe with a completely new “telescope”. So far, we have used and built all kinds of telescopes: infrared, ultraviolet, radio, optical… And the idea of recent years has been to look at the same things in different bandwidths.

However, no such previous instrument could have seen what we saw with the LIGO interferometers. Nature has been so generous with us that the very first event we have seen is new astrophysics, as astronomers had never seen stellar black holes of these masses.

With just the first glimpse at the universe with gravitational waves, we now know that they exist in pairs and that they can merge. This is all new astrophysics. When we designed LIGO, we thought that the first thing we would see gravitational waves emitted by was neutron stars. It would still be a huge discovery, but it would not be new astrophysical information. We have been really lucky.

Over the next century, this field will provide a completely new way of doing an incredible amount of new science. And somehow we had a glimpse of that with the first single event.

What were your feelings upon seeing the event on your screen?

We initially thought that it could be some instrumental crazy thing. We had to worry about many possible instrumental glitches, including whether someone had purposely injected a fake event into our data stream. To carefully check the origin of the signal, we tracked back the formation of the event data from the two interferometers, and we could see that the signal was recorded within seven milliseconds – exactly the time we expect for the same
Breakthrough

From sensors to equipment, find more solutions at

Magnets and coils

www.scanditronix-magnet.se

One of LIGO’s mirrors is inspected by a technician.

event to appear on the second interferometer. The two signals were perfectly consistent, and this gave us total trust in our data. I must admit that I was personally worried as, in physics, it is always very dangerous to claim anything with only one event. However, we proceeded to perform the analysis in the most rigorous way and, indeed, we followed the normal publication path, namely the submission of the paper to the referees. They confirmed that what we submitted was scientifically well-justified. In this way, we had the green light to announcing the discovery to the public.

At the seminar you were welcomed very warmly by the audience. It was a great honour for the CERN audience to have you give the talk in person, just after your colleagues’ announcement in the US. What are you bringing back from your experience?

I was very happy to be presenting this important achievement in the temple of science. The thing that made me feel that we made the case well was that people were interested in what we have done and are doing. In the packed audience, nobody seemed to question our methodology, analysis or the validity of our result. We have one single event, but this was good enough to convince me and also my colleagues that it was a true discovery. I enjoyed receiving all of the science questions from the audience – it was really a great moment for me.

The LIGO and Virgo collaborations are currently working on analysing the rest of the data from the run that ended on 12 January. New information is expected to be published in the coming months. In the meantime, the discovery event is available in open data (see https://losc.ligo.org) for anyone who wants to analyse it.

Résumé

LIGO : l’aboutissement d’un long chemin

Vingt ans de travail acharné par la conviction que ces efforts conduiraient un jour à une découverte historique : la première détection directe d’ondes gravitationnelles signe l’aboutissement de ce parcours. La découverte ouvre la voie à une méthode d’observation entièrement nouvelle pour l’astrophysique et la science gravitationnelle. Le jour de l’annonce officielle, Barry Barish, ancien directeur de l’expérience LIGO, était au CERN pour présenter un séminaire qui fera date, devant un auditoire nombreux rassemblé dans l’amphithéâtre principal. En cette occasion historique, il fait part de ses impressions au Courrier.

Science with a medical PET cyclotron

Beyond routine radioisotope production for medical imaging, compact PET cyclotrons can be at the heart of multidisciplinary research facilities. The cyclotron laboratory in Bern (Switzerland) sets an example.

Saverio Braccini, University of Bern, and Paola Scampoli, University of Napoli Federico I, and University of Bern.

Particle accelerators are fundamental instruments in modern medicine, where they are used to study the human body and to detect and cure its diseases. Instrumentation issued by fundamental research in physics is very common in hospitals. This includes positron emission tomography (PET) and cancer hadrontherapy.

To match the needs of a continuously evolving field and to fulfill the stringent requirements of hospital-based installations, specific particle accelerators have been developed in recent years. In particular, modern medical cyclotrons devoted to proton cancer treatments and to the production of radioisotopes for diagnostics and therapy are compact, user-friendly, affordable and able to ensure very high performance.

Medical PET cyclotrons usually run during the night or early in the morning, for the production of radiotracers that will be used for imaging. Their beams, featuring about 20 MeV energy and currents of the order of 100 µA, are in principle available for other purposes during the daytime. This represents an opportunity to exploit the science potential of these accelerators well beyond medical-imaging applications. In particular, they can be optimised to produce beams in the picocurie and nanogramme range, opening the way to nuclear and detector physics, material science, radiation biophysics, and radiation protection research.

The Bern medical PET cyclotron laboratory was conceived to use the accelerator for scientific purposes in parallel with radioisotope production. It is situated in the campus of the Inselspital, the Bern University hospital, and has been in operation since 2013. The heart of the facility consists of an 18 MeV cyclotron providing single or dual beams of H+ ions. A maximum extracted current of 150 µA is obtained by stripping the negative ions. Targets can be located in eight different out-ports. For four of them are used for fluorine-18 production, one is equipped with a solid target station, and one is connected to a 6 m-long beam transfer line (BTL). The accelerator is located inside a bunker, while a second bunker with independent access hosts the BTL and is fully dedicated to research. The beam optics of the BTL is realised by one horizontal and one vertical...
steering magnet, together with two quadrupole doublets, one in the cyclotron bunker and the other in the research area. A neutron shutter prevents neutrons from entering the research bunker during routine production, avoiding radiation damage to scientific instrumentation. The BTL, rather unusually for a hospital cyclotron, represents the pillar of this facility. Although initially more expensive than a standard PET cyclotron facility, this solution ensures complete exploitation of the accelerator beam time and allows for synergy among academic, clinical and industrial partners. The bunker containing the beam-transfer line dedicated to research activities.

Multidisciplinary research activities

The Bern facility carries out full multidisciplinary research activities by a team of physicists, chemists, pharmacists and biologists. The BTL and the related physics laboratory have so far been the main instrument for carrying out research on particle detectors, accelerator physics, radiation protection, and novel radioisotopes for diagnostics and therapy.

To reach beam currents down to the picoampere range, a specific method was developed based on tuning the ion source, the radiofrequency and the current in the main coil. These currents are far below those employed for radioisotope production, and PET cyclotrons are not equipped with sensitive enough instrumentation. A novel compact-profile monitor detector was conceived and built to measure, control and use these low-intensity beams. A scintillating fibre crossing the beam produces light that can be collected to measure its profile. Specific doped-silica scintillating fibres were formed in collaboration with the Institute of Applied Physics (IAP) in Bern. A wide-intensity-range beam-monitoring detector was realised, able to span currents from 1 pA to 20 μA. The versatility of the instrument attracted the interest of industry, becoming a spin-off of the research activity. Moreover, the beam monitor was used to measure the transverse beam emittance of cyclotrons, opening the way to further accelerator-physics developments.

