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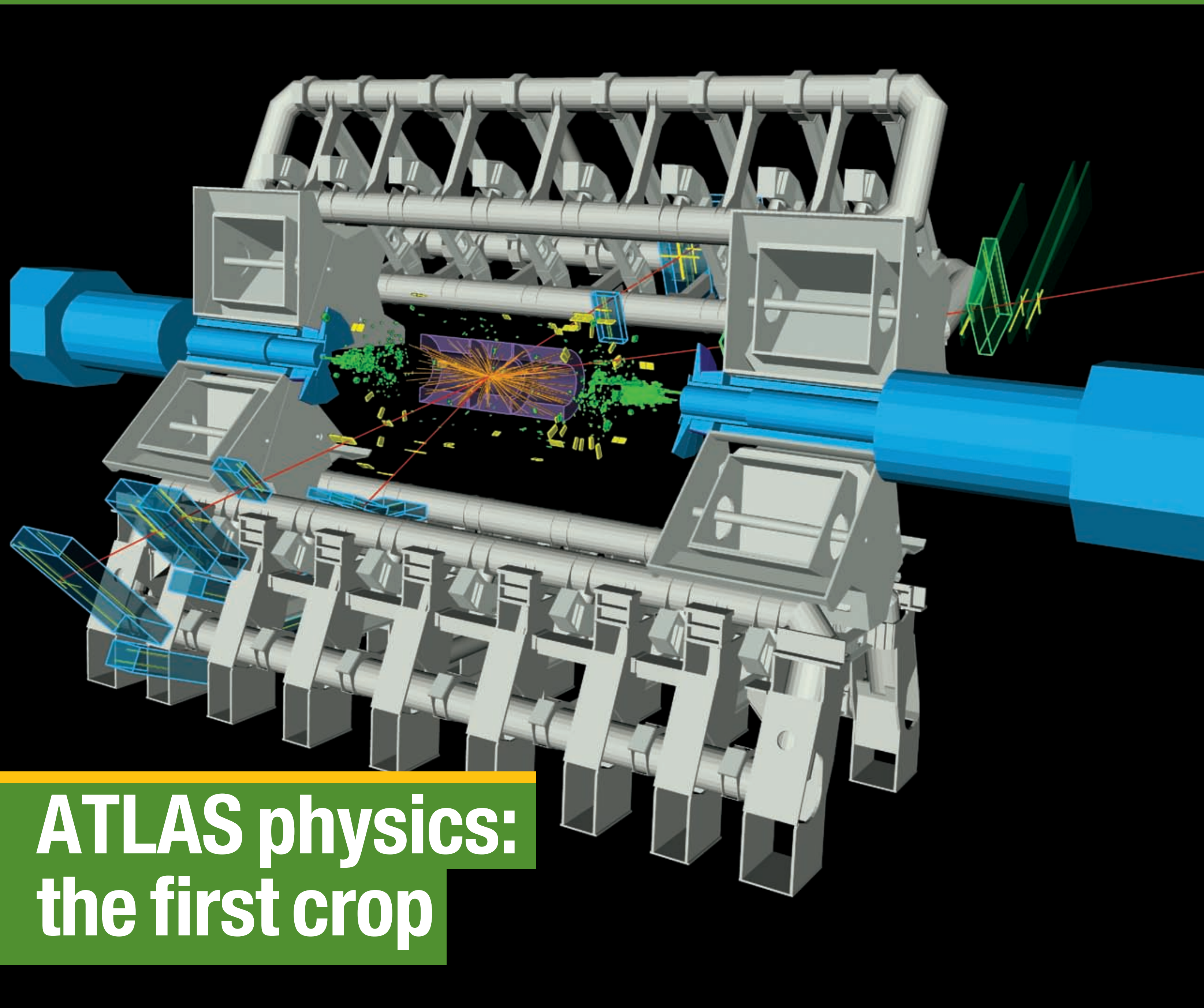
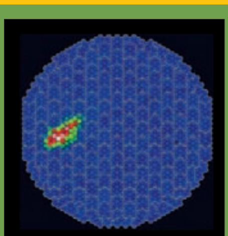


ATLAS physics: the first crop



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

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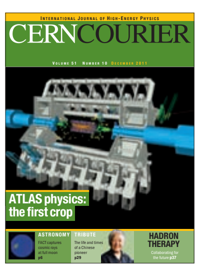


On the cover: An event with four muons in the ATLAS detector, which has had a hugely productive first two years of physics at the LHC (p23).

News

LHC NEWS

A bumper year nears its end

After some 180 days of running and 4×10^{14} proton–proton collisions, the LHC's 2011 proton run came to an end at 5.15 p.m. on 30 October. For the second year running, the LHC team has largely surpassed its operational objectives, steadily increasing the rate at which the LHC has delivered data to the experiments.

At the beginning of the year's run, the objective was to deliver an integrated luminosity of $1\,fb^{-1}$ during the course of 2011. This came on 17 June, setting the experiments up well for the major physics conferences of the summer and requiring the 2011 data objective to be revised upwards to $1.2\,fb^{-1}$. That milestone was passed by 18 October; when proton running ended, the LHC had delivered around $5.6\,fb^{-1}$ to both the ATLAS and CMS experiments, $1.2\,fb^{-1}$ to LHCb and $5\,fb^{-1}$ to ALICE. Physics highlights for these four big experiments include closing down the space available for the long sought Higgs and supersymmetric particles to hide in, putting the Standard Model of particle physics through increasingly gruelling tests and advancing our understanding of the primordial universe.

"At the end of this year's proton running, the LHC is reaching cruising speed," comments CERN's director for accelerators and technology, Steve Myers. "To put things in context, the present data-production rate is a factor of 4 million higher than in the first run in 2010 and a factor of 30 higher than at the beginning of 2011."

Time has also been devoted to some special physics runs for the smaller TOTEM and ALFA experiments, which probe small-angle (forward) scattering, allowing them to measure the total proton–proton cross-section and the absolute luminosity calibration. In these runs, the beam is de-squeezed to a β^* of 90 m in ATLAS and CMS. This is instead of the usual 1 m β^*, and gives a larger beam size at the interaction points – resulting in a reduced beam divergence there.

At the LHC controls earlier this year when the number of bunches had reached 1092 per beam, well on the way to 1380.

A number of factors have contributed to these impressive totals, including: the increase in the total number of bunches to 1380 during the first part of the year, the high bunch intensity and small beam sizes delivered by the LHC injectors, and the good aperture in the regions around ATLAS and CMS, which have allowed a squeeze to $\beta^* =$ 1 m. About 25% of the programmed physics time was spent with stable beams – which is not bad at this stage in the LHC's career, given its complexity and the operation with high-intensity beams.

Following the end of proton running, a week of machine development began. An early high point was the cohabitation of protons and lead ions in the LHC – low- intensity beams of protons (clockwise) and lead ions (anti-clockwise) were successfully injected and ramped together. A first test of proton–lead collisions was scheduled to follow after commissioning for the lead-ion run and a 5-day technical stop. If successful, these tests will lead to a new strand of LHC operation, using protons to probe the internal structure of the much more massive lead ions.

As in 2010, the main goal before the end of year, however, is a four-week period of lead-ion running before the machine closes down for the winter technical stop.

● For regular updates and detailed information about the LHC, follow CERN's *Bulletin* at http://cdsweb.cern.ch/journal/CERNBulletin/.

SURVEY

Help us make CERN Courier even better!

It has now been a full publishing year for the new-look design of *CERN Courier*. The dynamic layout, features and wide-ranging articles in 2011, as well as the lively covers, have all been well received by readers in the particle-physics community.

Now we would like your help to make *CERN Courier* magazine and the cerncourier.com website even better. This is your chance to tell us what you think and give us your suggestions and wish lists.

Complete the survey today for the chance to win one of five exclusive CERN fleeces. Just visit http://cerncourier.com/survey to have your say.

We look forward to hearing from you.

News

Astroparticle physics

Innovative camera records cosmic rays during full moon

On the night of 11–12 October, just a few hours after installation of its camera, the First G-APD Cherenkov Telescope (FACT) recorded flashes of Cherenkov light from air showers induced by cosmic rays. Remarkably, the shower images were recorded during a full moon – a feat that would not have been possible with a conventional air Cherenkov telescope.

