WELCOME

CERN Courier – digital edition

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

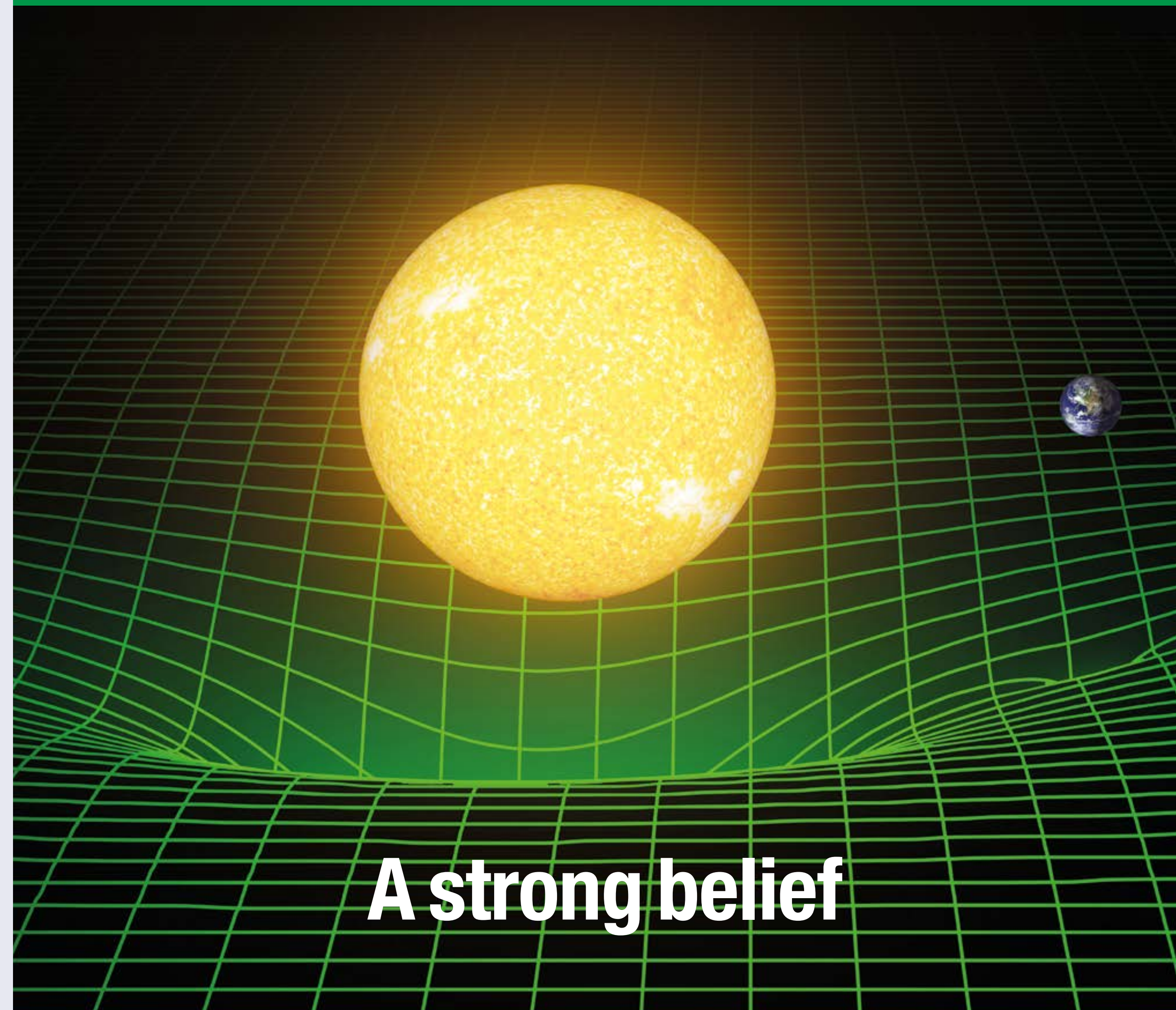
The issue went to print while the LHC resumed operation after the technical stop that started in December 2015. At the same time, in another accelerator, SuperKEKB in Japan, beams have completed their first turns. However, the spotlight these days is not so much on accelerator physics as on the discovery 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.

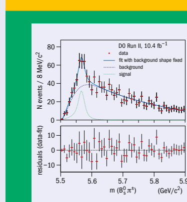
To sign up to the new issue alert, please visit:
http://cerncourier.com/cws/sign-up.

To subscribe to the magazine, the e-mail new-issue alert, please visit:
http://cerncourier.com/cws/how-to-subscribe.

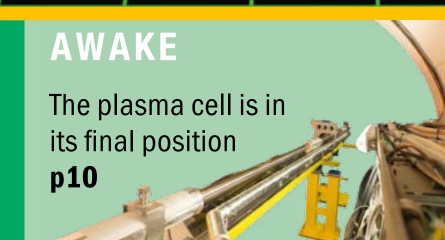
EDITOR: ANTONELLA DEL ROSSO, CERN
DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS
CERNCOURIER
VOLUME 56 NUMBER 3 APRIL 2016





TETRAQUARKS
DZero collaboration discovers a new particle
p13



AWAKE
The plasma cell is in its final position
p10

ACCELERATOR MILESTONE
Japan's SuperKEKB achieves "first turns" **p11**

Contents

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

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

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

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

Laboratory correspondents:
Argonne National Laboratory (US) Tom LeCompte
Brookhaven National Laboratory (US) P Yamin
Cornell University (US) D G Cassel
DESY Laboratory (Germany) Till Mundzeck
EMFCSC (Italy) Anna Cavallini
Enrico Fermi Centre (Italy) Guido Piragino
Fermi National Accelerator Laboratory (US) Katie Yurkewicz
Forschungszentrum Jülich (Germany) Markus Buescher
GSI Darmstadt (Germany) I Peter
IHEP, Beijing (China) Tongzhou Xu
IHEP, Serpukhov (Russia) Yu Ryabov
INFN (Italy) Antonella Varaschin
Jefferson Laboratory (US) Steven Corneliussen
JINR Dubna (Russia) B Starchenko
KEK National Laboratory (Japan) Saeko Okada
Lawrence Berkeley Laboratory (US) Spencer Klein
Los Alamos National Laboratory (US) Rajan Gupta
NCSL (US) Ken Kingery
Nikhef (Netherlands) Robert Fleischer
Novosibirsk Institute (Russia) S Eidelman
Orsay Laboratory (France) Anne-Marie Lutz
PSI Laboratory (Switzerland) P-R Kettle
Saclay Laboratory (France) Elisabeth Locci
Science and Technology Facilities Council (UK) Jane Binks
SLAC National Accelerator Laboratory (US) Farnaz Khadem
TRIUMF Laboratory (Canada) Marcello Pavan

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

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

Head of B2B & Marketing Jo Allen
Art director Andrew Giaquinto

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

General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland
E-mail: courrier-adressage@cern.ch
In certain countries, to request copies or to make address changes, contact:
China Jiang Ya'ou, Library, Institute of High Energy Physics,
PO Box 918, Beijing 100049, People's Republic of China
E-mail: jiangyo@ihep.ac.cn
Germany Antje Brandes, DESY, Notkestr. 85, 22607 Hamburg, Germany
E-mail: desypr@desy.de
UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ
E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive,
St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,
St Charles, IL 60174, US

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

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

 ISSN 0304-288X

IOP Publishing

CERNCOURIER

VOLUME 56 NUMBER 3 APRIL 2016

On the cover: Artwork showing how our Sun and Earth warp space and time. Gravitational waves are created when massive bodies accelerate through space and time. (Image credit: T Pyle/Caltech/MIT/LIGO Lab)

Viewpoint

The CERN effect

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

CERN

A student from CERN's Beamline for Schools competition explains his team's experiment to members of Council. Beamline for Schools is an important part of CERN's educational work.

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 on 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. 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: right from the 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 p5) 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.

Professor Sijbrand de Jong is President of CERN Council.

News

ACCELERATORS

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 fixing 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 will 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 2700 bunches per beam and $\beta^* = 40$ 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 and 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 1.3×10^{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.

Simon Mataguez/CERN

The wall current monitors are installed in the PS ring. Several maintenance activities were carried out in the whole CERN accelerator chain during the year-end technical stop, in preparation for the general restart.

Sommaire en français

LHC EXPERIMENTS

Searches with boosted topologies at Run 2

The first LHC run was highlighted by the discovery of the long-awaited Higgs boson at a mass of about 125 GeV, but we have no clue why nature chose this mass. Supersymmetry explains this by postulating a partner particle to each of the Standard Model (SM) fermions and bosons, but these new particles have not yet been found. A complementary approach to address this issue is to widen the net and look for signatures beyond those expected from the SM.

Searches for new physics in Run 1 found no signals, and from these negative results we know that new particles may be heavy. For this reason, their decay products, such as top quarks, electroweak gauge bosons (W, Z) or Higgs bosons, may be very energetic and could be highly boosted. When such particles are produced with large momentum and decay into quark final states, the decay products often collimate into a small region of the detector. The collimated sprays of hadrons (jets) originating from the nearby quarks are therefore not reliably distinguished. Special techniques have been developed to reconstruct such boosted particles into jets with a wide opening angle, and to identify the cores associated with the quarks using soft-particle-removal procedures (grooming). ATLAS performed an extensive optimisation of top, W, Z and Higgs boson identification, exploiting a wide range of jet clustering and grooming algorithms as well as kinematic properties of jet substructure before the second LHC run. This led to a factor of two improvement in W/Z tagging, compared with the technique used previously in terms of background rejection for the same efficiency for W/Z boson transverse momenta around 300–500 GeV.

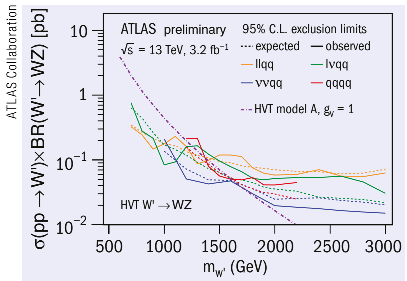


Fig. 1. Expected and observed limits on the cross-section times branching fraction to WZ for a new heavy-vector boson, W′, at $\sqrt{s}$ = 13 TeV. The different limit curves correspond to different decay modes for the W and Z bosons.

