WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the November 2014 issue of *CERN Courier*.

Summer is a time for conferences, and this issue brings reports on a few of the season's many meetings on particle physics in 2014. Some come round regularly, such as those in the ICHEP and Beauty series, while others are "one-offs". The meeting on the 50th anniversary of the discovery of CP violation brought together some of the leading players in the field, both to reminisce and to look to the future. Summer is also a time for "schools" on particle physics, with the African School of Fundamental Physics and its Applications now becoming well established. This summer also gave students who are still at school the opportunity to come to CERN, not for a standard visit but to work in a real test beam in the project "Beam line for schools".

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DIGITAL EDITION CREATED BY JESSE KARJALAINEN/IOP PUBLISHING, UK

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERNCOURIER

VOLUME 54 NUMBER 9 NOVEMBER 2014

Muon g-2 moves on to a new life

CERN60

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NEW RESULTS FROM AMS

Evidence for a new source of positrons **p6**

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On the cover: The muon g-2 storage ring approaches Fermilab after its long journey from Brookhaven by river, sea and road (p19). (Image credit: Fermilab.)

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

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

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

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or +44 (0)117 930 1164 (for recruitment advertising);
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 Keqing Ma, Library, Institute of High Energy Physics,
PO Box 918, Beijing 100049, People's Republic of China
E-mail: keqingma@mail.ihep.ac.cn
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UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ
E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive,
St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US
Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,
St Charles, IL 60174, US

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

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

ISSN 0304-288X

Advertising feature

High-Accuracy Digital Teslameter with Thin Three-Axis Hall Probe

Hall-effect-based teslameters are the mostly applied instruments for measuring DC and AC magnetic flux densities in the range from a few uT to about 30T. Modern science and industry have steadily increasing needs in accurate measurement of highly non-homogeneous magnetic fields. This trend introduces a number of additional requirements for good teslameters, particularly for their Hall probes.

Key Features
SENIS Teslameter measures magnetic field vectors from about 1μT to 30T, with the spatial resolution 100 μm, magnetic resolution ±2ppm of the range, the accuracy ±0.0001% of reading + 0.001% of range, temperature coefficient less than 5ppm/°C, angular errors less than 0.1°, and no planar Hall effect. The 3-axis Hall probe chip is encapsulated in a robust ceramic package, a version of which is only 250μm thick.

The SENIS new digital teslameter incorporates a 3-axis Hall probe, analog electronics based on the spinning-current technique, 24-bit analog-to-digital converter, computer, and 7-digit touch-screen display. The 3-axis Hall probe is a single silicon chip with monolithically integrated horizontal and vertical Hall magnetic sensors and a temperature sensor. The spinning-current eliminates most of the Hall probe offset, low-frequency noise, and the planar Hall voltage. The errors due to the Hall element non-linearity and the variations in the probe and electronics temperatures are eliminated by a calibration procedure based on a second-order polynomial. The errors due to the angular tolerances of the Hall probe are eliminated by a calibration of the sensitivity tensor of the probe.

Selectable measurement ranges and interchangeable probes
The high-accuracy teslameter with three-axis Hall probe can measure magnetic fields in the range of about a μT up to 30T. The measurement ranges are selectable and the auto-range option is available. The Hall probes are equipped with an EEPROM for storing the probe calibration data, which makes the probes interchangeable on a running teslameter. The teslameter also provides the analog outputs - three differential voltages that are proportional to the three components of the measured magnetic flux density and a single-ended voltage output that is proportional to the chip temperature. A user can easily integrate a measurement routine into its measurement system while using its own programming tools.

High resolution and accuracy
The magnetic resolution of the teslameter is ±2ppm of the range and the magnetic field measurement accuracy is ±0.0001% of reading + 0.001% of range. The probe can measure the magnetic fields with the highest resolution in the bandwidth from dc to 10Hz; and with a slightly lower resolution up to 1kHz; and further up to 4kHz.

Compensation of temperature drift and nonlinearity
The compensation of temperature drifts and nonlinearities are very efficient due to the use of the voltage signals that are proportional to the real probe and electronics temperatures. The resolution of the probe temperature is 0.001°C. The temperature compensation method, implemented in the digital module of the teslameter, allows a temperature coefficient of sensitivity less than 5ppm/°C and a temperature coefficient of the offset of ±0.1μT/°C. The long-term instability of sensitivity is less than 0.1% over 10 years of operation. The performance figures here refer to the measurement range 2T.

No planar Hall effect
The applied “spinning-current” method in the analog part of the teslameter cancels offset, 1/f noise, and the planar Hall voltage. The teslameter has virtually no crosstalk between the channels. The spinning-current and the tightly twisted thin probe cable make the teslameter immune to electromagnetic disturbances.

Small and compact sensitive volume
The teslameter operates with the low-noise integrated three-axis Hall probe. The probe integrates horizontal and vertical Hall devices on a single CMOS Si-chip. The integrated Hall probe allows a very small magnetic field sensitive volume of 100μm x 100μm x 10μm.

Miniaturized 3-axis Hall probe
The three-axis Hall probe is enclosed in a ceramic package. A version of the probe is only 250μm thick, which allows magnetic field measurement in a very small air-gaps (<300μm). The ceramic package is very rigid and robust and allows for a precise positioning of the probe during the measurement.

Correction of angular errors of the probe
The teslameter corrects the probe’s angular errors to below 0.1°. The correction is based on a calibration procedure of the teslameter, in which all components of the sensitivity tensor of the 3-axis Hall sensor are precisely determined and stored in the teslameter’s memory.

Some additional measures significantly increase the instrument stability, reduce the long-term drift in the electronics and Hall probe, and reduce the required instrument and Hall probe re-calibration rate.

The teslameter performances allow a very accurate measurement of the homogeneous and nonhomogeneous magnetic flux densities in research and development laboratories. Typical applications include: quality control and monitoring of permanent magnets and magnet systems (generators, motors); development of magnet systems and process control; and magnetic field mapping.

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SENIS
magnetic & current measurement

LIGHT SOURCES

SESAME boosts electrons to 800 MeV

A key accelerator at the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) facility in Allan, Jordan, has reached its top energy recently. After having successfully stored electrons in the Booster-Synchrotron in July, the SESAME team succeeded in accelerating electrons to their final energy of 800 MeV on 3 September.

The SESAME injector consists of a 20-MeV microtron and the 800-MeV booster synchrotron. Electrons are produced in the microtron and accelerated to 20 MeV before being transferred to the booster synchrotron. The microtron became operational in 2012 and installation of the booster was completed in 2013. Storage in the booster synchrotron of the electrons from the microtron in July saw them circulating several millions of turns at their initial energy of 20 MeV. Now, the electrons have been accelerated to 800 MeV, which is the top energy of the booster.

Bringing SESAME’s booster synchhrotron successfully to full operation is of particular significance because this is the first high-energy accelerator in the Middle East. The achievement is thanks to a team of young scientists and technicians from the region, for whom accelerator technology is a new field. They were led in this work by Erhard Huttel, the technical director of SESAME.

The SESAME building at Allan, 35 km north-west of Amman. (Image credit: SESAME.)

This success will lead towards the final goal, which is to make SESAME the first operational synchrotron light source in the Middle East, and to confirm its position as a truly international research centre. When the facility starts operations – probably in early 2016 – scientists from the Middle East and neighbouring countries, in collaboration with the international synchrotron light community, will have the possibility to perform world-class scientific studies. They will be able, for example, to determine the structure of a virus to improve medical remedies, gain insight into the interior and the three-dimensional microstructure of objects such as materials that are of interest to cultural heritage and archaeology, and investigate magnetization processes that are highly relevant for magnetic data storage.

● SESAME has had links with CERN from the start. Following a suggestion by Gus Voss (DESY) and Herman Winick (SLAC), Sergio Fubini (CERN and University of Turin, who chaired a Middle East Scientific Co-operation group) and Herwig Schopper (director-general of CERN in the years 1981–1987) persuaded the German government to donate the components of the then soon-to-be-dismantled Berlin synchrotron BESSY I for use at SESAME (CERN Courier September 2014 p46). At a meeting at UNESCO in 1999, an interim council was established with Schopper as president. SESAME is modelled closely on CERN, and shares CERN’s original aims and its governance structure. The current president of SESAME Council is Chris Llewellyn Smith, former director-general of CERN (1994–1998).

First industry magnet for SESAME storage ring

In July, a sextupole corrector magnet for the SESAME storage ring arrived at CERN for tests and magnetic measurements. It is the first unit out of 32 to be delivered by the CNE Technology Center, a Cypriot-based company under the EU-CERN CESSAMag project.

In November last year, a pre-series sextupole for SESAME was prepared at CERN, to check the design and to tune the manufacturing procedures before placing the order for the series production to industry. The contracts were then awarded to a Cypriot and a Pakistani company. The CERN team has been working closely with both companies to transfer the knowledge from CERN that is needed to build these magnets.

The first unit out of the 32 magnets from Cyprus has already arrived at CERN, where measurements carried out together with SESAME colleagues reveal a precise assembly, resulting in magnetic-field homogeneity of 0.2‰ within two thirds of the aperture. The unit is also mechanically, electrically and hydraulically sound, assuring good reliability during operation. This makes the magnet appropriate for the lattice of a synchrotron light source such as SESAME, and it is a major step in preparing the SESAME storage ring.

The Cypriot company has, in parallel, assembled more than 50% of the components needed for the rest of the contract. The first magnet from Pakistan is currently being assembled.

● CESSAMag is the FP7 project “CERN-EC Support for SESAME Magnets”, which aims at supporting the construction of the SESAME light source.

Sommaire en français

ASTROPARTICLE PHYSICS

AMS finds evidence of new source of positrons in cosmic rays

The Alpha Magnetic Spectrometer (AMS) on the International Space Station (ISS) has new results on energetic cosmic-ray electrons and positrons, based on analysis of the first 41 billion events. These results provide a deeper understanding of the nature of high-energy cosmic rays and could shed more light on the existence of dark matter.

Of the 41×10^9 primary cosmic-ray events analysed so far, 10.9×10^6 have been identified as electrons and positrons. Using these, the AMS collaboration has measured the positron fraction – the ratio of the number of positrons to the combined number of positrons and electrons – in the energy range 0.5–500 GeV (Accardo *et al*. 2014). When compared with the expectation based on the production of positrons in standard cosmic-ray collisions, the results show that the fraction starts to increase rapidly at 8 GeV (figure 1). This indicates the existence of a new source of positrons.

AMS has also accurately determined the exact rate at which the positron fraction increases with energy, and for the first time observed the fraction reach a maximum (figure 2). The data show that the rate of change of the positron fraction crosses zero at 275±32 GeV – indicating the energy at which the fraction reaches its maximum (Aguilar *et al*. 2014). The results also show that the excess of the positron fraction is isotropic within 3%, suggesting strongly that the energetic positrons might not be coming from a preferred direction in space. Moreover, the fraction shows no observable sharp structures.

AMS has also precisely determined the flux of electrons (figure 3) as well as for positrons (figure 4). These measurements reveal that the fluxes differ significantly in both their magnitude and energy dependence. The positron flux first increases (0.5–10 GeV) and then levels out (10–30 GeV), before increasing again (30–200 GeV). Above 200 GeV, it has a tendency to decrease. This is totally different from the scaled electron flux. The results show that neither flux can be described with a constant spectral index (figure 4, bottom). In particular, between 20 and 200 GeV, the rate of change of the positron flux is surprisingly higher than the rate for electrons. This is important proof that the excess seen in the positron fraction is from a relative excess of high-energy positrons, and not the loss of high-energy electrons.

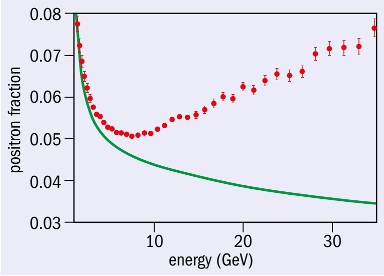


Fig. 1. The positron fraction measured by AMS (red circles) compared with the expectation from ordinary cosmic-ray collisions. The rapid rise at 8 GeV indicates a new source of positrons.

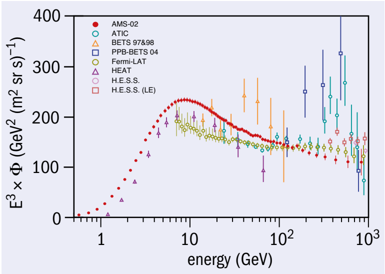


Fig. 3. AMS measurement of the electron flux (red dots), compared with results from other experiments.

Different models for dark matter predict different behaviours for the positron-fraction excess. The new results from AMS put much tighter constraints on the validity of these models. The results are consistent with a dark-matter particle (neutralino) of mass of the order of 1 TeV. To determine if the observed new phenomenon is indeed from dark matter or from astrophysical sources such as pulsars, AMS is now making measurements to determine the rate at which the positron fraction decreases beyond the turning point, as well as to determine the antiproton fraction.

- Fifteen countries from Europe, Asia and America participated in the construction of AMS: Finland, France, Germany, the Netherlands, Italy, Portugal, Spain, Switzerland, Turkey, China, Korea, Taiwan, Russia, Mexico and the US. AMS was launched by NASA to the ISS on 16 May 2011.

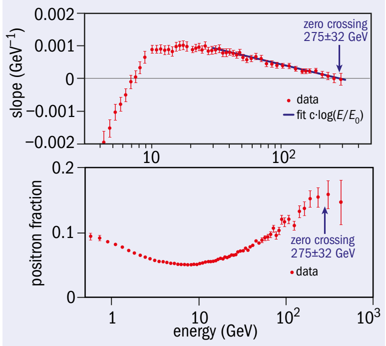


Fig. 2. Top: the slope of positron fraction measured by AMS (red circles) and a straight line fit at the highest energies (blue line). Bottom: the measured positron fraction as a function of energy.

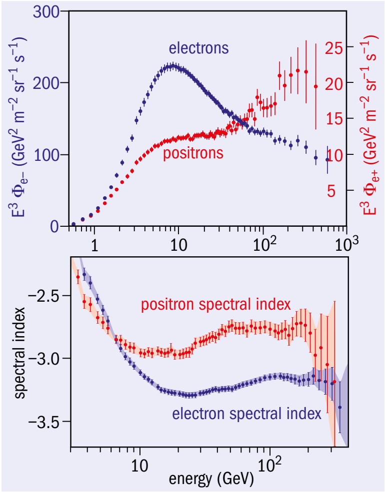


Fig. 4. Top: AMS measurements of the electron flux (left scale) and the positron flux (right scale). Bottom: the spectral indices of the fluxes as functions of energy.

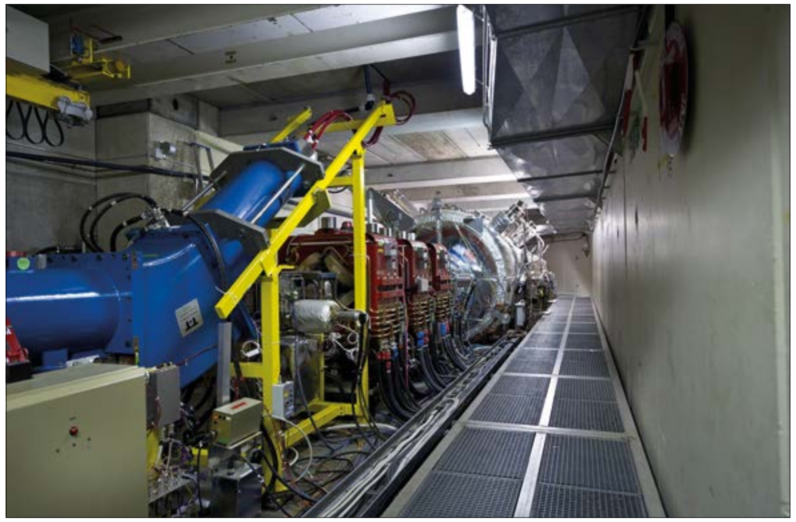
Data are transmitted to the AMS Payload Operations Control Center, located at CERN.

Further reading

L Accardo *et al.* AMS Collaboration 2014 *Phys. Rev. Lett.* **113** 121101.
M Aguilar *et al.* AMS Collaboration 2014 *Phys. Rev. Lett.* **113** 121102.

CERN

Beams back at the Antiproton Decelerator



Antiprotons returned to the Antiproton Decelerator at the beginning of August. (Image credit: CERN-EX-1105131-13.)

Antiprotons returned to CERN's Antiproton Decelerator (AD) on 5 August and experiments have been receiving beams since mid-September, following an intensive consolidation programme during the first long shutdown (LS1) of the accelerator complex. Work has involved some of the most vital parts of the decelerator, such as the target area, the ring magnets, the stochastic cooling system, vacuum system, control system and various aspects of the instrumentation.

The AD uses antiprotons produced by directing the 26 GeV/*c* proton beam extracted from the Proton Synchrotron (PS) onto an iridium target. In the AD target area, these antiprotons are produced, collimated and momentum-selected to prepare for their injection into the decelerator, where their energy is reduced to the level requested by the experiments.

Although the AD started operations for the antimatter programme in 2000, it reuses almost entirely the components and configuration of an older machine – the Antiproton Collector (AC) – built in 1986. When the AC was designed, the target area needed a high repetition rate of one proton pulse every 2.4 s. Now, the AD's repetition rate is just 90 s, so components wear out more slowly. Nevertheless, at the beginning of LS1 a problem was found in the transmission line for the electric pulse that goes into the magnetic horn – the device invented by Nobel laureate Simon van der Meer that focusses the diverging antiproton beam. As well as this, after 20 years of operation, the magnetic horn itself had been severely damaged by electric arcs.

The LS1 programme, involving teams of specialists from CERN's technology, engineering and beam departments, replaced the transmission line and magnetic horn. The horn assembly is composed of three main parts: the horn itself, which consists of two concentric aluminium conductors, a 6-m-long aluminium strip line that carries the current from the generators to the horn, and a movable clamping system that ensures the electrical continuity between the horn and the stripline. Given the critical situation, the teams decided to replace all three components. They had only six months to re-assemble and test spares more than 20 years old, and to construct additional pieces. The consolidated system was assembled and tested on the surface before being installed underground in the target area.

While repairing the damaged components, the teams also examined the 20-tonne dipole magnets. One magnet was removed from the ring and opened up for the first time in 30 years. The coils were in good condition, but the shimming that holds the coils had been completely transformed into dust and needed repair.

The consolidation work on the AD was completed at the end of July, and the first beam was sent to the target on 5 August. Debugging, adjustments and fine tuning were then carried out to deliver antiproton beams to the experiments in mid-September. The work also included the installation of a brand-new beam line for the new Baryon Antibaryon Symmetry Experiment (BASE) experiment, which aims to take ultra-high-precision measurements of the antiproton magnetic moment (*CERN Courier* July/August 2014 p8). The programme has been prompted by the start of the Extra Low ENergy Antiproton ring (ELENA) project. Planned to be operational in 2017, ELENA will allow further deceleration, together with beam cooling of the antiprotons, resulting in an increased number of particles trapped downstream in the experiments.

Elsewhere at CERN, 12 September saw the Super Proton Synchrotron accelerate its first proton beam after LS1. At the LHC, work continues towards the restart. Of the eight sectors, sector 6-7 is the first to have been cooled down to its nominal temperature of 1.9 K. The first powering tests began there on 15 September. Five other sectors were in the process of being cooled during September, with the seventh on track to begin its cool down in early October. All sectors are first cooled to 20 K for the copper-stabilizer continuity measurement tests, which allow the performance of the circuits to be checked when they are not superconducting. The finish line is in sight for the LHC's restart in spring 2015.

One of the 24 main bending magnets in the AD ring. Here the lower coil is being lifted out of the lower half of the magnet yoke. (Image credit: Tommy Eriksson.)

LHC EXPERIMENTS

The promise of boosted topologies

While analyses are progressing to ascertain the consistency of the new boson discovered at the LHC with the Standard Model Higgs boson (H), the LHC collaborations continue to develop tools in their search for new physics that could lead beyond the Standard Model, and cast light on the many fundamental open questions that remain.

The LHC can now reach energies far above those needed to produce Standard Model particles such as W/Z/H bosons and top quarks. The extra energy results in massive final-state particles with high Lorentz boosts ($\gamma > 2$), i.e. "boosted topologies". Searches for new physics at the LHC often involve these boosted topologies, so it is necessary to extend the particle-physicists' toolkit to handle these cases. This includes investigation of non-isolated leptons, overlapping jets that contain "substructure" from the decay of the Standard Model particles, and bottom-quark jets that merge with nearby jets. Classical techniques fail to capture these challenging topologies, so new techniques must be developed to ensure the broadest sensitivity to new physics.

To analyse these topologies, much theoretical and experimental understanding has been accomplished during the past few years. Now the CMS collaboration has published searches involving boosted W/Z/H bosons and top quarks, using a large suite of tools to improve sensitivity by factors of around 10 over classical techniques. This suite of tools includes identifying leptons within boosted top-quark decays, identifying W and top-mass peaks inside merged jets, and identifying bottom-quark jets embedded within merged jets.

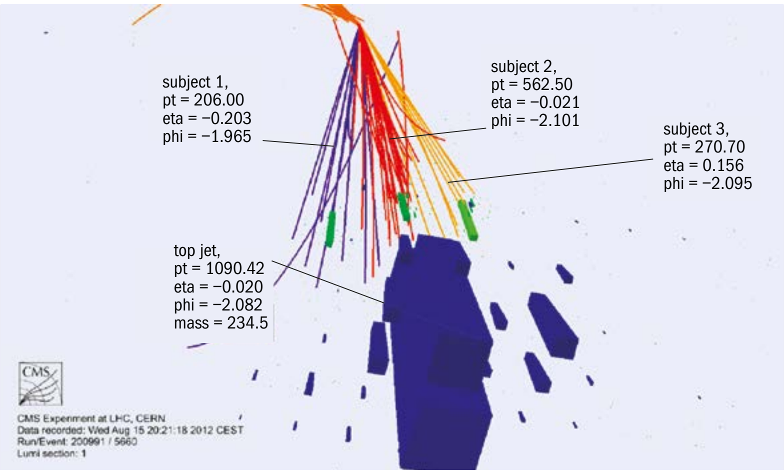


Fig. 1: Boosted top quark.

Figure 1 shows an event display of a boosted top-quark candidate recorded by CMS in 2012. The energy deposits in the calorimeters are shown as blue and green boxes, while the tracks are indicated with coloured lines. This jet has been found to exhibit a three-prong substructure that has been resolved with dedicated algorithms.

In the first analyses using these techniques, large improvements have been observed in high-mass sensitivity. Figure 2 shows the observed limits for a $t\bar{t}$ resonance search with and without using these boosted techniques. The blue line highlights the sensitivity of such a search using traditional, non-boosted techniques. The red and orange lines highlight the sensitivity using boosted techniques. At a mass, m, of 2 TeV, the sensitivity of the boosted techniques is 10 times better than traditional techniques.

This is just one of many analyses in which these new techniques have been deployed (see further reading below), and with a firm grasp on the relevant physics gained from experience in the LHC's Run 1, CMS is now poised to apply the techniques broadly in Run 2.

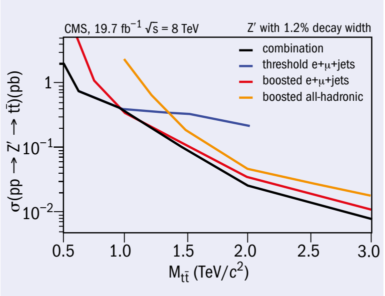


Fig. 2. Sensitivity of a search for $t\bar{t}$ resonances with traditional (blue) and boosted (red and orange) techniques. The boosted techniques improve over the traditional techniques by a factor of 10 at 2 TeV.

Further reading

Searches for $t\bar{t}$ resonances: 2013 *Phys. Rev. Lett.* **111** 211804.

Searches for tb resonances: http://cds.cern.ch/record/1751504?ln=en.

Searches for vector-like quarks: 2014 *Phys. Rev. Lett.* **112** 171801 and *Phys. Lett. B* **729** 149; http://cds.cern.ch/record/1599436?ln=en; http://cds.cern.ch/record/1752557?ln=en; https://cds.cern.ch/record/1706121?ln=en.

Searches for stop quarks: http://cds.cern.ch/record/1635353.

Searches for VV resonances: 2014 JHEP08(2014)173 and JHEP08(2014)174.