The large amount of daily produced fluoride-18 requires a complex radiation-protection monitoring system consisting of about 40 detectors. Besides γ and neutron monitoring, special care is paid to air contamination – a potential danger for workers and the population. This system is both a safety and research tool. Radioactivity induced in the air by proton and neutron beams was studied and the produced activity measured. The results were paid to air contamination – a potential danger for workers and the population. This system is both a safety and research tool. Radioactivity induced in the air by proton and neutron beams was studied and the produced activity measured. The results were

PET radioisotope, having nearly ideal nuclear-decay properties for PET. Furthermore, scandium is suitable for theranostics (combined diagnostics and therapy). The same biomolecule can in fact be labelled with a positron-emitting isotope for imaging and a β− one for cancer therapy. Advances in nuclear medicine will only be possible if suitable quantities of scandium-43 are available. The goal of the project is to produce clinically relevant amounts of this radioisotope with a quality appropriate for clinical trials.

The results described above represent examples of the wide spectrum of research activities that can be pursued at the Bern facility. Several other fields can be addressed, such as the study of materials by PIXE and PIGE ion-beam analysis, irradiation of biological samples, and investigation of the radiation hardness of scientific instrumentation.

The organisation of a facility of this kind naturally triggers national and international collaborations. The 12th workshop of the European Cyclotron Network (CYCLEUR) will take place in Bern on 23–24 June 2016, to bring together international experts. Last but not least, students and young researchers can profit from unique training opportunities in a stimulating, multidisciplinary environment, to move towards further advances in the application of particle-physics technologies.

For further reading, visit arxiv.org/abs/1601.06820.

Résumé
Faire de la recherche avec un cyclotron PET médical

Au-delà de la production courante de radio-isotopes pour l'imagerie médicale, les cyclotrons PET compacts peuvent être au cœur d'installations de recherche multidisciplinaires. C'est le cas du laboratoire cyclotron de Berne (BTL) conçu pour la production de radio-isotopes. Au fil des années, l'installation est devenue le principal instrument pour toute une série d'activités de recherche auxquelles participent des équipes de physiciens, de chimistes, de pharmaciens et de biologistes.

The ALICE experiment is devoted to the study of strongly interacting matter, where temperatures are sufficiently high to overcome hadronic confinement, and the effective degrees of freedom are governed by quasi-free quarks and gluons. This type of matter, known as quark–gluon plasma (QGP), has been produced in collisions of lead ions at the LHC since 2010. The detectors of the ALICE central barrel aim to provide a complete reconstruction of the final state of Pb–Pb collisions, including charged-particle tracking and particle identification (PID). The latter is done by measuring the specific ionisation energy loss, dE/dx.

The main tracking and PID device is the ALICE time projection chamber (TPC), with an active volume of almost 90 m³, the ALICE TPC is the largest detector of its type ever built. During the LHC's Runs 1 and 2, the TPC reached or even exceeded its design specifications in terms of track reconstruction, momentum resolution and PID capabilities. ALICE is planning a substantial detector upgrade during the LHC's second long shutdown, including a new inner tracking system and an upgrade of the TPC. This upgrade will allow the experiment to overcome the TPC's essential limitation, which is the intrinsic dead time imposed by an active ion-gating scheme. In essence, the event rate with the upgraded TPC in LHC Run 3 will exceed the present one by a factor of 100.

The rate limitation of the current ALICE TPC arises from the use of a so-called gating grid (GG) – a plane of wires installed in the MWPC-based read-out chambers. The GG is switched by an external pulser system from opaque to transparent mode and back. In the presence of an event trigger, the GG opens for a time window of about 10 μs, which allows all ionisation electrons from the drift volume to enter the amplification region. On the other hand, slow-moving ions produced in the avalanche process head back into the drift volume. Therefore, after each event, the GG has to stay closed for 300–500 μs to keep the drift volume free of large space-charge accumulations, which would create massive drift-field distortions.

This leads to an intrinsic read-out rate limitation of a few kHz for the current TPC. However, it should be noted that the read-out rate in Pb–Pb collisions is currently limited by the bandwidth of the TPC read-out electronics to a few hundred Hz.

In Run 3, the LHC is expected to deliver Pb–Pb collision rates of about 50 kHz, implying average pile-up of about five collision events within the drift time window of the TPC. Moreover, many of the key physics observables are on low-transverse-momentum scales, implying small signal-over-background ratios, which make conventional triggering schemes inappropriate. Hence, the upgrade of the TPC aims at a triggerless, continuous read-out of all collision events. Operating the TPC in such a video-like mode makes it necessary to exchange the present MWPC-based read-out chambers for a different technology, which eliminates the necessity of active ion gating, also including complete replacement of the front-end electronics and read-out system.
The main challenge for the new read-out chambers is the requirement of large opacity for back-drifting ions, combined with high efficiency to collect ionisation electrons from the drift volume into the amplification region, to maintain the necessary energy resolution. To allow for continuous operation without gating, both requirements must be fulfilled at the same potential setting. In an extensive R&D effort, conducted in close co-operation with CERN’s RD51 collaboration, it was demonstrated that these specific requirements can be reached in an amplification scheme that employs four layers of gas electron multiplier (GEM) foils, a technology that was put forward by Fabio Sauli and collaborators in the 1990s.

After approval of the Technical Design Report by the LHC Experiments Committee, and an in-depth Engineering Design Review of the new read-out chambers in 2015, the TPC upgrade project is presently in its pre-production phase, aiming to start mass production this summer.

Accurate knowledge of the interaction probability of neutrons with nuclei is a key parameter in many fields of research. At CERN, pulsed bunches from the Proton Synchrotron (PS) hit the spallation target and produce beams of neutrons with unique characteristics. This allows scientists to perform high-resolution measurements, particularly on radioactive samples.

The story of the n_TOF facility goes back to 1998, when Carlo Rabино (CERN Courier October 2014 p40) and colleagues proposed the idea of building a neutron facility to measure neutron-reaction data needed for the development of an energy amplifier. The facility eventually became fully operational in 2001 (CERN Courier July/August 2001 p7), with a scientific programme covering neutron-induced reactions relevant for nuclear astrophysics, nuclear technology and basic nuclear science. During the first major upgrade of the facility in 2009, the old spallation target was removed and replaced by a new target with an optimised design, which included a decoupled cooling and moderation circuit that allowed the use of borated water to reduce the background due to in-beam hydrogen-capture γ-rays. A second improvement was the construction of a long-awaited “class-A” workplace, which made it possible to use unsealed radioactive isotopes in the first experimental area (EAR1) at 200 m from the spallation target. In 2014, n_TOF was completed with the construction of a second, vertical beamline and a new experimental area – EAR2.