ATLAS exploited the optimised boson tagging in the search for heavy resonances decaying into a pair of two electroweak gauge bosons (WW, WZ, ZZ) or of a gauge boson and a Higgs boson (WH, ZH) at 13 TeV collisions. Events are categorised into different numbers of charged/neutral leptons, and all possible combinations are considered except for fully leptonic and fully hadronic WH or ZH decays. For the Higgs boson, only the dominant decay into b quarks is considered. Figure 1 shows the results of WZ searches with a 2015 data set corresponding to 3.2 fb^{-1}, presented as the lower limits on the production cross-section times the branching fraction for a new massive gauge boson with certain mass. No evidence for new physics has been found with these preliminary searches.

The boosted techniques have evolved into a fundamental tool for beyond SM searches at high energy. ATLAS foresees that the search will be greatly enhanced by the techniques, and seeks opportunities to adapt them in uncharted territory for the upcoming LHC run.

● Further reading

See papers and notes at https://twiki.cern.ch/twiki/bin/view/AtlasPublic/December2015-13TeV.

Anisotropic flow in Run 2

Exploiting the data collected during November 2015 with Pb–Pb collisions at the record-breaking energy of $\sqrt{s_{NN}}$ = 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 charge particles. The dominant flow coefficient, v_2, referred to as 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 flows v_2, v_3 and v_4 increase at the newly measured energy by (3.0±0.6)%, (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 $1/4\pi$, which corresponds to

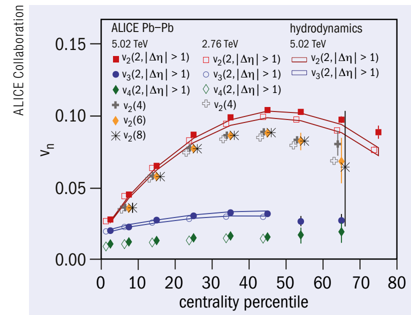


Fig. 1. Anisotropic flow, v_n, as a function of event centrality.

the lowest limits for a quantum fluid. It is observed in figure 1 that the magnitude and the increase of anisotropic flow measured at the higher energy remain compatible with hydrodynamic predictions, favouring a constant value for η/s going from $\sqrt{s_{NN}}$ = 2.76 to 5.02 TeV Pb–Pb collisions.

It is also observed that the results of the 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

J Adam *et al.* ALICE Collaboration, arXiv:1602.01119.

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 (squarks) 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, SUSY particles 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 "stransverse mass", MT2, to measure the transverse-momentum imbalance, which strongly suppresses fake contributions due to potential hadronic-jet mismeasurement. This allows us to control the background from copiously produced QCD multi-jet events. The remaining background comes from Standard Model processes such as W, Z and top-quark pair production with decays to neutrinos, which also produce a transverse-momentum imbalance. We estimate our backgrounds from orthogonal control samples in data targeted to each. To cover a wide variety of signatures, we categorise our signal events according to the number of jets, the number of jets arising from bottom quarks, the sum of the transverse momenta of hadronic jets (HT), and MT2. Some SUSY scenarios predict spectacular signatures, such as four top quarks and two LSPs, which would give large values for all of these quantities, while others with small mass splittings produce much softer signatures.

Unfortunately, we did not observe any evidence for SUSY in the 2015 data set. Instead, we are able to significantly extend the constraints on the masses of SUSY partners beyond those from the LHC Run 1. The gluino has the largest production cross-section and many potential decay modes. If the gluino decays to the LSP and a pair of quarks, we exclude gluino masses up to 1550–1750 GeV, depending on the

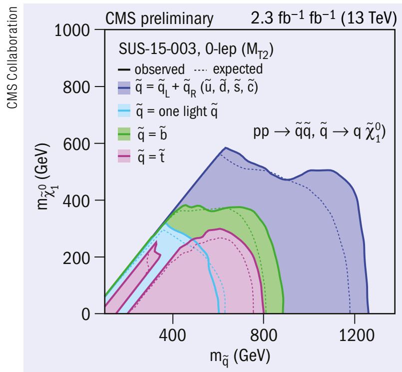


Fig. 1. Exclusion limits as a function of squark and LSP masses, for squark pair production with different flavours and mass-degeneracy scenarios.

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 600–1260 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

CERN-EP-2016-067.

LHCb awards physics prizes for its Kaggle competition

Machine learning, also known in physics circles as multivariate analysis, is used more and more in high-energy physics, most visibly 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, ▷


Marcin Chrzaszcz

LHCb Kaggle-competition participants.

$\tau \to \mu\mu\mu$. This decay is (almost) forbidden in the Standard Model, and therefore its observation would indicate a discovery of "new physics", which is now the key goal of the LHC. This Kaggle challenge (https://www.kaggle.com/c/flavours-of-physics) was conceived by a group of scientists from CERN, the University of Warwick, the University of Zürich and the Yandex School of Data Analysis. It was financially supported by the Yandex Data Factory, Intel and the University of Zürich. The competition took place over three months between July and October 2015. More than 700 people competed to achieve the best signal-versus-background discrimination and to win the prize awarded to the first three ranked solutions, totalling $15,000.

This particular challenge, using both "real" and simulated LHCb data, has been recognised by the community as more complicated than usual challenges, and therefore a refreshing problem to try and solve. The winners of the competition were awarded their prizes in December at one of the main conferences of the machine-learning community – the Twenty-ninth Annual Conference on Neural Information Processing Systems (NIPS).

In addition to the prizes for the best-ranked solutions, another prize was foreseen for the solution that is the most interesting from a physics point of view. In the event, LHCb decided to award two of these physics prizes of $2000 each to Vincens Gaitan (a former member of the ALEPH collaboration at CERN's Large Electron–Positron collider) and Alexander Rakhlin. Their solutions are innovative and particularly suitable for cases where the size of the samples used to train the multivariate operator is limited and when the training samples do not perfectly match the real data.

The two awardees collected their prize at a three-day workshop organised at the University of Zürich on 18–21 February, as a follow-up to the Kaggle challenge. This workshop brought together 55 people from the LHC and the machine-learning communities, and interesting ideas have been exchanged. The general conclusion from discussions at this event was that the exercise had been a very positive one, both for LHCb and those that entered the competition.

Further reading
https://indico.cern.ch/event/433556/.

ACCELERATION TECHNIQUES

Another important step for the AWAKE experiment

CERN

AWAKE's 10 m-long plasma cell in the experiment tunnel.

By harnessing the power of wakefields generated by a proton beam in a plasma cell, the AWAKE experiment at CERN (*CERN Courier* November 2013 p17) aims to produce accelerator gradients that are hundreds of times higher than those achieved in current machines.

The experiment is being installed in the tunnel that was previously used by the CERN Neutrinos to Gran Sasso facility. In AWAKE, a beam of 400 GeV protons from the CERN Super Proton Synchrotron will travel through a plasma cell and will generate a wakefield that, in turn, will accelerate an externally injected electron beam. A laser will ionise the gas in the cell to become a plasma and seed the self-modulation instability that will trigger the wakefield. The project aims to prove that the plasma wakefield can be driven with protons and that its acceleration will be extremely powerful – hundreds of times more powerful than that achieved today – and eventually to provide a design for a plasma-based linear collider.

The AWAKE tunnel is progressively being filled with its vital components. In its final configuration, the facility will feature a clean room for the laser, a dedicated area for the electron source and two new tunnels for two new beamlines: one small tunnel to hold the laser beam, which ionises the plasma and seeds the wakefields, and a second, larger tunnel that will be home to the electron beamline – the "witness beam" accelerated by the plasma. At the beginning of February, the plasma cell was lowered into the tunnel and moved to its position at the end of the proton line. The cell is a 10 m-long component developed by the Max Planck Institute for Physics in Munich (Germany). A first prototype successfully completed commissioning tests in CERN's North Area in the autumn of 2015. The prototype allowed the AWAKE collaboration to validate the uniformity of the plasma temperature in the cell.

AWAKE is a collaborative endeavour with institutes and organisations participating around the world. The synchronised proton, electron and laser beams provided by CERN are an integral part of the experiment. After installation of the plasma cell, the next step will be installation of the laser, the vacuum equipment and the diagnostic system for both laser and proton beams.

Beam commissioning for the proton beamline is scheduled to start this summer. The programme will continue with installation of the electron line, with the aim of starting acceleration tests at the end of 2017.

Further reading
https://cds.cern.ch/journal/CERNBulletin/2016/07/News%20Articles/2131154.

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

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

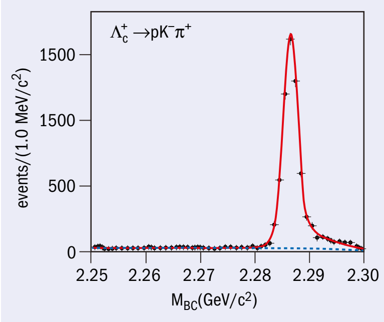
CHARM DECAYS

BESIII makes first direct measurement of the Λ_c at threshold

The charmed baryon, Λ_c, was first observed at Fermilab in 1976. Now, 40 years later, the Beijing Spectrometer (BESIII) experiment at the Beijing Electron–Positron Collider II (BEPCII) has measured the absolute branching fraction of $\Lambda_c^+ \to pK^-\pi^+$ at threshold for the first time.

Because the decays of the Λ_c^+ to hadrons proceed only through the weak interaction, their branching fractions are key probes for understanding weak interactions inside of a baryon. In particular, precise measurements of the decays of the Λ_c^+ will provide important information on the final-state strong interaction in the charm sector, thereby improving the understanding of quantum chromodynamics in the non-perturbative energy region. In addition, because most of the excited baryons of the Λ_c and Σ_c types, as well as the b-flavoured baryons, eventually decay into a Λ_c^+, studies of these baryons are directly connected to understanding the ground state, Λ_c^+.

Most decay rates of the Λ_c^+ are measured relative to the decay mode, $\Lambda_c^+ \to pK^-\pi^+$, but there are no completely model-independent measurements of the absolute branching fraction for this decay mode. Moreover, most measurements of the ground-state Λ_c^+ were made more than 20 years ago.



The figure shows the beam-constrained mass M_{BC} ($M_{BC}c^2 = \sqrt{(E^2_{beam} - p^2c^2)}$) distribution for the simple tag samples. The mass peak is at (2286.46±0.14) MeV/c^2.