FACT, installed at an altitude of 2200 m at the Roque de los Muchachos Observatory on La Palma, in the Canary Islands, uses newly developed Geiger-mode avalanche photo-diodes (G-APDs) instead of the photomultiplier tubes (PMTs) normally used in Cherenkov telescopes. These first images, taken in ambient light 100 times brighter than PMT-based telescopes could tolerate, demonstrate for the first time the use of silicon detectors capable of recording images at a rate of 10^9 a second.

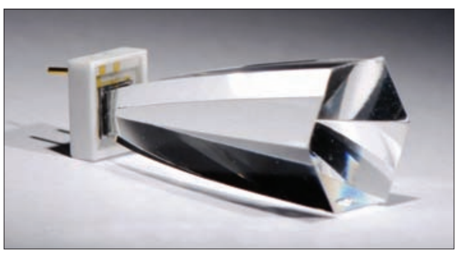
The pioneering camera was designed and built by a collaboration from the universities of Dortmund, Geneva and Würzburg as well as EPF Lausanne (EPFL) and led by ETH Zurich. It consists of 1440 G-APDs, each one a square with a side of only 3 mm. To increase the active area, the collaboration developed solid light concentrators together with the University of Zurich. Each concentrator has a hexagonal entrance window 9.5 mm across and a square exit window with a side of 2.8 mm to match onto a G-APD. The result is a 10-fold concentration area for light reflected from the telescope mirror, while at the same time rejecting background light from outside the area of the mirror. There is one concentrator glued to each G-APD, providing a field of view of 0.1° per pixel and 4.5° for the full camera.

The electronics to read each of the 1440 pixels individually is based on the DRS-4 analogue ring sampler chip operating at a frequency of 2 gigasamples/s. The complete electronics package is integrated into the camera body, and data are sent to the counting house via standard Ethernet. The complete camera weighs about 150 kg and has a power consumption of around 500 W.

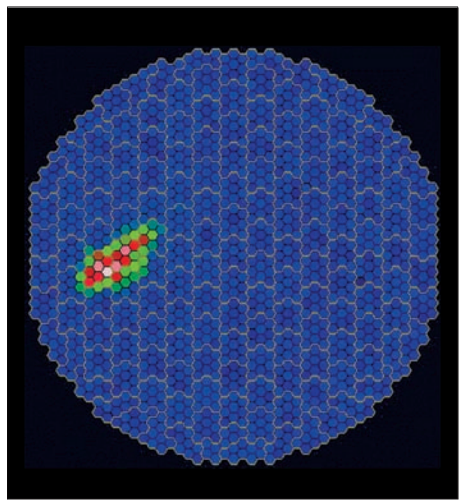
The camera was assembled and tested at ETH Zurich, before being installed in the refurbished HEGRA CT3 telescope at the Roque de los Muchachos Observatory, next to the MAGIC telescopes (*CERN Courier* June 2009 p20). The telescope, which has a total mirror area of 9.5 m^2, was equipped with a new drive system and improved mirror facets.

The installation of the camera is the first step towards establishing a monitor telescope for variable gamma-ray sources. It has already begun to demonstrate that G-APDs are a viable alternative to PMTs in Cherenkov telescopes. Future developments with these devices promise even higher photon detection efficiencies and availability at lower costs than PMTs. Moreover, their bias voltages of about 70 V render their operation under the harsh conditions of Cherenkov telescope sites stable and robust.

Above: FACT taking first data on 11 October during the full moon. (Image credits: FACT/ Th. Krähenbühl.)



Above: A single G-APD, only 2.8 × 2.8 mm^2, glued to its light concentrator.



Right: One of the first showers recorded by FACT during a full moon.

LHC PHYSICS

LHCb looks to the future

The LHCb collaboration pictured in front of the experiment as currently installed; an upgrade is being planned for data-taking in 2019.

The LHCb experiment has had a remarkable year, moving from first results to world-beating measurements of B-hadron properties, such as the oscillation frequency of the B_s meson, CP and forward-backward asymmetries, as well as limits on rare decays, for example $B_s \rightarrow \mu^+\mu^-$ (*CERN Courier* March 2011 p8, April 2011 p9, July/August 2011 p9, September 2011 p13, October 2011 p8). Even though the physics harvest is now in full flow, the collaboration is already planning for the eventual upgrade of the experiment, which is scheduled to be ready for data-taking in 2019.

The instantaneous luminosity delivered to LHCb has steadily increased throughout the year, reaching $4 \times 10^{32}\,cm^2\,s^{-1}$ by the end of the run, already twice the original design luminosity for the experiment. Unlike the general-purpose detectors at the LHC, ATLAS and CMS, LHCb has been specifically designed for the optimal study of B hadrons, covering an angular range of 10–300 mrad from the beam axis (the forward region). This gives it different constraints concerning the luminosity. The track density increases in this region, so detectors suffer from higher occupancy, and are potentially more prone to radiation damage. In addition, because the experiment is tuned for the precise study of B-hadron decay vertices, too many overlapping events can confuse the picture. Finally, the experiment's trigger has the special feature that it can select fully hadronic decays, rather than only relying on electron or muon signatures, and this trigger cannot handle too high an input rate without reducing its efficiency.

As a result, the luminosity cannot be pushed much higher in the current experiment. This has the positive aspect that next year should be one of continuous operation with the experiment in stable conditions, but eventually it means that the time taken to double the data-set will become long. The goal for this year was $1\,fb^{-1}$ of integrated luminosity, which (thanks to the excellent performance of the LHC) was comfortably passed with a few weeks to spare; it represents more than 30 times as much data as last year. The expectation is to at least double that sample again in 2012, but for the longer term the collaboration plans to upgrade the experiment so that it can operate at higher luminosity and accumulate an order of magnitude more data. This will allow even higher precision in the search for new physics in the flavour sector.

The key to the upgrade will be to read out the full experiment at 40 MHz, the design bunch-crossing rate of the LHC, and to perform the trigger in software in a powerful computer farm. For this to succeed, collisions will indeed have to be provided by the LHC at 40 MHz at the time of the upgrade, rather than at the current rate of 20 MHz.

The LHCb Collaboration submitted a Letter of Intent describing the proposed upgrade to the LHC Committee (LHCC) in March, and the committee endorsed the physics programme. A review panel looked into the proposed 40 MHz readout scheme and gave a positive report, so that the LHCC has now encouraged LHCb to proceed with preparing Technical Design Reports for the upgrade components. This will ensure the future of the experiment into the next decade.

Upgrades to the B-factory experiments are under consideration in Japan and Italy on the same timescale, and have a complementary reach for this physics. While they have strong performance for neutral decay products, they cannot compete with the enormous production rate at the LHC for charged modes, and the time-dependent study of B_s states will remain the province of LHCb. The upgrade will also allow the LHCb experiment to act as a general-purpose detector in the forward region, with the ability to search for exotic particles that might give long decay lengths, or to study in detail the influence of any new physics states that might be discovered at the LHC over the same period. The collaboration is now pressing ahead with the R&D necessary to ensure the upgrade's success.

● For more information see *Letter of Intent for the LHCb Upgrade*, CERN-LHCC-2011-001.

ALICE measures multi-strange baryons

The ALICE Collaboration has measured the production of baryons containing two or three strange quarks in lead–lead collisions at the LHC, at an energy of 2.76 TeV per nucleon pair, nearly 14 times larger than that obtained previously at Brookhaven's Relativistic Heavy Ion Collider (RHIC). The yields and transverse-momentum spectra of multi-strange baryons and antibaryons in heavy-ion collisions are important in characterizing the evolution of the hot-matter created, as it passes from the strange quarks and antiquarks of the early partonic stages to the subsequent hadronization.