One of the most striking features of neutron–nucleus interactions is the resonance structures observed in the reaction cross-sections at low-incident neutron energies. Because the electrically neutral neutron has no Coulomb barrier to overcome, and has a negligible interaction with the electrons in matter, it can directly penetrate and interact with the atomic nucleus, even at very low kinetic energies in the order of electron-volts. The cross-sections can show variations of several orders of magnitude on an energy scale of only a few eV. The origin of these resonances is related to the excitation of nuclear states in the compound nuclear system formed by the neutron and the target nucleus, at excitation energies lying above the neutron binding energy of typically several MeV. In figure 1, the main cross-sections for a typical heavy nucleus as a function of energy are shown as a function of energy. The position and extent of the resonances is related to the concept of nuclear states in the compound nuclear system formed by the neutron and the target nucleus, at excitation energies lying above the neutron binding energy of typically several MeV. In figure 1, the main cross-sections for a typical heavy nucleus are shown as a function of energy. The position and extent of the resonances depend on the nucleus. Also shown on the same energy scale are Maxwellian neutron energy distributions for fully moderated neutrons by water at room temperature, for fission neutrons, and for typical neutron spectra in the region from...
The high neutron energies are directly related to the 20 GeV/c time is measured in the EAR1 and EAR2 experimental areas. Related to their time-of-flight: the start time is given by the impact of the proton beam on the spallation target and the arrival, related to the n_TOF facility. The kinetic energy of the particles is directly proportional to the neutron binding energy of nuclei. Insight into the properties of these levels brings crucial input to nuclear-level density models. Finally, neutron-induced reaction cross-sections are a key ingredient in applications of nuclear technology, including future developments in medical applications and transmutation of nuclear waste, accelerator-driven systems and nuclear-fuel cycle investigations.

The wide neutron energy range is one of the key features of the n_TOF facility. The kinetic energy of the particles is directly related to their time-of-flight: the start time is given by the impact of the proton beam on the spallation target and the arrival time is measured in the EAR1 and EAR2 experimental areas. The high neutron energies are directly related to the 20 GeV/c proton-induced spallation reactions in the lead target. Neutrons are subsequently partially moderated to cover the full energy range. Energies as low as about 10 MeV corresponding to long times of flight can be exploited and measured at n_TOF because of its pulsed bunches spaced by multiples of 1.2 s, sent by the PS. This allows long times of flight to be measured without any overlap into the next neutron cycle.

Higher flux
Another unique characteristic of n_TOF is the very high number of neutrons per proton burst, also called instantaneous neutron flux. In the case of research with radioactive samples irradiated with the neutron beam, the flux results in a very favourable ratio between the number of signals due to neutron-induced reactions and those due to radioactive decay events, which contribute to the background. While the long flight path of EAR1 (200 m from the spallation target) results in a very high kinetic-energy resolution, the short flight path of EAR2 (20 m from the target) has a neutron flux that is higher than that of EAR1 by a factor of about 25. The neutron fluxes in EAR1 and EAR2 are shown in figure 2. The higher flux opens the possibility for measurements on nuclei with very low mass or low reaction cross-sections within a reasonable time. The shorter flight distance of about a factor 10 also ensures that the entire neutron energy region is measured in a 10 times shorter interval. For measurements of neutron-induced cross-sections on radioactive nuclei, this means 10 times less acquired detector signals due to radioactivity. Therefore the combination of the higher flux and the shorter time interval results in an increase of the signal-to-noise ratio of a factor 250 for radioactive samples. This characteristic of EAR2 was, for example, used in the first cross-section measurement in 2014, when the fission cross-section of the highly radioactive isotope 239Pu was successfully measured. An earlier attempt of this measurement in EAR1 was not conclusive. An example from 2015 is the measurement of the (n,α) cross-section of the also highly radioactive isotope 238Pu, relevant for the cosmological Li problem in Big Bang nucleosynthesis.

The most important neutron-induced reactions that are measured at n_TOF are neutron-capture and neutron-fission reactions. Several detectors have been developed for this purpose. A 4×4 calorimeter consisting of 40 BaF2 crystals has been in use for capture measurements since 2004. Several types of C6D6-based liquid-scintillator detectors are also used for measurements of capture γ-rays. Different detectors have been developed for charged particles. For fission measurements, ionisation chambers, parallel-plate avalanche counters and the fusion-fragment spectrometer STEPP have been operational. MicroMegas-based detectors have been used for fission and (n,α) measurements. Silicon detectors for measuring (n,α) and (n,p) reactions have been developed and used more recently, even for in-beam measurements.

The measurements at CERN’s neutron time-of-flight facility n_TOF, with its unique features, contribute substantially to our knowledge of neutron-induced reactions. This goes together with cutting-edge developments in detector technology and analysis techniques, the design of challenging experiments, and training a new generation of physicists working in neutron physics. This work has been actively supported since the beginning of n_TOF by the European Framework Programmes. A future development currently being studied is a possible upgrade of the spallation target, to optimise the characteristics of the neutron beam in EAR2. The n_TOF collaboration, consisting of about 150 researchers from 40 institutes, looks forward to another year of experiments from its scientific programme in both EAR1 and EAR2, continuing its 15-year history of measuring high-quality neutron-induced reaction data.

For further reading, see CERN-Proceedings-2015-001, p323.
ICTR-PHE 2016: the winning alliance

Where do physicists, experts in particle accelerators, engineers and computer scientists brainstorm with medical doctors, biologists, radiochemists and specialists in nuclear medicine? In one of the numerous sessions of ICTR-PHE. The 3rd biennial conference, held in Geneva from 15 to 19 February, was again a unique place where multidisciplinary scientists met to share knowledge and bridge gaps between the various disciplines involved in translational research, to boost advances in biophysics and to enhance the quality of transfer into clinical practice. As the motto of the conference says, the primary scope of the event is to “go from lab-to-bed” as efficiently as possible.

The conference went into full swing immediately after the opening addresses, with sessions on radiobiology and nuclear medicine. Michael Lassmann, of the University of Wurzburg (Germany), gave an overview of “theranostics,” a word coined in 2009 to describe the use of imaging for therapy planning in radiation oncology. Today, it is used in nuclear medicine to refer to the use of short-lived tracers for predicting the absorbed doses in molecular radiotherapy and, therefore, helping to evaluate the safety and efficacy of a treatment. New radiopharmaceuticals are becoming increasingly available for imaging and molecular radiotherapy, but the challenge of establishing reliable dose-response relationships remains.