In 2014, BESIII accumulated a data sample of e^+e^- annihilations with an integrated luminosity of 567 pb^{-1} at a centre-of-mass energy of 4.599 GeV. This is about 26 MeV above the mass threshold for a $\Lambda_c^+\bar{\Lambda}_c^-$, so no additional hadrons accompanying the $\Lambda_c^+\bar{\Lambda}_c^-$ are produced.

The BESIII collaboration measures hadronic branching fractions at the $\Lambda_c^+\bar{\Lambda}_c^-$ threshold using a double-tagging technique that relies on fully reconstructed $\Lambda_c^+\bar{\Lambda}_c^-$ decays. This technique obviates the need for knowledge of the luminosity or the $\Lambda_c^+\bar{\Lambda}_c^-$ production cross-section. To improve precision, BESIII combines 12 Cabibbo-favoured decay channels and implements a global least-squares fit by considering their correlations. This leads to a result for the branching fraction for $\Lambda_c^+ \to pK^-\pi^+$ of $B(\Lambda_c^+ \to pK^-\pi^+) = (5.84 \pm 0.27 \pm 0.23)\%$.

This is the first measurement of the absolute branching fraction of the decay $\Lambda_c^+ \to pK^-\pi^+$ at threshold, and it has the advantage of incorporating an optimal understanding of model uncertainty. In addition, BESIII has made significantly improved measurements of the other 11 Cabibbo-favoured hadronic-decay modes.

In 2015, based on the same data set, BESIII also measured the absolute branching fraction of the semi-leptonic decay $\Lambda_c^+ \to \Lambda e^+\nu_e$, using a missing-neutrino technique. In future, a larger Λ_c^+ threshold sample will help to improve further understanding of the properties of the Λ_c^+.

Further reading
BESIII Collaboration 2015 *Phys. Rev. Lett.* **115** 221805.
BESIII Collaboration 2016 *Phys. Rev. Lett.* **116** 052001.

NEW FACILITIES

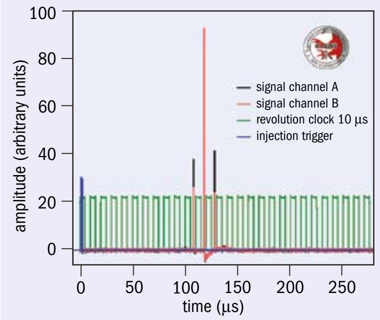
'First turns' for SuperKEKB

On 10 February, the SuperKEKB electron–positron collider in Tsukuba, Japan, succeeded in circulating and storing a positron beam moving close to the speed of light through 1000 magnets in a narrow tube around the 3 km circumference of its main ring. And on 26 February, it succeeded in circulating and storing an electron beam around its ring of magnets in the opposite direction.

The achievement of "first turns", which means storing the beam in the ring through many revolutions, is a major milestone for any particle accelerator.

SuperKEKB, along with the Belle II detector, is designed to search for new physics beyond the Standard Model by measuring rare decays of elementary particles such as beauty quarks, charm quarks and τ leptons.

Unlike the LHC, which is the world's highest-energy machine, 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 Belle II detector at SuperKEKB was designed and built by an international collaboration of more than 600 physicists from 23 countries. This collaboration is working closely with SuperKEKB accelerator experts to optimise the machine performance and backgrounds.

At the same time as first turns were achieved, the BEAST in its cave at Tsukuba Hall awakened from its slumber. The BEAST II detector is a system of detectors designed to measure the beam backgrounds of the SuperKEKB accelerator. The parasitic radiation produced by electromagnetic showers when the beam collides with the walls of the vacuum pipe not only obscure 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.

Further reading
https://twitter.com/belle2collab and https://www.facebook.com/belle2collab/.

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 31 December 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^{-7} Pa at 100 mA after feeding 35 amps-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.

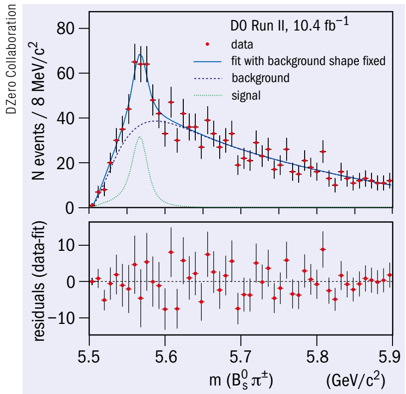
After several test runs in the fourth quarter of 2015, an unusual and unfamiliar phenomenon began to emerge, preventing the electron current from progressing beyond 230 mA. The pressure of the vacuum chamber located in the first dipole of the second arc section in the storage ring repeatedly surged to more than 300 times the normal value of 10×10^{-9} 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 12 December.

While the TPS was ramping up to 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



The $m(B_s^0\pi^\pm)$ distribution together with the background distribution and the fit results after applying the cone cut.

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 a 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**

arxiv.org/abs/1602.07588.

New experiments

Testing of DUNE tech begins

Reidar Hahn

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

The planned Deep Underground Neutrino Experiment (DUNE) (*CERN Courier* December 2015 p19) will require 70,000 tonnes of liquid argon, making it the largest experiment of its kind – 100 times larger than the liquid-argon particle detectors that came before. Scientists recently began taking data using a 35 tonne test version of their detector – a significant step towards building the four massive detectors at the Sanford Underground Research Facility (SURF), which will hold the 70,000 tonnes of liquid argon.

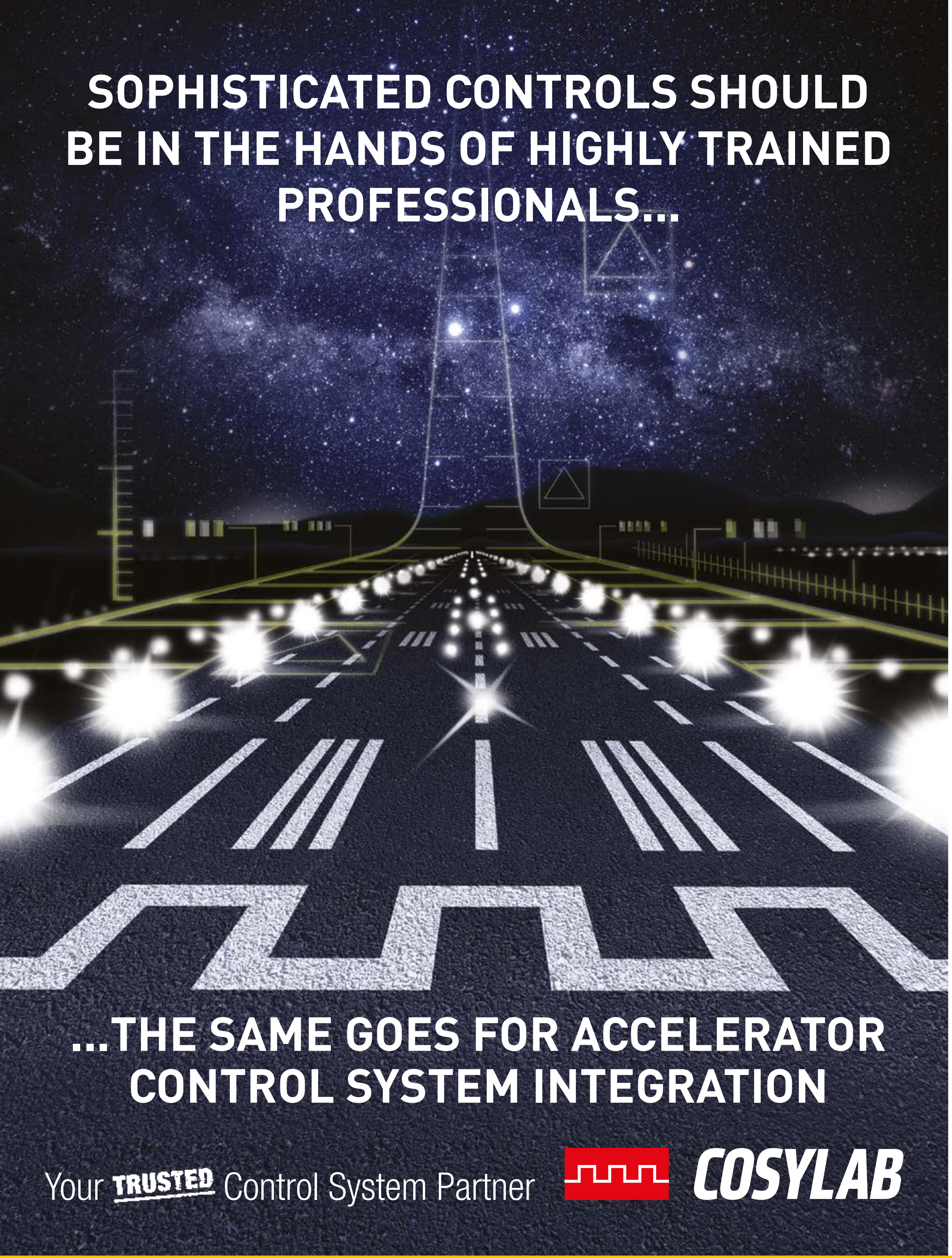
Built at the Department of Energy's Fermi National Accelerator Laboratory, the 35 tonne prototype allows researchers to check that the various detector elements are working properly and to start formal studies. Scientists also use the prototype to assess detector components that have not been tried before. The new parts include redesigned photodetectors – long rectangular prisms with a special coating that changes invisible light to a visible wavelength and bounces the collected light to the detector's electronic components.

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 down 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 –184 °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.



Sciencewatch

Compiled by John Swain, Northeastern University

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 6.6%, 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%).

Chuck Coker (CC)

New incandescent bulbs using a flat tungsten ribbon promise to beat LEDs for efficiency.

● **Further reading**
O Ilic *et al.* 2016 *Nature Nanotechnology* doi:10.1038/nnano.2015.309.

The brightest supernova

A new supernova is more than twice as luminous as any seen before, at its peak being brighter than 570 billion suns. Subo Dong of Peking University in Beijing, China, and colleagues found the supernova – dubbed ASASSN-15lh – at a redshift of 0.2326, apparently in a luminous galaxy with little star formation. The power it has radiated in the first four months post-detection strains conventional models for its power source, so in addition to breaking a record, it poses an astrophysical puzzle.

● **Further reading**
S Dong *et al.* 2016 *Science* **351** 257.

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.

● **Further reading**
E Virot *et al.* 2016 *Phys. Rev. E* **93** 023001.