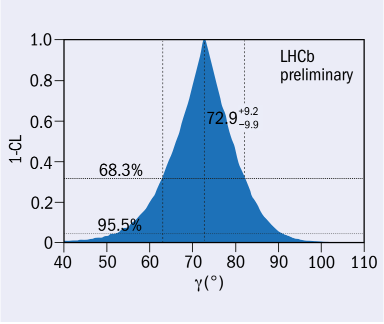
LHCb result tightens precision on angle γ

For the first time in a single experiment, LHCb has achieved a precision of better than 10° in measuring the angle γ that is linked to CP violation in the Standard Model.

In the celebrated Cabibbo–Kobayashi–Maskawa (CKM) picture of three generations of quarks, the parameters that describe CP violation are constrained by one of the six triangles linked to the unitarity of the 3 × 3 quark-mixing matrix (*CERN Courier* December 2012 p15). The angles of this triangle are denoted α, β and γ, and of these it is γ that is the least precisely known. The precise measurement of γ is one of the most important goals of the LHCb experiment because it provides a powerful method to probe for the effects of new physics.

At the 8th International Workshop on the CKM Unitarity Triangle, CKM2014, which was held in Vienna recently, the LHCb collaboration presented a combination of measurements of the angle γ that yields the most precise determination so far from a single experiment. Using the full data set of $3\,\text{fb}^{-1}$ integrated luminosity from the LHC running in 2011 and 2012, the collaboration has combined results on all its current measurements of "tree-level" decays. In particular, in combining results on $B_{(s)} \to D_{(s)}K^{(*)}$ decays – the "robust" combination, in which a B or B_s meson decays into a D or D_s meson, respectively, and a kaon – the researchers find a best-fit value of $\gamma = (72.9^{+9.2}_{-9.9})^\circ$ at the 68.3% confidence-level interval (see figure). The full combination presented at CKM2014 includes a large set of observables in $B \to D\pi$ decays that are also sensitive to γ, but to a lesser extent than the $B \to DK$-like decays (LHCb Collaboration 2014).

Signs of new physics are not expected to show up in these tree-level decays, but they set a precise base for comparison with measurements where the observation of effects of new physics is possible. Moreover, even before taking into account data from LHC Run 2 from spring 2015, LHCb will be able to improve this result further using the data that has already been collected, because there are important analyses that are still to be completed.



The confidence level (CL) curve for γ from the combinations involving decays of the kind $B_{(s)} \to D_{(s)}K^{(*)}$.

Further reading

LHCb Collaboration 2014 LHCb-CONF-2014-004.

Producing charm with light

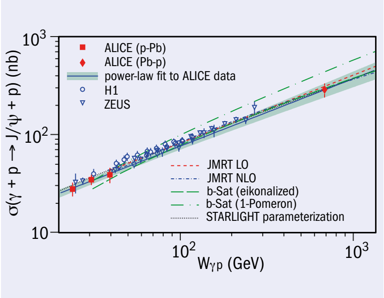
The electric charge of lead ions, when accelerated to ultra-relativistic velocities, is the source of an intense flux of high-energy quasi-real photons. Ultra-peripheral collisions – the interaction of a photon with a target at impact parameters larger than the sum of the radii of the incoming particles, where hadronic interactions are suppressed – provide a clean tool to study photon-induced production processes at the LHC (*CERN Courier* November 2012 p9).

ALICE has performed the first measurement of exclusive photoproduction of J/ψ mesons off protons in proton–lead collisions at the LHC, using data collected in early 2013 (Abelev *et al*. 2014). These data cover a range of photon–proton centre-of-mass energies that were not accessible previously. Such interactions have been studied at the electron–proton collider HERA, and are proposed as a key measurement at a future electron–hadron collider, to probe the gluon distribution in the proton.

The J/ψ mesons were reconstructed from their decay into a $\mu^+\mu^-$ pair, where the muons were measured by the ALICE muon spectrometer. Requiring no other activity to be present in the detector enforced the exclusivity condition. Around the middle of the data-taking period, the beam direction was inverted, allowing ALICE to take data first when protons, and later lead ions, were travelling towards the muon spectrometer, providing proton–lead and lead–proton collisions, respectively. The rapidity of the J/ψ, measured with respect to the direction of the proton beam, determines the photon–proton centre of mass energy ($W_{\gamma p}$). In lead–proton collisions, the acceptance of ALICE corresponds to values of $W_{\gamma p}$ more than twice as large as was reached at HERA by the H1 and ZEUS experiments, while the proton–lead collisions correspond to values of $W_{\gamma p}$ studied previously at HERA and in fixed-target experiments.

According to leading-order calculations in perturbative QCD, this process depends on the square of the gluon distribution in the proton evaluated at a scale close to the J/ψ mass ($M_{J/\psi}$) and at x-Bjorken $x = (M_{J/\psi}/W_{\gamma p})^2$. The range in x covered by ALICE therefore extends from about 2×10^{-2} (proton–lead) to 2×10^{-5} (lead–proton). It is then possible to study the evolution of the gluon density in the proton at a perturbative scale along three orders of magnitude in x, and probe into the region where the gluon density increases, possibly leading to a saturation regime, in which the proton wave-function is described by a coherent colour field created by the many overlapping gluons.

The cross-section measured by ALICE (see figure) has been compared with the predictions of models based on (i) perturbative QCD calculations at leading order (ii) and including the main next-to-leading order contributions, (iii) a saturation prescription including impact parameter dependence and (iv) a parameterization of HERA and fixed-target results. All models were fitted to HERA measurements, and are able to describe the current ALICE data.



The cross-section measured by ALICE for exclusive photoproduction of J/ψ mesons off protons in proton–lead collisions.

ALICE has found that a power law in $W_{\gamma p}$ can describe the measured cross-section. The value of the power-law exponent is compatible with those found by H1 and by ZEUS. Therefore, no deviation from the same power law is observed up to about 700 GeV, or in a leading-order perturbative QCD context, down to $x = 2 \times 10^{-5}$, extending by a factor five the maximum x value explored previously.

In conclusion, within the current precision, ALICE has observed no change of regime with respect to what was measured at HERA. Data to be collected during LHC Run 2 at beam energies increased by a factor of two will allow ALICE both to improve the precision of the measurement and to access larger values of $W_{\gamma p}$. Lowering the x value to values never reached before will open new opportunities to search for saturation phenomena.

Further reading

B B Abelev *et al.* (ALICE Collaboration) 2014 arXiv:1406.7819 [nucl-ex].

CERNCOURIER
VOLUME 54 NUMBER 9 NOVEMBER 2014
IOP Publishing

ATLAS observes and measures H → WW

The WW final state was a key component in the discovery of the Higgs boson with a mass of around 125 GeV, and remains essential for the ongoing measurements of the particle's properties. Now, the ATLAS collaboration has firmly established the existence of this process, observing an excess consistent with H → WW, with a significance of 6.1σ compared with the background-only hypothesis (ATLAS Collaboration 2014a). In addition, ATLAS has measured the inclusive signal strength with a precision of about 20%, thereby taking the next step towards a precision measurement of the strength of the HWW interaction.

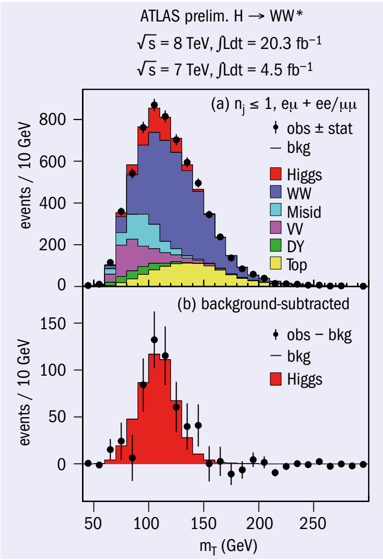
The new results are based on the combined 7-and-8-TeV ATLAS datasets from Run 1 of the LHC, and a total integrated luminosity of 25 fb^{-1}. The analysis selects Higgs boson candidate data from events that have two charged leptons: electrons or muons. Improvements since the previous result – including likelihood-based electron identification and missing transverse-energy reconstruction that is more robust to pile-up – have allowed ATLAS to lower kinematic thresholds and so increase the signal acceptance.

The main backgrounds are from WW and top-quark pair production, with important contributions from Drell–Yan, Wγ*, and inclusive W production with a second, "fake" lepton produced by a jet. Categorizing the events by the number of jets separates the signal from the otherwise dominant background of top-quark pair production, and distinguishes between the vector-boson-fusion (VBF) and gluon–gluon fusion (ggF) production modes. Within each category, subdividing the signal regions by the flavours and kinematic properties of the lepton pair enhances the sensitivity by further separating signal from background, and separating different background processes from each other.

The number of signal events is determined by a fit to the distribution of an event property to separate signal and backgrounds still further. For the ggF categories, the dilepton "transverse mass", m_T, is used. The figure shows the distribution of m_T for the 0 and 1 jet categories, compared with the summed signal and background expectation. It demonstrates the good agreement between the prediction, including the Higgs boson signal, and the observed data. For the VBF categories, a fit is made to the output of a boosted decision tree (BDT) – another new development since the previous ATLAS analysis. The BDT is trained using variables that are sensitive to the Higgs boson decay topology, as well as to the distinctive VBF signature of two energetic, well-separated jets.

At 125.36 GeV – the value of the Higgs boson mass measured by ATLAS from the γγ and ZZ* → 4l channels (ATLAS Collaboration 2014b) – the expected significance for an excess in H → WW is 5.8σ, and a significance of 6.1σ is observed. The measured signal strength, defined as the ratio of the measured H → WW cross-section to the Standard Model prediction, is $\mu = 1.08^{+0.16}_{-0.15}$ (statistical) $^{+0.16}_{-0.13}$ (systematic).

Evidence for VBF production can be seen also from analysis of the categories. The ratio of the VBF and ggF signal strengths does not assume a value for the H → WW branching ratio or the ggF cross-section. A nonzero ratio indicates the presence of the VBF production mode. The result is $\mu_{VBF}/\mu_{ggF} = 1.25^{+0.79}_{-0.52}$, which corresponds to a significance of 3.2σ, compared with 2.7σ expected for the Standard Model.



The distribution of transverse mass, m_T, for the event categories with 0 or 1 jet compared with the summed signal and background expectation (top), and with background subtracted.

This analysis represents a significant advance in the understanding of the signal and background processes in the challenging dilepton WW channel. It establishes the observation of this decay, and the signal-strength measurement is, at present, the most precise obtained in a single Higgs boson decay channel. The results are consistent with the predictions for a Standard Model Higgs boson, but they remain limited by the statistical uncertainty, pointing to the potential of future measurements with data from Run 2 at the LHC.

- **Further reading**

ATLAS Collaboration 2014a ATLAS-CONF-2014-060.
ATLAS Collaboration 2014b *Phys. Rev. D* **90** 052004.

FERMILAB

Neutrinos cast light on coherent pion production

Experiments at Fermilab are advancing an intriguing story that began three decades ago, with investigations of coherent neutrino interactions that produce pions yet leave the target nucleus unscathed.

When neutrinos scatter coherently off an entire nucleus, the exchange of a Z^0 or $W^\pm$ boson can lead to the production of a pion with the same charge. The first observations of such interactions came in the early 1980s from the Aachen–Padova experiment at CERN's Proton Synchrotron, followed by an analysis of earlier data from Gargamelle. A handful of other experiments at CERN, Fermilab and Serpukhov provided additional measurements before the end of the 1990s. These experiments determined interaction cross-sections for high-energy neutrinos (5–100 GeV), which were in good agreement with the model of Deiter Rein and Lalit Sehgal of Aachen. Published shortly after the first measurements were made, their model is still used in some Monte Carlo simulations.

More recently, the SciBooNE and K2K collaborations attempted to measure the coherent production of charged pions at lower neutrino energies (less than 2 GeV). However, they found no evidence of the interaction, and published upper limits below Rein and Sehgal's original estimation. These results, together with recent observations of coherent production of neutral pions by the MiniBooNE and NOMAD collaborations, have now motivated renewed interest and new models of coherent pion production.

In the NuMI beamline at Fermilab – which has a peak energy of 3.5 GeV and energies beyond 20 GeV – coherent charged-current pion production accounts for only 1% of all of the ways that a neutrino can interact. Nevertheless, both the ArgoNeuT and MINERvA collaborations have now successfully measured the cross-sections for charged-current pion production by recording the interactions of neutrinos and antineutrinos.

ArgoNeuT uses a liquid-argon time-projection chamber (TPC), and has results for coherent interactions of antineutrinos and neutrinos at mean energies of 3.6 GeV and 9.6 GeV, respectively (Acciarri *et al*. 2014). A very limited exposure produced only 30 candidates for coherent interactions of antineutrinos and 24 for neutrinos (figure 1), but a measurement was possible thanks to the high resolution and precise calorimetry achieved by the TPC. It is the first time that this interaction has been measured in a liquid-argon detector. ArgoNeuT's results agree with the state-of-the-art theoretical predictions (figure 2), but its small detector size (<0.5 tonnes) limits the precision of the measurements.

MINERvA uses a fine-grained scintillator tracker to fully reconstruct and select the coherent interactions in a model-independent analysis. With 770 antineutrino and 1628 neutrino candidates, this experiment measured the cross-section as a function of incident antineutrino and neutrino energy (figure 2). The measured spectrum and angle of the coherently produced pions are not consistent with models used by oscillation experiments (Higuera *et al*. 2014), and they will be used to correct those models.

The techniques developed during both the ArgoNeuT and MINERvA analyses will be used by larger liquid-argon experiments, such as MicroBooNE, that are part of the new short-baseline neutrino programme at Fermilab. While these experiments will focus on neutrino oscillations and the search for new physics, they will also provide more insight into coherent pion production.

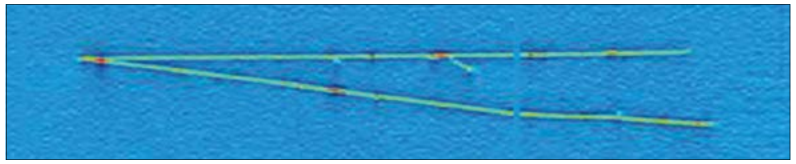


Fig. 1. ArgoNeuT's event display of a coherent pion-production candidate caused by a muon neutrino. The track at the top corresponds to a muon, the one below to a charged pion.

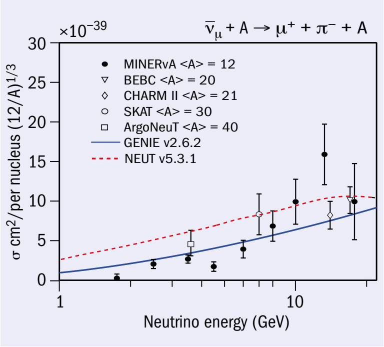


Fig. 2. Measurements by ArgoNeuT and MINERvA of cross-sections for coherent π^- production as a function of incident antineutrino energy. (The experiments find similar results for π^+ production by neutrinos.)

- **Further reading**

R Acciarri *et al.* ArgoNeuT Collaboration 2014 arXiv:1408.0598 [hep-ex]; submitted for publication.
A Higuera *et al.* MINERvA Collaboration 2014 arXiv:1409.3835 [hep-ex]; submitted to *Phys. Rev. Lett.*
S Boyd *et al.* 2009 *AIP Conf. Proc.* **1189** 60.

ACCELERATORS

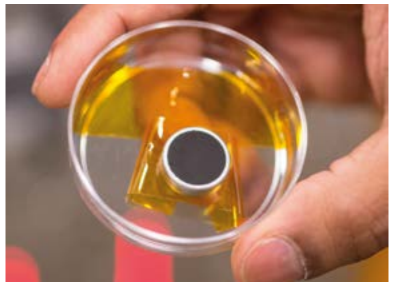
Nanotube cathode promises intense electron beam

It looks like a small black button, but in tests at Fermilab's High-Brightness Electron Source Lab it has produced beam currents 10^3–10^6 times greater than those generated with a large laser system. Designed by a collaboration led by RadiaBeam Technologies, a California-based technology firm actively involved in accelerator R&D, this electron source is based on a carbon-nanotube cathode only 15 mm across.

Carbon-nanotube cathodes have already been studied extensively in university research labs, but Fermilab is the first accelerator facility to test the technology within a full-scale setting. With its capability and expertise for handling intense electron beams, it is one of relatively few labs that can support a project like this.

Traditionally, accelerator scientists use lasers to strike cathodes to eject electrons through photoemission. With the nanotube cathode, a strong electric field pulls streams of electrons off the surface of the cathode though field emission. There were early concerns that the strong electric fields would cause the cathode to self-destruct. However, one of the first discoveries that the team made when it began testing in May was that the cathode did not explode. Instead, the exceptional strength of carbon nanotubes prevents the cathode from being destroyed. The team used around 22 MV/m to produce the target current of more than 350 mA.

The technology has extensive potential applications in medical equipment, for example, since an electron beam is a critical component in generating X-rays.



The dark carbon-nanotube-coated area of the new field-emission cathode. (Image credit: Fermilab.)

- A Department of Energy Small Business Innovation Research grant funds the RadiaBeam-Fermilab-Northern Illinois University collaboration.

News

DESIGN STUDY

An excellent start for the FCC collaboration

On 9–10 September, representatives of about 70 institutes worldwide met at CERN to establish the International Collaboration Board (ICB) at the Future Circular Collider (FCC) study. The study covers the designs of a 100-TeV hadron collider and a high-luminosity lepton collider, the associated detectors and physics studies, and a lepton–hadron collider option. These generic and mostly site-independent studies will be complemented by a civil-engineering study for the Geneva area, requested in the context of the European Strategy for Particle Physics. The large attendance at the preparatory ICB meeting testifies to the attractiveness of the FCC approach, which aims to explore the energy scale of tens of teraelectronvolts.

Opening the meeting, CERN's director-general, Rolf Heuer, outlined the planned organizational structure of the FCC study, which will operate as an international collaboration under the auspices of the European Committee for Future Accelerators. As the central overseeing body, the ICB will comprise representatives from all participating institutes. The proposed structure was endorsed by all attendees. Prior to the meeting, more than 20 institutes had already signed the FCC Memorandum of Understanding and become official members of the FCC collaboration. Several more institutes joined during the event. The institutes with confirmed participation endorsed Leonid Rivkin of Ecole polytechnique fédérale de Lausanne and PSI – a widely recognized accelerator expert – as interim chair of the ICB.

Delegates were impressed by the progress made on this design since the FCC kick-off event at the University of Geneva in February (*CERN Courier* April 2014 p16). The presentations reviewed the status of ongoing work for the study formation, accelerator designs, technologies, infrastructure, and experiments. They highlighted, in particular, the anticipated impact that the study should have on many different types of technologies, such as advanced cryogenics, new production procedures for RF cavities, novel surface treatments of vacuum-chamber materials, lower-cost and more compact high-field magnets. Representatives of most of the institutes participating also described their respective expertise and proposed contributions.

In parallel to the progress being made in forming the international FCC collaboration, a design-study proposal focused on the FCC hadron collider has been submitted to the European Commission in the context of the Horizon 2020 programme. The main technological R&D areas have been identified, and a work plan is being established with potential partners.

The coming months will see enhanced design activities aimed at convergence and down-selection between different alternative options for the overall collider layouts and beam parameters. The next major milestone for the FCC collaboration will be the first large annual workshop, which will take place in Washington DC on 23–27 March 2015.

Sciencewatch

Compiled by John Swain, Northeastern University

Bad news for artificial sweeteners

Sugar substitutes might affect bacteria in the gut in such a way as to exacerbate metabolic disorders. Eran Elinav of the Weizmann Institute of Science in Rehovot and colleagues have found that mice given water sweetened with saccharin develop glucose intolerance, whereas mice given water sweetened with glucose do not. However, glucose intolerance did not appear in mice that had their gut bacteria killed by antibiotics, while fecal transplants from glucose-intolerant mice induced the same intolerance in normal ones. This showed that the saccharin had made the mouse microbiome unhealthy, and the researchers obtained similar results with other artificial sweeteners, sucralose and aspartame.


It seems that sugar might be best after all. (Image credit: Marazem/Dreamstime.com.)

In a small trial, seven healthy, fit humans who did not use artificial sweeteners were given the maximum daily allowance of artificial sweeteners for a week. Four out of the seven developed glucose intolerance, with a corresponding shift in gut flora. It is interesting that the increase in the use of artificial sweeteners coincides with the increase in diabetes and obesity. Perhaps the best advice is to stick with sugar, just eat less.

- **Further reading**

J Suez *et al.* 2014 *Nature* **513** 290.

The origins of caffeine

Many people probably owe a significant part of their productivity to caffeine, from coffee, tea, or chocolate. So does this caffeine share a common origin? Victor Albert of the University of Buffalo in New York and colleagues sequenced the genome of robusta coffee, *Coffea canephora*, from which about a third of the world's coffee comes. They found that most of the genes unique to the plant are related to caffeine production, so a common caffeine-bearing ancestor to the three main sources appears unlikely. It seems that nature came up with caffeine at least twice.

- **Further reading**

V A Albert *et al.* 2014 *Science* **345** 1181.

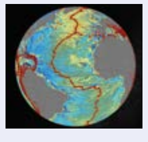
Possible origin for biomolecular chirality

One of the most striking features of living matter is that sugars all seem to be right-handed and amino acids left-handed. One resolution to the puzzle is the Vester-Ulbricht hypothesis, which is that chiral β-decay electrons might preferentially break down differently-handed molecules, although laboratory tests have been largely ambiguous or negative. Now, J M Dreiling and T J Gray of the University of Nebraska in Lincoln have demonstrated such a preferential dissociation of chiral molecules by chiral electrons. They used a 30% longitudinally polarized electron beam and bromocamphor – which comes in left- and right-handed forms – in the vapour phase. Looking at sub-electronvolt collisions, they find an energy-dependent asymmetry of about three parts in 10,000, giving support to one of the most promising theories of the origin of biomolecular chirality.

- **Further reading**

J M Dreiling and T J Grey 2014 *Phys. Rev. Lett.* **113** 118103.

Gravity mapping the sea floor



Using radar altimetry data from two satellites – CryoSat-2 from the European Space Agency and Jason-1 from NASA and the French Centre National d'Etudes Spatiales – David Sandwell of the Scripps Oceanographic Institute in La Jolla and colleagues have made the most detailed maps of the sea floor to date. Once effects of time-varying phenomena such as waves are removed, tiny changes in sea level reflect the gravitational tug of the mass below. The new maps show features rising less than about 2 km from the sea floor – the previous mapping limit – and have revealed more than 20,000 previously undiscovered seamounts 1.5–2 km high.

- **Further reading**

D T Sandwell *et al.* 2014 *Science* **346** 65.

Above: The gravity-based sea-floor map basin reveals new details on earthquakes (red dots), sea-floor spreading ridges, and faults. (Image credit: David Sandwell, Scripps Institution of Oceanography.)

A condensed-matter Higgs

It is well known that superconductors display a mechanism similar to the Brout–Englert–Higgs mechanism in the Standard Model, and now a condensed-matter analogue of the Higgs boson itself has been found. Ryusuke Matsunaga of the University of Tokyo and colleagues showed that strong terahertz light can produce oscillations in the superconducting order parameter in NbN at twice the frequency of the driving light. These oscillations, which correspond to a collective precession of Philip Anderson's pseudospins, are the analogue of the Standard Model Higgs boson. They are detected via a large third-harmonic signal, which is generated from a quadratic coupling between the Higgs mode and the exciting field. The work also points to nonlinear quantum optics in superconductors, and could help in understanding exotic superconductors.

- **Further reading**

R Matsunaga *et al.* 2014 *Science* **345** 1145.

News on neurons

Signal propagation in neurons has long been modelled as an electrochemical pulse, or "action potential", according to the textbook Hodgkin–Huxley model. Now, Thomas Heimburg and colleagues at the Niels Bohr Institute in Copenhagen have shown that, contrary to the model's prediction of a refractory period following a pulse, two colliding pulses do not annihilate but rather pass through each other. This is the case both in myelinated nerves from earthworms and unmyelinated ones from lobsters, and the observations contradict claims of annihilation made in the 1940s but not reproduced since. The results are consistent with soliton propagation in which nerve pulses are electromechanical waves, with a mechanical component allowing propagation after collision.

- **Further reading**

A Gonzalez Perez *et al.* 2014 *Phys. Rev.* X **4** 031407.