The collaboration identified multi-strange baryons mainly by a topological method, looking for their weak-decay products originating from secondary vertices well separated from the main interaction vertex. The researchers also exploited particle identification via specific energy loss in the time projection chamber (TPC). For example, the Ω^- baryon (consisting of three strange quarks) decays into a negative K meson and

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a neutral Λ baryon, which in turn decays into a proton and a negative π meson. A peak in the invariant mass spectrum of all (Λ, K^-) combinations provides a clearly identifiable signal (figure 1).

Good momentum resolution and a precise secondary-vertex reconstruction were essential for this result. A key element was the excellent performance of the main tracking detectors in ALICE's central barrel – the TPC and the internal tracking system (ITS) – in the challenging environment of central (head-on) lead–lead collisions.

The data were analysed in transverse momentum intervals up to 6–9 GeV/*c* for the doubly-strange baryons (Ξ^- and charge conjugate separately) and 6–8 GeV/*c* for the triply-strange baryons (Ω^- and charge conjugate separately), made possible by the examination of 30 million minimum-bias nuclear interaction candidate events. In addition, the centrality of the selected events was determined from signals collected in two scintillator hodoscopes at backward and forward rapidities (K Aamodt *et al*. 2011). This allowed the analysis to be repeated in four different centrality intervals, from the 0–20% most central (almost head-on) collisions to the 60–90% peripheral collisions, in order to compare with previous results at RHIC. Figure 2 shows the resulting transverse-momentum spectra, fully corrected for detector acceptance and efficiency; it also shows clearly how multi-strange baryon production increases with the centrality of the collision at LHC energy. The results were presented at the recent conference on Strangeness in Quark Matter (p20).

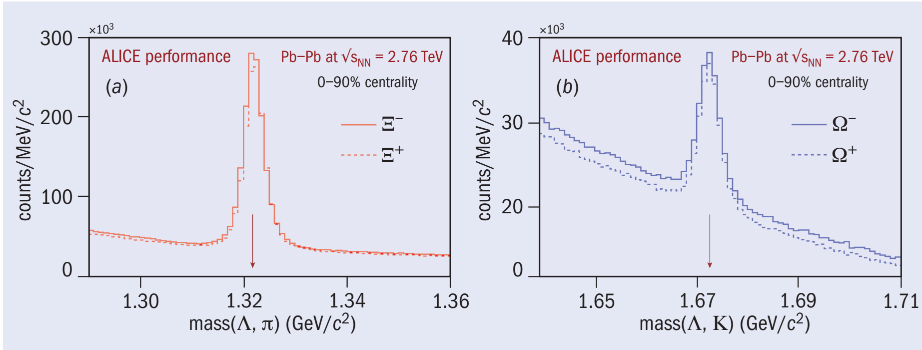


Fig. 1. Invariant mass spectra showing the Ξ (left) and Ω (right) baryon and antibaryon signals, for lead–lead (Pb–Pb) collisions in ALICE.

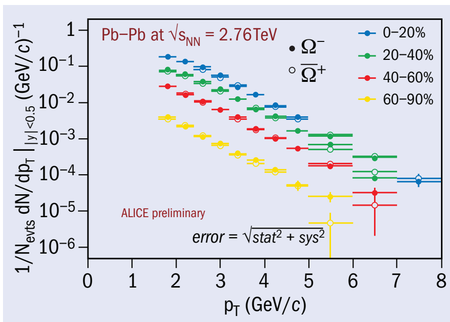


Fig. 2. Transverse momentum spectra of multi-strange baryons (Ω^-) and antibaryons in Pb–Pb collisions, in four different centrality bins.

Previous experiments at CERN's Super Proton Synchrotron (SPS) and at RHIC obtained multi-strange baryon spectra and yields in 17 GeV lead–lead and 200 GeV gold–gold collisions, respectively. The ALICE experiment not only finds higher yields in lead–lead collisions at the LHC energy, but also finds that the enhancement with respect to proton-proton collisions is greater for the Ω than for the Ξ, confirming the trend observed at both SPS and RHIC. Moreover, the enhancement with respect to proton–proton data increases with the centrality of the collision, in a similar way to previous observations.

Further reading

For more information, see ALICE contributions to SQM 2011 at http://indico.ujk.edu.pl/conferenceTimeTable.py?confId=0.

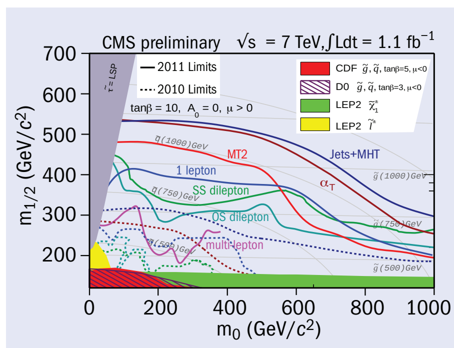
K Aamodt *et al.* (ALICE collaboration) 2011 *Phys. Rev. Lett.* **106** 032301.

SUSY: the search continues

Supersymmetry (SUSY) is still one of the strong candidates for physics beyond the Standard Model that could be detected in proton–proton collisions at the LHC. It could solve many of the outstanding issues in particle physics, such as the gauge hierarchy problem. SUSY can reveal itself through the production of new heavy particles and could therefore deliver a natural candidate particle to explain the large density of dark matter in the universe. However, it has so far evaded the current searches in both the CMS and ATLAS experiments.

The figure shows a compilation of many of the most recent public results of CMS for integrated luminosities of about 1–2 fb^{-1}. It illustrates the reach of the analyses with respect to pre-LHC experiments in the plane of the universal scalar and gaugino masses (m_0 and $m_{1/2}$, respectively) at the grand unified theory scale of the constrained minimal supersymmetric extension of the Standard Model (CMSSM).

A large increase in sensitivity was clearly obtained at the LHC with the data analysed, obtained in 2010 and until August 2011, but this parameter space is just one reference point among possible SUSY scenarios. Additional data will allow the exploration of other scenarios where each of the signatures, from no-leptons to multileptons, may have the most sensitivity. The search channels shown varied from having a few to many jets (α_T, Jets+MHT, MT2), and jets plus one lepton (i.e. generally one muon or electron), jets plus two leptons, with either opposite (OS) or the same (SS) charge. All of these channels were also required to have a large missing transverse energy. The latter is a key characteristic of many SUSY searches, reflecting the supposition that the lightest SUSY particle is expected to be neutral, stable and weakly interacting – thereby escaping detection.



Results of the CMS search for SUSY for different analysis channels. The area below the curves is excluded by this new measurement. Exclusion limits obtained from previous experiments are presented as solid areas. Grey lines indicate constant squark ($\tilde{q}$) and gluino ($\tilde{g}$) masses.

CMS recently released the results of SUSY searches for candidates containing at least three leptons. For these search channels, the

Standard Model background is low, mostly di-boson events; this allows the missing transverse energy requirement to be relaxed considerably and so provide sensitivity to SUSY models with so-called R-parity violation. In these models, SUSY particles decay to Standard Model particles and no dark-matter candidate can escape detection. Moreover, such studies are sensitive to the channel of direct electroweak gaugino production, important in scenarios that conserve R-parity.

CMS analysed a total of 2.1 fb^{-1} of data. In general no significant excess was observed in this new analysis – so SUSY, if it exits, still manages to hide away. As many as 52 different channels have now been looked into and although a few of them show a slight excess over the background estimated from data, all of them currently have a significance of less than 2σ. CMS will certainly continue to "watch this space".

At the time of this writing, more than 5 fb^{-1} of data have been recorded and are now being analysed. It promises to be an interesting winter for SUSY searches.

● **Further reading:**
For more on the multilepton analyses, see CMS-EXO-11-045 and CMS-SUS-11-013.

Dileptons: a window on force unification and extra-dimensions

The ATLAS Collaboration has published its latest search for neutral resonances decaying to pairs of leptons, either electrons or muons.

Searches for dilepton resonances have a history of discoveries, from the J/ψ and Υ to the Z boson. Now new neutral gauge bosons, Z', which would appear as resonances, are predicted by a number of theories. They are the mediators of new forces that allow the unification of all fundamental forces at some very large energy scale. Dilepton resonances are also predicted as gravitons in models of extra-dimensional gravity.