Google plays Go

A computer has finally beaten a human at the ancient board game Go – and rather dramatically. Developed by Google DeepMind in London, the program AlphaGo uses deep neural networks to get around the traditional problems of a simple search due to the size of the search space. The network training was from games with human experts and from random games of self-play, so in a sense there was a bit of human in the software, which some might find consoling because the score wasn't close: AlphaGo 5, European Go champion 0. Expectations had been that this would not happen for at least another decade.

● **Further reading**
D Silver *et al.* 2016 *Nature* **529** 484.

Babylonians tracked Jupiter

The idea of obtaining distance by integrating speed with respect to time is an elementary one today for anyone who has studied high-school calculus, but it now appears that the idea was used by astronomers in ancient Babylon to calculate the position of Jupiter. Mathieu Ossendrijver of Humboldt University in Berlin, Germany, studied four cuneiform tablets, part of a collection of some 450 from between 400 and 50 BC. It's not full calculus, but it is the trapezoidal rule, far earlier than anyone thought possible. Jupiter held special significance to the Babylonians because it represented Marduk, their patron god.

● **Further reading**
M Ossendrijver 2016 *Science* **351** 482.

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.

● **Further reading**
K Batygin and M E Brown 2016 *The Astronomical Journal* **151** 22.

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**
J Böhm *et al.* 2016 *Current Biology* **26** 286.

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**
M S Engel *et al.* 2016 *Current Biology* doi:10.1016/j.cub.2015.12.061.

Astrowatch

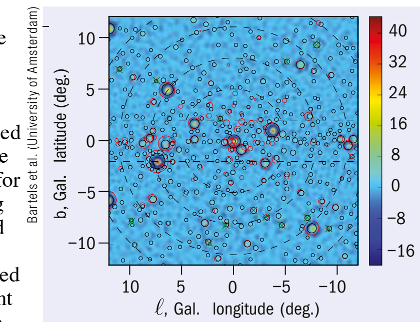
COMPILED BY MARC TÜRLER, ISDC AND OBSERVATORY OF THE UNIVERSITY OF GENEVA, AND CHIPP, UNIVERSITY OF ZURICH

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 p13). 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.



Gamma-ray map of an area (24° 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 point sources. The colour scale encodes the signal-to-noise ratio.

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° in the relevant energy band of 1–4 GeV. The intensity distribution of the derived wavelet peaks is found to be inconsistent with that expected from a truly diffuse origin of the emission. The distribution suggests instead that the entire excess emission is due to a population of mostly undetected point sources with characteristics matching those of millisecond pulsars.

These results are corroborated by another study led by Samuel Lee of the Broad Institute in Cambridge and Princeton University. This US team used a new statistical method – called a non-Poissonian template fit – to estimate the contribution of unresolved point sources to the gamma-ray excess emission at the galactic centre. The team's results predict a new population of hundreds of point sources hiding below the detection threshold of Fermi. The possibility of detecting the brightest ones in the years to come with ongoing observations would confirm this prediction.

In the coming decade, new facilities at radio frequencies will be able to detect hundreds of new millisecond pulsars in the central region of the Milky Way. This would definitively rule out the dark-matter interpretation of the GeV excess seen by Fermi. In the meantime, the quest towards identifying the nature of dark matter will go on, but little by little the possibilities are narrowing down.

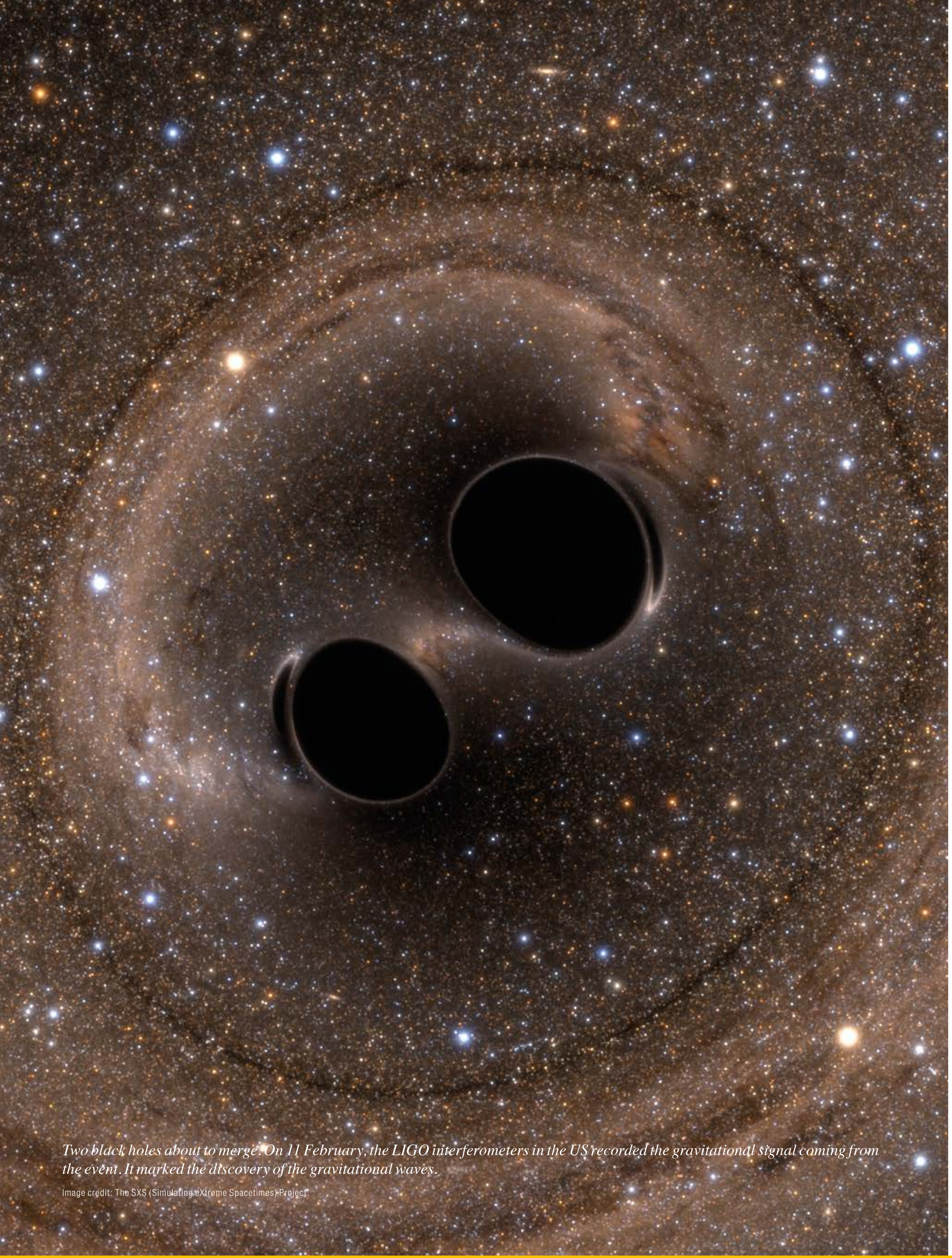
Further reading

R Bartels *et al.* 2016 *Phys. Rev. Lett.* **116** 051102.
S K Lee *et al.* 2016 *Phys. Rev. Lett.* **116** 051103.

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).

LIGO: a strong belief



Two black holes about to merge. On 11 February, the LIGO interferometers in the US recorded the gravitational signal coming from the event. It marked the discovery of the gravitational waves.

Image credit: The SXS (Simulating eXtreme Spacetimes) Project.

Twenty years of designing, building and testing innovative technologies, with the strong belief that the endeavour would lead to a historic breakthrough, have come to fruition in the first direct detection of gravitational waves. Former LIGO director **Barry Barish** shares his feelings on this momentous occasion.

Antonella Del Rosso, CERN.

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 5σ significance and is the first direct observation of gravitational waves.

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 in size also involved at least that in complexity and sophistication, eventually achieving more than 10,000 times the sensitivity of the original 40 m prototype.

The experimental confirmation of the existence of the gravitational waves could have a profound impact on the future of astrophysics and gravitational physics. 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 ▷


Matt Heintze/Caltech/MIT/LIGO Lab

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 this 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 porté 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 Courier.

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 II and University of Bern.


University of Bern

The acceleration chamber of the PET cyclotron, showing the out-port connected to the research beam transfer line.

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 fulfil 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 picoampere and nanoampere range, opening the way to nuclear and detector physics, material science, radiation biophysics, and radiation-protection research.

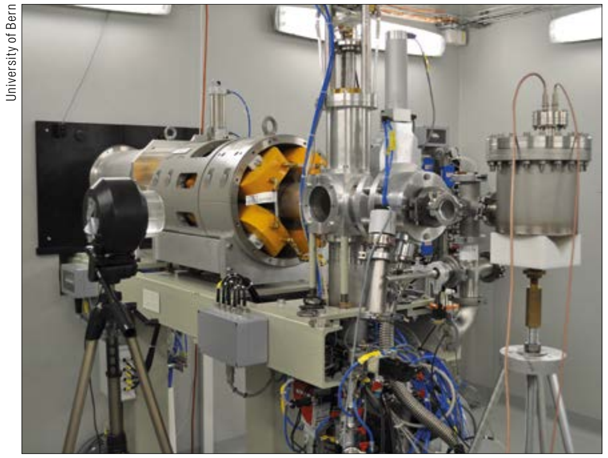
To perform cutting-edge multidisciplinary research, beams of variable shape and intensity must be available.

On the other hand, to perform cutting-edge multidisciplinary research, beams of variable shape and intensity must be available, together with the possibility to access the beam area. This cannot be realised in standard medical PET cyclotron set-ups, where severe access limitations occur due to radiation-protection issues. Furthermore, the targets for the production of PET radioisotopes are directly mounted on the cyclotron right after extraction, with consequent limitations in the use of the beams. To overcome these problems, medical PET cyclotrons can be equipped with a transport line leading the beam to a second bunker, which can always be accessible for scientific activities.

The Bern cyclotron laboratory

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. 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.


University of Bern

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 produced 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 fluorine-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 in good agreement with calculations based on excitation functions, and can be used for the assessment of radioactivity induced in air by proton and neutron beams in the energy range of PET cyclotrons. A direct application of this study is the assessment of radiation protection for scientific activities requiring beam extraction into air.