Astrowatch

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

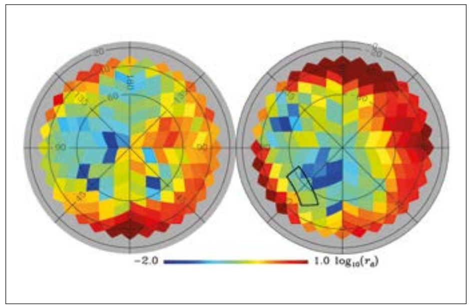
Planck confirms doubts on BICEP2 results

The Planck collaboration has published an all-sky map of the polarized thermal emission of dust grains in the Milky Way. It shows that the field used by the experiment for Background Imaging of Cosmic Extragalactic Polarization (BICEP2) to measure B-mode polarization of the cosmic microwave background (CMB) is contaminated significantly by galactic-dust emission. The B-mode signal detected by the BICEP2 collaboration would, therefore, at least in part, be due to dust, and not to the claimed primordial gravitational waves giving evidence for inflation (*CERN Courier* May 2014 p13).

The announcement on 17 March 2014 of the detection of swirling B-mode polarization in the CMB by the BICEP2 collaboration took the scientific community by surprise. This particular type of polarization is not spectacular by itself, but by the interpretation that it is due to primordial space–time metric fluctuations "frozen-in" by inflation and then amplified to degree-scale gravitational waves. The BICEP2 results were therefore seen as evidence for inflation, and for a quantum-gravitational process at an energy approaching the Planck scale, where all of the fundamental forces are thought to be unified.

Soon after the initial excitement about this extraordinary result, suspicion arose on the interpretation of the observations in view of possible foreground contaminations. A prime concern was the production of a similar B-mode polarization signal by the thermal emission of asymmetrical dust grains, which align on the magnetic field of the Galaxy (Picture of the month, *CERN Courier* June 2014 p17). Some researchers incriminated the weak accuracy of dust data used in the BICEP2 study to estimate foreground contamination. New results from ESA's Planck mission on galactic-dust polarization were therefore highly anticipated.

This paper appeared on the arXiv preprint server on 19 September. Although not yet peer reviewed, the study casts doubts on the interpretation of the B-mode signal being due to primordial gravitational waves. It shows that the amount of dust in the field observed by BICEP2 is significantly higher than was assumed in the paper by the scientists of the Harvard-Smithsonian Center for Astrophysics. How much of the measured B-mode signal is due to dust emission is not yet clear, owing to large uncertainties. The dust contribution extrapolated from the Planck 353 GHz band is, however, found to be at roughly the same level as the observed BICEP2 signal at 150 GHz.



Map of the northern (left) and southern (right) galactic hemispheres, showing the B-mode intensity (increasing from blue to red) of thermal dust emission as measured by Planck in wide patches of the sky. The outlined trapezoidal area shows the region observed by BICEP2. A region closer to the galactic south pole would have been less contaminated by dust. (Image credit: Planck Collaboration.)

To establish better whether the entire alleged cosmological signal is due to dust foreground, a more detailed analysis of both the BICEP2 and Planck data is currently being carried out jointly by the two teams. The Planck collaboration expects the results of this cross-correlation of the two maps to be published in the same time frame as the next release of Planck data, and results are foreseen for the end of November 2014.

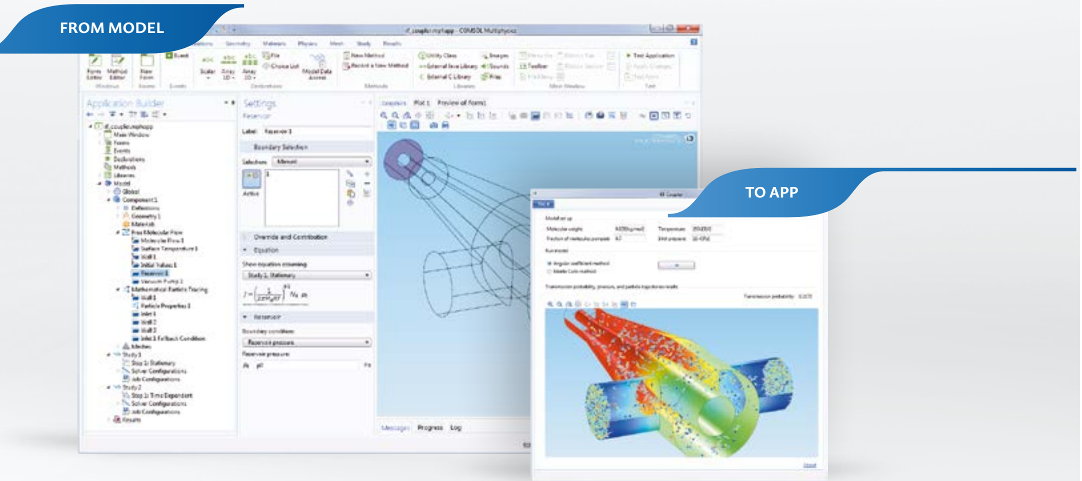
Even if it turns out that the published BICEP2 signal is due to dust solely, this is not the end of the story. Indeed, Planck has shown that there are other regions in the sky with less dust emission. These would be prime targets to observe primordial B-modes by the next-generation instrument, BICEP3, which will soon improve in sensitivity and operate at a frequency of 100 GHz, which is less affected by dust contamination.

- **Further reading**

Planck Collaboration, Adam *et al.* 2014 arXiv:1409.5738 [astro-h.CO]; submitted to *A&A*.

Picture of the month

This delicate galaxy pictured by the NASA/ESA Hubble Space Telescope is a nice example of a nearby, recently formed galaxy. Galaxies in our cosmic neighbourhood are usually mature, with a mix of stars formed at different epochs across the billions of years of cosmic time. Young, irregular galaxies like DDO 68, depicted here, are more common in the distant universe, where galaxies appear to us as they were billions of years ago. DDO 68 lies only about 39-million light-years away, and looks youthful based on its irregular structure and the little amount of heavy elements in the composition of its stars. The pink nebulae – hydrogen ionized by the ultraviolet radiation of young, bright stars – bear witness to an active star formation. It is, however, not excluded that DDO 68 contains a fraction of older stars, as with I Zwicky 18, which was also first thought to be a "baby" galaxy (Picture of the month *CERN Courier* January/February 2005 p12). (Image credit: NASA & ESA/A Aloisi, Space Telescope Science Institute.)



CERN Courier Archive: 1971

A look back to CERN Courier vol. 11, November 1971, compiled by Peggie Rimmer

SEEING BEAMS

Sodium gas ionization

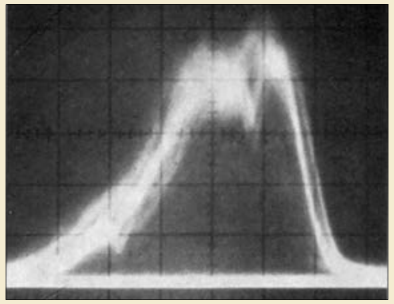
The range of beam detectors at the ISR has been increased by the installation of a novel beam-profile detector, which observes the ionization caused in a sodium curtain through which the beam passes. It is a distant relative of the familiar luminous screen, which lights up when placed in the path of the beam. The high intensity of ISR beams, and the catastrophic effects such a screen would have on a beam intended to circulate for hours, rule out the use of a fixed solid screen.

One way to solve the problem involves the use of a curtain of gas – sodium was chosen. Because of the low density in a gas curtain, the light emitted is too weak for photography or observation with a TV camera. If, however, an electric field (4 kV cm) is set up perpendicular to the beam, electrons coming from collisions between beam particles and gas atoms can be accelerated sideways, so as to strike a fluorescent screen and produce an image of the beam [that is deflected by a mirror onto a TV camera]. Light output is thus increased about 10,000 times.

The gas curtain consists of a flat jet of sodium, 1 mm thick, issuing from a slit inclined at 45° to the beam and projected at supersonic speed towards an exit slit on the opposite side of the vacuum chamber.

The detector was fitted in Ring I in October, while waiting for delivery of the gas jet generation system. After the optical system had been connected, what became visible on the screen was an image one would see looking from above the beam, due to electrons coming from ionization of the residual gas. Despite the very low residual pressure (less than 10^{-10} torr), the acceleration given to the electrons and the extreme sensitivity of the television camera yield a visible signal.

Using this signal, it was possible to produce the shape shown in the photograph, where the beam intensity is proportional to the height, and to follow the process of formation of the beam and its radial movements during stacking. Thus, even before the sodium curtain is installed (scheduled for Spring 1972), we have a beam-profile detector already providing a great deal of useful information.



This oscilloscope photograph shows the signal from an ISR beam-profile detector collecting electrons from ionization of the residual gas in Ring I. The signal is proportional to the radial density of the beam.

- Compiled from texts on pp324–325.

Synchrotron radiation

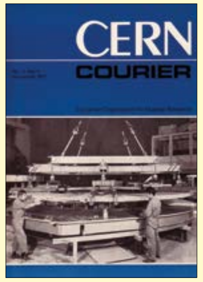
At the end of October, V L Auslandet and S G Popov from Novosibirsk visited CERN, and some accelerator physicists were able to see again the famous films of the synchrotron light emitted by beams orbiting the storage ring VEPP 2.

As shown in the photograph, the beam had effectively broken into two groups of particles – one forming a central stable core, the other executing large-amplitude horizontal oscillations. The oscillations are believed to have been caused by an induced voltage, possibly on the clearing plates in the ring. The vertical separation of the oscillations is due to coupling of the two transverse planes. Particles could swap from one group to the other via the amplitude dependence of the Q-shift. Thus when particles reach the extreme amplitudes (about 1 cm in either direction) they get out of tune with the mechanism exciting the oscillations and fall back into the stable group.

- Compiled from texts on p329.

Looking like a view of the planet Saturn, this "still", above right, is from one of the films recording the synchrotron light from a positron beam in VEPP 2 (integrated over many turns by the photographic film). (Photo Novosibirsk.)

Compiler's Note



In storage rings, residual gas causes beam loss and synchrotron radiation causes energy loss. A priori unwelcome, these effects are profitably exploited at the LHC (and elsewhere).

The well-being of the LHC vacuum system is monitored using beam-loss monitors (BLMs) that measure beam-residual gas interactions. BLMs are particularly useful in transition zones of changing gas density, for example between cryogenic and room-temperature pipes, and in machine sections where vacuum gauges are infrequent, such as the arcs.

Although it is usually associated with electron accelerators, proton machines that reach sufficiently high energies can use synchrotron radiation for diagnostic purposes. At the LHC, an optical arrangement focuses synchrotron light from two magnets to image the cross-section of the beams, and so determine both spatial (transverse) and temporal (longitudinal) profiles.

Today, synchrotron radiation has come into its own in dedicated electron storage rings, producing high-intensity light sources that can readily be polarized, collimated, tuned and pulsed. Found around the globe, major applications range from condensed-matter physics and materials science, where matter is probed at sub-nanometre levels, to biology and medicine, which require inspection at micrometre and millimetre levels.

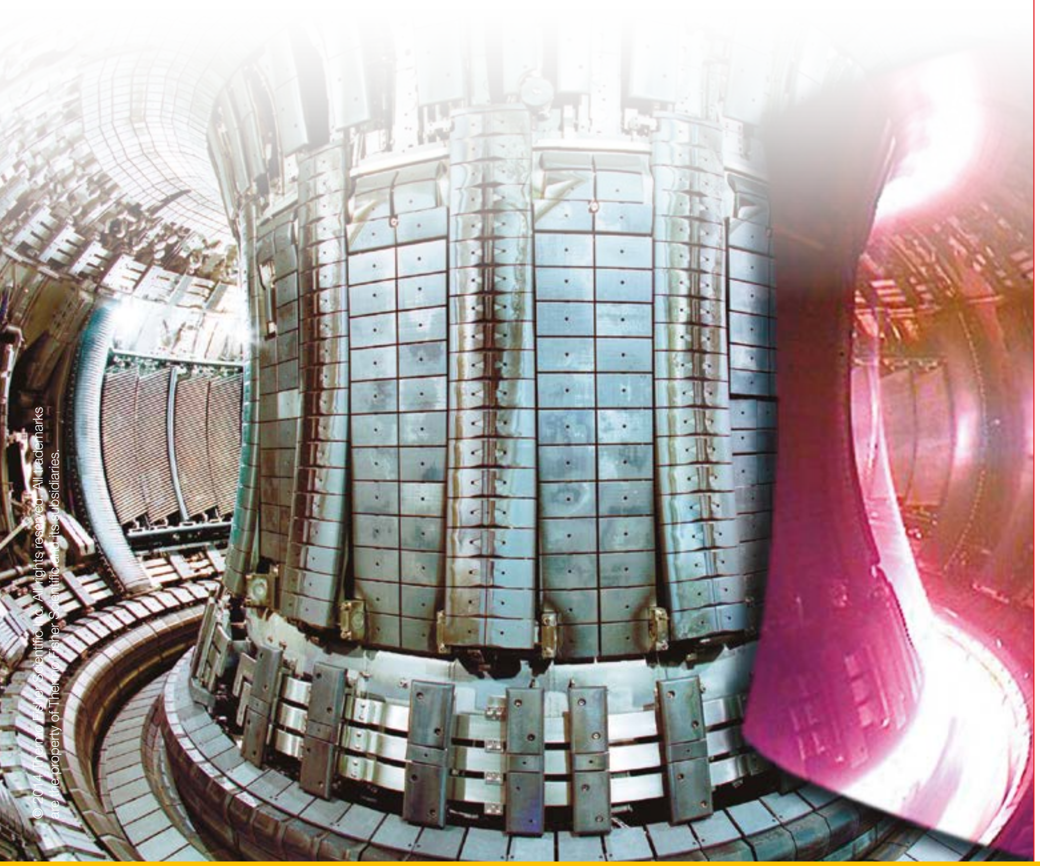


Fig. 1. The new MC-1 building at Fermilab, where the muon g-2 storage ring is being reassembled in the larger part to the left. The part to the right houses the counting room, electronics, etc, with cryogenics services further right. (Image credit: Fermilab.)

Muon g-2 storage ring starts a new life

The Brookhaven muon storage ring is being re-assembled at Fermilab and prepared for a new round of measurements.

In March 2001, the Brookhaven g-2 storage ring was retired, after producing the world's best measurements of the muon's anomalous magnetic moment, $a_\mu = (g-2)/2$. However, the experiment produced a cliffhanger: the experimental result differed by 3–4σ from the theoretical prediction for a_μ, hinting potentially at the presence of new physics beyond the Standard Model.

Now, a new experiment to measure a_μ is under construction at Fermilab, with the goal of confirming or refuting the evidence produced at Brookhaven. The new Muon g-2 collaboration will reuse Brookhaven's storage-ring magnet and several of its subsystems to do the experiment with a precision four times better. In the summer of 2013, a company specializing in moving large objects brought the centrepiece of the storage-ring system – a 14-m-diameter electromagnet – from Brookhaven to Fermilab (*CERN Courier* July/August 2013 p11). Then, during summer this year, the next milestone was achieved as re-assembly of the storage ring began in the newly completed MC-1 building at Fermilab (figures 1 and 2).

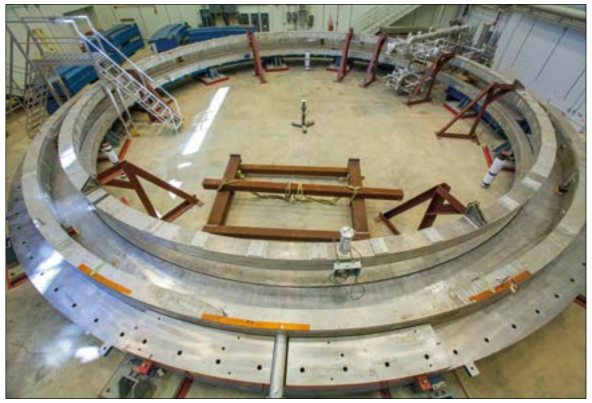


Fig. 2. Re-assembly of the g-2 storage-ring magnet at Fermilab, after the three superconducting coils were positioned gently on top of the newly assembled bottom ring of steel yoke segments. The coils and their complex interconnect system (top right in photo) were transported as a single unit from Brookhaven to Fermilab by land, sea and river, in 2013. (Image credit: Fermilab.)

The superconducting magnet – the design led by Gordon Danby, Hiromi Hirabayashi and Akira Yamamoto, beginning in the late 1980s – provides a highly uniform, essentially pure, 1.45-T dipole field throughout its 44.7-m circumference (Danby *et al.* 2001). The storage-ring system includes a unique superconducting inflector magnet that enables bunches of 3.1 GeV/*c* muons produced in a pion-decay channel to enter the magnetic-field region along a nearly field-free path. A pulsed kicker applies a magnetic ▷

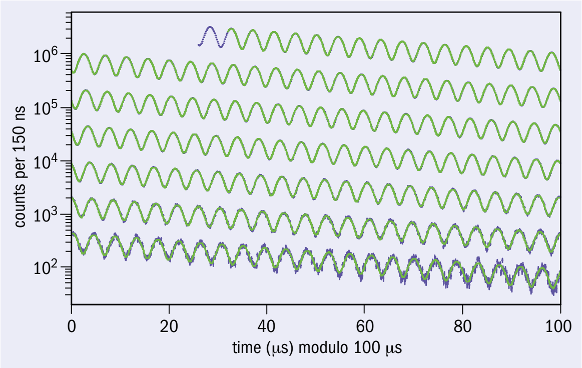
The muon g-2 storage ring during its time at Brookhaven (left), before it embarked on the journey to Fermilab by sea (right)...

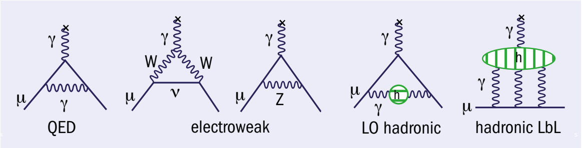
...river (left) and road (right). (Image credits: Brookhaven National Laboratory, opposite page far left, and Fermilab.)

deflection to redirect the incoming muons into the ring's storage volume. A set of four electric quadrupoles provide vertical focusing without perturbing the critical uniform magnetic field. This unique system of devices allows direct injection of the muons – a breakthrough compared with previous g-2 experiments – allowing the Brookhaven experiment to improve the precision by a factor of 14, compared with the series of experiments that took place at CERN in the mid 1970s. The final result from the Brookhaven E821 experiment is $a_\mu = 116\,592\,089\,(63) \times 10^{-11}$ – a precision of 0.54 ppm – where the error is dominated by statistics, not systematics (Muon g-2 Collaboration 2006).

To measure g-2, polarized muons are injected into the storage ring and their spin evolution is tracked as they circulate. If g were exactly equal to 2, the muon spin would remain in the direction of its momentum. For $g > 2$, the spin advances, or precesses, proportionally to the anomalous part of the magnetic moment. In this particular storage ring, on every 29.4 revolutions, the spin orientation advances by one turn compared with the momentum. Parity violation in the weak decay of the muon then serves as the spin analyser. The higher-energy electrons in the $\mu \rightarrow e\nu\bar{\nu}$ decay chain are emitted preferentially in the direction of the muon spin at the time of the decay. Because the electrons have lower momentum compared with the muons, they curl to the inside of the storage ring, where they can be detected. Figure 3 shows a histogram of the arrival time vs the time after injection for the higher-energy electrons, measured when they struck one of 24 symmetrically placed electromagnetic calorimeters located just to the inside of the storage volume in the E821 experiment. The characteristic anomalous precession frequency is clearly visible. When combined with the integrated magnetic field that is measured using pulsed proton NMR, the ratio of these quantities – precession frequency to field – leads directly to the quoted result for g-2.

To push further requires 'more muons'. The winning concept came from a clever reuse of the Fermilab accelerator complex.





Top: Fig. 3. The number of high-energy electron decays vs time after injection from the Brookhaven E821 experiment. The green line is a fit and the blue points are data. The dominant feature of these data – the oscillation on top of the exponentially falling rate – gives the precession frequency of the muon spin. Bottom: Fig. 4. Representative diagrams of the Standard Model contributions to a_μ. The QED and electroweak contributions are well known. The hadronic contributions remain the topic of intense study.

The g-2 measurement tests the completeness of the Standard Model, because a_μ arises from quantum fluctuations, as figure 4 illustrates. The theory must account for the quantum fluctuation effects from all known Standard Model particles that influence the muon's magnetic moment. If something is left out, or there is a contribution from new physics, the theory would not match the experiment. While the contributions from QED and the weak interaction are well known, those from hadronic terms drive the overall theoretical uncertainty of about 0.46 ppm. The largest uncertainty comes from hadronic vacuum-polarization contributions. They can be determined directly from cross-section measurements at e^+e^- colliders, and vigorous programmes are underway in Novosibirsk, Beijing and Frascati to improve these measurements. More difficult to assess, although much smaller in magnitude, is the $(\alpha/\pi)^3$ hadronic "light-by-light" diagram. However, a recent dedicated workshop reports significant progress and plans to improve this situation, including progress in lattice-gauge calculations (Benayoun *et al.* 2014).

The next steps

The Brookhaven measurement differs from the prediction of the Standard Model by roughly 3–4σ, depending on the details of the hadronic contribution used in the comparison (Blum *et al.* 2013). While the present comparison is tantalizing, it does not meet the 5σ standard required for a discovery. Nevertheless, many theorists have speculated on what might be implied if it holds up to further scrutiny. Dominant themes include low-energy supersymmetry, dark gauge bosons, Randall–Sundrum models and others with large extra dimensions, to name a few. The impact of the result – whether it remains large and significant, or in the end agrees with the Standard Model – will constrain many theories of new physics.

To push further requires "more muons". Following the completion of E821, a number of ideas were considered, but the winning concept came from a clever reuse of the Fermilab accelerator complex – in particular, much of the antiproton production facility – to produce a rapidly cycling injection of a pure, high-intensity muon beam, with nearly 100% polarization, into the storage ring. The plan, now part of a more global "Muon Campus" concept that includes the muon-to-electron search experiment (Mu2e), will result in a 20-fold increase in statistics compared with Brookhaven. The only obstacle was that the specialized storage-ring system was in New York and had not been powered for more than a decade. So, how to move it? And, once moved, would it still work? The delicate transcontinental move – by lorry, barge across sea and along river, and finally again by lorry – to deliver the 14-m-diameter superconducting coils to the Fermilab site enjoyed much publicity. With far less fanfare, 50 lorries hauled 650 tonnes of steel and other equipment westward.

The new Muon g-2 experiment at Fermilab, also known as E989, is now a mature effort. The collaboration of 36 institutions from eight countries will use or refurbish many of the components from the past. Nevertheless, much is totally new. With a higher expected beam rate, more rapid filling of the ring, and even more demanding goals in systematic uncertainties, the collaboration has had to devise improved instrumentation. The ring kicker-system will be entirely new, optimized to give a precise kick on the first turn only, to increase the storage fraction. The magnetic field will be even more carefully prepared and monitored. The detectors and electronics are entirely new, and a state-of-the-art calibration system will ensure critical performance stability throughout the long data-taking periods. New *in situ* trackers will provide unprecedented information on the stored beam. The first physics data-taking is expected in early 2017. The next critical milestone will be the cooling of the superconducting coils and powering of the storage-ring magnet, which is expected by spring 2015.

Further reading

M Benayoun *et al.* 2014 arXiv:1407.4021.
T Blum *et al.* 2013 arXiv:1311.2198.
G T Danby *et al.* 2001 *Nucl. Instrum. Meth.* **A457** 151.
Muon (g-2) Collaboration, G W Bennett *et al.* 2006 *Phys. Rev. D* **73** 072003.

Résumé

Nouvelle vie pour l'anneau de stockage de muons g-2

En 2001, l'anneau de stockage g-2 à Brookhaven a été mis hors service après avoir permis d'obtenir les meilleures mesures qui soient sur le moment magnétique anormal du muon. $a_m = (g\text{-}2)/2$. Les résultats signalaient toutefois une nouvelle physique au-delà du Modèle standard. La nouvelle collaboration g-2 réutilisera l'aimant de l'anneau de stockage pour une expérience quatre fois plus précise, au Fermilab cette fois. En 2013, l'électroaimant a été transporté de Brookhaven au Fermilab par voies maritime, fluviale et routière. Les travaux de réassemblage de l'anneau de stockage ont à présent commencé dans un nouveau bâtiment au Fermilab. Les premières données sont attendues début 2017.