In the radiobiology session, Michael Story, of the University of Texas Southwestern Medical Center, discussed novel potential biomarkers, while Ahmed Mansoor, of the US National Cancer Institute, confirmed the importance of immunology in radiation biology; new clinical trials have recently shown that when these are combined, it is possible to obtain a higher survival rate with respect to just immunotherapy.

Detectors and imaging are key factors in the fight against cancer. Thomas Bortfeld, of Massachusetts General Hospital and Harvard Medical School, discussed an issue that is critical for hadron-therapy effectiveness: beam spatial control. The biggest advantage of particle beam therapy, which is the finite range of the beam, can be a double-edged sword because the over- or under-shoot of the beam requires extra margins, but this can compromise the dose distribution and the efficacy of the therapy. That is why substantial effort is being put into developing imaging techniques for beam-range assessment. A number of possibilities are being studied, but according to Bortfeld, prompt gamma imaging appears to be the most promising, currently. It is based on the detection of secondary gamma radiation emitted from nuclear reactions of protons with tissue. It would allow detecting the position of the beam in the body of the patient with an accuracy of about 1 mm, in real time, during treatment. With such precision, the range margins could be reduced, resulting in significant improvements in treatment quality. The development and clinical use of a prompt gamma camera was presented in detail by Christian Richter of Oncoray, Dresden.

Fast-emerging concept
Radiomics is a term that refers to the extraction of quantitative imaging features (multimodality imaging) to effectively define tumour phenotypes. At the conference it appeared clear that this is a fast-emerging concept, because many speakers, covering topics as broad as liquid biopsy analysis and personalised medicine, referred to this concept. In particular, Klaus Maier-Hein, of the University of Heidelberg, showed a novel method to anticipate the development and progression of tumours — still a work in progress but already very promising. Big data used in the framework of the fight against cancer was, for the first time, given prominence at this 3rd edition of the conference. Philippe Lambin, of the University Medical Centre of Maastricht, presented the idea of “radial learning” — that is, the use of data routinely generated through patient care and clinical research that feed an ever-growing database. Thanks to this database, Lambin hopes to be able to develop mathematical models — following the example of weather models — capable of “predicting the future”. Indeed, as Klaus Maier-Hein showed earlier, simulation models really are a promising way to greatly improve cancer treatment and research.

To achieve this, computing scientists need huge amounts of data — data they are eager to collect worldwide through programmes such as the Euroradiological Computer Assisted Theranostics project (EuroCAT).

In his lecture supported by the European Society for Therapeutic Radiology and Oncology (ESTRO), Eric Deutsch, of the Gustave Roussy Cancer Campus Grand Paris, gave an overview of some new concepts leading to a new understanding of the biological response to radiotherapy. Personalised medicine is the “holy grail” of today’s doctors. In his GHF award lecture, Søren Bentzen, of the University of Maryland, discussed the need to combine precise medicine with multimodality treatment (surgery, radiotherapy, chemotherapy) in order to tailor therapy to the patient. The award is testimony to Bentzen’s lifelong dedication to this field.

About 440 scientists from a variety of fields gathered in Geneva for the 2016 edition of the ICTR-PHE multidisciplinary conference.
The conference was also an opportunity for the 440 participants to gain an exhaustive overview of the current hadrontherapy centres across the world. The US situation was presented by James Cox, of the MD Anderson Cancer Centre in Texas. In the US, there are 17 particle therapy centres across the world. Cox, of the MD Anderson Cancer Centre in Texas, highlighted that today, 30 African and Asian countries still do not have access to interventions to prevent and treat cancer and its symptoms, and there is still a shortfall of 5000 radiotherapy machines in the developing world. The mission of the ICEC is to implement a global force to address this problem through a mentoring network of cancer professionals who work with local and regional in-country groups to develop and sustain expertise for better cancer care.

In addition to senior and prestigious speakers, ICTRP-H/E also featured the work of younger researchers. More than 100 presented their latest research in posters that arrived carefully rolled up in their bags. Pinned one-by-one on the main conference hall panels, the posters raised a great deal of interest and triggered many discussions throughout the week.

The presentation of the six winning posters on the last afternoon was a highlight of the conference. The special session, presented by the conference chairs, CERN’s Manjit Dousah and Jacques Bernier of Clinique de Genolier, awarded

Emanuele Scioli (EHEC Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany); Mattia Donzelli (European Synchrotron Radiation Facility of Grenoble, France); Grischa Klimpnik (Paul Scherrer Institute, Switzerland); Karol Brzzerzinski (Université de Valenciennes, Spain, and University of Groningen, the Netherlands); Pankaj Chaudhary (University of Bufiast, UK); and Brent Huismann (Université de Lyon, France).

In line with its goal of merging different approaches and disciplines, the public talk proposed by ICTRP-H/E introduced a novel methodology that uses sound to improve our knowledge and understanding of human motor control. Domenico Vicinianza, of the Department of Computing and Technology, Anglia Ruskin University and GÉANT, Cambridge, UK, and Genevieve Williams, of the Department of Life Sciences, Anglia Ruskin University, Cambridge, UK, presented their novel studies on sonification, and showed the incredibly strong link that exists between music and the life sciences: both are dependent on the idea of cycles, periodicity, fluctuations, transitions and, in a fascinating sense, harmony.

**Regional Events**

**Conferences for Undergraduate Women in Physics confirm their success**

More than 1200 young women from colleges across the US came together in January to learn about careers, graduate school and research opportunities in a range of fields associated with physics. The participants attended one of nine regional events, held on 15–17 January, under the aegis of the American Physical Society and dubbed the Conferences for Undergraduate Women in Physics (CUWiP).

The first CUWiP conference was held in 2006 at the University of Southern California. Interest in the event took root and it has grown every year since. The 2016 CUWiP events were held at Black Hills State University, Georgia Institute of Technology, Ohio State University, ODU/ Jefferson Lab, Oregon State University, Syracuse University, University of California (San Diego), University of Texas (San Antonio) and Wesleyan University.

In the US mid-Atlantic region, Old Dominion University (Norfolk) and the Department of Energy’s Jefferson Lab (Newport News, Virginia) co-hosted one of the geographically separated conferences.

**ICHEP 2016**

ICHEP 2016 is the 28th International Conference for High Energy Physics, the primary purpose of the conference is to review the status of the field of neutrino physics, the impact of neutrino physics on astronomy and cosmology, and the vision for future development of these fields.

**NEUTRINO 2016**

NEUTRINO 2016 is a conference to review the latest theoretical and experimental results in heavy-flavour physics.