The analysis by ATLAS used a data sample corresponding to an integrated luminosity of 1.1 fb^{-1}. The sensitivity to new physics extends to 1.8 TeV, similar to that of recent preliminary results from CMS and far beyond the limits achieved at lower-energy accelerators. The observed dilepton mass distributions (for example, the di-electron distribution of figure 2) are in good agreement with the spectrum predicted by the Standard Model including higher-order QCD and electroweak corrections.

The search technique employed by ATLAS involves the comparison of the dilepton mass distribution with the predicted spectrum over the entire high-mass range. The prediction includes a series of hypothetical resonance line-shapes with different masses and couplings. The dominant sources of systematic uncertainty are of a theoretical nature, arising from the calculations of the production rates.

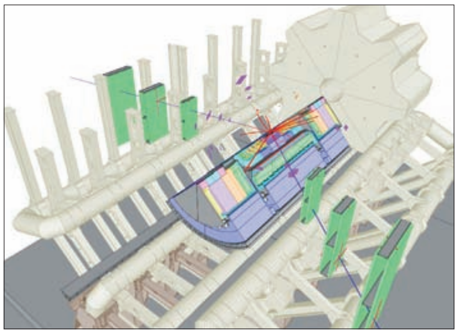


Fig. 1. Event display of the highest invariant-mass dimuon event, with an invariant mass of 959 GeV, collected by ATLAS in the first 1.1 fb^{-1} of data. The transverse momenta of the muons are 510 GeV and 437 GeV.

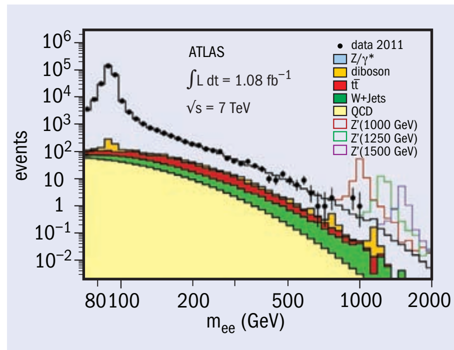


Fig. 2. Di-electron invariant mass distribution, compared to the stacked sum of all expected backgrounds, with three example Z' signals overlaid.

The ATLAS detector will measure the mass of any resonance observed quite accurately. The liquid argon calorimeter provides a linear and stable response for electrons up to the highest energy, and the combination of the inner detector and the muon spectrometer provides muon measurement at the highest momenta. ATLAS will also measure the cross-section, couplings, spin and interference properties of a resonance.

Work is ongoing to increase the lepton acceptance further, and ATLAS will extend the kinematic reach of these exciting measurements with much larger datasets in 2011–2012.

● **Further reading:**
ATLAS collaboration 2011 arXiv:1108.1582, accepted for publication by *Phys.Rev.Lett.*
CMS collaboration 2011 CMS-PAS-EXO-11-019.
For these results and more, see https://twiki.cern.ch/twiki/bin/view/AtlasPublic.

Astrophysics

Scalar field could unlock supernova mystery

A new component of gravity, the scalar gravitational field, may explain the mechanism that allows the immense explosions of type II supernovae to take place. However, this could happen only through a dynamic process – parametric instability – that dates back to work by Lord Rayleigh in the 1880s.

When the central core of a massive star runs out of nuclear fuel (having been converted mainly into iron), it collapses under its own weight in less than a second into an extremely dense neutron star, releasing an enormous amount of gravitational energy. A supernova results, but only a small fraction of the total energy released appears as electromagnetic radiation (light) of the "new star". The kinetic energy of the exploding stellar envelope is 10 times greater, but the greatest part of the energy by far is carried away by neutrinos, which can more easily escape the dense material of the core.

Detection of neutrinos from supernova SN1987A did much to verify this picture (*CERN Courier* January/February 2007 p23). During core-collapse, the density at the centre of the star rapidly increases, finally forming dense nuclear matter that is extremely difficult to compress. The collapsing material rebounds from this nuclear matter, resulting in an outgoing pressure wave, which soon becomes a huge shock wave.

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Extensive studies have attempted to decide whether this "prompt shock" travels all of the way out and ejects the outer part of the star. Indeed, simulations suggest that it stalls at distances of about 300 km from the centre because of the immense energy required to dissociate iron and other nuclei. However, further simulations have found that the shock could restart if the electrons could absorb about 1% of the energy carried by neutrinos. In the neutrino-plasma coupling model, collective interactions between the neutrinos and the plasma could initiate the required energy transfer. Alternatively, recent research suggests that the solution to re-energizing the shock may lie in a fundamental field that takes the simple form of a scalar (like the Higgs field).

Gravity containing a scalar field (originally proposed by Carl Brans and Robert Dicke in the 1960s as an additional component of the gravitational field) has been considered as a promising extension to Einstein's general relativity in connection with quantum gravity and grand unification. The theory of Brans and Dicke was based on a relatively simple linear coupling to the scalar gravitational field. A few years ago, this linear coupling was shown to be negligible, using radio signals transmitted from the Cassini spacecraft when it was near Saturn.

The Tarantula Nebula in the Large Magellanic Cloud, with the supernova SN1987a clearly visible as the very bright star. At the time of this image, the supernova was visible with the unaided eye. (Image credit: ESO.)

Now, researchers in the UK and Portugal have analysed the nonlinear coupling to a scalar gravitational field. They find that under extreme conditions with strong time-varying gravity such as may be found in the interior of a newly born neutron star, the scalar gravitational field may be stimulated via parametric instability. The resulting emission of scalar gravitational waves from the neutron core of a collapsing heavy star may be sufficient to re-energize the stalled shock, thus providing a 19th-century solution to a 20th-century problem.

Further reading

C H-T Wang *et al.* 2011 *Phys. Letts. B* **705** 148.

Sciencewatch

Compiled by John Swain, Northeastern University

Brown algae give a boost to batteries

Lithium-ion batteries are typically made with conductive carbon electrodes, but with the use of silicon instead of carbon their capacity could be dramatically increased. The stumbling block has been that silicon-based electrodes tend to degrade quickly. But that has now been overcome thanks to an unlikely source – brown algae, which include giant kelp.

Igor Kovalenko of the Georgia Institute of Technology and colleagues have shown that electrodes made from silicon nanopowder and alginate – a natural polysaccharide obtained from brown algae – makes for a stable battery that has eight times the capacity of state-of-the-art graphitic electrodes. Alginate also has the advantage of being cheaper and more environmentally friendly than the plastics used instead in current technologies. The increased lifetime is a really remarkable improvement that would will undoubtedly by welcomed by anyone with a laptop computer.

*Giant kelp (*Macrocystis pyrifera*) could help to power your laptop for up to eight times longer than with current battery technology. (Image credit: Naluphoto/Dreamstime.com)*

Further reading

I Kovalenko *et al.* 2011 *Science* **334** 75.

Gravity on large scales

In cosmology, general relativity is often assumed to be valid out to arbitrarily large scales, but whether this is true or not has been difficult to test directly. Now, Radosław Wojtak and colleagues of the Niels Bohr Institute in Copenhagen have managed to use archived data from galaxies in clusters to make a direct test of general relativity out to scales of 1–10 megaparsecs. Working from a new galaxy cluster catalogue from the Sloan Digital Sky Survey they used data on 7800 galaxy clusters and 120 000 galaxy redshifts.

The new technique may be extended in the future, but for now it means that the standard gravitational redshift has been tested over scales spanning 22 orders of magnitude. Still viable are models such as f(R) gravity, which can be used to explain dark energy. However, the tensor–vector–scalar (TeVeS) theory, a relativistic version of modified Newtonian dynamics (MOND) that eliminates the need for dark matter, seems to be excluded.

Further reading

R Wojtak 2011 *Nature* **477** 567.

Word order

Little is known about the hypothetical protolanguage from which all modern ones descended, which could date back 50 000 years. However, Merritt Ruhlen of Stanford University and Murray Gell-Mann of the Santa Fe Institute in New Mexico argue that the word order must have been subject-object-verb. In a family tree of 2200 languages, living and dead, based on how similar sounds were used to convey similar meanings, they found that subject-verb-object (*I drink beer*) languages always descended from subject-object-verb (*I beer drink*) ones – never the other way round.