David Hertzog, University of Washington, and **Lee Roberts**, Boston University.

Edinburgh takes on the flavour of beauty

Highlights from the host of exciting results presented at Beauty 2014.

Beauty 2014 participants line up for the traditional conference photo. (Image credit: Greig Cowan.)

The magnificent Playfair Library in the historic centre of Edinburgh provided a spectacular setting for the scientific presentations of the 15th International Conference on B-Physics at Frontier Machines (Beauty 2014). The purpose of this conference series is to review the state of the art in the field of heavy-flavour physics, and to address the physics potential of existing and future B-physics experiments. This line of research aims to explore the Standard Model at the high-precision frontier, the goal being to reveal footprints of "new physics" originating from physics beyond the Standard Model in observables that can be predicted reliably. Hosted by the University of Edinburgh on 14–18 July, Beauty 2014 attracted around 90 physicists, including leading experts on flavour physics from across the world, to present and discuss the latest results in the field.

The key topics in flavour physics are strongly suppressed rare decays and decay-rate asymmetries that probe the phenomenon of CP violation. The non-invariance of weak interactions under combined charge-conjugation (C) and parity (P) transformations was discovered 50 years ago through the observation of $K_L \rightarrow \pi^+\pi^-$ decays (*CERN Courier* July/August 2014 p21). The Cabibbo–Kobayashi–Maskawa (CKM) mechanism, postulated 10 years later, allows CP violation to arise in the Standard Model, in particular in the decays of B mesons (*CERN Courier* December 2012 p15). These particles are hadronic bound states of a b antiquark and a u, d, s or c quark. In the case of the neutral B^0_d and B^0_s mesons, quantum-mechanical particle–antiparticle oscillations give rise to interference effects, which can induce manifestations of CP violation. Flavour-changing neutral currents are forbidden at the tree level in the Standard Model, and are therefore sensitive to new particles that might reveal themselves indirectly through their contributions to loop processes. These features are at the basis of the search for new physics at the high-precision frontier.

The exploration of B physics is dominated by the dedicated LHCb experiment, as well as the general-purpose ATLAS and CMS experiments at the LHC. The completion of the upgrade of the KEKB collider and the Belle detector in Japan in the coming years will see KEK re-join the B-physics programme, when the Belle II experiment starts up at SuperKEKB (*CERN Courier* January/February 2012 p21).

At Beauty 2014, the programme of 13 topical sessions included 61 invited talks. The majority covered a variety of new analyses and experimental results, complemented by a series of review talks on theoretical aspects. In addition, seven early-career researchers (PhD students and postdocs) presented posters in a dedicated session.

Highlights of the conference included a measurement of CP violation in the decay $B^0_s \rightarrow \phi\phi$, new results on the determination of the angle γ of the unitarity triangle from B → DK and $B^0_s \rightarrow D^{\pm}_s K^{\mp}$ decays – the former of which receives contributions from "tree" topologies only – and $B^0_s \rightarrow K^+K^-$ and $B^0_d \rightarrow \pi^+\pi^-$ decays, which also receive "penguin" contributions where new particles might enter in the loops. The results for γ are consistent among one another within the uncertainties and the information on the unitarity triangle coming from global fits of various observables. The error on direct γ measurements is now approximately 9°, with significant contributions from the latest results from LHCb, which will continue to improve this precision. Impressive new measurements of the weak phase ϕ_s and decay-width difference $\Delta\Gamma_s$ were presented by CMS and LHCb in $B^0_s \rightarrow J/\psi\phi$ and $B^0_s \rightarrow J/\psi\pi\pi$ decays. The latter is now the most precise ϕ_s ▷

The goal is to reveal footprints of "new physics" in observables that can be predicted reliably.

result, with an uncertainty of 68 mrad, and the results are in agreement with the predictions of the Standard Model.

In the field of rare B-meson decays, there were reports on impressive theoretical progress for $B_s^0 \to \mu^+\mu^-$ decays. This is one of the rarest decays that nature has to offer, and is therefore a very sensitive probe of new physics. Theoretical improvements relate to the calculation of higher-order electroweak and QCD corrections, which resulted in a higher precision on the predicted theoretical Standard Model branching ratio for this channel. The experimental evidence for this decay was reported by the CMS and LHCb collaborations in the summer of 2013, and is one of the highlights of Run 1 of the LHC. New combined results have recently been made public by the two collaborations.

Measurements of the angular distribution of the rare $B_d^0 \to K^{*0}\mu^+\mu^-$ decay and comparison with respect to calculations within the Standard Model was another hot topic. A discrepancy is observed in a single bin in the distribution of the so-called P_5' observable. The key question is whether strong-interaction processes or new physics effects are causing this discrepancy. The possibilities led to interesting discussions during the session, which continued during the coffee breaks. Improved statistics on this and related channels from Run 2 at the LHC are awaited eagerly.

In the ratio of the rates of $B^+ \to K^+\mu^+\mu^-$ and $B^+ \to K^+e^+e^-$ decays, which test lepton-flavour universality, LHCb reported a new 2.6σ deviation from the Standard Model, which has to be explored in more detail. Moreover, first results on measurements of the photon polarization in $b \to s\gamma$ by the B factories and LHCb were presented, and this will be studied in a more powerful way by Belle II and the upgraded LHCb.

Many other interesting measurements and developments were discussed at the conference. One of these concerned the first observation of a heavy-flavoured spin-3 particle, the $D_s^*(2860)^-$ meson, observed by LHCb in the decay of a B_s^0 meson (*CERN Courier* September 2014 p8). Another was the confirmation of an exotic resonance Z(4430) composed of four quarks, also by LHCb (*CERN Courier* June 2014 p12). In addition, many more results were presented on heavy-flavour production and spectroscopy at the B factories, at Fermilab's Tevatron and at the ALICE, ATLAS, CMS and LHCb experiments.

On the theory frontier, there was an excellent review of the spectroscopy of B hadrons and bottomonium. Impressive progress reported in the calculation of non-perturbative parameters with lattice QCD has already had an important impact on various analyses. Other topics included the status of lepton-flavour violation and models of physics beyond the Standard Model, searches for exotic new physics such as Majorana neutrinos, charm physics and rare kaon decays.

The opening talk of the conference was given by John Ellis of King's College London and CERN, who presented his perspective and vision for the search for new physics – in particular supersymmetry – at the LHC and beyond. A whole session was devoted to prospects for the future B-physics programme, addressing the upgrades of LHCb, ATLAS, CMS and Belle II. An exciting summary and outlook talk by Hassan Jawahery of the University of Maryland concluded the conference.


Coffee-break discussions in the Playfair Library. (Image credit: Stephan Eisenhardt.)

The University of Edinburgh provided an impressive social programme. No visit to Scotland is complete without whisky tasting, and participants were treated to the option of 25 different samples. A walking tour of the historic Edinburgh Castle was complemented by a bus tour and a boat ride under the famous Forth Bridge. The conference dinner, held at the Dynamic Earth museum, included another Scottish speciality – haggis.

In conclusion, the 15th Beauty conference was a great success, with presentations of exciting new results. Now it is time to look forward to the next edition, to be held in the spring of 2016.

● Further reading

A detailed programme, including the presentations, is available at www.ph.ed.ac.uk/beauty2014.

Résumé

Édimbourg s'imprègne de la saveur de la beauté

Le centre historique d'Édimbourg a accueilli en juillet les participants à la 15^e Conférence internationale sur la physique des B auprès des machines frontières (Beauty 2014). Ce domaine de recherche étudie le Modèle standard aux frontières de la haute précision, dans le but de découvrir des traces d'une « nouvelle physique » dans des observables pouvant être prédites avec une bonne fiabilité. Parmi les temps forts de la conférence, on peut noter une mesure de la violation de CP dans la désintégration $B_s^0 \to \phi\phi$, *de nouveaux résultats pour la mesure de l'angle* γ *du triangle de l'unitarité, des progrès théoriques remarquables concernant les désintégrations* $B_s^0 \to \mu^+\mu^-$, *et de nombreux résultats sur la production et la spectroscopie des saveurs lourdes.*

Robert Fleischer, Nikhef and Vrije Universiteit Amsterdam, **Neville Harnew**, University of Oxford, and **Franz Muheim**, University of Edinburgh.

Valencia welcomes the world of particle physics

For the first time since its inception, the International Conference on High Energy Physics went to Spain this year.

In the field of elementary particle physics, the International Conference on High Energy Physics (ICHEP) is the largest meeting organized at a global level. Having started in 1950 at Rochester in New York, it was for several years known simply as the "Rochester Conference". Organized by Section C11 (Particles and Fields) of the International Union for Pure and Applied Physics (IUPAP), the conferences have since taken place across the world, in recent years in Philadelphia (2008), Paris (2010) and Melbourne (2012), for example.

For its 37th edition, ICHEP went to Spain for the first time, where it took place at the Valencia Conference Centre on 2–9 July. The selection of Spain as host of the prestigious conference is recognition of the country's progress in this field of fundamental knowledge. Its importance for Spain was clear from the presence at the inaugural session of Carmen Vela, secretary of state for research, development and innovation from the Ministry of Economy and Competitiveness, as well as several other academic and regional government representatives. ICHEP 2014 attracted a total of 967 scientists from 53 countries, with the largest delegation of 193 participants coming from Spain. The main international laboratories in the field were well represented, many at a high level: the directors of CERN, DESY, Fermilab, KEK and the Institute of High Energy Physics, Beijing, attended the conference, and participated actively in several sessions.


ICHEP 2014 took place at the Valencia Conference Centre – the first time that ICHEP has visited Spain. (Image credit: M Aguilar.)

After the formidable impact in the media of the announcement of the discovery of the Brout–Englert–Higgs (BEH) boson at CERN on 4 July 2012, on the eve of the opening of the previous ICHEP in Melbourne (*CERN Courier* September 2012 p53), it was somehow unrealistic to hope that an announcement or confirmation of a result of similar outstanding scientific consequences would happen in Valencia. In this field of science, spectacular milestones alternate with less glamorous phases in which levels of knowledge are consolidated. In many cases, the construction of complete sets of precision measurements, and a deep understanding of them, reveal the way towards progress, and indicate the right roads of exploration to follow. In this respect, and given the large variety of data sets, analyses and interpretations of results presented, ICHEP 2014 did not disappoint.

Following what has become common practice in the ICHEP series, the programme in Valencia consisted of parallel and plenary sessions. In the 15 parallel sessions, 538 experimental and theoretical communications were presented, covering most of the areas in the field. A summary of the results discussed in these sessions was then given in 55 talks in the 42 plenary sessions that took place in the second half of the conference. The scientific programme was completed with 18 additional talks, as well as a display of more than 200 posters summarizing the work of young researchers.

In this field of science, spectacular milestones alternate with less glamorous phases of consolidation.

The results of the experiments at CERN's LHC and Fermilab's Tevatron – studying proton–proton, proton–lead, lead–lead and proton–antiproton collisions at high energy – were presented in detail, those from the LHC being based on all of the data collected up to the start of the first long shutdown early in 2013. In particular, the ▷

Celebrating CERN's 60th anniversary

On the occasion of CERN's 60th anniversary, the ICHEP 2014 organizing committee thought it appropriate to schedule a special session to highlight the contributions of this unique organization to the acquisition of scientific and technological knowledge in basic science, as well as the important role that CERN has played in fostering international collaboration, in the worlds of academia and education, in the training of researchers, engineers and technicians, and in activities dealing with knowledge and technology transfer to the industrial and business communities.

Speaking first, Rolf Heuer, CERN's director-general, stressed the relevance of basic research in fostering technological development and innovation in a global and open worldwide environment, and sent encouraging key messages to the youngest sector of the audience. Lyn Evans, former head of the LHC Project, then gave a lively recollection of the technical developments and immense challenges involved in bringing the LHC construction project to a happy conclusion. He was followed by Sergio Bertolucci, director of research and computing technology, who reviewed CERN's current activities and some of its past achievements, as well as the ongoing tasks related to future options following the road map defined by the European Strategy for Particle Physics approved by CERN Council in 2013 (*CERN Courier* July/August 2013 p9). The many ongoing technical activities related to the LHC – which will start a new phase of operation at higher energy and luminosity in the spring of 2015 – were then presented by Miguel Jiménez, head of the technology department. Finally, Manuel Aguilar of CIEMAT summarized the successful evolution of high-energy particle physics in Spain, and the important role that CERN has played in this context (see "CERN and Spain", opposite).

At the opening ceremony, left to right, Maria José Catalá, of the Valencian Ministry of Education, Culture and Sports, Carmen Vela, Spanish secretary of state for research, development and innovation, and Rolf Heuer, CERN's director-general. (Image credit: ICHEP2014.)

dynamical features of the processes in these energy ranges (the QCD domain), the static and dynamical properties of the BEH boson, the properties of the top quark, the extremely rare decay modes and very small branching ratios of hadrons containing a b quark, and appropriate comparisons with the Standard Model figured in many of the presentations.

Although, the Standard Model explains most of the precise measurements collected up to now at a variety of experimental facilities, it is accepted widely that there are still plenty of questions to be answered – a situation that underlies the need to modify and extend the current paradigm to cure the detected weaknesses. Among the most notorious of these is the lack of understanding of the nature of dark matter – an intriguing form of matter that cannot be explained by the quarks and leptons of the Standard Model, and so points towards new physics. The capability of new models, such as supersymmetry, theories with extra dimensions, technicolour, etc, to overcome this and other conceptual and observational difficulties must be evaluated in the coming years, when the availability of new sets of data become a reality, in particular from the upgraded LHC.

The presentation and discussion of new and relevant results in neutrino physics, obtained in a diverse set of experimental facilities, was another highlight of the conference, together with many topics in astroparticle physics and cosmology. The recent results obtained at the BICEP2 telescope at the South Pole – which might provide the first experimental evidence of cosmic inflation – and the current status of the analysis of the data collected by the European satellite Planck, together with the theoretical implications of these measurements, deserved particular attention. This special session on cosmology and particle physics, which was a major highlight of the conference, was closed beautifully with a splendid lecture by Alan Guth, one of the distinguished proponents of the theory of cosmic inflation.

The status of projects at different stages of design and prototyping for the construction of new large scientific installations (linear and circular colliders, neutrino beams and detectors, underground laboratories for the study of neutrinos and dark-matter candidates, detector arrays for high-energy cosmic rays, satellites and other space platforms, etc), and the regional strategies and road maps, are topics that were included in another interesting session, leading to ample discussions. The programme of the parallel sessions also included presentations dealing with the formidable effort that, at the global level, is carried out in R&D activities on detectors, accelerators, data acquisition and trigger issues, and computing technologies. Last but not least, the role and relevance of outreach and the relations between science, technology, industry and society were analysed and discussed.

The plenary sessions provided summaries of the contributions presented in the parallel sessions, as well as a concluding synthesis of the contents of the conference and on the future of the field. As emphasized in the closing talks by Young-Kee Kim of the University of Chicago and Antonio Pich of the University of Valencia, a wealth of new data has led to considerable advances in many areas since the previous ICHEP two years ago. However, it became equally clear that, in the years to come, there remains plenty of challenging work to be done to answer the many intricate and fundamental open questions that the field still faces. One subject that will trigger further attention in future is the possible connection between the scalar field responsible for electroweak-symmetry breaking (the BEH boson) and the scalar field that might be at the origin of cosmic inflation in the early stages of the universe (the inflaton). The solution to this and many other fascinating questions is awaiting new experimental data and revolutionary theoretical ideas. With all of these ingredients, this area of fundamental knowledge is clearly facing a challenging and exciting future.

It is accepted widely that there are still plenty of questions to be answered.

Participants gather between sessions at the Valencia Conference Centre. (Image credit: ICHEP2014.)

CERN's travelling exhibition – "Accelerating Science" – attracted the public in Valencia. (Image credit: ICHEP2014.)

CERN and Spain

This year has seen celebrations of the 30th anniversary of the return of Spain to CERN in November 1983, after a long period of absence that began in 1969. Many generations of Spanish researchers, engineers and technicians have been educated and trained in the international, highly competitive and technological CERN environment, At the same time, numerous companies and industrial firms in Spain have become acquainted with a diverse range of techniques, procedures and innovations, many of them at the forefront of technology and with remarkable potential. It is appropriate to recognize not only the nurturing effect that CERN has had in the positive evolution of science in Spain – particularly the experimental and technological components – but also the importance for CERN of having Spain among its member states. Today, Spain contributes approximately 8.5% to the CERN budget and, beyond this substantial support, brings a well-trained and motivated community that is eager to take part in the CERN adventure.

In addition to the scientific programme, participants at the conference were able to appreciate an exhibition of posters concerning the situation of women studying physics in Palestine, while another exhibition showed the connection between art and scientific research. CERN's travelling exhibition "Accelerating Science", displayed at the Ciudad de las Artes y las Ciencias in Valencia's town centre, received plenty of attention from the general public. The conference also had impressive media coverage in the press, the main broadcasting networks and in national and regional television channels. Around 15 journalists from the most relevant media in science communication attended sessions, reported on the main events and interviewed numerous participants.

A highlight of the social programme was the marvellous concert on the theme of "Science and music working for peace", given by the Orchestra and Chamber Choir of the Professional Conservatoire of Music of Valencia. This was accompanied by the projection of images – many unpublished – relating to the history of CERN and the development of particle physics in Spain. Finally, the conference banquet at the wonderful Huerto de Santa María provided a brilliant ending for the social programme.

● The Spanish institution in charge of organization was the Instituto de Física Corpuscular (IFIC), Joint Centre University of Valencia – CSIC (Council for Scientific Research). There was also ample sponsorship from several domestic and international institutions.

Résumé

Valence accueille la crème de la physique des particules

Pour la première fois depuis sa création, la Conférence internationale sur la physique des hautes énergies a eu lieu en Espagne, à Valence, au mois de juillet. Les résultats des expériences menées au LHC (CERN) et au Tevatron (Fermilab) y ont été présentés de manière détaillée. Ceux du LHC concernaient l'ensemble des données collectées jusqu'au début du premier long arrêt, début 2013. Autres temps forts de la conférence, la présentation et la discussion de nouveaux résultats obtenus dans le domaine de la physique des neutrinos auprès de diverses installations d'expérimentation, des questions liées à l'astrophysique des particules et à la cosmologie, et la présentation de projets de nouvelles installations à grande échelle.

Manuel Aguilar, CIEMAT, and **Juan Fuster**, IFIC, co-presidents of the local organizing committee, ICHEP 2014.

CERN celebrates 60th anniversary in style

Throughout 2014, CERN and its member states have been celebrating 60 years of science for peace with events, exhibitions, talks and more. At CERN, these reached a climax with the official ceremony on 29 September, but much else was happening during the preceding days. The ceremony was attended by official delegations from 35 countries, while other events attracted people from CERN and in the surrounding area to listen to talks, hear music, and see science in the streets. At the same time, webcasts took many of the activities to a much wider "internet" audience, who could also participate in the celebrations via social media.

Celebrations will continue in many different places during the rest of the year. To find out more, visit http://cern60.web.cern.ch/.

Kate Kahle, CERN.

Above: The official CERN60 ceremony on 29 September featured the European Union Youth Orchestra, directed by Maestro Vladimir Ashkenazy, with 42 musicians covering all of CERN member and observer states. (Image credit: CERN-PHOTO-201409-196-120.)

Above: On 19 September, during a week of CERN Council meetings, a symposium celebrated the 60th anniversary of the first Council session, held in October 1954, just one week after the CERN Convention entered into force. Speakers included CERN's librarian, Jens Vigen, who presented highlights of Council's history, here with a view of the Council chamber at CERN. (Image credit: CERN-PHOTO-201409-179-8.)

Left: An address by the president of the CERN Council, Agnieszka Zalewska, marked the culmination of speeches that had been given by official delegates from the UK, France, Switzerland, Italy, Germany and Portugal. (Image credit: CERN-PHOTO-201409-196-79.)

Left: On 29 September, the German federal minister of education and research, Johanna Wanka, was one of the 35 official delegations to sign the guestbook, with Sigurd Lettow, CERN's director for administration and general infrastructure. (Image credit: CERN-PHOTO-201409-194-82.)

Above: Croatian students of Gymnasium "Fran Galović" Koprivnica were just some of many who sent in images via social media, with the hashtag #MyCERN60, to wish CERN a happy 60th birthday. Through drawings, cakes, parties and more, people around the world contributed in beautiful and heart-warming ways. (Image credit: Marina Furkes/Gymnasium "Fran Galović" Koprivnica.)

Left: On 17 September, a symposium on "60 years of CERN – 60 years of Science for Peace" took place in the Globe of Science and Innovation. It focussed on the human achievements throughout CERN's history, and the role that the organization has played in promoting international co-operation. Talks included "SESAME: a parallel universe in the Middle East?" by Eliezer Rabinovici, of the Hebrew University in Jerusalem. (Image credit: CERN-PHOTO-201409-178-42.)

Above: CERN took part in the annual European Researchers' Night on 26 September with "Pop Science", in which CERN researchers showcased their work at multiple venues in Geneva and neighbouring France. The event mixed arts, poetry, theatre, music and science, and included shows with liquid nitrogen, CERNLand games for young people and numerous talks and discussions. (Image credit: CERN-PHOTO-201409-198-64.)

Below: The United Nations Orchestra performed a concert at CERN on 19 September to celebrate the 60th anniversary. Under the baton of conductor and artistic director Antoine Marguier, the orchestra accompanied soloist Matteo Fedeli, who, under the patronage of the Permanent Mission of Italy to the United Nations, performed on a Stradivarius violin. (Image credit: CERN-PHOTO-201409-180-26.)

Below: CERN Courier joined in the celebrations with a 60 made from issues from the past few years, including the one for the anniversary itself. (Image credit: Steve Trevett/ IOP Publishing.)

Left: The second TEDxCERN event took place on 24 September, with the theme "Forward: Charting the future with science". Of the many inspirational talks, Jamie Edwards, now 14, received a standing ovation after he spoke about attempting to achieve nuclear fusion in his school lab by colliding the nuclei of hydrogen atoms via inertial electrostatic confinement. (Image credit: CERN-PHOTO-201409-183-237.)

CP violation: past, present and future

Highlights from a meeting to celebrate the 50th anniversary of a surprising discovery that continues to tantalize.

Jim Cronin opened the meeting, 50 years after the famous paper was published. (Image credits: all photos Honor-Clare Elliot.)

Fifty years after the seminal discovery of CP violation by James Christenson, James Cronin, Val Fitch and René Turlay, Queen Mary University of London held a meeting on 10–11 July to celebrate the anniversary. This stimulating retrospective was attended by around 80 participants, many of whom had been involved in the numerous experimental and theoretical developments in CP-violation physics during the intervening half-century. The primary focus was to review the experimental and phenomenological aspects of CP violation during the past 50 years, but the meeting also included talks on the future of CP-violation experiments with heavy flavours as well as with neutrinos.

The meeting got off to a barnstorming start with talks by Nobel prize laureates Jim Cronin (1980) and Makoto Kobayashi (2008). Cronin explained that since René Turlay had sadly passed away in 2002, while Val Fitch was no longer able to travel and contact with Jim Christenson appeared to have been lost, he alone of the original team was available to attend such meetings. He carefully outlined the historical context in neutral-kaon physics surrounding the discovery of CP violation at Brookhaven in 1964, giving significant credit to Robert Adair, whose earlier experiment had discovered “anomalous regeneration of K^0_L mesons” in 1963. This in turn had stimulated Fitch to suggest to Cronin that the latter’s existing apparatus might be used to repeat and improve upon that measurement with 10 times the sensitivity. A search for CP violation in K^0 decays to two charged pions would be an additional test that could be made as a by-product of the new experiment.

The proposal was made in 1963 and the experiment commenced within three weeks (*CERN Courier* July/August 2014 p21). Illustrating his talk with photographs of the original laboratory notebooks kept by the team, Cronin explained that it was Turlay alone who performed the analysis for the CP-violation signal, and found a signal corresponding to 40 two-pion K^0_L decays by Christmas 1963. This result implied that CP violation was manifest in the neutral-kaon system, corresponding, for example, to an admixture of the CP = +1 component in the long-lived K^0 at the level of 2.3×10^{-3} – a result later confirmed by other experiments.