**IOP Conferences**

IOP Conferences is part of IOP Publishing, a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.

IOP Publishing is a not-for-profit foundation.
Synchrotrons

New Technology for Synchrotrons

SiPM / MPPC®
the ultimate detector

Make every photon count
You might know it as SiPM or Silicon Photomultiplier, but at Hamamatsu we know it as “MPPC®” (Multi-Pixel-Photon-Counter), the ultimate in detection efficiency.
MPPCs deliver superior high photon detection efficiency, low afterpulses, low cross talk and low dark count characteristics. We offer the world’s most diverse product line-up, package types and the latest technology such as TSV, all available in mass production.

We know that choice and flexibility is key; you can select one of our standard high-sensitivity optical sensors, package type and electronics, or we can develop customised solutions to meet your requirements.

If you are looking for the ultimate low-light detector and you want to make every photon count, then look to Hamamatsu.

www.hamamatsu.com

Hi-tech

The Asian Committee for Future Accelerators (ACFA) and the 7th International Particle Accelerator Conference (IPAC’16) have named the winners of the ACFA/IPAC’16 Accelerator Prizes for outstanding and original contributions to the field. The recipients, selected by the ACFA/IPAC’16 Accelerator Prizes Committee, under the chairmanship of Shin-ichi Kurokawa, COSYLAB and KEK, will receive their awards at the IPAC’16 conference in Busan on 8–13 May.

Derek Lowenstein of Brookhaven National Laboratory (BNL) receives the Xie Jialin Prize for outstanding work in the accelerator field, with no age limit. In particular, he led the construction of the Alternating Gradient Synchrontron (AGS) Booster, which culminated in a world-record proton intensity in the AGS. He continued his leadership in overseeing the commissioning, operation and upgrades of BNL’s Relativistic Heavy-Ion Collider (RHIC), the world’s first heavy-ion and polarised-proton collider. He was also instrumental in the establishment, at the AGS Booster, of the NASA Space Radiation Laboratory – a facility dedicated to the study of radiobiological effects important to human space flight to Mars or other planetary missions.

The Nishikawa Tetsuji Prize for a recent, significant, original contribution to the accelerator field, no age limit, is awarded to Gwo-Huei Luo, of the National Synchrotron Radiation Research Center (NSSRC). He receives the prize in particular for his leading role in the management, construction and commissioning of the Taiwan Photon Source (TPS), which has exceeded its design goal as one of the world’s brightest light sources. His dedication, broad expertise and leadership contributed in a critical way to the success of the TPS, which had to satisfy a number of challenges including the use of superconducting cavities for high current and high RF power.

Last, the Hogil Kim Prize for a recent, significant, original contribution to accelerator technology, especially to the development of Nb$_3$Sn-filmed superconducting RF cavities. His achievements include developing a process for producing a special Nb$_3$Sn film on niobium and demonstration of its excellent performance in terms of the critical field and Q factor, which are expected to outperform traditional niobium cavities.

For more about IPAC’16, see www.ipac16.org/.

Accelerator prize winners, from left to right, Derek Lowenstein, Gwo-Huei Luo and Sam Posen.

Gianpaolo Bellini receives the 2016 Pontecorvo Award

Gianpaolo Bellini has been awarded the prestigious 2016 Bruno Pontecorvo Prize by the Joint Institute for Nuclear Research (JINR). Bellini is honoured for his “outstanding contributions to the development of low-energy neutrino-detection methods, their realisation in the Borexino detector, and the important solar and geo-neutrino results obtained in this experiment”.

Emeritus scientist of the Italian National Institute of Nuclear Physics (INFN) and full professor (now retired) at the University of Milan (Italy), Bellini is an experimental physicist in the fields of elementary-particle and astroparticle physics.

In the various experiments that he has carried out at major international laboratories, Bellini has achieved many important scientific results, including breakthroughs such as the first measure of the lifetime of a particle with charm by an exponential method, performed at CERN (the FRAMM experiment, in collaboration with an INFN Pisa group). Since 1990, Bellini has designed, installed and managed the Borexino experiment (in the Gran Sasso Laboratory, Italy) as spokesman, for more than 20 years.

Over recent years, the Borexino collaboration has published many important results, including the first measurement of the total solar energy via neutrinos and of the neutrino fluxes produced by the various nuclear reactions in the Sun; the first measurement of the neutrino oscillation in a vacuum; and evidence of geo-neutrinos with more than 99.9999999% probability.

Currently, Borexino is working to obtain the first measurement of the important CNO cycle, and probe short-range (10 m) neutrino oscillations with an artificial neutrino source.
OBITUARIES

Alice-Anne Martin 1926–2016

A beloved teacher and influential scholar, Alice-Anne Martin passed away on 23 January in her 88th year, after a severe and long illness. Shirkov was an academician of the Russian Academy of Sciences and a world-renowned theoretical physicist. He was a highly regarded member of The World Academy of Sciences, Academia Europaea, as well as of the Science Academy in Turkey and the Swiss Confederation, prepared the “Yellow Reports” that have marked key points in the laboratory’s history. For example, using a special typewriter with two keyboards – Latin and Greek – she typed the Yellow Report on the KAM and represented the country at high levels in international committees, namely at ICTP. In Turkey, he started his career as a scientist, and held academic positions at the Lawrence Berkeley Laboratory, and his PhD from the Institute of Theoretical Physics at the University of California, Berkeley. In 1972, he held academic positions at the Lawrence Berkeley Laboratory, SLAC, CERN and ICTP in Italy, where he was a faculty member at the University of California. He also worked with Felix Bloch, the father of quantum mechanics, and developed the first CERN librarian. She was head of the team that edited the proceedings of the 1956, 1958 and 1959 international conferences in Geneva. In addition to a very rich professional life, Schu enjoyed representing CERN in skiing competitions organised by various international organisations, including the International Ski Federation, the French and Italian Ski Associations, and at the same time he devoted herself to her children and family life. However, she kept in contact with CERN, in particular through the CERN Women’s Club, founded by Jenny Van Hove. All who knew her say she was a wonderful person.

And Martin.

Namik Kemal Pak 1949–2015

A beloved teacher and influential scholar, Namık Kemal Pak passed away on 10 November in Ankara. He was one of Turkey’s leading theoretical particle physicists. Born in 1949 in Samsun, Turkey, Namik Kemal Pak earned his BSc in physics from Ankara University, and his PhD from the University of California, Berkeley. In 1972, he held academic positions at the Lawrence Berkeley Laboratory, SLAC, CERN and ICTP in Italy, where he was a faculty member at the University of California. He also worked with Felix Bloch, the father of quantum mechanics, and developed the first CERN librarian. She was head of the team that edited the proceedings of the 1956, 1958 and 1959 international conferences in Geneva. In addition to a very rich professional life, Schu enjoyed representing CERN in skiing competitions organised by various international organisations, including the International Ski Federation, the French and Italian Ski Associations, and at the same time he devoted herself to her children and family life. However, she kept in contact with CERN, in particular through the CERN Women’s Club, founded by Jenny Van Hove. All who knew her say she was a wonderful person.