Another distinctive feature of the Bern cyclotron is its radiopharmacy, conceived to bring together industrial production for medicine and scientific research. It features three Good Manufacturing Practice (GMP)-qualified laboratories, among which one is fully devoted to research. The existence of this laboratory and of the BTL brought together physicists and radiochemists of the University of Bern and of the Paul Scherrer Institute (PSI), triggering a multidisciplinary project funded by the Swiss National Science Foundation (SNSF). Scandium-43 is proposed as a novel 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

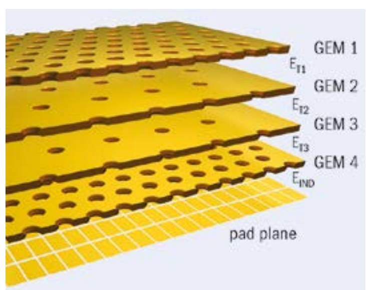
Au-delà de la production courante de radio-isotopes pour l'imagerie médicale, les cyclotrons PET compacts peuvent être au cœur d'installations de recherche multidisciplinaires. C'est le cas au laboratoire cyclotron de Berne (BTL), conçu pour une utilisation de l'accélérateur dans des buts scientifiques, parallèlement à 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.

ALICE selects gas electron multipliers for its new TPC

Although the ALICE TPC has reached its design specifications, intrinsic limitations remain, which will be removed with the planned upgrade.

Harald Appelshäuser, Johann Wolfgang Goethe-Universität Frankfurt am Main (Germany).


Image credits: ALICE Collaboration



Left: Fig. 1. Schematic view of a 4-GEM stack.

Above: Fig. 2. Large-size GEM foils produced with so-called single-mask technology.

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 m^3, 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 about 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 100 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.

A schematic view of a 4-GEM stack is shown on the previous page (figure 1). Optimal performance is reached in a setting where the amplification voltages ΔV across the GEMs increase from layer 1 to 4. This maximises the average number of GEMs that the produced ions have to pass on their way towards the drift volume, hence giving rise to minimal ion-escape probability. Moreover, the electron transparency and ion opacity can be optimised by a suitable combination of high and low transfer fields E_T. Finally, the hole pitch of the GEM foils has proven to be an important parameter for the electron and ion transport properties, leading to a solution where two so-called standard-pitch GEMs (S, hole-pitch 140 μm) in layers 1 and 4 sandwich two GEMs with larger pitch (LP, hole-pitch 280 μm) in layers 2 and 3.

After being developed in small-size prototype tests in the laboratory, a full-size TPC inner read-out chamber (IROC) with 4-GEM read-out was built and tested in beams at the PS and SPS. To this end, large-size GEM foils were produced at the CERN PH-DT Micro-Pattern Technologies Workshop, in so-called single-mask technology (figure 2). As a main result of the test-beam campaigns, the dE/dx performance of the 4-GEM IROC was demonstrated to be the same as for the existing MWPC IROCs, and the stability against discharge is well suited for operation at the LHC in Run 3 and beyond.

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.

Résumé

ALICE opte pour des multiplicateurs d'électrons à gaz pour sa nouvelle TPC

Le dispositif principal d'ALICE pour la trajectographie et l'identification des particules est la chambre à projection temporelle (TPC). Même si la TPC a atteint, et même dépassé, ses spécifications nominales lors de la première et de la deuxième période d'exploitation du LHC, il reste des limites intrinsèques, qui pourront être dépassées grâce à l'amélioration prévue. La nouvelle TPC utilisera un système d'amplification faisant appel à quatre couches de feuilles de multiplicateurs d'électrons à gaz (GEM).

Neutrons in full flight at CERN's n_TOF facility

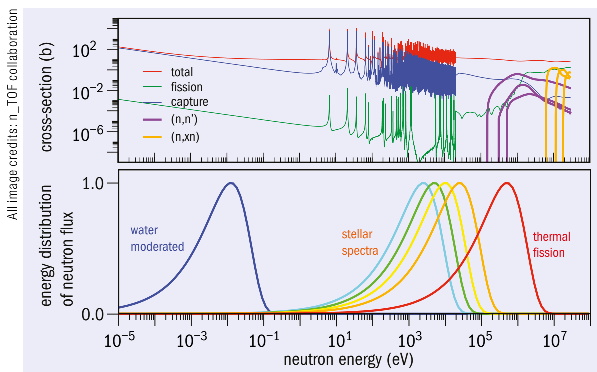
n_TOF is CERN's neutron time-of-flight facility. Featuring two neutron beamlines and two experimental halls, n_TOF is producing results that are important for nuclear astrophysics and to develop novel nuclear-technology solutions.

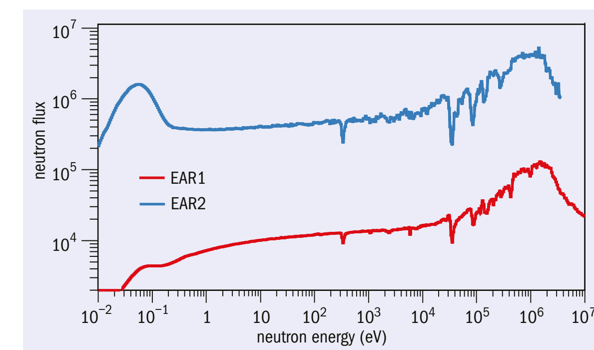
On behalf of the n_TOF Collaboration, **Frank Gunsing**, n_TOF physics co-ordinator, and **Enrico Chiaveri**, n_TOF spokesperson.

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 Rubbia (*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





(Top) Fig. 1. Neutron-induced reaction cross-sections for a typical heavy nucleus as a function of the neutron kinetic energy, together with characteristic neutron fluxes present in stellar environments or in technological applications. (Above) Fig. 2. The neutron flux at EAR1 and EAR2 of the n_TOF facility.

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 are shown as a function of energy. The position and extent of the resonance structures 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 ▷

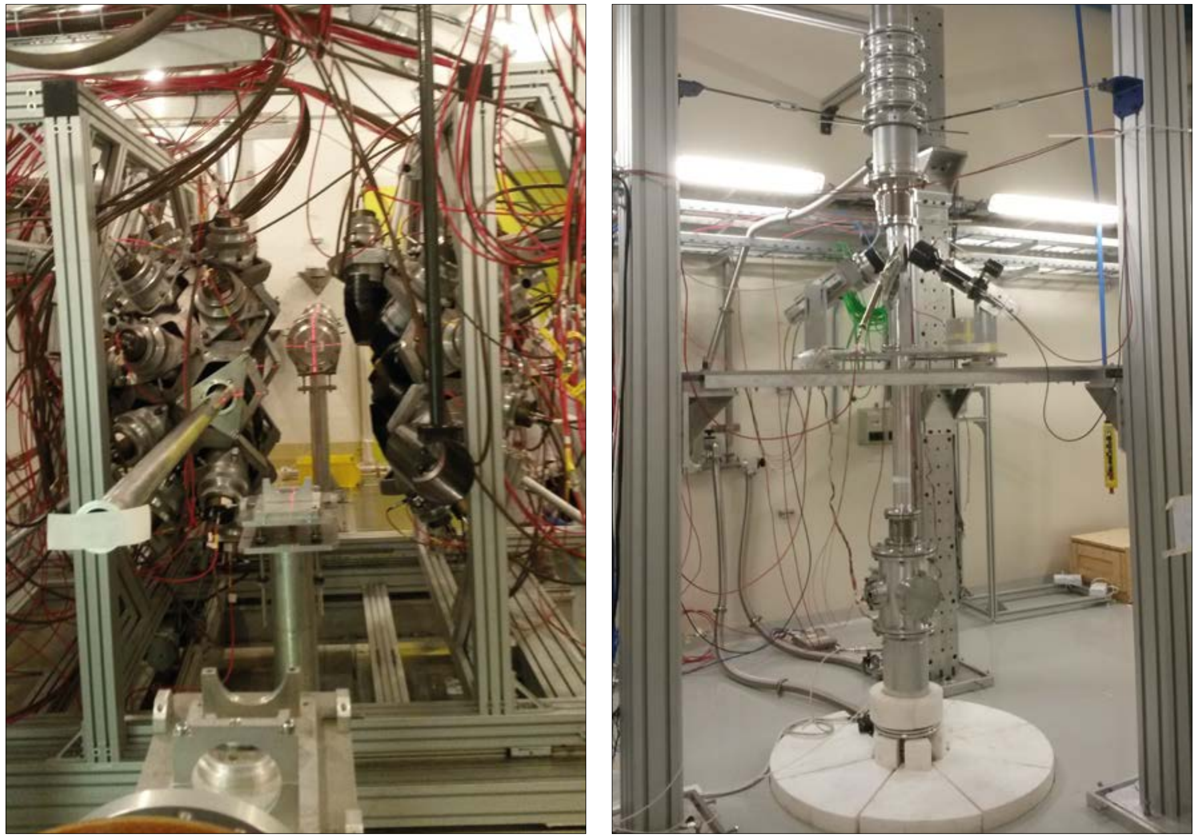


Fig. 3. The horizontal neutron beamline in EAR1 (left) and the vertical neutron beamline in the newly constructed EAR2.

5 to 100 keV, corresponding to the temperatures in stellar environments of importance for nucleosynthesis.

In nuclear astrophysics, an intriguing topic is understanding the formation of nuclei present in the universe and the origin of chemical elements. Hydrogen and smaller amounts of He and Li were created in the early universe by primordial nucleosynthesis. Nuclear reactions in stars are at the origin of nearly all other nuclei, and most nuclei heavier than iron are produced by neutron capture in stellar nucleosynthesis. Neutron-induced reaction cross-sections also reveal the nuclear-level structure in the vicinity of 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 the 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 high 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

Neutron facilities

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 ^{240}Pu 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 ^{7}Be, 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 4π calorimeter consisting of 40 BaF_2 crystals has been in use for capture measurements since 2004. Several types of C_6D_6-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 fission-fragment spectrometer STEFF 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.

Résumé

Des neutrons en plein vol à l'installation n_TOF du CERN

n_TOF est l'installation de mesure de temps de vol des neutrons du CERN. Disposant de deux lignes de faisceau et de deux halls d'expérimentation, n_TOF produit des résultats qui sont importants pour l'astrophysique nucléaire et pour l'élaboration de solutions innovantes en technologie nucléaire. L'installation est caractérisée par le large spectre d'énergies couvertes, puisqu'on va de la région du meV jusqu'à la région du GeV, et par le très grand nombre de neutrons par impulsion de protons. Constituée d'environ 150 chercheurs de 40 instituts, la collaboration n_TOF s'apprête à commencer une nouvelle année d'expériences basées sur son programme scientifique.