Cronin continued by reviewing the later experimental work in CP-violation physics with neutral kaons, confirming and building upon the original discovery, and culminating in the unequivocal demonstration, almost 40 years later, of direct CP violation in the kaon system (*CERN Courier* July/August 2014 p23). His talk stimulated several questions. One participant commented that the time from submission of the seminal paper to publication was very short. Another asked if there had been any expectation or indication of a CP-violation signal before the experiment. Cronin responded in the negative: “We did not even think CP violation was the most important thing – we really wanted to measure K^0_S regeneration.” A former student of Cronin commented that at the time he was “having lectures from these guys”, and that he “could tell that something exciting was going on behind the scenes”.

Towards a theory

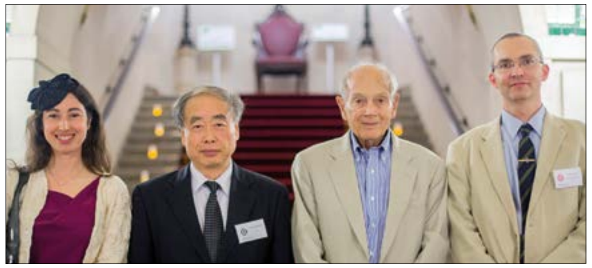
The second talk was by Kobayashi, who together with Toshihide Maskawa had shown in 1973 how to accommodate CP violation into the gauge theory of electroweak interactions, albeit necessitating their bold suggestion of a third family of quarks – insight for which they were to receive the Nobel prize in 2008. Kobayashi carefully outlined the context in which his decisive work with Maskawa on CP violation was performed. He had entered graduate school in 1970 at Nagoya, where the theoretical physics group was led by Shoichi Sakata, and where Maskawa had completed his PhD in 1967. Kobayashi explained how their theoretical ideas had been influenced deeply by Sakata’s work, especially by his 1956 model of hadrons. This was a forerunner to the quark model that, in particular, stimulated the study of the SU(3) group in the context of particle physics. Moreover, a paper by Sakata together with Ziro Maki and Masami Nakagawa in 1962 had included a theory describing mixing in the lepton sector using a 2×2 matrix with a single mixing angle.

Maskawa had moved to Kyoto in 1970 and Kobayashi followed him there in 1972, at which point they started to work together on trying to incorporate CP violation into the recently formulated gauge theory of electroweak interactions. They quickly realized that it would not be possible to achieve this goal with only four quarks, and concluded that extra particles would be needed. Their paper enumerated several possibilities, including the six-quark model with their 3×3 mixing matrix, which would turn out to be correct. This work, as Kobayashi pointed out, “only took a couple of months”.

Two talks followed on the experimental search for CP-violating phenomena with neutral kaons – past and future – by Marco Sozzi of the University of Pisa and Taku Yamanaka of Osaka University. The search for direct CP violation had needed measurements of K^0_L decaying to two π^0s. This was dubbed the “decay where nothing goes in and nothing comes out”, but successive experiments succeeded in studying it with staged experimental innovations. Between the first observation of CP violation and the eventual demonstration of direct CP violation in neutral kaons, the number of K^0 decays observed increased by 5–6 orders of magnitude as a result of technological innovations. Much was made of the long drawn-out history of measurements of $\mathrm{Re}(\varepsilon'/\varepsilon)$ – the observable manifestation of direct CP violation in neutral kaons – with apparent fluctuations (albeit within experimental uncertainties) in its value throughout two generations of experiments on both sides of the Atlantic, before it settled down eventually to its current value of $(1.65\pm0.26)\times10^{-3}$. One participant asked what value of η – Wolfenstein’s CP-violating imaginary parameter in the Cabibbo–Kobayashi–Maskawa (CKM) matrix – does the measured value of ε' correspond to? Sozzi responded that the cancellations in the calculation of ε' in terms of η are so complete that it is not possible to make such a one-to-one correspondence.

In considering the legacy of the neutral-kaon experiments, Cronin commented that although a great deal of work had been done during the years to measure the values of the elements of the CKM matrix, it was still a great mystery as to why their values are what they are, and he asked whether theory had left the field “in trouble” over this. However, Yamanaka could “only share his frustration”. The baton for CP-violation experiments with kaons now passes to the KOTO (K^0 to Tokai) experiment at the Japan Proton Accelerator Research Complex (J-PARC), and the NA62 experiment at CERN.

The meeting moved on next to the B factories, with two historical talks by Jonathan Dorfan, now of the Okinawa Institute of Science and Technology, and Masanori Yamauchi of KEK, respectively, on the PEP-II storage rings at SLAC and the KEK-B collider. The large mixing among neutral B mesons and their relatively long lifetimes offered the possibility to observe large CP violation in their decays, but it was necessary to produce them in motion to allow their decay times to be resolved. The large cross-section in the region of the $\Upsilon(4S)$ made it the ideal production environment, but symmetric collisions would have implied near-stationary B mesons. Pier Oddone, together with Ikaros Bigi and Tony Sanda, proposed a solution in 1987 by suggesting the production of boosted neutral B mesons using asymmetric pairs of e^+ and e^- beams tuned to the $\Upsilon(4S)$ resonance. This approach has been vindicated by the success of the B factories in comparison with competing ideas, such as fixed-target production by a hadronic beam, for example, at the HERA-B project.



Nobel laureates Makoto Kobayashi, second from left, and Jim Cronin, with the organizers from QMUL, Adrian Bevan, right, and Marcella Bona.

Even BaBar came along to take part in the exhibition.

These talks thoroughly reviewed many interesting details of the beam designs. PEP-II and KEK-B pioneered true “factory running” of colliders, with continuous injection used for the first time in these projects. In the end, PEP-II produced a total integrated luminosity of 557 fb^{-1} between 1999 and 2008, and KEK-B produced 1000 fb^{-1} by its shutdown in 2010. PEP-II was built by an innovative collaboration between the Lawrence Berkeley Laboratory, the Lawrence Livermore National Laboratory, and SLAC. Asked if this was a model for the future, Dorfan replied: “The time was right. The [US Department of Energy] let us manage ourselves. There was no messing with our budget by Congress, which was a great advantage. Physicists were very involved. It couldn’t be done now!”

BaBar and Belle

Next came talks on the experiments at the B factories, BaBar and Belle, in which their histories were given a thorough airing. The BaBar collaboration had asked Laurent de Brunhoff for permission to use the name and image of his father’s famous fictional elephant, which was duly given with certain conditions attached. (For example, the elephant can be shown holding something only if he is using his trunk, not his hands or feet.) The collaboration went on to pioneer the technique of blind analysis – not as the first experiment to exploit it, but the first to make it standard throughout its analyses. As David Hitlin of the California Institute of Technology, the first spokesperson of BaBar, recalled in his talk, one collaborator had insisted early on that “we don’t need a blind analysis because we know the answer already,” which had convinced Hitlin of the need for it.

The presentations gave a virtual tour of BaBar’s and Belle’s CP-violating and T-violating measurements with B mesons, probes of new physics, tests of penguin amplitudes, neutral-meson mixing with charm, and tests of CP violation in tau decays. Both experiments proved spectacularly that the CKM ▷

Kobayshi speaks after accepting the book Physics at the B Factories *at the conference dinner.*

description of CP violation in the Standard Model is correct. In question time, one collaboration member reported a conversation with a journalist at a conference in Tokyo in 2000. "What's it like to do a blind analysis? – It's the scariest thing I've ever done in my life," had been the candid response. The meeting then turned its attention to the Tevatron at Fermilab, where precise measurements of B_s oscillations and related observables gave valuable new constraints on the unitarity triangle, and again provided further detailed confirmation of the Standard Model.

Gilad Perez of the Weizmann Institute then gave a theoretical talk outlining how the physics of the top quark could offer new insights into the flavour problem in the future, especially at the LHC, with unique opportunities for flavour-tagging in top decays. The extremely large mass of the top quark makes it the only quark to decay before it forms hadrons, and this gives unique access in hadron physics to a decaying quark's spin, charge and flavour. Another important effect of the top's large mass is its importance for fine tuning the weak vacuum – had its mass been a mere 3% greater, the weak vacuum would have been unstable and there would have been no weak interaction in the form observed. The ATLAS and CMS experiments at the LHC have already collected more than five million $t\bar{t}$ pairs, with many more to come. Semi-leptonic decays of t quarks provide a strong flavour-tagging of the resulting b quarks, making such decays akin to a new type of B factory, barely explored so far.

In an historical overview of the LHCb experiment's genesis, the first spokesperson, Tatsuya Nakada, now of the École polytechnique fédérale de Lausanne, described how it was born out of the "shotgun marriage" of the three earlier proposals for B physics at the LHC: COBEX – a collider-mode forward-spectrometer concept to exploit the large $b\bar{b}$ cross-section in high-energy proton–proton collisions; LHB – using a bent crystal for extraction of the beam halo for a fixed-target B experiment; and GAJET – using the gas-jet target concept. The LHC Committee had reviewed the three ideas, and in its wisdom stipulated that there should be a collider-mode experiment, but redesigned under new management to allow the three proto-collaborations to merge into a single entity, which became LHCb. "The first time I think a committee was really clever," Nakada commented. Approval was not trivial, but the impressive results to date have already vindicated the approach taken. A second talk on LHCb by Steve Playfer of Edinburgh University gave a detailed review of its physics output, where the cleanliness of the signatures has surprised even the participants. CP violation in B-baryon decays is a promise for the future.

There were also presentations on the contributions to CP-violation physics from ATLAS and CMS at the LHC. These experiments cannot measure CP violation in purely hadronic B decays because they do not have the required particle identification to reconstruct the exclusive final states. However, with the huge cross-sections available at these energies and the experiments' good lepton-identification capabilities, they are well placed to surpass the B factories in sensitivity to CP violation in final states in which J/ψ particles decay to leptons.

Further talks reviewed the theoretical and experimental status of CP violation in charm and the prospects for its discovery, as well as future prospects at the planned upgrades to both Belle and LHCb, and also at neutrino facilities. The discovery of CP violation in neutrinos would be the crowning achievement of neutrino-oscillation studies. There were also two detailed reviews of the history of T violation, first in kaon physics and then in B decays.

A final talk by Marco Ciuchini of INFN/Roma Tre University reviewed the theoretical implications and future perspectives on CP violation. Again, Cronin wondered why the community is not yet in a position to understand the spectra of fermion masses and mixings, including CP violation. The speaker responded that "this is the hardest problem". One questioner asked if a deviation from the Standard Model were to be observed with the upgraded LHCb or Belle II, thereby indicating some new physics in virtual-loop processes, what energy machine would be needed to observe such physics directly? The answer, said Ciuchini, would depend on the details of the new physics.

The conference dinner took place at the Law Society in the City of London, in grand surroundings appropriate for a 50th anniversary. During the past six years, BaBar and Belle have been collaborating on a grand review of *Physics at the B Factories*, and the occasion was used to announce the completion of this monumental tome. It was also a fitting opportunity to present complimentary copies to Cronin and Kobayashi, in honour of their personal contributions to the current understanding of CP violation.

● For more details on all of the speakers and presentations at the symposium, visit http://pprc.qmul.ac.uk/research/50-years-cp-violation.

Résumé

La violation de CP : passé, présent et avenir

Pour célébrer le cinquantenaire de la découverte décisive de la violation de CP, l'Université Queen Mary de Londres a accueilli les 10 et 11 juillet derniers une réunion spéciale. Cet événement a rassemblé quelque 80 participants, qui étaient nombreux à avoir contribué aux développements expérimentaux et théoriques de la physique de la violation de CP au cours de ce demi-siècle. Si la rencontre visait essentiellement à passer en revue les aspects expérimentaux et phénoménologiques de la violation de CP durant ces 50 dernières années, les participants ont pu également entendre des exposés sur les futurs projets d'expériences de violation de CP avec les saveurs lourdes et les neutrinos.

Paul Harrison, University of Warwick.

CERN

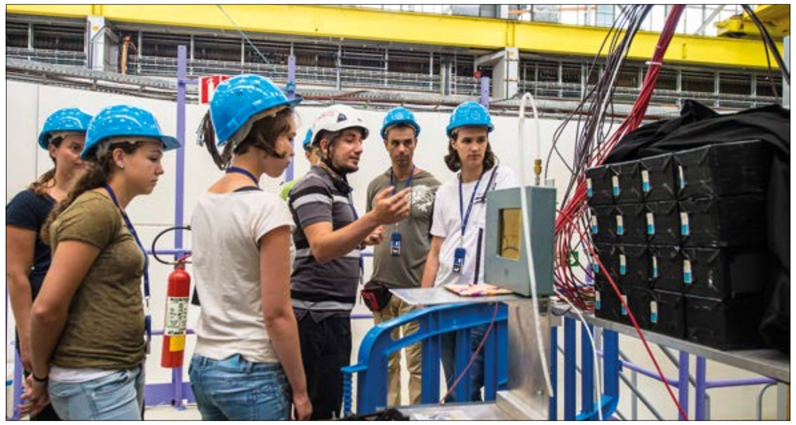
Students thrive at first 'Beam line for schools'

CERN welcomes many visitors from schools each year, but two small groups who arrived in September had a particularly special experience when they worked in a real beam line and collected data for their own experiments. The student teams from Athens and Nijmegen were the winners of CERN's first "Beam line for schools" competition. Selected out of nearly 300 entries, they were able to spend 10 days conducting their proposed experiments in the T9 test beam at CERN's Proton Synchrotron (PS).

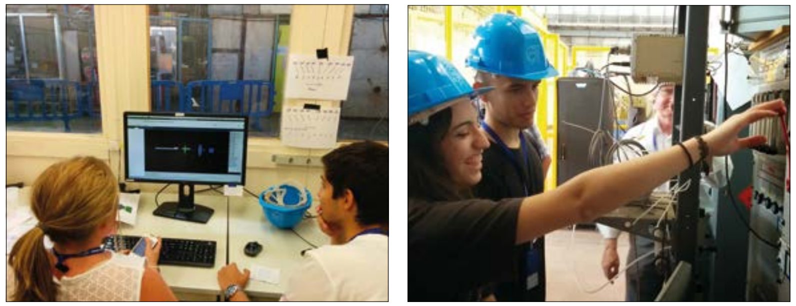
The idea of the competition – planned to coincide with CERN's 60th anniversary – was to make a fully equipped beam line available for high-school students to run an experiment in the same way that the laboratory's researchers do. In proposals of fewer than 1000 words, teams had to explain why they wanted to come to CERN, what they hoped to take away from the experience, and give thoughts on how they would use the particle beam for their experiment. They also had to summarize their written proposal in a creative and entertaining video.

Launched at the end of November 2013, the competition mirrored the real way that researchers bid for access to the laboratory's facilities. Student teams needed first to register by the end of January, with a 140-character "tweet of intent", and then submit the proposal and video by the end of March. By the time the competition closed, 292 proposals had been submitted. Teams of scientists from CERN then evaluated proposals based on creativity, motivation, feasibility and scientific method. After two rounds of evaluation, 16 teams were highly commended and put forward for final selection by the committee that assigns beam time to all of the experiments at the PS and the Super Proton Synchroton (SPS) – the SPSC. In the end, the committee decided to choose not one but two winning teams, both of which were invited to CERN to carry out their experiments together.

The Odysseus' Comrades were a team of 12 from Varvakios Pilot School in Athens. Their proposal was to look at the decay of charged pions – specifically the rare decay to an electron and a neutrino, first observed in 1958 at CERN's Synchrocyclotron. The five-member team from Dominicus College in Nijmegen proposed growing their own heavy crystals to make a calorimeter and to test it with the beam at CERN.



Physicist Cenk Yildiz, white helmet at centre, introduces some of the students to the apparatus in the T9 test beam. (Image credit: CERN-PHOTO-201409-174-1.)



Students at work in the control room, left, and in the experimental area, right. (Image credits: Cenk Yildiz.)

After arriving on 7 September, the students spent their first day at CERN on safety awareness and training, during which they followed standard presentations for anyone working at CERN. These included a safety drill in a mock-up of the LHC tunnel. Then the work of learning how to run an experiment began, with members of CERN staff and users to guide them. Physicists Cenk Yildiz and Saime Gurduk, who had spent weeks writing data-acquisition software and preparing T9 to run the experiments, were on hand all week to train the students in the specifics of shift work and taking data.

After two days of calibration, the calorimeters were integrated as a component in the pion-decay experiment, which succeeded in collecting plenty of data.

During their stay at CERN, the students also had visits to the ATLAS, CMS and CAST experiments, as well as to the Antiproton Decelerator and the new exhibit centred on the old Synchrocyclotron – the site of the experiment that the Greek students were emulating. After 10 days at CERN, the students returned home, with the next challenge to write a paper and so complete the real science experience. However – appropriately in CERN's 60th-anniversary year – the best part of the project was seeing the Greek and Dutch students working so well together.

Conference

Rencontres du Vietnam: physics at the LHC and beyond

Participants of the 10th Rencontres du Vietnam standing in front of the new ICISE in Quy-Nhon. (Image credit: Rencontres du Vietnam.)

Around 120 particle-physics theorists, experimentalists from ATLAS, CMS and LHCb, together with accelerator designers, charted "Physics at [the] LHC and Beyond" during the 10th Rencontres du Vietnam, which took place on 10–17 August at the International Centre for Interdisciplinary Science and Education (ICISE) in Quy-Nhon, in the province of Binh Dinh.

The participants came from many countries around the globe, including Australia, Belgium, France, Germany, India, Israel, Italy, Japan, the Netherlands, Pakistan, Switzerland, Taiwan, Thailand, the UK, the US and Vietnam. All were hosted in the hotel Seagull at Quy-Nhon, which provided excellent infrastructure and a welcome opportunity for participants to meet each other for discussions at breakfast and dinner. The ICISE, inaugurated in August 2013, offers all of the facilities needed for hosting meetings and conferences for up to 250 people, including a main auditorium and four smaller rooms, where the parallel sessions took place. Lunches at the workshop were enjoyed on the centre's balconies, and the participants also had the opportunity to swim at the nearby sandy beach during breaks.

The programme was defined by a committee composed of members of the three LHC collaborations attending, particle-physics theorists and accelerator experts. The workshop sessions reviewed several topics, including the legacy of the LHC's Run 1 concerning precision measurements in Standard Model physics, searches for possible extensions, the latest results from heavy flavour physics and the properties of the new scalar boson; the status of the readiness of the three LHC experiments a few months before the start of the next run; the challenges of the detector upgrades and expectations for Run 2 and for the High Luminosity LHC (HL-LHC); progress on the theoretical computations achieved during Run 1 and the improvements required to constrain further the corresponding uncertainties; and the future machines that could allow knowledge to be pushed further by performing precision measurements and/or by searching for new particles. At the end of each session, long and lively discussions took place, animated by selected senior physicists who highlighted some of the key questions raised by the respective presentations.

The various presentations and discussions illustrated how ATLAS and CMS are on the way towards precision measurements of electroweak symmetry breaking through detailed studies of the top quark and the Brout–Englert–Higgs (BEH) boson, including the latter's couplings and exotic decays. They also demonstrated that LHCb is pursuing a rich programme that is constraining new physics through the measurement of many B-meson decay channels. Precision physics of the BEH boson also provide another portal to new physics. Supersymmetry has so far been elusive, but it is possible that it will be observed with the LHC at centre-of-mass energies of 13–14 TeV. Alternatively, other models, for example with three new right-handed neutrinos, could explain many of the open issues, while representing a minimum extension of the Standard Model, and could be observable at the HL-LHC and, later on, in Z factories.

A panel of nine experts from France, Japan, Switzerland, the UK/US discussed the plans, strategies and prospects for future accelerators, as well as the globalization of the next machine. The scientific strategies of the different countries were described, and it was emphasized that 2018 will be a crucial year. By then, the results from the LHC Run 2 at 13–14 TeV will have answered the question of what new physics exists in this higher-energy range, so that the landscape of the new machines will have taken a much clearer shape.

Two presentations by the 2013 Nobel laureate François Englert provided a special highlight: one on the scope of fundamental research – also translated into Vietnamese for the local authorities – and the other on the history and subtleties of the BEH mechanism. Final summary talks were presented on the last morning by Jim Virdee, of Imperial College London, on the experimental side, and by Benjamin Grinstein, of the University of California, San Diego, on the theoretical developments.

● For more information about the meeting, visit http://events.lal.in2p3.fr/Physics-LHC-2014/index.html.

*ALICE collaboration members, left to right, Paolo Giubellino of INFN Turin and CERN, Peter Braun-Munzinger of GSI, Johanna Stachel of Heidelberg University, and Jürgen Schukraft of CERN, were presented the 2014 Lise Meitner Prize at a private ceremony held in the Globe of Science and Innovation at CERN on 3 September. They received the prize, awarded by the European Physical Society (EPS), for their work with ALICE on the experimental exploration of the quark–gluon plasma using ultra-relativistic nucleus–nucleus collisions (*CERN Courier *September 2014 p31). Douglas MacGregor and Victor Zamfir from the EPS were at the ceremony to present the award. (Image credit: CERN-PHOTO-201409-170-4.)*

Publishing

CERN and APS joint open-access initiative

The American Physical Society (APS) and CERN have announced a partnership to make all CERN-authored articles published in the APS journal collection open access. The agreement covers articles published in the APS journals *Physical Review Letters*, *Physical Review D*, and *Physical Review C*, in 2015 and 2016.

Thanks to this partnership, articles will be available free of charge for everyone to read. Copyright will remain with the authors and permissive Creative Commons CC-BY licences will allow reuse of the information – for example, in books, review articles, conference proceedings and teaching material – as well as text- and data-mining applications.

CERN and the APS have long been co-operating to support APS's pioneering open-access journal *Physical Review Special Topics Accelerator and Beams*, which publishes articles on topics of technical innovation at CERN and elsewhere. The two bodies are committed to continue to work together to find new ways to collaborate, to provide for the widest dissemination of physics results through global open-access initiatives.

Another organization celebrating its 60th anniversary this year is the Guinness World Records, which recently awarded CERN and the ATLAS and CMS collaborations the world record for "the first proof of the existence of a Higgs boson". The LHC already has world records for the largest scientific instrument, most powerful particle accelerator and the highest man-made temperature. Representatives of Guinness World Records came to CERN to present certificates. (Image credit: Achintya Rao/OPEN-PHO-ACCEL-2014-005-4.)

Schools

Physics training in Africa

Participants during the first week of ASP2014. (Image credit: NSRC/Amanda Thomsen.)

The third biennial African School of Fundamental Physics and its Applications (ASP) took place in Dakar, Senegal, on 3–23 August. The aim of the African School of Fundamental Physics is to build capacity to harvest and interpret the results of current and future physics experiments with particle accelerators, and to increase proficiency in related applications, such as in medicine and information technology. Organized in a Sub-Saharan African country every second year, it is based on a close interplay between theoretical, experimental and applied physics and computing.

This year, ASP2014 attracted 328 applicants, of which 69 were selected, given budget and logistical considerations, and 56 ultimately attended. The selected students came from 21 African countries – the highest number so far – in addition to one student from Iran and another from the US. As many as 32% of the students were female, which is a significant increase compared with the previous two schools.

ASP2014 also saw a broader sponsorship with the increasing role of the United Nations, offering, via the International Telecommunication Union (ITU), scholarships to 10 students from the least developed countries, including five female students. The EU-funded Cryogenics, Accelerators and Targets at HIE-ISOLDE (CATHI) Marie Curie Initial Training Network, hosted at CERN, also offered nine scholarships and the participation of two lecturers. In total, the school received financial support from 42 institutions in Africa, Europe, Asia and the US, including the International Centre for Theoretical Physics (ICTP), INFN, CERN and other major particle-physics laboratories, as well as governmental institutions in Africa, Europe and the US – all of whom foster the goals of the school. In particular, ICTP provided secretarial assistance for student selection and travel arrangements, as well as financial support for 14 students and one lecturer.

As in previous years, topics included particle physics, particle detectors, astroparticle physics and cosmology, accelerator technologies and some of the applications, such as medical physics and light sources, as well as Grid computing. However, the programme continues to evolve to take account of feedback from the students, and there is now more emphasis on, for example, digital libraries, the Grid and using Linux.

An additional "Forum and Outreach" event took place on 16 August, organized with students, lecturers and local policymakers. This year, they were honoured to welcome the secretary-general of the ITU, Hamadoun Touré, who gave an inspiring speech. The day also served to emphasize the development of the Digital Library, thanks to the effort of CERN and UNESCO.