Namik Kemal Pak was always interested in science, technology and innovation policies. He edited several books and reports. He also had a lifelong interest in philosophy and the history of science, and reached several generations with his popular science articles and talks. The scientific community of Turkey is deeply saddened by the loss of Namik Kemal Pak. He will be remembered by his students and colleagues as a brilliant theoretical physicist, inspiring teacher, speaker, adviser, science policy maker and, without doubt, a scientist who shaped the scientific culture and the science and technology policy in Turkey. He will also be remembered for his excellent outreach talks to raise the public awareness of science. We will miss him greatly.

Seckin Karakocoglu, Iznal Turan and Mehmet Zeyrek, METU/Ankara.

Dmitry Vasilievich Shirkov 1928–2016

Dmitry Vasilievich Shirkov passed away on 23 January in his 88th year, after a severe and long illness. Shirkov was an academician of the Russian Academy of Sciences and a world-renowned theoretical physicist. He was a highly regarded member of The World Academy of Sciences, Academia Europaea, as well as of the Science Academy in Turkey and the Swiss Confederation, prepared the “Yellow Reports” that have marked key points in the laboratory’s history. For example, using a special typewriter with two keyboards – Latin and Greek – she typed the Yellow Report on the KAM and represented the country at high levels in international committees, namely at ICTP. In Turkey, he started his career as a scientist, and held academic positions at the Lawrence Berkeley Laboratory, and his PhD from the Institute of Theoretical Physics at the University of California, Berkeley. In 1972, he held academic positions at the Lawrence Berkeley Laboratory, SLAC, CERN and ICTP in Italy, where he was a faculty member at the University of California. He also worked with Felix Bloch, the father of quantum mechanics, and developed the first CERN librarian. She was head of the team that edited the proceedings of the 1956, 1958 and 1959 international conferences in Geneva. In addition to a very rich professional life, Schu enjoyed representing CERN in skiing competitions organised by various international organisations, including the International Ski Federation, the French and Italian Ski Associations, and at the same time he devoted herself to her children and family life. However, she kept in contact with CERN, in particular through the CERN Women’s Club, founded by Jenny Van Hove. All who knew her say she was a wonderful person.

And Martin.

Namik Kemal Pak was always interested in science, technology and innovation policies. He edited several books and reports. He also had a lifelong interest in philosophy and the history of science, and reached several generations with his popular science articles and talks. The scientific community of Turkey is deeply saddened by the loss of Namik Kemal Pak. He will be remembered by his students and colleagues as a brilliant theoretical physicist, inspiring teacher, speaker, adviser, science policy maker and, without doubt, a scientist who shaped the scientific culture and the science and technology policy in Turkey. He will also be remembered for his excellent outreach talks to raise the public awareness of science. We will miss him greatly.

Seckin Karakocoglu, Iznal Turan and Mehmet Zeyrek, METU/Ankara.

Dmitry Vasilievich Shirkov.

Dmitry Vasilievich Shirkov, which Shirkov wrote together with N N Bogoliubov and V V Tolmachev. Shirkov achieved many fundamental results in various fields of theoretical physics. He elaborated methods to solve the kinetic equation describing the processes of neutron diffusion and moderation – of great importance in the theory of nuclear reactors. In quantum field theory, he developed the renormalisation group method, which remains one of his most significant achievements. Shirkov also made a significant contribution to developing the theory of the scattering matrix, and to developing a rigorous formulation of the method of renormalisation of ultraviolet divergences. These results were included in the book Introduction to the Theory of Quantized Fields, co-authored with N N Bogoliubov. The book is a classic of theoretical physics and is distributed in numerous countries. In his second book, Dispersion Theories of Strong Interactions at Low Energies, co-authored with V A Meshcheryakov and V V Serebrov, Shirkov developed a new method to describe the low-energy scattering of strongly interacting particles. The application of quantum field theory methods to the theory of superconductivity was published in the book A New Method in the Superconductivity Theory, which Shirkov wrote together with N N Bogoliubov and V V Tolmachev.

Shirkov initiated the development of analytical calculation systems on computers at JINR. Studies in this direction led to the world-famous results obtained by Dubna theoreticians in calculations of higher orders in perturbation theory in chomodynamics and supersymmetry theories.

Shirkov was fairly devoted to science and had a rare sense of purpose and commitment. He demanded a lot from himself and his colleagues at the laboratory, and at the same time he remained a kind and thoughtful person. His passing is an irreparable loss to the world of science.

JINR.
Recruitment

For advertisers’ enquiries, contact CERN Courier recruitment/classifieds, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
Tel: +44 (0)117 930 1266 Fax: +44 (0)117 930 1178 E-mail: sales@cerncourier.com
Please contact us for information about rates, colour options, publication dates and deadlines.

University of HUDDERSFIELD
Inspiring tomorrow’s professionals

Get your hands on the problem solvers of tomorrow, today.

The White Rose Industrial Physics Academy is seeking industrial projects for groups of 3rd and 4th year undergraduate physics students.

Course Length: 1 year full time
This course covers the fundamental techniques and tools of accelerator science, equipping you for a successful career in working with accelerators.

Entry requirements: A good Bachelor’s degree in physics or a similar subject, such as mathematics or engineering.

For more information:
Website: https://www.hud.ac.uk/courses/full-time/postgraduate/accelerator-science-msc/ Contact: compeng@hud.ac.uk

Accelerator Science MSc
Course length: 1 year full-time
This course covers the fundamental techniques and tools of accelerator science, equipping you for a successful career in working with accelerators.

Course Structure: 6 project based modules + laboratory module + research project
Entry requirements: A good Bachelor’s degree in physics or a similar subject, such as mathematics or engineering.

For more information:
Website: https://www.cie.org.uk/makeyourmark
To apply, please visit the Cambridge website at www.eli-np.ro/jobs.php

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

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

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

The Epistemology of the Large Hadron Collider (LHC)

This research unit investigates a variety of themes concerning the experimental and theoretical research at the Large Hadron Collider (LHC) from an interdisciplinary perspective. It involves problems and methods from philosophy, history and science studies:

A1: The formation and development of the concept of virtual particles;
A2: Hierarchy, fine tuning and naturalness from a philosophical perspective;
A3: LHC and gravity;
B1: The impact of computer simulations on the epistemic status of LHC Data;
B2: Model building and dynamics;
B3: Producing novelty and securing credibility.