Further reading

M Ruhlen and M Gell-Mann 2011 *PNAS*.

The biggest virus

Viruses are often thought of as being tiny, but some are relatively huge and may have actually descended from cells. The giant mimivirus *Acanthamoeba polyphaga mimivirus*, for example, is some 400 nm across. Discovered in 2003, it has many genes previously thought to be unique to cellular life, but it was an open question as to whether it might have stolen them from some sort of cell. Jean Michel Claverie of the Structural and Genomic Information Laboratory in Marseille and colleagues have now found a huge new virus in sea water off the coast of Chile. The discovery of *Megavirus chilensis* – which seems to be a distant relative of the mimivirus and shares its cell-like genes – bolsters the case that at least some viruses had cells as ancestors.

Further reading

D Arslan *et al.* 2011 *PNAS*, doi:10.1073/pnas.1110889108.

Underground ice

In winter it is easy to see how much damage ice causes when it forms underground, but there may be more to the process than meets the eye. Robert Style of the University of Oxford and colleagues have created a physically intuitive model that goes a long way towards explaining what goes on, and in particular how "ice lenses" form, pushing up large regions of ground. Naively it might seem that this is a result of ice taking up more space than water, but similar behaviour is found with liquids that do not shrink on freezing.

A key insight is a new concept called "geometrical supercooling". The idea is that ice crystals can be prevented from growing through more water freezing if they are confined and under pressure. More and more water can be drawn up into a supercooled region via thermomolecular pressure gradients or "cryosuction", until the soil gives way and an ice lens forms. In this case, it is not just that water expands on freezing, but crystal growth that does the pushing.

Further reading

R W Style *et al.* 2011 *Phys. Rev.* **E84** 0414202.

Lizards with placentas

Recent work with lizards has shaken the long-standing assumption in biology that only mammals have placentas. Daniel G Blackburn of Trinity College in Hartford, Connecticut, and Alexander F Flemming of Stellenbosch University have found that a lizard – the skink *Trachylepsis ivensii* – is an exception. While many reptiles give birth to live young, they do not have embryos that implant themselves into the mother and connect to her circulatory system via a true placenta. The discovery of placentas in two distinct groups of animals may help biologists to figure out how they evolved.

Further reading

D J Blackburn and A F Flemming 2011 *Journal of Morphology*, doi: 10.1002/jmor.11011.

Astrowatch

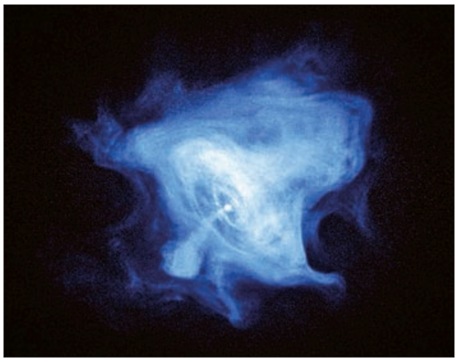
COMPILED BY MARC TÜRLER, ISDC AND OBSERVATORY OF THE UNIVERSITY OF GENEVA

VERITAS detects Crab pulsations at very high energies

The Crab nebula is the brightest persistent gamma-ray source in the sky with radiation detected up to very high energies (VHE), above 100 GeV. The surprising result of the Very Energetic Radiation Imaging Telescope Array System (VERITAS) is the detection of pulsed radiation from the Crab in this extreme energy range, a new challenge for theorists.

VERITAS is an array of four 12-m telescopes using the imaging air Cherenkov technique (IACT) to detect VHE gamma-rays. Located in Arizona, it is the American equivalent of two European Cherenkov telescope facilities: the Major Atmospheric Gamma-ray Imaging Cherenkov telescope (MAGIC) on the Canary Islands and the High Energy Stereoscopic System (HESS) (*CERN Courier* January/February 2005 p30 and June 2009 p20). The IACT uses the Earth's atmosphere as a gamma-ray detector where VHE photons interact with atomic nuclei to produce electron–positron pairs, which create a cascade of charged particles. The latter can travel faster than light in the air, thus producing a flash of Cherenkov radiation in the optical-UV range that is recorded by the telescopes on the ground. The telescope's camera is an array of photomultipliers that produce an image of the particle shower, which develops at an altitude of 10–20 km and retains the information on the direction and energy of the incoming gamma-ray photon.

The Crab nebula is the remnant of a supernova explosion witnessed by Chinese and Arab astronomers in 1054 AD and its pulsed emission at radio frequencies was discovered in 1969. The regular pulses revealed the presence of a strongly magnetized neutron star – the collapsed core of the defunct star only about 30 km across – rotating 30 times per second. The same periodic signal from the pulsar was subsequently detected in the optical, X-ray and gamma-ray domain. In 2008, MAGIC was the first Cherenkov telescope to detect pulsed radiation from the Crab above an energy of 25 GeV. It was, however, generally thought that the gamma-ray emission spectrum of the pulsar would cut off at higher energies preventing a detection with current instrumentation above 100 GeV.



X-ray image of the Crab nebula by the Chandra X-ray Observatory showing the complex geometry of electron radiation in the magnetic field of the pulsar (bright dot near the centre). (Image credit: NASA/CXC/SAO/F Seward et al.*)*

As VERITAS has a higher energy-threshold than MAGIC, there was only a faint hope that a long observation of the Crab nebula could provide a meaningful detection. Nevertheless, with 107 hours of observations between September 2007 and March 2011 the challenge paid off and the VERITAS collaboration has reported a 6σ detection of the VHE pulsed emission from the Crab. The observed spectrum published in the *Science* covers the 100–400 GeV range at a flux of about 1% that of the nebula at 150 GeV. Combining the VERITAS data with the lower-energy measurements by MAGIC and the Fermi gamma-ray space telescope provides a broad spectrum extending from 100 MeV to 400 GeV. The new observations clearly disfavour a power-law model with an exponential cut-off. Instead they suggest that the pulsed gamma-ray emission from the Crab is a broken power-law with a break at a photon energy of about 4 GeV.

The unexpected VHE observations are extremely difficult to reconcile with emission from the magnetic poles of the neutron star. Indeed, the authors of the paper find that the highest energy gamma-rays they measure can only be emitted at a distance of more than 10 stellar radii from the neutron star's surface. They also find that curvature radiation – the emission of electrons following curved magnetic field lines – is unlikely to produce gamma rays above 100 GeV. A plausible alternative could be inverse-Compton scattering, but the theory is not yet able to define clearly where such a process could take place. The fact that the pulses observed by VERITAS are narrower by a factor two to three compared with those observed by Fermi at 100 MeV and that the secondary pulse becomes the dominant one in the VERITAS energy range could be interesting clues for theorists.

Further reading

VERITAS collaboration, Aliu *et al.* 2011 *Science* **334** 69.

Picture of the month

The remains of the oldest documented supernova are beautifully displayed here by combining images from four different space telescopes. The exploding star was observed during eight months by Chinese astronomers back in 185 AD (*CERN Courier* January/February 2006 p10). X-ray emission from an expanding shock wave is shown in blue and green colours based on observations by ESA's XMM-Newton satellite and NASA's Chandra X-ray Observatory. Infrared emission from cool gas is shown in yellow and red as observed by two other NASA satellites: the Spitzer Space Telescope and the Wide-field Infrared Survey Explorer. The combined view allowed astronomers to determine that the supernova was of type Ia and that the remnant, called RCW 86, expanded rapidly into a cavity that was likely to have been blown out in the interstellar medium by a wind from the white dwarf star prior to exploding. (Image credit: NASA/ESA/JPL-Caltech/UCLA/CXC/SAO.)