● ASP2014 was sponsored by Academia Sinica (Taiwan); ALBA (Spain); American Physical Society (US); BNL (US); CATHI Network; CEA (France); CERN; COMSTECH; CNRS/IN2P3 (France); DST (South Africa); EPFL (Switzerland); ESS (Sweden); FNAL (US); French Embassy in Dakar; GSSI (Italy); IBS (Korea); ICTP; INFN (Italy); International Science Program, Uppsala University (Sweden); IPHC (France); ITU; IUPAP; JLab (US); JSA (US); Louisiana Tech University (US); McGill University (Canada); MCNet; NRF (South Africa); NSF (US); NSRC (US); Oklahoma University (US); PSI (Switzerland); Rutgers University (US); Sandia National Laboratory (US); Shui-Chin Lee Foundation for Basic Science (Taiwan); SLAC (US); UCL (UK); University of Chicago (US); University of Kansas (US); University of Glasgow (UK); University of Texas Arlington (US).

● For more about the school, visit www.africanschoolofphysics.org.

AWARDS

Lebrun receives the Tesla Prize

CERN's Philippe Lebrun, who led the accelerator-technology department during the construction of the LHC, has been awarded the Tesla Prize. He receives the prize for his role during the construction of the cryogenic high-field magnets that form the most delicate part in the functioning of the collider, contributing to the discovery of a Higgs boson at CERN in 2012. He is also cited as "a remarkable heir to the tradition initiated by Nikola Tesla".

The award ceremony took place on 20 September in the Montenegro National Theatre in Podgorica, in the presence of Crown Prince Nicolas Petrović Njegoš of Montenegro, who established the prize in the framework of the Petrović-Njegoš Foundation. The foundation aims to affirm the Montenegrin culture, and participation in humanitarian and development activities. Tesla's own contribution to the field of magnetism is honoured in the name of the SI-derived unit of magnetic flux density, the tesla.

Philippe Lebrun receives the prize from the US ambassador to Montenegro, Sue K Brown – Tesla was both Serbian and American. (Image credit: Foundation Petrović Njegoš.)

ANNIVERSARY

Georges Charpak: Bringing nations together through science

Organizers of the Charpak event and TESHEP. Left to right: S Barsuk (LAL), H Sobczuk (Polish Academy of Science), M Titov (IRFU), Z Nazarchuk (National Academy of Science of Ukraine), A Stocchi (LAL), M-H Schune (LAL), A Zalewska (president of CERN Council), N Alamanos (IRFU), G Mametz (French Embassy in Ukraine), B Grinyov (State Agency on Science, Innovation and Information of Ukraine), I Ryabchyj (Young Academy of Sciences of Ukraine). (Image credit: TESHEP.)

A mini-conference dedicated to the 90th anniversary of the birth of Georges Charpak took place on 21 July in Lviv, Ukraine, during the Trans-European School of High-Energy Physics (TESHEP), which was held on 17–24 July.

Charpak was born in 1924 in Dabrowica, Poland – now Dubrovytsia in Ukraine. He moved to France at the age of seven, and went on to join CERN in 1959. In 1968, he invented the multiwire proportional chamber, which revolutionized particle physics and brought him the 1992 Nobel Prize in Physics (*CERN Courier* December 2010 p33).

A passionate physicist, Charpak was also involved in many social, educational and humanitarian projects, and served as a source of inspiration to many scientists. In 1992 he founded the organization Physique sans frontiers, and supported its effort to set up the Four Seas Conference series. Starting in Trieste in 1995, these took place later in Sarajevo (1998), Thessalonika (2002), Istanbul (2004) and Iasi (2007). Their focus on south-eastern Europe gave the region's young scientists the opportunity to learn about the most recent advances in science and technology. The conferences also served as a way to express the solidarity of the European scientific community with all those who, under difficult conditions, seek to keep alive diverse intellectual and cultural links, and to emphasize the unity of science.

This year, when Charpak would have been 90, CERN is celebrating 60 years of science for peace, following its foundation in 1954. During a particularly fragile time for Ukraine, scientists from France, Ukraine, Poland and CERN met together in the National University "Lviv Polytechnic" in memory of Charpak and to continue his scientific and cultural traditions. The "Charpak Event" was organized as part of TESHEP, which, for the sixth year in a row, brought together high-energy-physics students with the aim of reinforcing east–west scientific and pedagogical links in Europe. Despite the current situation in Ukraine, the event attracted around 100 participants, and was attended not only by local authorities and well-known scientists, but also by students of Lviv University and members of the Lviv department of the Minor Academy of Sciences of Ukraine.

Welcoming talks were given by Borys Grinyov, of the State Agency on Science, Innovation and Information, as well as by representatives of the National Academy of Science of Ukraine, Lviv City Administration and Lviv Polytechnic University. "Charpak is the symbol of scientific co-operation", was the leitmotiv of the opening talk by Gilles Mametz, the attaché for scientific and university co-operation of the French embassy in Ukraine. Then, in her talk on the theme "CERN: Science unites nations", Agnieszka Zalewska, the president of CERN Council, emphasized the idea that Charpak always aimed for physics in the service of humankind – with scientists working together peacefully at the frontiers of research and disseminating results as widely as possible.

Building on the existing partnership between France and Ukraine, Achille Stocchi, director of Laboratoire de l'accélérateur linéaire (LAL), Orsay, summarized the pedagogical and scientific relations between the two countries and ways to expand the collaboration in the context of experiments at CERN. Nicolas Alamanos, deputy-head of Institute of Research into the Fundamental Laws of the Universe (IRFU), Saclay, then spoke on technology domains of potential co-operation between France and Ukraine, and about the Micromegas detector concept developed in 1996 in a collaboration between Charpak and scientists from Saclay. Following a discussion of the French–Ukraine activities, Henry Sobczuk of the Polish Academy of Science emphasized a key partnership between the two countries.

The programme of the mini-conference was complemented by a documentary film about Charpak, *The Nobel prize*, and the presentation of the Ukrainian version of his autobiography. Last but not least, the event ended with two presentations about future projects in high-energy physics, and a look at the history of instrumentation, from multiwire proportional chambers to novel gaseous detectors. The latter provided a complementary view on the history of particle physics, which is often told from a theoretical perspective.

A physicist who transformed the measurement of high-energy particles, a fascinated educator, and a magician – Georges Charpak contributed a significant part of his efforts to enhance the role of science diplomacy in opening up the possibility to tackle global challenges and improve the lives of people via the development of novel technologies, and in ensuring cultural exchanges between different nations.

- The one-day "Charpak Event" was organized jointly by the French Embassy in Ukraine, the EU/Science and Technology Centre in Ukraine (STCU), LAL/IN2P3-CNRS, IRFU/CEA Saclay, CERN, the RD51 Collaboration, the Ukrainian State Agency on Science, Innovation and Information, and Lviv Polytechnic University. For more information about the event, visit https://indico.cern.ch/event/331478/.

LIGHT SOURCES

Riding the waves of new electrons at the NSRRC Users' Meeting

There was great expectation and eagerness at the 2014 National Synchrotron Radiation Research Center (NSRRC) Users' Meeting, which took place at the NSRRC's new activity centre in Hsinchu on 10–12 September. The workshop not only gathered users of the NSRRC's first accelerator facility, the Taiwan Light Source (TLS), but also had the mission to outline developments for the coming decades at the recently completed second accelerator, the Taiwan Photon Source (TPS).

With the 1.5 GeV TLS available to researchers since 1994, NSRRC currently operates 26 beamlines in the TLS and two beamlines at SPring-8 to support experiments conducted by more than 2000 users in 2013. The TPS – a $230-million project – is based on a 3 GeV electron accelerator and a low-emittance synchrotron storage ring of 518.4 m circumference (*CERN Courier* June 2010 p16). Involving more than 145 full-time staff in design and construction, it is now ready for commissioning.

The dual accelerators of NSRRC – TPS (big) and TLS (small). (Image credit: NSRRC.)

Shangjr (Felix) Gwo, appointed as director of the NSRRC on 1 August, is ready to bring the NSRRC staff and users, collaboration partners, academic researchers and industrial customers to the table for discussions on future developments. These include the construction plan for the TPS phase-I beamline, preferred research programmes at the TPS, reinventing the services of the existing TLS experimental stations, and promoting the design and manufacture of various insertion devices and accelerator subsystems, to transform the TPS accelerator team into a service provider with an "engagement with industry", after the completion of the TPS project.

As the users' meeting unfolded, the preparation of TPS commissioning, led by Chien-Te Chen, director-general of the TPS Construction Project, and Gwo-Huei Luo, NSRRC deputy-director, continued to progress. The completion of TPS construction and the integration tests of all its subsystems provided momentum for the discussions on future research and developments at the accelerator. NSRRC's director, Shangjr Gwo, hosted the "town meeting" held on the first day immediately after six selected users had reported on their research, offering a glimpse of how they make use of the capabilities of the TLS. Inputs from users will be taken into account for strategic decisions on the role and operational mode of the TLS, a stable light source for mainly soft X-rays, after some of its beamlines and experimental stations are relocated to the TPS.

Following the town meeting, four workshops proceeded to offer an overview of existing research projects and the opportunity to compare techniques and methodologies practiced at facilities elsewhere, with speakers invited from institutes in Australia, China, France, Germany, Japan, Korea, the Netherlands, Singapore, Switzerland and the US. The discussions in the workshops will be extended to become a part of the initiatives for future implementation and advances at the TPS. The programmes of four workshops highlighted the diverse applications of the scientific fields that exist in Taiwan on a variety of X-ray analysis and scattering techniques.

- For more on the NSRRC Users' Meeting, visit http://regis.nsrrc.org.tw/index_en.html.

CAS participants on board the Vyšehrad steamboat. (Image credit: Michal Marcisovsky/ CTU Prague.)

SCHOOLS

CAS introduces accelerator physics in Prague

The CERN Accelerator School (CAS) and the Czech Technical University in Prague jointly organized a course providing an introduction to accelerator physics, held in Prague on 31 August to 12 September. The course, which took place in the Hotel Don Giovanni on the outskirts of the city, attracted 111 participants of 29 nationalities, coming from countries as far away as Armenia, Argentina, Canada, Iceland, Thailand and Russia.

The intensive programme comprised 41 lectures, three seminars, four tutorials and six hours of guided and private study. A poster session and a one-minute/ one-slide session were also included in the programme, where the students were able to present their work. During the second week, the afternoon lectures were held in the Czech Technical University in Prague. In addition to the academic programme, the students had the opportunity to visit the medieval site of Kutna Hora and the Velke Popovice Czech brewery. A special dinner was organized on the Vyšehrad steamboat on the Vltava.

Next year, CAS will organize a specialized course on accelerators for medical applications, to be held in Brunn am Gebirge, Austria, on 26 May–5 June 2015. The next course on advanced accelerator physics will be held in Poland in the autumn of 2015.

- For further information on forthcoming CAS courses, visit www.cern.ch/schools/CAS.

CORRECTION

The review of the book *Portrait of Gunnar Källén*, published in the October 2014 issue of *CERN Courier* (p74), unfortunately made a mistake in the first name of Källén's wife. It should be Gunnel. Many apologies to all concerned.

OBITUARIES

Colin Ramm 1921–2014

One of the pioneering figures of CERN, Colin Ramm, passed away on 23 June.

Colin was born in Perth, Western Australia, in 1921. He obtained a scholarship to study at the University of Melbourne, but was unable to accept it and instead joined the Commonwealth Meteorological Bureau. There he began to study part-time with a free place at the University of Western Australia (UWA), where he was to gain a first-class honours degree in physics in 1942.

With the Second World War, the Meteorological Bureau became part of the Royal Australian Air Force, from which Colin was seconded to UWA for optical-munitions work. Skilful at experimental techniques, he spent much time on the final polishing of lens test-plates, which had to be accurately figured to around a ten-thousandth of a millimetre. He therefore became acquainted with optical techniques and metrology, and learned the connection between patience and precision.

After the war, he stayed on at the university, becoming interested in cosmic rays, klystrons and teaching. In 1947 he accepted an invitation from Marcus Oliphant to be a lecturer at Birmingham University, where Europe's first proton synchrotron, to give an energy of 1 GeV, was being built. After obtaining his doctorate in 1951, Colin stayed with the synchrotron team until completion of the machine, and designed and built the injection system.

At about this time, plans were being made for the 28 GeV Proton Synchrotron (PS) at CERN. Like many others, Colin was stirred by the deep significance of an international collaboration to build a much larger accelerator. In 1954 he joined the PS Division, as leader of the magnet group, which became responsible for the whole of the synchrotron's magnet system. Exceptional uniformity had to be obtained in the magnetic properties of the individual components, so it was essential to find physical principles by which the process of construction would in itself produce the necessary precision.

Colin Ramm as dean of science at UWA. (Image credit: Ramm family.)

With work on the magnet system finished, the magnet group – which became the Nuclear Physics Apparatus Division in 1961 – turned towards helping to make the PS usable as an experimental device, and in the course of time a number of projects took shape under Colin's leadership: a heavy-liquid bubble chamber, magnets and lenses for guiding secondary beams, electrostatic separators, a high-energy antiproton beam, scanning apparatus for bubble-chamber photographs, a fast beam-ejection system, and finally an enhanced neutrino beam. Under Colin, the division viewed its task as primarily one of helping the advancement of physics, convinced that the best ideas can only come from close contact with experiments. For this reason, a small experimental physics group was formed to analyse a proportion of the pictures from the heavy-liquid bubble chamber.

The Ramm chamber – with a volume of 500 litres – was then the largest heavy-liquid chamber in the world operating in a magnetic field. The maximum field of 26.7 kG was a record for a large chamber. Completed in 1960, it was used in CERN's first neutrino experiments.

The electrostatic separators built by Colin's division gave CERN some of the world's highest-energy beams of separated particles, as well as leading to research into the basic principles of high-voltage breakdown. However, it was the enhanced neutrino beam that quickly became the division's main preoccupation. A group under Berend Kuiper and Gunther Plass was already working on a proposal they had made for extracting protons from the synchrotron, when it became obvious that with the ejected beam a greater pion flux could be obtained in the experimental areas. Simon van der Meer produced the idea of a magnetic horn, to concentrate the pions so that an even larger number of neutrinos from their decays would be directed towards the detectors. It was an outstanding success.

Colin returned to Australia in 1972, when invited to become the first full-time dean of the faculty of science at the University of Melbourne. After being re-elected twice, he became the longest-serving dean of the faculty to that point. During this period he was also appointed professor. With his pragmatic approach during a period of severe financial cutbacks, he won many admirers. He also instituted major new initiatives in interdisciplinary research, most notably in marine science. At the same time, he continued his own research by analysing bubble-chamber neutrino data obtained from CERN.

After retiring as dean in 1983, Colin joined the School of Physics, and after a gap of almost 30 years, he returned to teaching, one of his first loves. He also found new challenges in experimental research, exhibiting his great talents in building and operating experimental equipment. He retired in 1988.

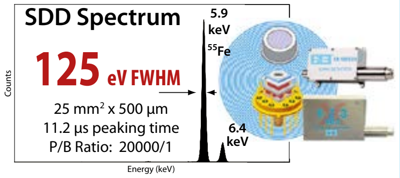
Sadly, his wife Muriel died some years ago, but with his family Colin made a major donation, in 1998, to establish the Muriel Ramm Science Bursary in her memory. He and his family have since made further donations to increase the fund for this bursary, and also for a prize in experimental physics. Furthermore, Colin and his family made a donation to his alma mater, the UWA, to establish the Muriel and Colin Ramm Medal and Scholarship in Experimental Physics.

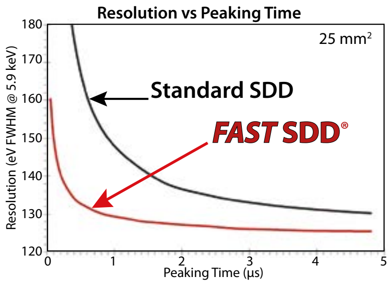
He leaves behind a daughter and a son, who went on to practise one of Colin's great interests – marine science.

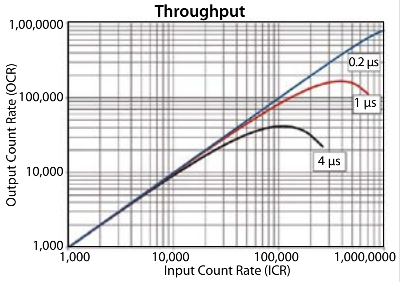
- *Friends from Melbourne and CERN.*

***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.







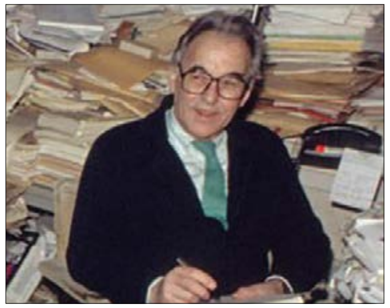
Louis Dick 1921–2014

Louis Dick, a CERN experimental physicist of international renown, passed away on 14 July.

Born in Geneva on 27 April 1921, Louis obtained a physics degree at ETH-Zurich in 1946 before moving to the Institut du Radium in Paris, where he joined the group led by Frédéric and Irène Joliot-Curie. His work on low-energy experiments and on the development of fast-coincidence techniques using scintillators included the construction of a magnetic spectrometer to measure electron spectra from nuclear β decay and the detection of $\alpha - \gamma$ coincidences in radioactive decays. He took leave of absence in 1957 to go to CERN, where he remained until well beyond his retirement in 1986, although his original plans were to return to Paris.

In the late 1950s and early 1960s, Louis worked with Robert Keller and Maria Fidecaro on a polarized proton source to be used at CERN's 600 MeV Synchrocyclotron (SC). Although successfully tested in a 4.5 MeV cyclotron, this source was never installed, because the invention of polarized proton targets in the early 1960s allowed the study of spin effects in meson–proton and proton–proton collisions, making the acceleration of polarized protons less attractive. The group also worked on the development of "stochastic acceleration" to improve the duty cycle of secondary beams from the SC by increasing the spill time – a method used routinely for SC operation after 1963.

In 1963, together with Louis Feuvrais, Leon Madansky and Valentine Telegdi, Louis proposed to measure the helicity of positrons by stopping them in a scintillator to form positronium. The scintillator was placed in a magnetic field parallel to the helicity direction. Reversing the field produced a change of the positronium populations in the singlet and triplet states, proportional to the positron helicity. The states were distinguished through the lifetimes of the 2γ decay – 0.2 (2) ns for the singlet (triplet) state in dense matter. Thanks to Louis's competence in the measurement of very short lifetimes, the method was applied to positrons from ^{22}Na and ^{8}B decay, giving a result consistent with the 100% helicity predicted by the V-A theory. However, the helicity of positrons from μ^+ decay was found to be (28±16)%. Following this surprising result, three experiments – one involving Louis's group – used more conventional methods at the SC to measure the helicity of inflight positrons from μ^+ decay. These experiments agreed with the 100% V-A prediction. The earlier result was explained by the depolarization of the positron as it slowed down in a moderator before stopping in the scintillator, as Louis confirmed in a subsequent experiment.



Louis in his office, a veritable archaeological wonder, with strata of documents corresponding to various physics eras. (Image credit: CERN-MI-9612016-02.)

The first polarized proton target arrived in 1963 at CERN from Saclay, where it had been developed and built by Anatole Abragam and his group. It was used to measure the relative parity of the proton and Ξ^-, and so verify that they belong to the same SU(3) octet. As well as Louis, the team included Carlo Rubbia, Georges Charpak, J C Sens, Herbert Steiner of Berkeley and Abragam himself. Their method was to measure the right–left asymmetry in $K^- p \rightarrow K^+ \Xi^-$ on polarized protons, using a 1.8 GeV/c beam from the Proton Synchrotron (PS).

Louis then proposed using the polarized target for studies at the PS of spin effects in πp elastic scattering at small four-momentum transfers of $0.1 < |t| < 0.75$ (GeV/c)^2. Between 1964 and 1966, sizeable spin effects were found at energies of 6–12 GeV, with polarization parameters of 10–20% and a negative (positive) sign for π^- (π^+). These results were interpreted in the context of Regge-pole theory as resulting from the interference of the spin-flip amplitude associated with the ρ trajectory and that from Pomeron exchange. Louis continued these studies with physicists from CERN, the Institut de Physique Nucléaire (IPN) Orsay and Pisa, using beams of 6–17 GeV produced with an external proton target. With higher beam intensities, a new detector, and a new polarized target with around 25% free protons developed at CERN by Michel Borghini and his group, the data covered $\pi^\pm$, $K^\pm$, p and $\bar{p}$ scattering, and reached $|t|$ of 3 (GeV/c)^2. Later, Louis extended these measurements to $\pi^\pm$ backward scattering at 6 GeV in a CERN–Oxford–IPN Orsay collaboration. In 1975 the target was taken to the Rutherford Laboratory, where the polarization parameter in pp elastic scattering was measured for $1 < |t| < 7$ (GeV/c)^2, using 7 GeV protons from the NIMROD synchrotron.

At the end of the 1970s, the Super Proton Synchrotron (SPS) $\bar{p}p$ collider made possible the comparison of $\bar{p}p$ and pp interactions at $\sqrt{s} = 24.3$ GeV, using an internal hydrogen-jet target in the UA6 experiment. Louis's initial idea was to use the polarized proton source that he had developed for the SC, but the calculated luminosity was too low to produce significant results. Instead, in collaboration with CERN's Werner Kubischta, he developed a dense, unpolarized hydrogen-cluster-jet target that gave enough luminosity for this comparison. In a CERN–Lausanne–Michigan–Rockefeller collaboration, Louis proposed UA6 to study the inclusive production of particles with large transverse-momentum (p_T) – a process probing parton interactions. Installed at the SPS in 1983, UA6 included a magnetic spectrometer and an electromagnetic calorimeter, and measured inclusive π^0, single-photon and J/ψ production at $4.1 \le p_T \le 7.7$ GeV/c. It also determined the gluon distribution in the proton for $x > 0.2$ and extracted the strong coupling constant α_s from the $\bar{p}p$–pp single-photon cross-section difference. The detection of recoil protons near 90° to the beam using solid-state counters allowed the measurement of the cross-section for pp and $\bar{p}p$ elastic scattering at $0.001 < |t| < 0.014$ (GeV/c)^2 in the Coulomb interference region, and the determination of the ratios of the real to the imaginary parts of the scattering amplitudes.

In 1986 Louis reached CERN retirement age, but continued to work as a visiting scientist with INFN/Milan. He remained active, taking part in lively discussions of possible new projects and detector concepts.

An experimentalist full of original ideas, Louis had great competency in detectors, which he always tried to push to their ultimate performance. He tended to favour unconventional experiments, not fashionable among theorists, and pursued his ideas even when not immediately accepted. One important trait was the attention he paid to the young people around him, supporting many of them, and encouraging technicians to broaden their competencies through university evening courses. Lastly, his CERN office was a veritable archaeological wonder, with strata of documents corresponding to various physics eras.

Louis will be sorely missed by those who worked with him or even had only occasional physics discussions with him. Much sympathy goes to his wife Line, to his two daughters Anne-Fabienne and Emmanuelle, and to their families.

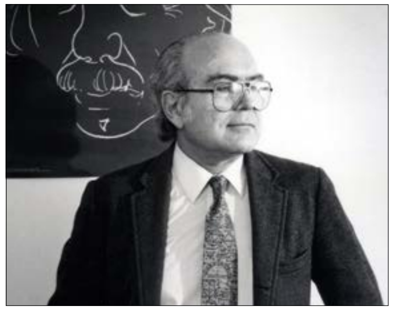
● *His colleagues and friends.*

Bruno Zumino 1923–2014

Bruno Zumino, emeritus professor at the University of California, Berkeley, since 1994, died at home in Berkeley on 22 June, aged 91. His name is associated mainly with the formulation of supersymmetry in four-dimensional space–time.

Bruno was born in Rome on 28 April 1923, and graduated in physics at the University of Rome in 1945. In Göttingen during the following years, he wrote important papers with Gerhart Luders on the consequences of the CPT theorem in relativistic quantum field theories. Then, in 1951, he moved to New York University, where he ultimately became chair of the physics department. During this time he did significant work on "algebras of fields" with Tsung-Dao Lee and Steven Weinberg, and on "phenomenological Lagrangians" with Sidney Coleman of Harvard, Julius Wess of Karlsruhe and Curtis Callan of Princeton.