The Principal Investigators of each project come from both physics and the respective other discipline.

The positions are initially for three years. After a successful evaluation of the research unit, the postdoctoral positions may be extended for another three years. Depending on the project the positions will be hosted by the TU Bilk, the RWTH Aachen University; the Karlsruhe Institute for Technology, the Alpen-Adria-Universität Klagenfurt in Vienna, or the Bergische Universität Wuppertal. The positions will be filled around June 1, 2016. Deadline for applications: April 15, 2016.

More detailed descriptions of the individual projects, the job requirements, salaries and benefits can be found under http://www.lhc-epistemologie.uni-wuppertal.de.

Applications should be sent electronically to lhc.epistemologie@uni-wuppertal.de. They should include a letter of motivation, a ranked indication of the projects applied for, a cv, a list of publications, copies of diploma, and the name and addresses of referees. For predoctoral positions we expect at least one, for postdoctoral positions at least two references.

Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

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

- A very high intensity laser beams from two 10 PW lasers;
- A very intense, brilliant γ beam, very low bandwidth, with Eγ > 19 MeV, which is obtained by incoherent Compton back scattering of a laser light off an intense electron beam (Ee > 7000 MeV) produced by a warm linac.

The White Rose Industrial Physics Academy (WRIPA) is a HEFCE funded initiative to increase the interaction between undergraduate physics students and UK Technical Industry. WRIPA is coordinated by the Universities of York and Sheffield and is focused on increasing the flow of relevantly trained graduates into technical careers.

This call for projects is associated with modules running across the WRIPA universities. Project start dates will be October 2016 and run until May 2017. Successful projects will be allocated to the most appropriate University based on access to relevant academic expertise and specialist equipment.

For recent case studies see www.wripa.ac.uk
To discuss an idea please email: info@wripa.ac.uk

Become a Physics examiner with Cambridge

Cambridge International Examinations is growing and over 10 000 schools in more than 160 countries are now part of the Cambridge learning community.

To support our continued growth worldwide, we are expanding our examiner network, and inviting teachers to develop their professional practice by becoming Cambridge examiners.

We are welcoming new examiners across the Cambridge curriculum but are in particular need of examiners for Cambridge International AS and A Level Physics.

We offer:
- a powerful insight into the teaching and assessment of Cambridge qualifications
- support in developing your own professional practice
- the highest standards of training and support and competitive rates
- freelance opportunities, based on contracts for services for each examination series, which fit around your existing commitments

To apply, please visit the Cambridge website at www.cie.org.uk/makeyourmark

The White Rose Industrial Physics Academy (WRIPA) is a

HLF funded initiative to increase the interaction between undergraduate physics students and UK Technical Industry. WRIPA is coordinated by the Universities of York and Sheffield and is focused on increasing the flow of relevantly trained graduates into technical careers.

This call for projects is associated with modules running across the WRIPA universities. Project start dates will be October 2016 and run until May 2017. Successful projects will be allocated to the most appropriate University based on access to relevant academic expertise and specialist equipment.

For recent case studies see www.wripa.ac.uk
To discuss an idea please email: info@wripa.ac.uk

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

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

- A very high intensity laser beams from two 10 PW lasers;
- A very intense, brilliant γ beam, very low bandwidth, with Eγ > 19 MeV, which is obtained by incoherent Compton back scanning of a laser light off an intense electron beam (Ee > 7000 MeV) produced by a warm linac.

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

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

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

Open access (OA) publishing is proving to be a very successful publishing model in the scholarly scientific field today, more than 10,000 journals are accessible in OA, according to the Directory of Open Access Journals. Building on this positive experience, ebooks are also becoming available under this free-access scheme.

The economic model is largely inspired by the well-established practice in scientific article publishing, and several publishers have expanded their catalogues to include OA books. Under an appropriate licensing system, the authors retain copyright but the content can be freely shared and reused with appropriate author credit.

The ebooks system, in addition to expanding the diffusion of knowledge, overcomes the production and distribution costs of paper books that result in high prices for titles often acquired only by libraries. OA ebooks are also the ideal outlet for the publication of conference proceedings, maximising their visibility, and with great benefits for library budgets.

Five key works written or edited by CERN authors are already profiting from this impact that comes from their free dissemination.

Three of them are already accessible online:

- 50 Years of CERN Experiments and Discoveries by Herwig Schopper and Luigi De Lella (eds), published by World Scientific (dx.doi.org/10.1142/9781118322402).
- The High Luminosity Large Hadron Collider: The New Machine for Illuminating the Mysteries of Universe by Lucio Rossi and Oliver Brittin (eds), published by World Scientific (dx.doi.org/10.1142/9789814656973).

Two further OA titles will appear in 2016:

- The Standard Theory of Particle Physics: 60 Years of CERN by Luciano Maiani and Luigi Rolando (eds), published by World Scientific.
- Technology Meets Research: 60 Years of Technological Achievements at CERN, Illustrated with Selected Highlights by Chris Fabjan, Thomas Taylor and Horst Wenninger (eds), published by World Scientific.

Members of the organising committee of a conference, looking for an OA outlet for the proceedings, and authors who are planning to publish a book, are invited to contact the CERN Library, so that the staff there can help them to negotiate conditions with potential publishers.

Today, their dream is to become scientists. Tomorrow, their discoveries will change the world.

Help the students of today become the scientists of tomorrow!
unification of all forces of nature, including gravity. That coverage is the topic of this book, which aims to provide a concise and complete overview of the mathematical-physics tools that are required in the following chapters, such as Fourier analysis and Laplace transform. Ordinary differential equations, vector fields, leading naturally to the continuity equation and to the Liouville theorem. Hamiltonian systems are elegantly introduced, with mathematical pendulums as well as a LC circuit used as examples. This second chapter provides the necessary background for any engineer or physicist willing to enter the field of accelerator physics. The basic formulas and concepts of electromagnetics and special relativity are briefly recalled. The text is completed by a useful set of tables and diagrams in the appendix. An extensive set of references is given, although no non-negligible number are in German and might not be helpful for the English-speaking reader. This feature is also found in the third chapter, the longitudinal dynamics in synchrotrons is detailed. The basic equations and formulas describing synchrotron motion, bunch and bucket parameters are derived step-by-step, confirming the educational vocation of the book. The examples of a ramp and of multicavity operation are developed. I would have further developed the evolution of the RF parameters in a ramp using one of the GSI accelerators as a more concrete numerical example.