Interactions & Crossroads

REPORTS

ICTR-PHE 2016: the winning alliance

Salvatore Fiore

About 440 scientists from a variety of fields gathered in Geneva for the 2016 edition of the ICTR-PHE multidisciplinary conference.

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 2005 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 and analysis of large amounts of advanced 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 "rapid 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. But to achieve this, computing scientists need huge amounts of data – data they are eager to collect worldwide through programmes such as the Euregional Computer Assisted Theragnostics project (EuroCAT).

In his lecture supported by the European Society for Therapeutic Radiotherapy 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, etc) to offer tailored therapy to the patient. The award is testimony to Bentzen's lifelong dedication to this field ▷

and to his commitment to providing the best possible outcome for patients.

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 facilities delivering protons, while there are none to perform carbon-ion treatment yet. Clinical trials, which follow precise protocols, are necessary to demonstrate that proton therapy can be a more effective treatment than photons in terms of tumour control, patient survival and treatment toxicity. According to Cox, clinical trials for particle therapy cannot be readily conducted in the US, due to a number of structural biases such as cost (influencing the age and the social status of the patients); subjectivity in scoring acute and subacute effects; patient acceptance; and the expertise of the investigators. Moreover, most of the studies do not take into account late effects, which, on the contrary, are very important in assessing treatment toxicity.

Unfortunately, the situations for cancer care in other parts of the world is not all positive. Norman Coleman, senior scientific adviser to the International Cancer Expert Corps (ICEC) and a member of the US National Cancer Institute, 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, ICTR-PHE 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 Dosanjh and Jacques Bernier of Clinique de Genolier, awarded Emanuele Scifoni (GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany); Mattia Donzelli (European Synchrotron Radiation Facility of Grenoble, France); Grischa Klimpki (Paul Scherrer Institute, Switerland); Karol Brzezinski (Universitat de València, Spain, and University of Groningen, the Netherlands); Pankaj Chaudhary (University of Belfast, UK); and Brent Huisman (Université de Lyon, France).

In line with its goal of merging different approaches and disciplines, the public talk proposed by ICTR-PHE introduced a novel methodology that uses sound to improve our knowledge and understanding of human motor control. Domenico Vicinanza, 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.

Trigger and data-acquisition experts gather at ISOTDAQ 2016

Fifty-two MSc and PhD students from 21 nations, selected from almost 80 applications, attended ISOTDAQ 2016, the 7th International School of Trigger and Data Acquisition, held at the Weizmann Institute of Science in Rehovot, Israel.

As in previous editions of the school, a full programme consisting of equal time for lectures and hands-on exercises aimed at giving the students an introduction to the many concepts and technologies used in the field. A total of 26 lecturers and tutors from CERN, worldwide research institutes and industry came to the school to share their knowledge, not only during the lectures and laboratory exercises but also in many face-to-face discussions during the coffee and lunch breaks.

The lectures covered both enabling technologies such as FPGAs, A/D converters, networks and bus systems, and the design of software and overviews of selected TDAQ systems from large and small experiments and related fields, such as medical imaging.

In the lab exercises, the students had the opportunity to operate the hardware introduced to them in the lectures, and to work under the supervision of an experienced tutor on small projects. To make the hands-on practice possible, 500 kg of electronics modules and computers, prepared for the 13 exercises, were shipped from CERN to the Weizmann Institute.

During the school, the students also had an opportunity to visit the production facility for a large fraction of the existing Atlas TGC detectors and the future sTGC detectors for the ATLAS Phase 1 upgrade. This provided them with an impression of the research activities and facilities available at the Weizmann Physics Department.

ISOTDAQ 2016

The 52 selected students who participated in this year's edition of the International School of Trigger and Data Acquisition.

REGIONAL EVENTS

Conferences for Undergraduate Women in Physics confirm their success

ODU/JLab

Nearly 140 women and men attended the CUWiP event organised at Jefferson Lab.

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 Weslyan 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.

Nearly 140 women and four men attended the ODU/Jefferson Lab conference, which included workshops, panel discussions, lectures, a student poster session, graduate school and careers fair, and Jefferson Lab tour.

"The value of the conference is in showing undergraduate women that in spite of classroom numbers, they are not alone, and that there are many role models for them," commented Gail Dodge, a professor of physics at ODU and co-chair for the joint ODU/JLab conference. "They particularly appreciated career advice, both from the panel discussions and the graduate school and careers fair. We want these women to know they have many options and that there are many ways to be a physicist."

According to Latifa Elouadrhiri, Jefferson Lab staff scientist and ODU/Jefferson Lab co-chair, the conference programme was designed with the goal of giving the students an opportunity to experience the dynamics of a professional physics conference. It also provided them with the opportunity to meet and network with other women in physics at many different levels – peers, graduate students, postdocs, faculty, researchers and leaders of technical projects and institutions – both in academia and industry. Through the graduate school and careers fair, with 32 institutions and employers represented, the students became more aware of the wide variety of opportunities available to them.

"It was very exciting to be in a room with so many women physicists, seeing the lively dialogue between the students and senior women as well as the interactions between the students, discussing physics questions and career opportunities," Elouadrhiri said. "Jefferson Lab and ODU are committed to increasing the representation of women in physics. We hope that hosting this conference has a positive impact on the young women who attended and helps them in making informed decisions about their future."

● For further information, see https://www.aps.org/programs/women/workshops/cuwip.cfm.

EVENTS CALENDAR

2–6 May
BEAUTY 2016
Marseille, France
The aim of this conference is to review the latest theoretical and experimental results in heavy-flavour physics.
https://indico.cern.ch/event/352928/

13–18 June
LHCP 2016
Lund, Sweden
The programme will be devoted to a detailed review of the latest experimental and theoretical results on collider physics, particularly the first results of the LHC Run II.
https://indico.cern.ch/event/442390/

4–9 July
NEUTRINO 2016
London, UK
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.
http://neutrino2016.iopconfs.org/home

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

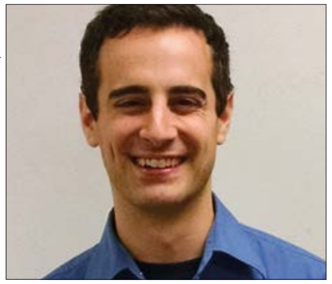
Faces & Places

Awards

ACFA and IPAC announce accelerator prizes


BNL


G-H Luo


Yulia Trenikhina, Fermilab

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

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 Synchrotron (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, with 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 the accelerator field – awarded to an individual in the early part of his or her career – goes to Sam Posen of Fermilab. He is recognised for recent important, original contributions to accelerator technology, especially to the development of Nb_3Sn-film-coated superconducting RF cavities. His achievements include developing a process for producing a special Nb_3Sn 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/.

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


G Bellini

Gianpaolo Bellini.

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 99.9999993% 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

Gérard Bertin

Alice-Anne "Schu" Martin.

Alice-Anne Martin, known as "Schu" from her maiden name Schubert, passed away on 8 January.

Hired the year that CERN was founded, 1954, when the construction of the laboratory had not even begun, Schu first worked at the Villa de Cointrin (a historic building now within the grounds of Geneva airport) as a secretary. In this role, she typed the convention between CERN and the Swiss Confederation, prepared by Stéphanie Tixier, as well as some of 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 theorem by Rolf Hagedorn.

Schu also worked with Felix Bloch, the first Director-General of CERN, and later became the secretary of Herbert Coblenz, 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 UN, ILO, ITU and WHO. She won three such competitions, and was personally congratulated by CERN's Director-General Cornelius Bakker.

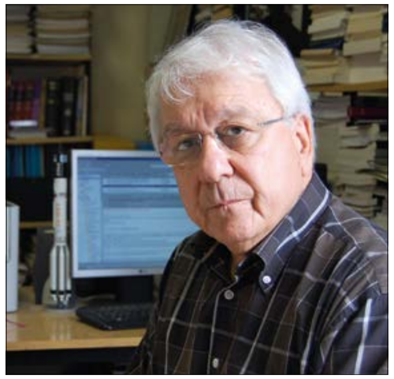
In 1959, she was introduced by Julius Wess, one of the inventors of the theory of supersymmetry, to André Martin, a Parisian physicist, and very soon they were married. She then became the secretary of Pierre Lapostolle, who was head of the Synchro-Cyclotron Division. However, in 1963, when her husband was invited by Robert Oppenheimer to join the Institute for Advanced Study, she had to quit the Organization because, at that time, non-scientific staff were not allowed to take leave of absence.

Upon returning to Geneva, she decided to devote 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.

● *André Martin.*

Namık Kemal Pak 1949–2015

METU



Namık Kemal Pak.

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, Namık 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 Turkey, he started his career as a faculty member at Hacettepe University, and joined the Physics Department of Middle East Technical University (METU) in Ankara in 1982, where he became a full professor and worked ever since. He held many administrative duties in Turkey and represented the country at high levels in international committees, namely at NATO, OECD and ESF. Most importantly, he served as president of the Scientific and Technological Research Council of Turkey (TUBITAK) from 1999 to 2003, where he made substantial contributions to shaping science and technology policies, and promoting science in Turkey. He was one of the main figures in Turkey's involvement with the LHC experiments. TUBITAK decided to fund the ATLAS and CMS experiments in 1996, when Namık Kemal Pak was its vice president. He was a member of The World Academy of Sciences, Academia Europaea, as well as of the Turkish Academy of Sciences from 1993 to 2011, and of the Science Academy in Turkey from 2012 to 2015.

Throughout his career, Namık Kemal Pak made significant contributions to quantum field theory on a range of topics. From the late 1970s to the 1980s, he worked extensively on chiral effective Lagrangians in QCD. The work he did with H C Tze on the Skyrme model and its "solitons" caused a revival of interest in the topic. Later, this led to identification of the topological charge of skyrmions with the Baryon number, as demonstrated by A P Balachandran and his collaborators. In the 1990s and up until the beginning of the 2000s, even though Namık Kemal Pak was heavily involved in nationwide administrative duties, he continued to carry out research on various subjects, concentrating predominantly on phenomenological studies such as non-perturbative calculations using QCD sum rules, flavour-changing neutral currents in flavour physics (mainly B physics) including polarisation effects, various asymmetries within the Standard Model framework, as well as beyond non-supersymmetric scenarios like fourth-generation, extra dimensions, unparticles, and the minimal supersymmetric Standard Model and its abelian extensions. These topics are still active domains of research worldwide, which is only a part of what Namık Kemal Pak has done to make the METU high-energy physics group internationally recognised.