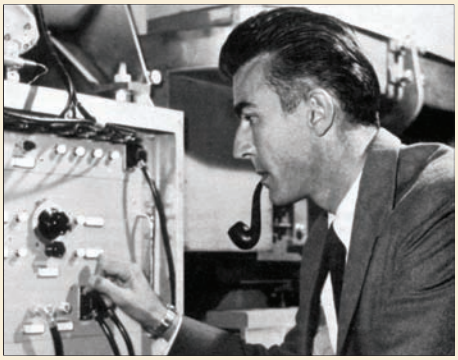
CERN Courier Archive: 1968

A LOOK BACK TO CERN COURIER VOL. 8, DECEMBER 1968, COMPILED BY PEGGIE RIMMER

FACES AND PLACES

CERN and other laboratories

On 18 December, the Council agreed to offer John Bertram Adams the position of 300 GeV Project Director. The choice came as no surprise and the news has been greeted with a wave of enthusiasm throughout CERN. To a great number of people he is inextricably linked with memories of the adventure of constructing the 28 GeV proton synchrotron, when he demonstrated both his great technical ability and qualities as a leader. The 300 GeV laboratory is a sterner proposition, worthy of his talents.



John Adams.

Last year, the highest-energy electron synchrotron in the world was brought into operation at Cornell University, USA. The project had been instigated and led by Prof. R R Wilson prior to his moving to Batavia to direct the 200 GeV project. In tribute to his leadership, the laboratory housing the synchrotron has been named the Wilson Synchrotron Laboratory and a dedication ceremony was held on 10 October.

H A Bethe (left) who was awarded the 1967 Nobel Prize for Physics, mainly for his work on the energy processes in stars, tours the magnet ring of the 10 GeV electron synchrotron at Cornell accompanied by the director of the laboratory, B P McDaniel. (Image credit: World wide photo.)

On 1 December, a "ground breaking" ceremony took place at the National Accelerator Laboratory where the USA 200/400 GeV accelerator is being constructed. Over 1000 people came together, despite the snow, to attend the ceremony, which took place at the intersection of the linac and the booster ring.

Construction of prototype underground enclosures for the Booster Ring and the Main Ring are under way. Detailed design of the Booster building has been completed. It is scheduled to be ready by May 1970 to enable the Booster to produce 10 GeV beams by July 1971.

● Compiled from texts on pp310, 311–313.

ELECTRONICS

International collaboration

Many research centres have felt, for some time, the need for a modular mechanical system to be used with compact integrated circuitry. When small, cheap computers came onto the market this need increased, perhaps especially in subnuclear physics research. Up to now, various local solutions have been evolved – virtually one for each research centre. This imposed restrictions on the interchangeability of equipment and meant that manufacturers had no guarantee of a large market when building units of a particular system.

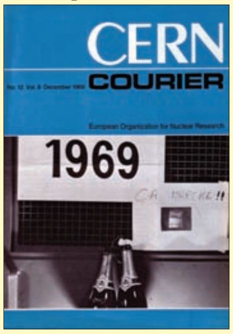
CERN first broached this problem by adopting the NIM [Nuclear Instrumentation Module] standard, originally specified by the Atomic Energy Commission in the USA to achieve standardization in government centres throughout the United States. This was taken over by CERN with a minor modification in that small LEMO coaxial connectors are used instead of BNC, leading to compact instrumentation even for large experiments (BNC/LEMO adaptors are available). Some 500 NIM units have been successfully used at CERN. The system will continue to be used until the need for computer control of these fast-logic instruments becomes paramount.

CAMAC [Computer Automated Measurement And Control] is a new modular electronics system well adapted to the data-handling field. It has resulted from discussions involving all members of the ESONE committee (European Standard for Nuclear Electronics), triggered by the UK AERE [Atomic Energy Research Establishment] delegation in autumn 1966.

By the beginning of 1968, the system had evolved to a stage where it seemed to suit everyone's major requirements. Representatives of almost all large European laboratories and universities met in May and the first official announcement of the agreement reached was made in "Nuclear Instruments and Methods" in September. It represents an important advance in standardization throughout Europe, offering an electronic system with wide applications other than in nuclear physics. One direct result will probably be substantial support from industry.

● Compiled from text on p314.

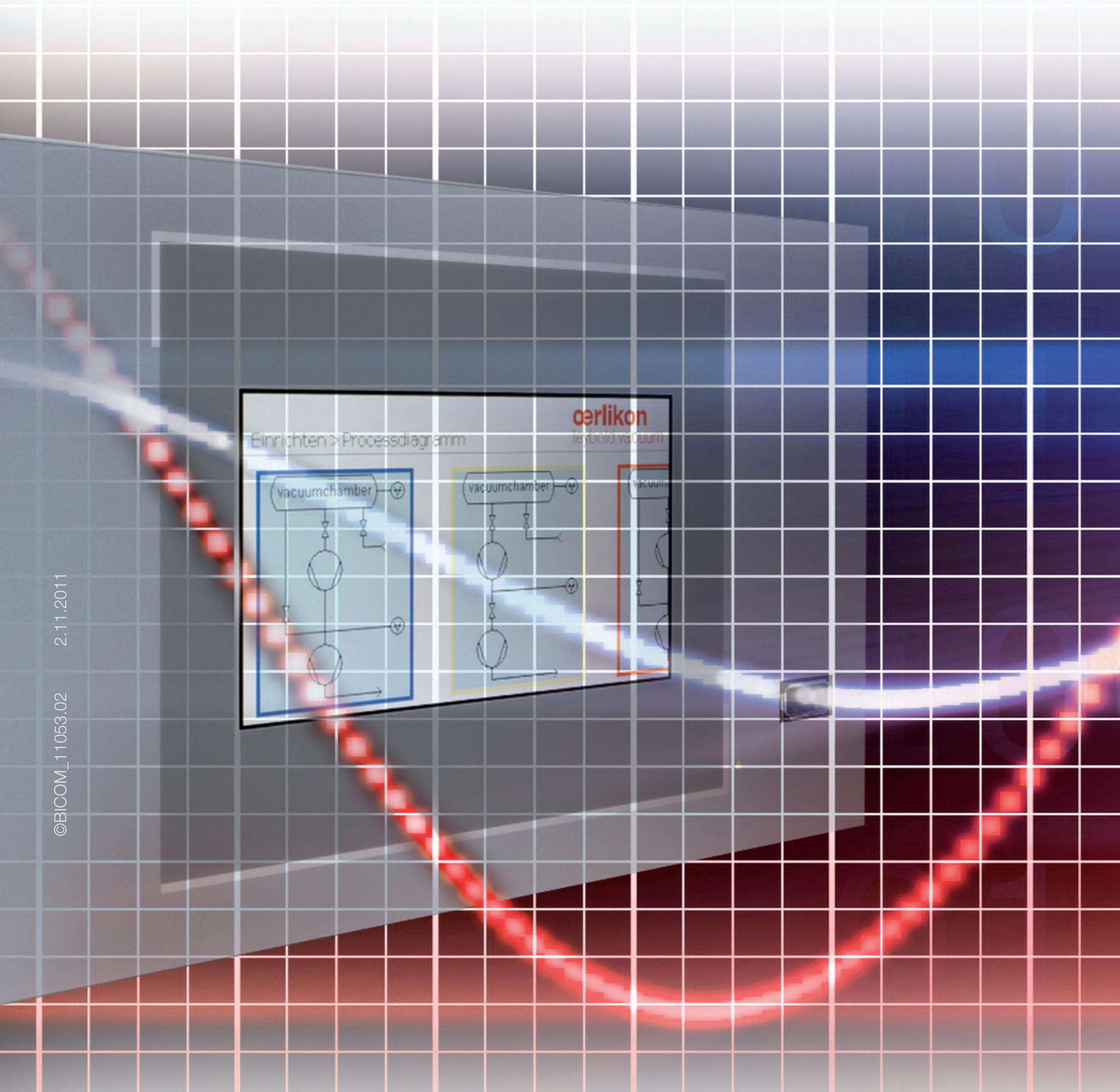
Compiler's Note



With the advent of electronic detectors, CERN became an enthusiastic participant in international efforts to standardize the associated data collecting and recording hardware, although the temptation to tweak occasionally proved irresistible.