In the fourth chapter, the two most common types of RF cavities (ferrite-loaded and pillbox) are discussed in detail (in particular, the ferrite-loaded ones used in low- and medium-energy accelerators), providing detailed derivations and the basics of the various parameters and completing them with two examples referring to two specific applications.

The fifth chapter contains an interesting and thorough discussion on the theoretical description of beam manipulation in synchrotrons, with particular emphasis on the notion of adiabaticity, which is crucial for emittance preservation in operation with high brightness beams. This concept is normally dealt with in a qualitative way, while in this book a more solid background, derived from classical Hamiltonian mechanics, is provided. In the second part of the chapter, after an introduction to the description of a bunch by means of momenta, including the concept of RMS emittance, a description of longitudinal bunch oscillations and their spectrals representation is given, providing the basis for the study of longitudinal beam stability. This is not addressed in the book, and the notion of impedance is briefly introduced in the case of space charge, while some references covering these subjects are provided.

The last two chapters are devoted to the engineering aspects of RF accelerator systems: power amplifiers and closed-loop controls. The chapter on power amplifiers is mainly focused on the solutions of interest for low- and medium-energy synchrotrons, whereas high-frequency narrowband power amplifiers like klystrons are very briefly discussed. The chapter on low-level RF is rather dense but still clearly written, and is built around a specific example of an amplitune control loop. That easing the understanding of concepts and criteria underlying feedback stability and the impact of time delays and disturbances. The necessary mathematical tools are presented with a due level of detail, before delving into the stability criteria and into a discussion of the chosen example.

The volume is completed by a rich appendix summaring basic concepts and formulas required elsewhere in the book (e.g. some notions of transverse beam dynamics and the characterisation of fixed points) or working out in detail some examples of subjects treated in the main text. Some handy recalls of calculus and algebra are also provided.

This book undoubtedly fills a gap in the panorama of textbooks dedicated to accelerator physics. I would recommend it to any physicist or engineer entering the field. Enjoying reading it as a comprehensive and clear introduction to some aspects of accelerator RF engineering, as well as to some of the theoretical foundations of accelerator physics and, in general, of classical mechanics.

Gábor Tóth: CERN.
BUBBLING UP AT CERN AND SLAC

BEBC getting ready to operate

First tracks were taken in the 3.7 m Big European Bubble Chamber (BEBC) in March. A hydrogen leak that interrupted the tests was repaired quickly and operation continued up to 2.6 T. No troublesome effects appeared due to eddy currents in the metal piston that is temporarily replacing the plastic piston. BEBC has now been “warmed up” to receive the last touches before the physics programme is launched in about two months (with protons from the PS).}

Gargamelle getting ready to operate again

The heavy-liquid bubble chamber Gargamelle is being prepared for operation again. Its first task will be to supply photographs of neutrino interactions from Fermilab. Scheduled for December 1972, this had to be postponed because vibrations during expansion of the chamber led to fractures in some of the pipework of the pressure system.

The expansion system was completely dismantled during the annual PS shutdown (January and February). The trolley which carries the recompression tanks as well as the expansion tank and storage tanks was all rebuilt. The girders were reinforced and the whole structure was strengthened with struts. The trolley no longer stands on wheels but on supports set in the floor and has arms resting on the edge of the pit to prevent the assembly from moving during operation.

RCBC operating

At Stanford, the 15 inch Rapid Cycling Bubble Chamber (RCBC) is being used for physics (January and February). A beam of about 10 positive pions is being directed at the 15 inch chamber. A trigger chamber will require collecting 20 million pictures. Operation without the possibility to analyse the experiments is being prepared for operation again. Its first task will be to supply photographs of neutrino interactions from Fermilab. Scheduled for December 1972, this had to be postponed because vibrations during expansion of the chamber led to fractures in some of the pipework of the pressure system.

The expansion system was completely dismantled during the annual PS shutdown (January and February). The trolley which carries the recompression tanks as well as the expansion tank and storage tanks was all rebuilt. The girders were reinforced and the whole structure was strengthened with struts. The trolley no longer stands on wheels but on supports set in the floor and has arms resting on the edge of the pit to prevent the assembly from moving during operation.

Compiler’s Note

In the 30 years following their invention in the 1950s, more than 100 bubble chambers were built and 100 million stereo photographs were taken. Scientifi cally, among many seminal results was the discovery of the Omega-minus in the 80 inch hydrogen chamber at BNL, and the neutral weak current in Gargamelle at CERN.

Sociologically, effects were twofold. As chambers increased in size, they were housed as facilities in central laboratories and the community of users formed international collaborations. In addition, bubble-chamber photographs offered an intuitive view of subatomic interactions that aided the public understanding of particle physics.

Technically, mainframe computing capacity at host labs grew to meet the needs of bubble-chamber physics, while smaller, dedicated, online computers became an integral part of film-scanning machines.
A perfect solution to implement Logic Functions such as Coincidence, Trigger Logic, Gate and Delay Generator, Input/Output Register and more.

Features
• User Programmable FPGA
• Up to 162 inputs, up to 130 outputs
  LVDS/ECL/PECL/NIM/TTL
• 3 expansion slots for piggyback board:
  - A395A 32 LVDS/ECL/PECL input ch.
  - A395B 32 LVDS output ch.
  - A395C 32 ECL output ch.
  - A395D 8 NIM/TTL input/output ch.
  - A395E 8 Analog output 16bit ch.
• 32 independent programmable Gate and Delay Generators
• Mini-USB 2.0 Connection
• Available in Desktop version DT2495 (coming soon)
Contents

5  Viewpoint

7  News
   • The LHC is restarting   • Searches with boosted topologies at Run 2   • Anisotropic flow in Run 2   • CMS hunts for supersymmetry in uncharted territory   • LHCb awards physics prizes for its Kaggle competition   • Another important step for the AWAKE experiment   • BESIII makes first direct measurement of the Λc at threshold   • ‘First turns’ for SuperKEKB   • TPS exceeds design goal of 500 mA stored current   • DZero discovers new four-flavour particle   • Testing of DUNE tech begins

15  ScienceWatch

17  Astrowatch

18  Features
   LIGO: a strong belief
   Twenty years of hard work with a strong belief that the endeavour would lead to a historic breakthrough.

21  Science with a medical PET cyclotron
   Medical PET cyclotrons can be used for multidisciplinary research.

23  ALICE selects gas electron multipliers for its new TPC
   The experiment plans a major upgrade for its TPC.

25  Neutrons in full flight at CERN’s n_TOF facility
   The facility features two beamlines and two experimental halls.

29  Interactions & Crossroads

33  Faces & Places

36  Recruitment

39  Bookshelf

42  Archive