In 1968, Bruno joined the Theory Division at CERN, where he stayed until 1981. It was here that he did his pioneering work with Wess in which they formulated the first supersymmetric four-dimensional quantum field theory – the Wess–Zumino model – and proved its renormalizability. In this theory the infinities of perturbation theory were found to be milder than in non-supersymmetric theories, giving rise to so-called "non-renormalization theorems", which appeared originally in papers written in the mid-1970s in several collaborations with Wess, Jean Iliopoulos of the Ecole Normale Supérieure in Paris and myself (at the time a postdoctoral fellow at CERN). Working together we solved the problems of combining supersymmetry with non-Abelian (Yang–Mills) gauge symmetry, thereby opening the way to apply supersymmetry to the fundamental non-gravitational forces – the electroweak and strong interactions.



Bruno Zumino in 1985. (Image credit: Lawrence Berkeley National Laboratory.)

The case for supersymmetry in the low-energy world that we inhabit was mostly advocated to solve the so-called naturalness and hierarchy problems, but it could also play an important role in the formulation of grand unified theories and in providing some candidate particles for dark matter. It is a strong candidate for physics beyond the Standard Model, and although no particles predicted by supersymmetry have so far been detected, there is still hope that they will show up in the tera-electron-volt mass range when CERN's LHC reaches the design energy of 14 TeV.

In 1976, two years after its formulation, supersymmetry was combined with the gravitational force, giving birth to supergravity and stunning developments that included superstring theory and M-theory. The original formulation of supergravity by Dan Freedman of MIT, Peter van Nieuwenhuizen of Stony Brook and myself (at the time at INFN-LNF/Frascati and Ecole Normale Supérieure) was soon followed by an elegant formulation by Bruno and Stanley Deser of Brandeis, using the so-called first-order formalism.

In his last year at CERN, Bruno, collaborated with Berkeley physicist Mary K Gaillard in pioneering work on the application of duality to field theories. A generalization of the "electric-magnetic duality" that exchanges electric fields with magnetic fields, duality plays a fundamental role in connecting diverse formulations of string theory and in relating weakly coupled theories in one formulation to strongly

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coupled theories in other formulations. In 1982, Bruno joined Gaillard as a faculty member at the University of California, Berkeley.

As a final part of this tribute to Bruno, I would like to make some personal recollections. I had the privilege of being his closest collaborator next to Wess, with 14 jointly published papers during different epochs of my career. I was proud to share with him and Gabriele Veneziano, of CERN and Collège de France, the 2005 Enrico Fermi Prize awarded by the Italian Physical Society. When I visited Bruno in 2008, as a Miller visiting professor at Berkeley, we started to collaborate again on aspects of duality applied to black holes. Our joint papers were his last ones.

Bruno's last trip to Europe, to attend a conference as invited speaker, was in the summer of 2011 to celebrate the 80th birthday of Raymond Stora, his friend and collaborator. The proceedings of that meeting included a report on a joint study with Stora on the algebraic approach to anomalies. In May 2013, a conference to celebrate Bruno's 90th birthday took place at Berkeley. Many distinguished physicists spoke on his behalf, including Fields Medalist Edward Witten and Nobel laureate Steve Weinberg. Unfortunately, Bruno became ill just before the beginning of the meeting, and could come to the inaugural banquet only. That was the last time I saw him.

Bruno won many other prestigious international prizes, among them the Dirac Medal (1987), the APS Dannie Heineman Prize (1988), the 1989 Max Planck Medal, the 1992 Wigner Medal and the 1999 Giancarlo Wick Gold Medal. Survived by his wife Mary K Gaillard and three stepchildren, he leaves an enormous legacy, and will be remembered for his achievements by future generations. I sincerely hope that his predictions will be proved right by nature.

- *Sergio Ferrara, CERN. Based, with permission, on the obituary first published by the Italian Physical Society, in* Il Nuovo Saggiatore ***30*** *87 (2014). See also www.sif.it/attivita/saggiatore/ricordo/zumino.*

Johan de Swart 1931–2014

Johan de Swart passed away on 10 June in Nijmegen, where he had been professor of theoretical physics since 1963. He is known for his work in group theory, notably SU(3), as well as that on nucleon–nucleon and hyperon–nucleon interactions and quark-model applications. Colleagues and students remember him as a passionate physicist and an excellent teacher.

Johan de Swart. (Image credit: Anna Bakker.)

Johan was born on 31 January 1931 in Dordrecht. He studied physics at Delft Technical University, followed by postgraduate research on the photodisintegration of the deuteron under the supervision of Robert Marshak at Rochester University, where he obtained his PhD in 1959. By then he was already exploring the use of the first computers, which was to be a characteristic of his approach to theoretical research. After spending some time at the University of Chicago and at CERN, he was appointed professor of theoretical physics at the University of Nijmegen in 1962, at the age of 31.

At CERN, Johan worked on flavour-SU(3) symmetry, developing and establishing the conventions for the Clebsch–Gordan coefficients, tables of which continue to form a part of *The Review of Particle Properties*. In Rochester, with Cees Dullemond, he had already begun pioneering work on applying SU(3) symmetry to baryon–baryon interactions, which he continued in Nijmegen with several PhD students, leading to the well-known "Nijmegen potentials". His studies of meson-exchange interactions contributed to the renowned overviews "Compilation of coupling constants and low-energy parameters" in the 1970s. Applications in the late 1970s and early 1980s to quark models used the unitary symmetries for spin, flavour and colour to understand details in the spectrum of baryons and mesons and their excitations, and to make predictions for possible multiquark states.

In the 1980s and early 1990s, Johan and his group developed a new approach to energy-dependent partial-wave analysis (PWA) of the nucleon–nucleon (NN) scattering data, based on the so-called P-matrix and field theory for the long-range electromagnetic and strong NN interactions. This resulted in the famous and highly influential PWA93 solution and new, high-quality phenomenological NN potential models. Later developments in the 1990s incorporated chiral perturbation theory for the long-range NN interaction.

At the University of Nijmegen, Johan gave brilliant lectures on many topics, for which he made beautiful, detailed lecture notes, often including derivations and educating the students on the required mathematical background. He also participated in the first PhD schools in the Netherlands, where many senior physicists remember his lectures. In sharp contrast to his love of teaching stood his aversion to administration and faculty meetings, which he tried to avoid. His diplomacy was not particularly well suited for such tasks. Research and teaching were his passions.

- *Piet Mulders, VU University/Nikhef, Tom Rijken, Radboud University, and Rob Timmermans, University of Groningen.*

NEW PRODUCTS

Optical Surfaces supply high-precision toroidal mirrors (toroids) made to exact specifications. Toroidal mirrors are normally used where a beam needs to be focused or folded. The design of toroidal mirrors eliminates astigmatism normally caused by concave spherical mirrors. They are widely used for correction of aberration in a range of applications served by spectroscopic instruments, monochromators and imaging devices that require pinpoint focusing. For further information, tel +44 208 668 6126, e-mail sales@optsurf.com or visit www.optisurf.com/index.php/products/toroids/.

The **ORTEC Products Group** of AMETEK Advanced Measurement Technology has introduced ICS, an integrated cryocooling system that supports premium detector resolution without the use of liquid nitrogen (LN_2). ICS is the newest integrated electromechanical cooling system from ORTEC for high-purity germanium (HPGe) radiation detectors, and exploits the latest advancements in cryogenic technology to provide LN_2-free operation with no loss of detector performance. For more information, tel +1 865 482 4411 or visit www.ortec-online.com.

Specialised Imaging offers the SIMX ultra-high-speed framing camera to provide ultra-high-speed imaging performance to scientists and engineers across all disciplines. The proprietary optical design of the camera offers up to 16 images without compromising shading, or parallax. Capable of capturing up to 16 images at one-billion frames per second, the cameras can be configured to give up to 16 different multi-spectral images with an R, G and B filter on each channel. For more details, tel +44 1442 827728, e-mail: info@specialised-imaging.com or visit www.specialised-imaging.com.

Spectrum has created new firmware options that allow its high-speed M4i series digitizer cards to perform peak detection and output the corresponding statistical data. The M4i series cards offer real-time sampling rates of up to 500 MS/s with 14-bit resolution and 250 MS/s with 16-bit resolution. The M4i series cards are available with two or four channels, and use a fast PCIe bus to transfer acquired or processed data to a host PC at speeds of up to 3.4 GB/s. For more details, tel +49 4102/6956-0, e-mail Info@spec.deInternet or visit www.spectrum-instrumentation.com.

The Proton Synchrotron (PS) control room on the Meyrin site in 1963 (top left) was all manual: for each parameter, a knob or a button to control it, for each signal, a light or meter or oscilloscope to monitor it. Carefully written pages served as the data bank, phones and intercom for communication.

A decade later, in 1974, the control room looked much the same (top right), although white coats were no longer in fashion. However, a revolution was on hand, developed in the early 1970s for the Super Proton Synchrotron (SPS), which was controlled from a separate centre on the Prévessin site.

*The SPS was controlled centrally from three desks, each with its own minicomputer (bottom left). Only a few knobs and switches were used for all of the many thousands of digital and analogue parameters of the accelerator, and a half-a-dozen displays. This saw the introduction of the first touch screens (*CERN Courier *April 2010 p13). In the late 1980s, the Large Eelectron–Positron (LEP) collider was also controlled from Prévessin.*

By the 1990s, as well as the PS, all of its related machines (Linacs 1, 2 and 3; the PS-Booster; LEP-Injector Linacs and the Electron–Positron Accumulator; the Antiproton Accumulator, Antiproton Collector, Low Energy Antiproton Ring and more recently the Antiproton Decelerator) were controlled from the PS control room at Meyrin, while the SPS and LEP were controlled from Prévessin.

With the imminent start up of the LHC, in 2005 all controls were transferred to a new CERN Control Centre at Prévessin (bottom right), bringing together all of the operators and facets of the LHC injector chain, and also managing the beams to other experimental facilities in CERN's unrivalled accelerator complex.

(Image credits clockwise from top left: CERN-CO-6301349, CERN-PHOTO-7402124-1, CERN-AC-1111289-08, CERN-PHOTO-7701610-1.)

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
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International Max Planck Research School for Precision Tests of Fundamental Symmetries:

PhDs in Fundamental Physics

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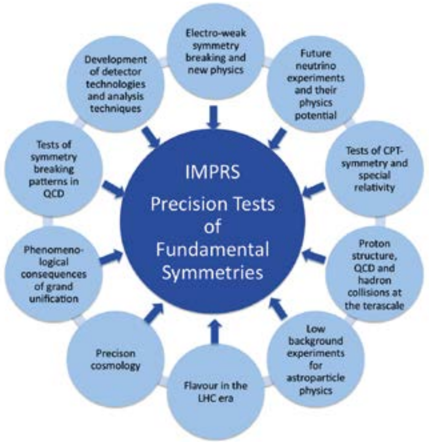
The IMPRS-PTFS is a joint venture of the Max-Planck-Institute for Nuclear Physics and the University of Heidelberg.

Students will work under the supervision of leading scientists on exciting and current topics in the fields of particle and astroparticle physics, cosmology, atomic and nuclear physics. The members of the school can work on both theoretical and experimental aspects.
Regular seminars and soft skills courses will add to the broad education of the students.

We invite applications for 3-4 fellowships for PhD positions, with deadline November 17th.

Please refer to
http://www.mpi-hd.mpg.de/imprs-ptfs
for more information and details of the application procedure.



INDIANA UNIVERSITY

ATLAS Postdoctoral Position with Indiana University

The Indiana University High Energy group on the ATLAS experiment at the Large Hadron Collider seeks an outstanding applicant for a postdoctoral associate position, beginning at a negotiated date. Applicants should have a Ph.D. in High Energy Particle Physics, and demonstrated experience in physics analysis, preferably on a colliding beam experiment. Experience with detector hardware, electronics or computing is also valuable.
The successful applicant will be expected to reside at CERN.

Application should be made via the portal located at **http://indiana.peopleadmin.com/postings/926** that also provides application requirements and details, including descriptions of the group and our research interests and directions.

Indiana University is an equal employment and affirmative action employer and a provider of ADA services. All qualified applicants will receive consideration for employment without regard to age, ethnicity, color, race, religion, sex, sexual orientation or identity, national origin, disability status or protected veteran status.

NATIONAL TAIWAN UNIVERSITY
Leung Center for Cosmology
and Particle Astrophysics

Distinguished Junior Fellowship

The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University is pleased to announce the availability of several Post-Doctoral Fellow or Assistant Fellow positions in theoretical and experimental cosmology and particle astrophysics, depending on the seniority and qualification of the candidate. Candidates with exceeding qualification will be further offered as LeCosPA Distinguished Junior Fellows with competitive salary. LeCosPA was founded in 2007 with the aspiration of contributing to cosmology and particle astrophysics in Asia and the world. Its theoretical studies include inflation, dark energy, dark matter, large-scale structure, cosmic neutrinos, and classical and quantum gravity. The experimental investigations include the balloon-borne ANITA project in Antarctica, the ground-based ARA Observatory at South Pole, and the TAROGE Observatory in the east coast of Taiwan in search of GZK neutrinos, and a satellite GRB telescope UFFO that can slew to the burst event within 1sec. These positions are available on August 1, 2015. Interested applicant should email his/her application with curriculum vitae, research statement, publication list and three letters of recommendation before December 1, 2014 to
Ms. Yen-Ling Lee **ntulecospa@ntu.edu.tw**
For more information about LeCosPA, please visit its website at
http://lecospa.ntu.edu.tw/

Three letters of recommendation should be addressed to
Prof. Pisin Chen, Director
Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

LIGO

Postdoctoral Research Positions
LIGO Laboratory

California Institute of Technology (Caltech)
Massachusetts Institute of Technology (MIT)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) has as its goal the development of gravitational wave physics and astronomy. The LIGO Laboratory is managed by Caltech and MIT, and is funded by the National Science Foundation. It operates observatory sites equipped with laser interferometric detectors at Hanford, Washington and Livingston, Louisiana. The initial LIGO detectors performed better than their design sensitivity and data sets spanning over three years of coincident operation have been collected. Analysis is ongoing, with extensive participation by the LIGO Scientific Collaboration (LSC). A major upgrade (Advanced LIGO) is almost complete which will increase the sensitivity of the detectors by tenfold once commissioned. In addition, an R&D program supports the development of enhancements to the detectors as well as future capabilities.

The LIGO Laboratory anticipates having one or possibly more postdoctoral research positions at one or more of the LIGO sites – Caltech, MIT and at the two LIGO observatories – beginning in Fall 2015. Hires will be made based on the availability of funding. Successful applicants will be involved in the operation of LIGO itself, analysis of data, both for diagnostic purposes and astrophysics searches, as well as the R&D program for future detector improvements. We seek candidates across a broad range of disciplines. Expertise related to astrophysics, modeling, data analysis, electronics, laser and quantum optics, vibration isolation and control systems is desirable. Most importantly, candidates should be broadly trained physicists, willing to learn new experimental and analytical techniques, and ready to share in the excitement of building, operating and observing with a gravitational-wave observatory. Appointments at the post-doctoral level will initially be for one-year with the possibility of renewal for up to two subsequent years.

Applications for post-doctoral research positions with LIGO Laboratory should indicate which LIGO site (Caltech, MIT, Hanford, or Livingston) is preferred by the applicant. Applications should be sent to **HR@ligo.caltech.edu** (Electronic Portable Document Format (PDF) submittals are preferred). Caltech and MIT are Affirmative Action/Equal Opportunity employers. Women, minorities, veterans, and disabled persons are encouraged to apply.

Applications should include curriculum vitae, list of publications (with refereed articles noted), and the names, addresses, email addresses and telephone numbers of three or more references. Applicants should request that three or more letters of recommendations be sent directly to HR@ligo.caltech.edu (Electronic Portable Document Format (PDF) submittals are preferred). Consideration of applications will begin December 1, 2014 and will continue until all positions have been filled.

Caltech and MIT are Affirmative Action/Equal Opportunity Employers
Women, Minorities, Veterans and Disabled Persons are encouraged to apply
More information about LIGO available at www.ligo.caltech.edu

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Universidad de los Andes
Colombia

Faculty Position in Experimental High Energy Physics

UNIVERSIDAD DE LOS ANDES – BOGOTA, COLOMBIA

The Physics Department at Universidad de los Andes, Colombia, is seeking to fill a position in Experimental High Energy Physics for a faculty member at the level of assistant or associate professor.

Applicants are expected to have a PhD degree with postdoctoral experience in experimental High Energy Physics, in hardware and software, with emphasis in Collider experiments. Commitment to excellence in research and teaching are required.

The new faculty will join the High Energy Physics group of our department, who is collaborating in the CMS experiment at the LHC, with responsibilities in the RPC detector and in data analysis for SUSY searches and Higgs studies. In the near future we will also contribute to the CMS GEM project.

More information about the physics department can be found at:
http://fisica.uniandes.edu.co/index.php/en/

Applicants should send a curriculum vitae, a description of research and teaching interests, and arrange to have three recommendation letters sent to:

Carlos Avila,
Chairman, Physics Department, Universidad de los Andes
e-mail: director-fisica@uniandes.edu.co
A.A. 4976, Bogotá, Colombia.
Phone (57-1)-332-4500, Fax (57-1)-332-4516.

Review date: October 31st 2014
Desired starting date: January 2015, however the position will remain open until a suitable candidate is found.

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

POSTDOCTORAL FELLOWS
Kavli Institute for the Physics and Mathematics of the Universe, The University of Tokyo, Japan

The "Kavli Institute for the Physics and Mathematics of the Universe" (Kavli IPMU) is an international research institute with English as its official language established in October 2007. The goal of the institute is to discover the fundamental laws of nature and to understand the universe from the synergistic perspectives of mathematics, statistics, theoretical and experimental physics, and astronomy. We are particularly interested in candidates with broad interests and a willingness to interact with people across disciplines.

We intend to offer more than a dozen postdocs to three-year terms. We seek to build a diverse, highly interactive membership, and female and international applicants are strongly encouraged. We have generous travel support for our postdocs, and encourage full-time members to be away from the Institute for between 1 and 3 months every year.

The focus of Kavli IPMU includes but is not limited to: all areas of mathematics (e.g. algebra, geometry, analysis, and statistics); string theory and mathematical physics; particle theory, collider phenomenology, beyond the standard model physics phenomenology; cosmology and astrophysics theory; astronomy and observational cosmology; and particle and underground experiments.

We are leading efforts on the XMASS dark matter experiment, the KamLAND-Zen neutrino experiment, the Hyper Suprime-Cam (HSC) project for weak lensing surveys and Prime Focus Spectrograph (PFS) for the dark energy at the Subaru Telescope, GADZOOKS! at Super-Kamiokande, the Belle II experiment, T2K long baseline neutrino experiment, SDSS-IV for a survey of galaxies, POLARBEAR CMB B-mode polarization measurement and R&D for future large neutrino detectors.

The search is open until filled, but for full considerations please submit the applications and letters on our web site by Dec 1, 2014.

Further information can be found here: **http://www.ipmu.jp/job-opportunities**

For inquiries please contact: **application-inquiry@ipmu.jp**

UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

The **Heidelberg Graduate School of Fundamental Physics (HGSFP)** at the Department of Physics and Astronomy at Heidelberg University, a School funded by the German Excellence Initiative, invites applications for

DOCTORAL FELLOWSHIPS

in the following areas of modern fundamental physics: (a) Astronomy and Cosmic Physics, (b) Quantum Dynamics and Complex Quantum Systems, (c) Fundamental Interactions and Cosmology, (d) Complex Classical Systems, (e) Mathematical Physics, and (f) Environmental Physics. Thesis research topics cover areas such as experimental and theoretical astrophysics, cosmology, accelerator based particle physics, precision measurements in physics, study of quantum systems – many body as well as small systems, low as well as high temperature physics, atomic, molecular and optical physics, mathematical physics and string theory. In addition, fundamental problems in biophysics, e.g. in materials science aspects of cell biology, and in environmental physics are studied. The HGSFP combines doctoral projects at the forefront of international research in the areas mentioned above with a rich and thorough teaching programme. Further information can be found on the School's web site: **http://www.fundamental-physics.uni-hd.de.**

The branch Astronomy & Cosmic Physics is the International Max Planck Research School (IMPRS) for Astronomy and Cosmic Physics at the University of Heidelberg **(http://www.mpia.de/imprs-hd)**. Students accepted into the Graduate School will automatically be members of the IMPRS-HD and conversely. Admission to the IMPRS for Precision Tests of Fundamental Symmetries **(www.mpi-hd.mpg.de/imprs-ptfs)**, to the IMPRS for Quantum Dynamics in Physics, Chemistry and Biology **(http://www.mpi-hd.mpg.de/imprs-qd)**, or to the RTG Particle Physics Beyond the Standard Model **(http://www.thphys.uni-heidelberg.de/~gk_ppbsm)** is also possible. The IMPRS and RTG offer doctoral positions and fellowships as well, and are combined efforts of Heidelberg University with the Max Planck Institutes for Astronomy and Nuclear Physics, which form an integral part of the exciting and broad research environment in Heidelberg.

Highly qualified and motivated national and international students are invited to apply. Applicants should preferably hold a Master of Science or equivalent degree in physics. Excellent candidates holding a four year bachelor degree and proof of research experience may also be considered. At equal level of qualification, preference will be given to disabled candidates. Female students are particularly encouraged to apply.

Applicants have to initiate their application registering via a web form available at **http://www.fundamental-physics.uni-hd.de/fellowships**. Applications should be completed by November 17, 2014.

UNIVERSITY OF
OXFORD

DPhil in Astrophysics Instrumentation
HARMONI: E-ELT First Light Spectrograph

HARMONI is the first light spectrograph for the European Extremely Large Telescope (E-ELT), a 39-m telescope that will be the world's largest optical / infrared telescope, when it starts operation in 2024. HARMONI is a workhorse instrument for the E-ELT. The project is being led from Oxford, and is about the start its preliminary design phase.

Two project themes are offered, in the areas of

A/ **Spectrograph Instrument development**

This project focuses on leading prototyping studies that will take place during the preliminary design phase and the development of a full-scale engineering model, including cryogenic testing during the subsequent detailed design phase.

B/ **High-contrast capability (exo-planet direct imaging)**

The D.Phil student will focus on ascertaining contrast levels that can be achieved by HARMONI, specifically for spectroscopic characterisation of extra-solar planets. The work includes optics design, post-processing of data cubes, and detailed performance simulations of high-contrast observations.

In addition to the instrumentation research and development, the successful candidate will be expected to conduct astronomical research using similar integral field spectrographs world-wide. The 3.5 year studentship is funded by the STFC, and open to applicants from the UK or EU. Application deadline: midday, 23 Jan 2015. For further details, please see **http://www2.physics.ox.ac.uk/study-here/postgraduates/astrophysics/dphil-projects-for-2015**

Faculty Position in Particle Theory Phenomenology
University of Pittsburgh
Department of Physics and Astronomy

The Department of Physics and Astronomy at the University of Pittsburgh is recruiting an Assistant Professor in particle theory phenomenology. This tenure stream appointment, which is subject to budgetary approval, will begin in the Fall Term 2015, or thereafter.

All candidates should have the potential to teach effectively at both the graduate and undergraduate levels, to attract external funding for a creative, independent and broad-based research program, to provide cohesion with existing efforts and potentially to initiate new research directions.

Preference will be given to candidates with expertise in physics beyond the Standard Model and/or LHC physics. We expect the new faculty member to be active in our PITTsburgh Particle physics, Astrophysics and Cosmology Center (PITT PACC).

To ensure full consideration, complete applications should be received by November 30, 2014. However, applications will be accepted until the position is filled. Applicants should email PDF documents (preferably a single document) containing curriculum vitae, a statement of research interests, and a brief teaching statement to pasearch+particletheory@pitt.edu. In addition, applicants should arrange to have at least three letters of reference sent to pasearch+particletheory@pitt.edu.

The University of Pittsburgh is an Affirmative Action, Equal Opportunity Employer. Women and members of minority groups under-represented in academia are especially encouraged to apply.

Northern Illinois University

Fermilab

NIU-Fermilab ACCELERATOR RESEARCH CLUSTER

A new joint initiative between Northern Illinois University (NIU) and Fermi National Accelerator Laboratory (Fermilab) envisages developing a collaborative program with targeted and matched mutual investments to create a cluster of research excellence in advanced accelerator science and technology. The research cluster will enable "discovery-class" science driven by charged particle beams and associated advanced techniques and technologies of superconducting cavity electrodynamics, high-field magnets, lasers and nonlinear dynamical control of particle, atomic and molecular beams. The R&D will be directed towards developments in particle physics and related disciplines of cosmology, material and life sciences and their applications to societal grand challenges of energy, environment, health and security.