With the advent of affordable computers, a plethora of operating systems, languages and communication protocols – some proprietary, some home-grown – made it difficult to achieve common solutions to common problems. Brand and tribal loyalties set in, not unlike today's MAC versus PC fan bases. For example, CERN developed its own network, CERNET, and even an in-house dialect of FORTRAN! Nonetheless, it seemed clear that real benefits could accrue from conformity, wherever and whenever possible, and this conviction persisted until eventually Tim Berners-Lee was able to get his standards – URLs, the HTTP and HTML – accepted, worldwide. The rest, as they say, is history.

High Vacuum Monitoring and Control



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IPAC'11 brings the world to San Sebastián

The second International Particle Accelerator Conference brought members of the world's accelerator community together in northern Spain to exchange ideas and hear about the latest news in the field.

Three years ago the last in the series of European Particle Accelerator Conferences took place in the Italian seaport of Genoa. Now, reflecting the increasingly worldwide nature of the subject, Europe plays host every three years to the new International Particle Accelerator Conference (IPAC) series, with Asia and North America taking turns in the other two years. Following a successful first meeting in Kyoto in 2010, this year it fell to Europe to organize the 2nd IPAC and once again accelerator specialists found themselves by the sea, this time at San Sebastián on Spain's Atlantic coast. There, on 4–9 September, the sea and surf provided a fitting setting for a meeting where wave motion figured in many presentations.

The Kursaal conference centre on the water's edge was an ideal place to house the sessions for around 1100 participants. As at many conferences these consist of plenary, parallel and poster sessions but the balance at IPAC – as at the regional conferences held in the past – makes for a different mixture. A pair of parallel sessions provides a straight choice between two oral presentations, allowing much of the "business" of the conference to occur in busy afternoon poster sessions, which cover different topics each day. These are like scientific bazaars where vendors show off their wares to anyone interested and information is traded freely.

IPAC'11 was truly international, with participants from some 30 countries, around half from Europe and the other half from Asia and North America. The programme spanned four and a half days, with plenary sessions on two mornings, as well as on one afternoon. The two parallel sessions took place on other mornings and afternoons, with the poster sessions (supplied with plenty of refreshments) scheduled alone at the end of four afternoons. Altogether, 1300 posters were scheduled, which is a clear indication of the vibrancy of the field. A special poster session for young

Cristina Garmendia, the Spanish minister of science and innovation, welcomed participants to the conference. (All image credits: Terry Pritchard.)

scientists – with a prize for the best two – took place on the first day during registration (see box, p16).

At the opening plenary session the Spanish minister of science and innovation, Cristina Garmendia, welcomed participants to the Basque country – her home region – and drew attention to Spain's increasing involvement in accelerator science. ALBA, the synchrotron light source near Barcelona, was the topic of the first of the session of invited talks, which went on to highlight a leading facility in the areas of hadron accelerators (the Japan Proton Accelerator Research Complex, J-PARC), circular colliders (the LHC), linear colliders (the International Linear Collider, ILC) and synchrotron light sources and FELs (the Japanese-XFEL at SPring-8). These were four of the main themes for the conference, the others being accelerator technology, beam instrumentation and feedback, beam dynamics and electromagnetic fields, as well as applications of accelerators. ▷

IPAC'11 was truly international... The presentations demonstrated just how far and wide accelerator technology has spread.

Rewarding achievement – now and future

A highlight of the conference was the award of the EPS-AG prizes, which were announced earlier this year (*CERN Courier* July/August 2011 p44). Shin-Ichi Kurokawa of KEK, Yasushige Yano of RIKEN and Rogelio Tomás García of CERN were presented their awards by the chair of the Prizes Selection Committee, Christopher Prior.

In addition the EPS-AG awarded a prize for a student registered for a PhD or diploma in accelerator physics or engineering or a trainee accelerator physicist or engineer in the educational phase of their professional career, for the quality of work and promise for the future. This was presented to Pei Zhang of the University of Manchester, for his contribution entitled, "Study of Beam Diagnostics with Trapped Modes in Third Harmonic Superconducting Cavities at FLASH".

The prize for someone still in the educational phase of their career in accelerators, awarded to Pei Zhang of Manchester University, provided the opportunity to make a short presentation.

Best Student Poster Prizes were presented to Aleksandar Angelovski, TU Darmstadt, for his contribution on "Realization of a High Bandwidth Bunch Arrival Time Monitor with Cone-shaped Pickup Electrodes for FLASH and XFEL" and to Sam Posen of Cornell University for his poster on "Cornell SRF New Materials Program".

The attendance of more than 107 young scientists from all over the world was made possible through the sponsorship of societies, institutes and laboratories worldwide (in alphabetical order): ACFA (IPAC'10), ALBA/CELLS, APS-DPB, CEA, CERN, CNRS-IN2P3, DESY, DIAMOND Light Source, ESRF, FZD, FZJ, GSI,HZB, HIC for FAIR, INFN, JAI, Lund University, Max-lab, MSL, PSI, Synchrotron SOLEIL and STFC.

The presentations on light sources served to demonstrate just how far and wide accelerator technology has spread to provide valuable research tools for other areas of science. ALBA, built and operated by the CELLS consortium, is based on a 3 GeV booster synchrotron that feeds a storage ring located in the same tunnel (*CERN Courier* November 2008 p31). The storage ring accumulated first beam on 16 March and by 7 June had achieved a current of 170 mA in readiness for beamline commissioning. Other similar synchrotron-based facilities that are now being designed elsewhere include the Polish facility Solaris and the Iranian Light Source Facility. The design of Sirius, at the Brazilian Synchrotron Light Laboratory, São Paulo, takes a slightly different approach. The dipoles of the 3 GeV ring will be based on permanent magnet technology – for reduced operational costs and increased reliability – and it will combine low-field magnets (0.5 T) for guiding the main beam with short "slices" of high-field magnets (2.0 T) to generate 12 keV photons for the beamlines.

Synchrotron light sources are now being joined increasingly by facilities that use FELs to produce light at ever decreasing wavelengths. In Italy, for example, the 2.4 GeV Elettra synchrotron light source is being supplemented by FERMI, an externally seeded soft X-ray FEL. Its first seeded FEL coherent output at 43 nm, achieved last December, was followed by commissioning of the beamlines and the first tests with users in March and April. In Japan, the SPring-8 Angstrom Compact free electron LAser (SACLA) is the world's first compact X-ray FEL based on in-vacuum undulators. Commissioning started there in February and the FEL produced its first X-ray laser light at 0.12 nm on 7 June (*CERN Courier* July/August p9). In the UK, meanwhile, the ALICE Accelerator R&D Facility at Daresbury, has built Europe's first FEL to be driven by a superconducting energy-recovery linac. The infrared FEL achieved lasing for the first time in October 2010. ALICE is also a source of high-power terahertz radiation, which has potential use in studies of living cells. In June, beam was transferred to a tissue-culture laboratory some 30 m from the accelerator.

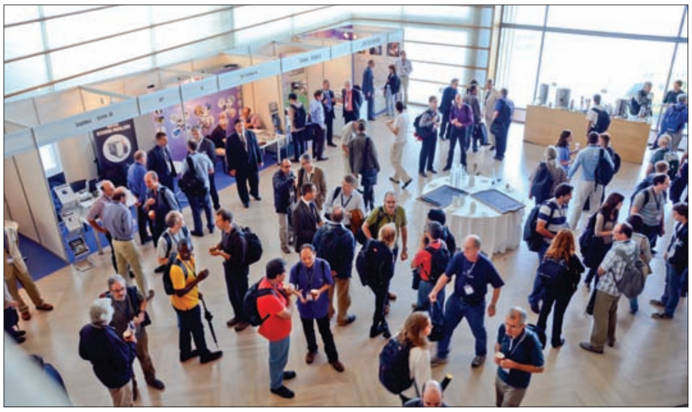
Hadron power

While electron accelerators find applications in light sources, hadron accelerators have a role as powerful drivers for a range of facilities. J-PARC, for example, is a multipurpose proton accelerator facility aiming ultimately at an output beam power in the megawatt range. Commissioning started with the 400 MeV H^- linac in November 2006 and by 2011 output beam power from the 3 GeV Rapid-Cycling Synchrotron to the Materials and Life Science Facility had reached 220 kW and a 145 kW beam was produced by fast extraction from the Main Ring for neutrino production. This progress came to an abrupt halt in March when the massive earthquake struck the north-east of Japan. With its epicentre 270 km from J-PARC, the magnitude 9.0 event caused subsidence of up to 1.5 m at the entrance to the linac but – although the tunnel floor was deformed by as much as 45 mm – the linac structures did not topple. Simulations have shown that misalignment of up to 0.2 mm in the drift-tube quadrupoles can be tolerated by compensating with beam steering. This is speeding up recovery because only the drift-tube structures with the most essential realignment need to be opened up. Beam tests following recovery are planned for December, with a restart in January 2012.