Namık Kemal Pak was always interested in science, technology and innovation policies. He edited several books and published a number of articles 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 Namık 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 policies 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 Kurkcuoglu, Ismail Turan and Mehmet Zeyrek, METU/Ankara.*

Dmitry Vasilievich Shirkov 1928–2016

JINR

Dmitry Vasilievich Shirkov.

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 honorary director of JINR's N N Bogoliubov Laboratory of Theoretical Physics.

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 constructing the general 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 Serebryakov, 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 chromodynamics and supersymmetry theories.

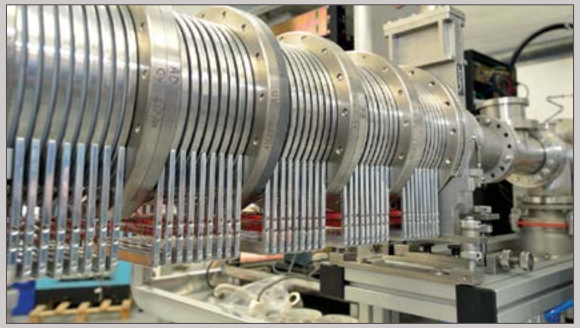
Shirkov was fully devoted to science and had a rare sense of purpose and commitment. He demanded a lot from himself and his colleagues at the laboratory, and at the same time he remained a kind and thoughtful person. His passing is an irreparable loss to the world of science.

● *JINR.*

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
Tel +44 (0)117 930 1264 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



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.hud.ac.uk/courses/full-time/postgraduate/accelerator-science-msc/**
Contact: **compeng@hud.ac.uk**

WHITE ROSE INDUSTRIAL PHYSICS ACADEMY

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.

Computation; simulation; instrumentation; metrology; materials; big data. Our students are ready for any technical challenge you can throw at them.

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 Professional Development

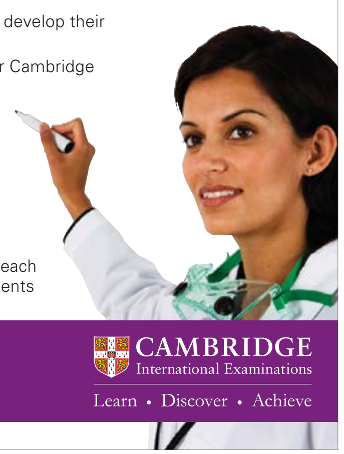
Cambridge International Examinations is growing and over 10 000 schools in more than 160 countries are now part of our Cambridge learning community.

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.

Requirements are:
- Applicants should have teaching experience with a degree in a physics subject.
- Applicants for senior roles will need previous examining experience.
- Successful applicants will require a PC and broadband to allow them to access Cambridge on-screen marking systems.

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

CAMBRIDGE International Examinations
Learn • Discover • Achieve

IFIN-HH

Senior and Junior Researchers, Postdoctoral research assistants, PhD students, Engineers, Physicists and Technicians at

Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

eli Nuclear Physics

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

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 $E\gamma > 19$ MeV, which is obtained by incoherent Compton back scattering of a laser light off an intense electron beam ($Ee > 700$ MeV) produced by a warm linac.

IFIN-HH - ELI-NP is organizing competitions for filling the folowing positions:

Senior and Junior Researchers, Postdoctoral research assistants, PhD students, Engineers/ Physicists (particle accelerators, mechanics, optics), Engineers (physics, laser, electronic, electrical, electrotechnical, instrumentation and control), Technicians, Engineers for RA 1 (laser, control systems, contamination control, project engineer) and Vacuum Systems Technicians for RA 1.

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)

BERGISCHE UNIVERSITÄT WUPPERTAL · RWTH AACHEN UNIVERSITY · Technische Universität Berlin · ALPEN-ADRIA UNIVERSITÄT KLAGENFURT | WIEN GRAZ · KIT Karlsruher Institut für Technologie

For a newly established interdisciplinary project "Epistemology of the LHC", we invite applications for

6 Postdoctoral and 5 for Doctoral Student positions

in philosophy of science, physics, history of science, and science studies.

This research unit investigates a variety of themes centring on 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 reflective disciplines.

We are looking for candidates, who are willing to engage in interdisciplinary work and have some relevant experience in 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 Berlin, the RWTH Aachen University, the Karlsruhe Institut für Technologie, 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.epistemology@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.

Bookshelf

COMPILED BY VIRGINIA GRECO, CERN

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.

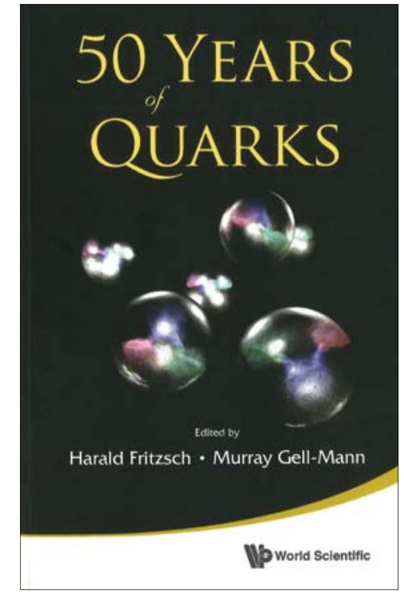
Five key works written or edited by CERN authors are already profiting from the impact that comes from their free dissemination.

Three of them are already accessible online:

- *Melting Hadrons, Boiling Quarks – From Hagedorn Temperature to Ultra-Relativistic Heavy-Ion Collisions at CERN: With a Tribute to Rolf Hagedorn* by Johann Rafelski (ed), published by Springer (link.springer.com/book/10.1007%2F978-3-319-17545-4).
- *60 Years of CERN Experiments and Discoveries* by Herwig Schopper and Luigi Di Lella (eds), published by World Scientific (dx.doi.org/10.1142/9441#t=toc).
- *The High Luminosity Large Hadron Collider: The New Machine for Illuminating the Mysteries of Universe* by Lucio Rossi and Oliver Brüning (eds), published by World Scientific (dx.doi.org/10.1142/9581#t=toc).

Two further OA titles will appear in 2016:

- *The Standard Theory of Particle Physics: 60 Years of CERN* by Luciano Maiani and Luigi Rolandi (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.

● *Tullio Basaglia, CERN Library.*

50 Years of Quarks

By Harald Fritzsch and Murray Gell-Mann (eds)
World Scientific
Also available at the CERN bookshop

This book was written on the occasion of the golden anniversary of a truly remarkable year in fundamental particle physics: 1964 saw the discovery of CP violation in the decays of neutral kaons, of the Ω baryon (at the Brookhaven National Laboratory), and of cosmic microwave background radiation. It marked the invention of the Brout–Englert–Higgs mechanism, and the introduction of a theory of quarks as fundamental constituents of strongly interacting particles.

Harald Fritzsch and Murray Gell-Mann, the two fathers of quantum chromodynamics, look back at the events that led to the discovery, and eventually acceptance, of quarks as constituent particles. Why should we look back at the 1960s? Besides the fact that it is always worthwhile to reminisce about those times when theoretical physicists were truly eclectic, these stories are the testimony of a very active era, in which theoretical and experimental discoveries rapidly chased one another. What is truly remarkable is that, even in the absence of an underlying theory, piecing together sets of disparate experimental hints, the high-energy physics community was always able to provide a consistent description of the observed particles and their interactions. In fact, it was general principles such as causality, unitarity and Lorentz invariance that allowed far-reaching insights into analyticity, dispersion relations, the CPT theorem and the relation between spin and statistics to be obtained.

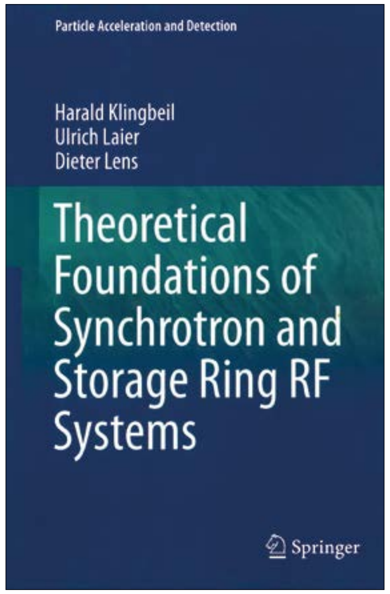
In this volume, Fritzsch and Gell-Mann present a collection of contributions written by renowned physicists (including S J Brodsky, J Ellis, H Fritzsch, S L Glashow, M Kobayashi, L B Okun, S L Wu, G Zweig and many others) that led to crucial developments in particle theory. The individual contributions in the book range from technical manuscripts, lecture notes and articles written 50 years ago, to personal, anecdotal and autobiographical accounts of endeavours in particle physics, emphasising how they interwove with the conception and eventually acceptance of the quark hypothesis. The book conveys the enthusiasm and motivation of the scientists involved in this journey, their triumph in cases of success, their amazement in cases of surprises or difficulties, and their disappointment in cases of failures. One realises that while quantum chromodynamics seems a simple and natural theory today, not everything was as easy as it now looks, 50 years later. In fact, the paradoxical properties of quarks, imprisoned for life in hadrons, had no precedent in the history of physics.

The last 50 years has witnessed spectacular progress in the description of elementary constituents of matter and their fundamental interactions, with important discoveries that led to the establishment of the Standard Model of particle physics. This theory accurately describes all observable matter, namely quarks and leptons, and their interactions at colliders through the electromagnetic, weak and strong force. Yet many open questions remain that are beyond the reach of our current understanding of the laws of physics. Of central importance now is the understanding of the composition of our universe, the dark matter and dark energy, the hierarchy of masses and forces, and a consistent quantum framework of ▷

unification of all forces of nature, including gravity. The closing contributions of the book put this venture in the context of today's high-energy physics programme, and make a connection to the most popular ideas in high-energy physics today, including supersymmetry, unification and string theory.
● *Giulia Zanderighi, CERN.*

Theoretical Foundations of Synchrotron and Storage Ring RF Systems

By Harald Klingbeil, Ulrich Laier, and Dieter Lens
Springer
Also available at the CERN bookshop



This book is one of few, if not the only one, dedicated to radiofrequency (RF) accelerator systems and longitudinal dynamics in synchrotrons, providing a self-contained and clear theoretical introduction to the subject. Some of these topics can be found in separate articles of specialised schools, but not in such a comprehensive form in a single source. The content of the book is based on a university course and it is addressed to graduate students who want to study accelerator physics and engineering.