Opportunities exist to contribute to large scale national and international accelerator activities such as the development of the long-baseline neutrino facility at Fermilab and TeV-scale collider developments world-wide as well as cutting edge innovative research in laboratory –scale experiments to investigate the "dark" sector of the vacuum and other precision experiments e.g. "g-2" and "mu-to-e".

Working seamlessly with the outstanding accelerator research staff at Fermilab, NIU physics and engineering departments and its Northern Illinois Centre for Accelerator and Detector Development (NICADD) and the consortium of mid-western universities and laboratories, with access to advanced accelerator test facilities at Fermilab, ANL and other international laboratories such as CERN (Switzerland), DESY (Germany), ESS (Sweden), John Adams Institute and Cockcroft Institute (UK), the cluster will offer unique collaborative research opportunities. Details of specific opportunities and recruitment will be announced in near future.

Prospective Masters- and PhD-level students, postdoctoral fellows, research scientists and aspiring academic faculty members should contact **Professor Swapan Chattopadhyay** (**schaterji@niu.edu** or **swapan@fnal.gov**) for further details and send early expressions of interest and professional background information in advance.

JOIN THE FRIB TEAM

The Facility for Rare Isotope Beams (FRIB) will be a new scientific user facility for nuclear science. It is under construction now on the campus of Michigan State University. Funded by the U.S. Department of Energy Office of Science, FRIB will provide intense beams of rare isotopes enabling scientists to make discoveries in the physics of atomic nuclei, nuclear astrophysics, fundamental interactions, and applications for society.

We seek talented leaders looking for a once-in-a-lifetime ground-floor opportunity to build an accelerator.

Current opportunities:

- Faculty in Superconducting Radiofrequency Accelerator Physics
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- Cryogenic Engineering Group Leader
- Vacuum Systems Group Leader
- Front-End Systems Engineer
- Ion Source Lead Mechanical Engineer
- Remote-Handling Engineer
- Applications Software Engineer/Physicist
- EPICS Control System Engineer
- Postdoctoral Research Associates in Accelerator Physics

MSU is an affirmative-action, equal-opportunity employer.

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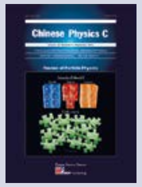
Visit **frib.msu.edu/careers** for more information and to apply



Bookshelf

Accelerator Physics at the Tevatron Collider

By Valery Lebedev and Vladimir Shiltsev (eds)

Springer

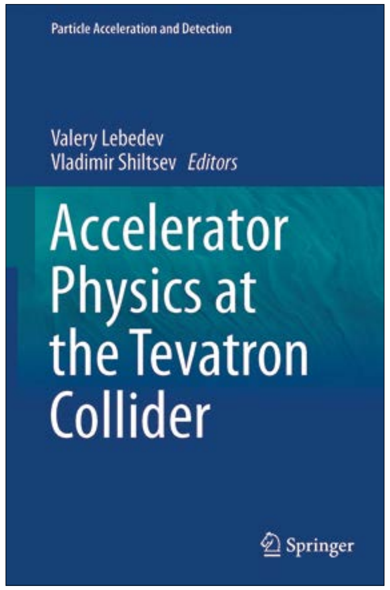
Hardback: £99 €116.04 $149

E-book: £79 €91.62 $119

This fascinating book, compiled and edited by two of the leaders of Tevatron's Run II, describes the achievements and lessons from Fermilab's famous machine, which shut down for the last time at the end of September 2011. The authors and editors take us on a mesmerizing tour through the components and history of this remarkable accelerator, and provide a lively account of how, across the years, numerous obstacles were overcome, and how novel technologies contributed to the astonishing success of "one of the most complex research instruments ever to reach the operation stage". Not only was the Tevatron the highest-energy particle collider for about a quarter of a century, it was also a pioneering accelerator in almost every regard.

In the first of nine chapters, Steve Holmes, former Fermilab accelerator director, John Peoples, former Fermilab director, together with Ronald Moore and Vladimir Shiltsev, recall the history of Fermilab and the "Energy Saver/Doubler", which was later to become known as the Tevatron. Across almost three decades, the peak luminosity of this collider was increased by four orders of magnitude. The second chapter, in which Alexander Valishev joins the two editors as author, surveys the Tevatron's linear and nonlinear beam-optics control. I particularly enjoyed the review of the intricate and spectacular nonlinear dynamics experiments performed in the late 1980s and early 1990s, which had been conceived to unveil the origin of dynamic aperture (e.g., the famous "E778 experiment") and the effect of tune modulation.

The third chapter, by Jerry Annala and co-workers, brings us to the heart of the accelerator. As the first superconducting hadron storage ring, the Tevatron designers and operators had many issues to tackle. These included the effects of large intrinsic nonlinear field errors; the dynamic chromaticity drifts owing to the decay of persistent-current field errors, whose successful automatic compensation depended on many details of the preceding magnet cycles, such as the length of the flat top, the ramp rate, etc; and, last but not least, the "snapback" – i.e. the sudden re-induction of the persistent currents in the superconducting cable at the start of the energy ramp. From my student days, I vividly remember how much the Tevatron experience guided the development of the later superconducting machines, such as HERA at DESY. This chapter also presents the Recycler, the first large-scale all-permanent-magnet storage ring, operating at 8 GeV.



In the following chapter, Chandra Bhat, Kiyomi Seiya and Shiltsev present two of the most fascinating techniques of longitudinal beam manipulation – slip stacking, which has doubled the proton intensity in the Main Injector, and radiofrequency barrier buckets, used for the accumulation and processing of antiprotons. Next, Alexey Burov, Lebedev and their colleagues discuss the Tevatron's impedance and collective effects. There are noteworthy handy formulae for the transverse and longitudinal impedance of laminated vacuum chambers developed for the Tevatron, which I have used myself often.

Chapter six, by Richard Carrigan and several co-authors, treats mechanisms of emittance growth and beam loss, including important mitigation measures such as collimation, beam removal from the abort gap using the "Tevatron electron lens" as a pulsed exciter, tests of halo deflection with bent crystals, and the Tevatron luminosity model. Lebedev, Ralph Pasquinelli and others then delve into antiproton production, stochastic cooling and the first relativistic electron cooler, based on a 4.3 MV pelletron, which many of my colleagues had thought to be unfeasible. The antiproton source technology, which had begun at CERN, was brought to maturity at the Tevatron complex, where from 1994 to 2010 the antiproton intensity was raised by another factor of 10, making this the most powerful antiproton source constructed, by far. In chapter eight, Shiltsev and Valishev discuss beam–beam effects, including the famous "scallop"-shaped pattern of emittance growth along the antiproton bunch trains, which I witnessed myself fill after fill around the year 2002, while visiting the Tevatron control room. Finally, advanced beam instrumentation, including Schottky monitors and proton synchrotron-light diagnostics, are summarized in chapter nine.

At the end of the book I found a list of about 30 PhD theses, completed on accelerator-physics topics at the Tevatron across a span of about 25 years. I smiled when I realized that many of these earlier PhD students have become today's leaders in the accelerator field. This illustrates the exceptional training experience from participating in a demanding and inspiring collider programme such as the Tevatron's.

Undoubtedly, this book will serve as a wonderful and unique reference for many decades to come. The authors and editors are to be congratulated for their effort to compile and preserve the accelerator knowledge of the Tevatron, accumulated during 25 years of successful struggle and permanent innovation. The Tevatron's lessons and achievements would be all too easily forgotten without such a written record. In conclusion, I recommend this book highly to accelerator professionals around the world. Reading it should be all but compulsory for anyone wishing to improve the performance of an existing frontier machine, or design the next generation of highest-energy colliders.

● *Frank Zimmermann, CERN.*

Beam Dynamics in High Energy Particle Accelerators

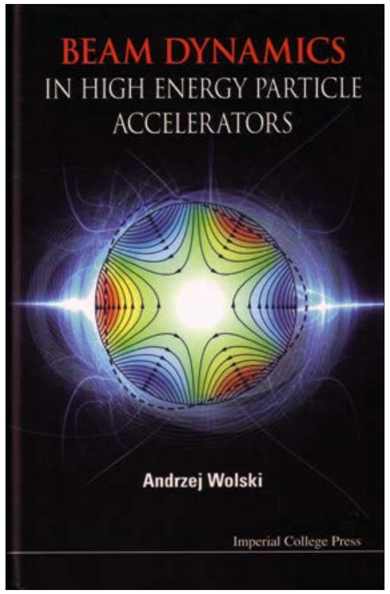
By Andrzej Wolski

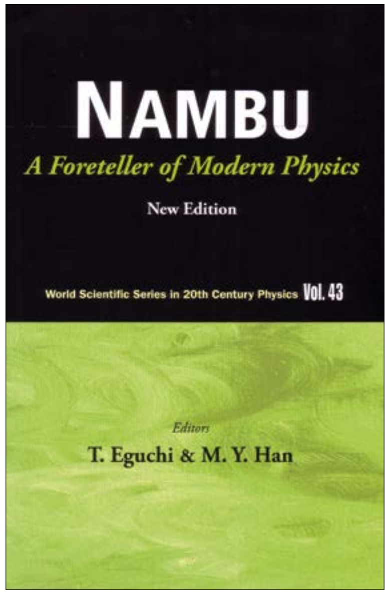
World Scientific

Hardback: £98

E-book: £74

This book by Andrzej Wolski is not a general textbook but, rather, a theoretical monograph on some of the basic physics of particle accelerators, with a strong emphasis on what can be treated analytically. It is decidedly not an introduction to accelerators. Indeed it contains no description, photo or diagram of





what a particle accelerator looks like, no list of numerical parameters, nor any indication of what purposes such a device might serve. I could find no mention of the name, or energy, of any past or present accelerator. The unit of MeV first appears in relation to the spacing of spin resonances. I wonder whether the author consciously sought to imbue his work with a whiff of Whittaker's treatise? No criticism intended – I rather admire his temerity – just make sure that you have some background before tackling this 590-page opus.

The first two words of the title are key to its coverage: beam dynamics is treated as an application of classical Hamiltonian mechanics and electrodynamics. These are the explicit prerequisites. Among existing books, those of S Y Lee (a little shorter and denser) and H Wiedemann (almost twice as long), are pitched at a similar level, but structured as textbooks with exercises and more applications.

I liked chapter one, a useful description of the electromagnetic fields in magnets and RF cavities that goes into more depth than most, and is careful to explain some key practical concepts that are sometimes taken for granted. On the other hand, there is no mention of how strong you can make those fields. Subsequent chapters cover thoroughly the well-trodden ground of linear single-particle dynamics and optics in the two transverse degrees of freedom, taking a Hamiltonian approach *ab initio*. I was a little disappointed in the perpetuation of an unfortunate choice of the canonical variables for longitudinal motion, first made in a well-known computer program in the 1980s. Perhaps it is as well to follow the crowd now, but subsequent Hamiltonians become messier than necessary, and there is some unnatural fudging around the dispersion function.

Unusually, but logically, longitudinal motion is treated in the context of a chapter on coupling, before the introduction of a formalism for full linear coupling. There is a standard discussion of synchrotron radiation (omitting the quantum lifetime) and low-emittance lattice modules for light sources. Nonlinear dynamics gets a great deal of attention, with discussions of the traditional topics of Lie transformations, canonical perturbation theory, symplectic integrators, nonlinear resonances, dynamic aperture and frequency map analysis. Practical results on linear perturbations are also worked in.

Like Lee and Wiedemann, Wolski says surprisingly little about colliders. There is no mention of low-beta collision optics, dispersion suppressors or separation schemes. A brief discussion of the head-on beam–beam effect and a passing mention of luminosity are appended to a more comprehensive discussion of single-beam space charge. Perhaps this reminds us that most accelerators are not colliders. There is a good derivation of the Touschek lifetime, but the standard results on intra-beam scattering (Piwinski, Bjorken–Mtingwa) are only quoted.

The final chapters cover wake-fields and impedances, and the collective instabilities they drive. The formal approach works well here, imposing order and clarity on what can be a confusing array of concepts and definitions. Several important beam-instability mechanisms are treated in detail.

The book seems relatively free of misprints (although there is a glaring one after equation 2.17). Overall, this is a recommendable addition to the literature, covering its topics clearly and thoroughly.

● *John Jowett, CERN.*

Nambu: A Foreteller of Modern Physics

By T Eguchi and M Y Han (eds)
World Scientific
Hardback: £45
E-book: £23

Seeds for many developments in contemporary particle physics were sown by Yoichiro Nambu in his lectures and papers in the 1960s and 1970s – in particular, his work on the mechanism of spontaneous broken symmetry, for which he was to receive the Nobel prize (*CERN Courier* November 2008 p6). Tackling first the problem of maintaining gauge invariance in a field theory of superconductivity, he went on to develop these ideas in field theories for elementary particles, in particular inspiring the important work that led to the Brout–Englert–Higgs (BEH) mechanism for generating mass through spontaneous symmetry breaking in the Standard Model. These developments culminated at CERN in July 2012 (not 2011, World Scientific please note) with the discovery of an appropriate scalar particle – a Higgs boson. This book collects together the important papers related to this story and much more, some never published before in book form. The text is not only of historical value, but also provides a window into the mind of a man that many refer to as "Nambu the seer". It is a valuable resource for researchers in elementary particle theory, and for those who are interested in the history of modern physics.

● *Christine Sutton, CERN.*

Books received

Path Integrals and Hamiltonians: Principles and Methods

By Belal E Baaquie
Cambridge University Press
Hardback: £75 $120
E-book: £96

Providing a pedagogical introduction to the essential principles of path integrals and Hamiltonians, this book describes cutting-edge quantum-mathematical techniques applicable to a vast range of fields, from quantum mechanics, solid-state physics, statistical mechanics, quantum field theory and superstring theory to financial modelling, polymers, biology, chemistry and quantum finance. The powerful and flexible combination of Hamiltonian operators and path integrals is used to study a range of different quantum and classical random systems. With a practical emphasis on the methodological and mathematical aspects of each derivation, this introduction to these mathematical methods is suitable for researchers and graduate students in physics and engineering.

Principles of Discrete Time Mechanics

By George Jaroszkiewicz
Cambridge University Press
Hardback: £85 $130
E-book: $104

Could time be discrete on some unimaginably small scale? Exploring the idea in depth, this book systematically builds the theory up from scratch, beginning with the historical, physical and mathematical background to the chronon hypothesis. Covering classical and quantum discrete-time mechanics, the author presents all of the tools needed to formulate and develop applications of discrete-time mechanics in a number of areas, including classical and quantum mechanics and field theories.

Reviews of Accelerator Science and Technology: Volume 6 – Accelerators for High Intensity Beams

By Alexander W Chao and Weiren Chou (eds)
World Scientific
Hardback: £98
E-book: £74
Also available at the CERN bookshop

As particle accelerators strive for ever-increasing performance, high-intensity particle beams are becoming one of the critical demands from a majority of users – whether for proton, electron or ion beams – and for most applications. The accelerator community has therefore put a great deal of effort into the pursuit of high-intensity accelerator performance, on a number of fronts. Recognizing the topic's importance, the editors have dedicated this volume of *Reviews of Accelerator Science and Technology* to accelerators for high-intensity beams. As well as reviews of applications at the intensity frontier in particle and nuclear physics, this volume also looks at applications, for example, in radiography and the production of radiopharmaceuticals, as well as in accelerator-driven systems and the inertial production of fusion energy. Other chapters deal with different types of accelerator, such as superconducting hadron linacs and rapid-cycling synchrotrons, and accumulator rings for high-intensity hadron beams. Key accelerator subsystems that allow high-intensity operation are also covered, with chapters on ion injectors, ion charge-strippers, targets and secondary beams, neutron-beam lines and beam-material interactions. The final chapter follows the journal's tradition of looking at people who have shaped the field. This time, Giorgio Brianti and David Plane contribute their personal recollections about John Adams, who made so many pioneering contributions to CERN's unrivalled accelerator complex. In particular, it outlines Adams's abilities as an international collaboration leader.

Theory at CERN turns 62

Cecilia Jarlskog looks at CERN Theory's roots, and recalls some interactions with the organization.

One of my most memorable experiences of CERN is from an early morning in the summer of 1966. I drove to CERN with my two small children, one and three years of age, to fetch their dad who had been on a night shift – there were no guards at the entrance in those days. I found him outside the experimental hall being interviewed by a friendly looking gentleman, who after greeting us continued asking questions and taking notes. The gentleman, as I found out afterwards, was the director-general of CERN, Bernard Gregory. This was for me an inspiring and instructive experience. Since then, CERN has grown a great deal, and attracts so many more people that the probability of a young visiting PhD student being interviewed alone by the director-general must not be so large. For me, there are other exciting new features of CERN these days, such as encountering crowds of enthusiastic young people from across the world.

The young CERN has now turned 60, its official foundation being on 29 September 1954. Its creation was a unique act, based on an unprecedented common effort by a number of distinguished scientists from several countries, not only from Europe but also from the US, among them Robert Oppenheimer and Isidor Rabi. We are all impressed by their dedication and commitment, and are grateful to them for the creation of this organization for basic research in science for peace. Since its creation, CERN has served as a "standard model" for several other international scientific organizations.

However, while CERN has just celebrated its 60th anniversary, there is one part of it that is a little older. The CERN "Group of Theoretical Studies" was created through a resolution passed by the CERN Interim Council in Amsterdam in May 1952. It was possible to form this group very quickly and for it to start work, in Copenhagen, even before the decision had been made as to where CERN would be located. Copenhagen had already been a world centre for theoretical physics for several decades. It was clear that CERN Theory would thrive there, owing to the presence of the great and incredibly influential theoretical physicist Niels Bohr, and his competent local staff. Victor Weisskopf, who was director-general of CERN in the years 1960–1964, knew Bohr well, and used to refer to him as the greatest founder of CERN. CERN Theory in Copenhagen was a lively place, and attracted many distinguished international scientists.


Cecilia Jarlskog with colleagues at the Nordic Institute of Theoretical Physics (NORDITA) in Copenhagen, in the early 1980s. (Image credit: NORDITA.)

The CERN Annual Report for 1955 informs us that: "The Theoretical Study Division is located in the Theoretical Physics Institute, University of Copenhagen. The work of the Division has proceeded according to the programme fixed during the interim period and includes: a) scientific research on fundamental problems of nuclear physics, including theoretical problems related to the focusing of ion beams in high energy accelerators; b) training of young theoretical physicists; c) development of active co-operation with the laboratories of Liverpool and Uppsala, whose machines and equipment have been placed at the disposal of CERN." This was what CERN's "founding fathers" had in mind that the theorists should be doing. But, of course, except for b, that was not what the theorists actually did.

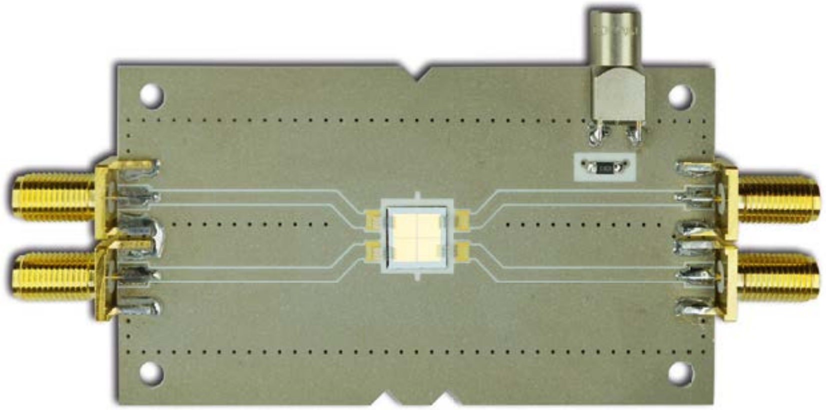
The 1955 CERN Annual Report also informs us that the Theoretical Study Division in Copenhagen had two full-time senior staff members: Gunnar Källén and Ben R Mottelson (who was to receive the 1975 Nobel Prize in Physics). Note that these "leaders", both born in 1926, were at the time below the age of 30. This was a general feature of the young CERN – even the accelerators were built by people who many of us would now consider as "youngsters".

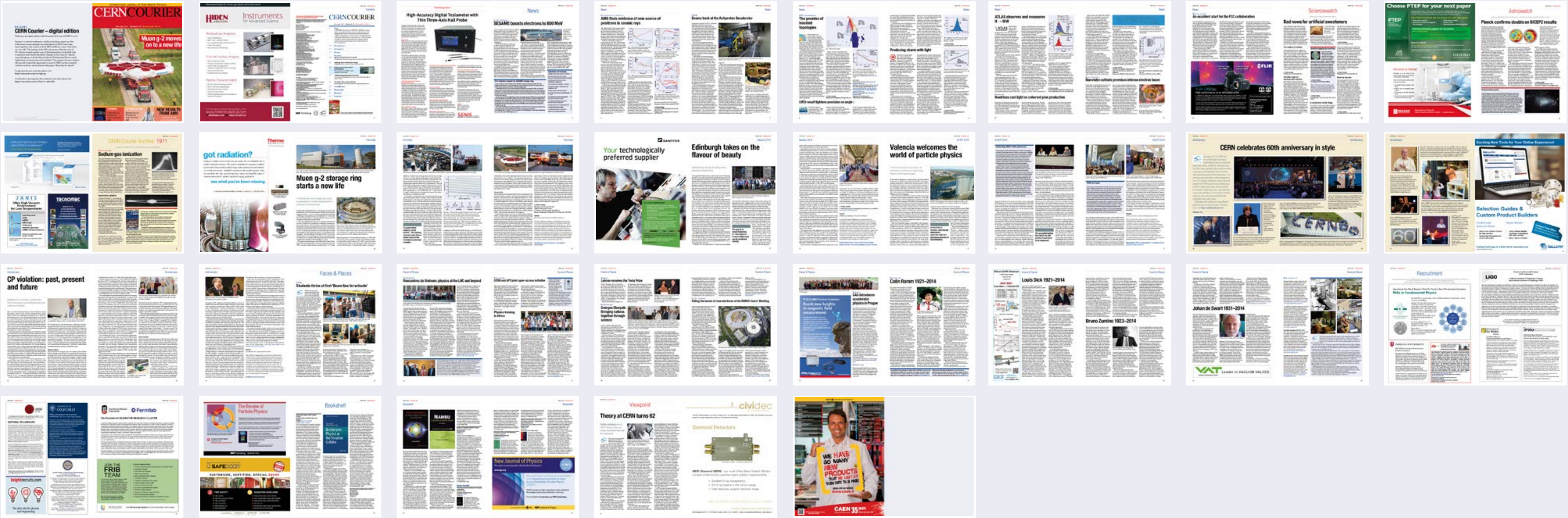
CERN Theory was expected to move gradually to Geneva. However, this took in total about five years, until 1 October 1957, when the Theory Group in Copenhagen was officially closed. The theorists who came to Geneva had their offices first at the University of Geneva, then in barracks at Geneva Airport, until they moved to the current CERN site in Meyrin. Theory went on to flourish at CERN, and the subsequent history of the Theory Division deserves a book of its own.

In 1971, I became the first female fellow of the CERN Theory Division, in 1982 the first female member of CERN's Scientific Policy Committee, and in 1988 this committee's first female "old boy". Later, in the years 1998–2004, I was the adviser on member states to CERN's director-general. I have enjoyed CERN's international atmosphere enormously, which has given me ample opportunity to meet and talk with inspiring physicists from across the world. I also feel fortunate to have lived in a period when the amount of information revealed about the nature of the elementary constituents of matter and their interactions has been mind-boggling. CERN has been an important contributor in this respect. Who could have imagined that we would arrive at the Standard Model so "soon" – a highly successful theory of weak, electromagnetic and strong interactions?

In 2004, during the mandate of Robert Aymar as director-general, the CERN Theory Division turned into the Theory Unit, under the CERN Physics Department. Does this imply that CERN wishes to guide the theorists to work on the "focusing of ion beams", and machines as well as equipment, as envisaged by the founding fathers in 1952? Fortunately, during my visits to CERN since, I have seen no such trend. Long live theory at CERN.

● *Cecilia Jarlskog, Lund University and first female president of IUPAP. She has written recently about the early days of theory at CERN, in the book* Portrait of Gunnar Källén *(*CERN Courier *October 2014 p74).*





CERNCOURIER

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