After a short introduction on accelerators, the second chapter provides a concise but complete overview of the mathematical-physics tools that are required in the following chapters, such as Fourier analysis and Laplace transform. Ordinary differential equations and the basics of non-linear dynamics are presented with the notions of phase space, phase flow and velocity vector fields, leading naturally to the continuity equation and to the Liouville theorem. Hamiltonian systems are elegantly introduced, and the mathematical pendulum as well as a LC circuit are 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 electromagnetism 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 a non-negligible number are in German and might not be of help for the English-speaking reader. This feature is also found in other chapters.

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 sketched out. 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 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 critical 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 moments, including the concept of RMS emittance, a description of longitudinal bunch oscillations and their spectral 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 amplitude control loop. That eases 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.

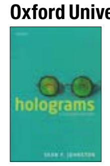
The volume is completed by a rich appendix summarising basic concepts and formulas required elsewhere in the book (e.g. some notions of transverse beam dynamics and the characterisation of fixed points) or working out in detail some examples of subjects treated in the main text. Some handy recalls of 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. I enjoyed 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.
● *Gianluigi Arduini, CERN.*

Books received

Holograms: A Cultural History

By Sean F Johnston
Oxford University Press



The book is a sort of biography of holograms, peculiar optical "objects" that have crossed the border of science to enter other cultural and anthropological fields, such as art, visual technology, pop culture, magic and illusion. No other visual experience is like interacting with holograms – they have the power to fascinate and amuse people. Not only physicists and engineers, but also artists, hippies, hobbyists and illusionists have played with, and dreamed about, holograms.

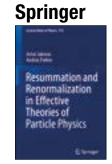
This volume can be considered as complementary to a previous book by the same author, a professor at the University of Glasgow, called *Holographic Visions: A History of New Science*. While the first book gave an account of the scientific concepts behind holography, and of its development as a research subject and engineering tool, the present text focuses on the impact that holography has had on society and consumers of such technology.

The author explores how holograms found a place in distinct cultural settings, moving from being expressions of modernity to countercultural art means, from encoding tools for security to vehicles for mystery.

Clearly written and full of interesting factual information, this book is addressed to historians and sociologists of modern science and technology, as well as to enthusiasts who are interested in understanding the journey of this fascinating optical medium.

Resummation and Renormalization in Effective Theories of Particle Physics

By Antal Jakovác and András Patkós
Springer



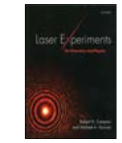
The book re-collects notes written by the authors for a course on finite-temperature quantum fields, and more specifically on the application of effective models of strong and electroweak interactions in particle-physics phenomenology.

The topics selected reflect the research interests of the authors, nevertheless in their opinion, the material covered in the volume can help students of master's degrees in physics to improve their ability to deal with reorganisations of the perturbation series of renormalisable theories.

The book is made up of eight chapters and is organised in four parts. An historic overview of effective theories (which are scientific theories that propose to model certain effects without proposing to adequately model their causes) opens the text, then two chapters provide the basics of quantum field theory necessary for following the directions of contemporary research. The third part introduces three different and widely used approaches to improving convergence properties of renormalised perturbation theory. Finally, results that emerge from the application of these techniques to the thermodynamics of strong and electroweak interactions are reviewed in the last two chapters.

Laser Experiments for Chemistry and Physics

By R N Compton and M A Duncan
Oxford University Press



The book provides an introduction to the characteristics and operation of lasers through laboratory experiments for undergraduate students in physics and chemistry.

After a first section reviewing the properties of light, the history of laser invention, the atomic, molecular and optical principles behind how lasers work, as well as the kinds of lasers that are available today, the text presents a rich set of experiments on various topics: thermodynamics, chemical analysis, quantum chemistry, spectroscopy and kinetics.

Each chapter gives the historical and theoretical background to the topics covered by the experiments, and variations to the prescribed activities are suggested.

Both of the authors began their research careers at the time when laser technology was taking off, and witnessed advances in the development and application of this new technology to many fields. In this book they aim to pass on some of their experience to new students, and to stimulate practical activities in optics and lasers courses.

CERN Courier Archive: 1973

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

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].
● Compiled from text on p109.

CERN

Right: Part of the control room of BEBC, giving an idea of the complexity of the many systems involved in the operation of the chamber.

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 in freon. 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 were 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.
● Compiled from text on p112.

CERN

Right: Gargamelle after repairs. The top half of the photograph shows the magnet; the chamber itself is inside the magnet. The tanks of the expansion system have been reinstalled on the trolley, in the foreground, with struts fitted for added rigidity.

RCBC operating

At Stanford, the 15 inch Rapid Cycling Bubble Chamber (RCBC) is being used for physics for the first time. The experiment, carried out by a Purdue, Indiana, SLAC, Vanderbilt collaboration, began in March. It is a search for "exotic" mesons with double charge. The quark model maintains that mesons are built up of quark and antiquark pairs. Thus, since a quark is supposed to carry a charge of 1/3 or 2/3, no doubly charged mesons can be built up.

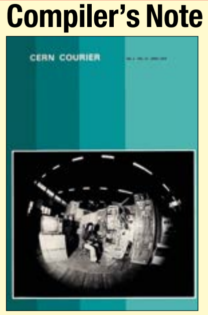
Observation of such mesons will obviously be extremely rare. So the rapid cycling chamber is used in a hybrid system with spark chambers, to select only likely events.

A beam of about 10 positive pions per pulse is fired into the chamber. If exotic mesons exist, they could appear as $\pi^+ + p \rightarrow n + X^{++}$. The emerging neutron is converted into charged particles that fire an optical spark chamber.

It is expected that the hybrid system will be triggered once every 200 pulses. The collaboration is hoping to collect 100,000 pictures. Operation without the possibility to trigger the chamber would require collecting and analysing 20 million pictures.
● Compiled from texts on pp114–115.

The body of the Stanford RCBC receiving the final touches before installation. It was successfully tested for two-million pulses at a rate of 20 Hz before data-taking started. The peak operating frequency of the chamber is 60 Hz.

Compiler's Note

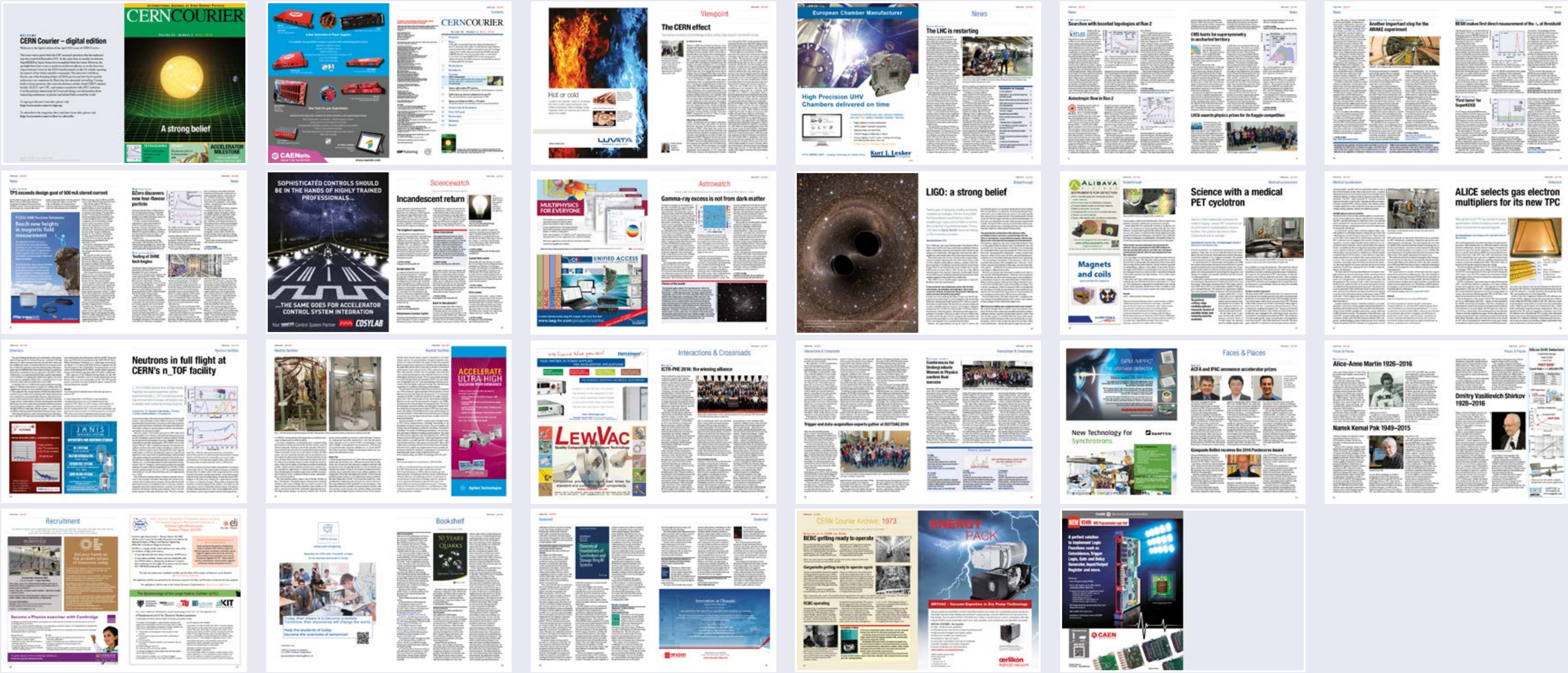


In the 30 years following their invention in the1950s, more than 100 bubble chambers were built and 100 million stereo photographs were taken.

Scientifically, 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 subnuclear 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.



CERNCOURIER

VOLUME 56 NUMBER 3 APRIL 2016

Contents