Spallation neutron sources require powerful proton accelerators to drive them. The China Spallation Neutron Source is being designed to operate with an initial proton beam power of 100 kW, upgradeable to 500 kW. Construction was scheduled to start in September and should take six and a half years. It is the first large-scale, high-power accelerator project to be constructed in China.

In Europe, there is a growing need for a new high-flux source of cold neutrons because many research reactors are scheduled to close in the coming decade. The European Spallation Neutron Source (ESS) to be built in Lund should fill this gap. In terms of proton energy, its requirements are modest – 2.5 GeV – but the challenges will come in providing the 5 MW beam power and the 50 mA current in 2.9 ms pulses at 14 Hz. As many as 17 countries are involved in the accelerator development, with a target date of 2020 for first operation.

High-power proton accelerators are equally important for future



The industrial exhibition spread over two floors provided a chance to make valuable contacts between sessions.

Vladimir Shiltsev from Fermilab, left, passes the "high-energy frontier" baton to CERN's Mike Lamont, symbolizing the passage from the Tevatron to the LHC.

high-intensity neutrino sources. In Europe the EC has funded EUROnu, a design study to investigate three options for a future high-intensity neutrino oscillation facility: a CERN to Frejus Super-Beam, a Neutrino Factory and a Beta Beam. At CERN, meanwhile, Linac 4 represents the first step in a long-term programme to increase luminosity in the LHC. Civil engineering for a new building has recently finished and construction of the main accelerator components for the 160 MeV H^- linac has started with the support of a network of international collaborations. Linac 4 should double the intensity from the Proton Synchrotron Booster; commissioning is currently planned for 2013–2014.

Frontier colliders

At IPAC'11 the LHC had a starring role as a circular collider. It passed the peak luminosity record of the Tevatron – its predecessor as the world's highest-energy collider – on 21 April and has since gone on to deliver more than 5 fb^{-1} integrated luminosity to the ATLAS and CMS experiments. As the world's first superconducting accelerator, the Tevatron blazed an important pioneering trail, which was reviewed by Fermilab's Vladimir Shiltsev after passing a symbolic baton to Mike Lamont, head of the Operations Group at CERN. While the spotlight is now on physics at the LHC, the accelerator experts are looking increasingly towards the future with upgrades to take the luminosity to an average of $5\times10^{34}\,cm^{-2}s^{-1}$ in the High-Luminosity LHC project. The main goal is to reach 3000 fb^{-1} of accumulated luminosity in the 10–12 years following the upgrade.

One of the issues with increasing energy (and intensity) in hadron beams concerns collimation. Crystal collimation has been studied for a number of years at CERN. Most recently, tests by the UA9 experiment at the Super Proton Synchrotron show that halo collimation with bent crystals could help to enhance collimation efficiency at the LHC. Another novel idea uses a hollow low-energy electron beam in which the proton halo experiences non-linear transverse kicks. This requires a special electron gun to create the hollow beam; tests with mainly antiprotons have already taken place at Fermilab.

In parallel to the LHC luminosity upgrade, plans are being studied to transform the LHC into the LHeC – a high-luminosity electron–nucleon collider of 1.3 TeV centre-of-mass energy (*CERN Courier* April 2009 p22). This could be achieved by adding a 60 GeV electron ring or linear accelerator to the existing proton and ion facility; it would complement the LHC's physics potential and build on the existing LHC investments and its high-luminosity upgrade.

Circular electron colliders have been at the intensity frontier for a number of years, in particle "factories". With KEKB and PEP II reaching peak luminosities of $10^{34}\,cm^{-2}s^{-1}$ they delivered a combined integrated luminosity of more than 1 inverse attobarn (1 ab^{-1}). Now the aim is to go 50 times higher, with two facilities, SuperB in Italy and SuperKEKB in Japan. Large crossing-angles are a common feature for increased luminosity. At lower energies, a technique using round beams is being developed to give higher luminosities at the VEPP2000 facility at the Budker Institute of Nuclear Physics in Novosibirsk.

The high-energy frontier with electron machines rests with a linear collider. The ILC and Compact Linear Collider (CLIC) design studies exemplify the necessary international approach (*CERN Courier* December 2010 p7). Excellent results have demonstrated the feasibility of the CLIC concept for a high-energy linear collider based on the two-beam scheme and normal conducting RF cavities. These concepts and results will be the basis for the CLIC Conceptual Design Report to be completed in 2012. Another technology that could be key, developed in the context of the ILC design study, is superconducting RF and a 9-cell cavity is undergoing intensive R&D around the world. As many as 14 560 such cavities would be required for an eventual machine, housed in 1680 cryomodules. So far some 12 cryomodules have been made, with one from KEK operating at more than 35 V/m in tests.

As the world's first superconducting accelerator, the Tevatron blazed an important pioneering trail.

R&D for the ILC is having spin-off in other research areas, for example, in rare isotope production. This is typically an application for high-power proton beams, but at TRIUMF, the Advanced Rare Isotope Laboratory will couple proton-induced spallation with electron-driven photo-fission for the production of proton-rich isotopes below the line of stability. The latter requires an electron linac delivering 0.5 MW to give some ▷

Accelerators

10^4 fissions per second and the plan is to use 9-cell 1.3 GHz cavities developed for the ILC.

Although the frontiers of fundamental particle physics may drive the push particularly to higher energy accelerators, IPAC is a showcase for the applied side of this research and its close links with industry. An industrial exhibition on the first three days of the conference allowed 76 companies to present their hi-tech products and services. A special session on "Spanish Science Industry" also took place one evening.

Hadron therapy is one high-profile application of particle accelerators that now has close links with industry (p37). In the final session, invited speaker Koji Noda, of the National Institute of Radiological Sciences (NIRS) in Japan, reviewed accelerator and beam-delivery technologies for hadron-therapy facilities around the world. The number of facilities is set to grow from around 30 to more than 50 in the coming decade, thanks to the development of suitable technologies. These include gated irradiation linked to beam extraction, which can switch the beam on or off within a millisecond in response to breathing – one of several techniques pioneered in Japan. For the future more compact machines have the potential to reduce costs, for example, with laser-ion acceleration or with fixed-field alternating gradient (FFAG) machines. Another interesting development centres on the non-scaling FFAG concept, using permanent magnets for a compact proton accelerator.

In another talk that showed that the field has social awareness, Colin Carlile posed the question: "Is it possible to operate a large research facility with wind power?" The answer seems to be, "yes, to a certain degree". As director-general of the ESS he is in a position to lead by example and showed schemes to reduce electricity consumption from 350 GW to 250 GW, with CO_2 savings of 165 000 tonnes each year. A final, sobering note for the conference came from John Duncan, until recently the UK Ambassador for Arms Control and Disarmament, with his talk "Towards a World Without Nuclear Weapons: How can Scientists Help?"

The success of IPAC'11 was a result of the excellent collaboration between the international teams of the Organizing Committee and the Scientific Programme Committee, and the Local Organizing Committee. The large number of participants and the enthusiasm shown in San Sebastián indicate the strong mandate for the IPAC series from the worldwide accelerator community. This community will be looking forward to the next edition, which will take place in New Orleans on 20–25 May 2012.

● IPAC'11 was organized under the auspices of the European Physical Society Accelerator Group (EPS-AG) and the International Union of Pure and Applied Sciences (IUPAP). The proceedings of IPAC'11 are published on the JACoW site: www.jacow.org. Thanks to the JACoW team of seasoned experts and freshly trained volunteers, led by Christine Petit-Jean-Genaz of CERN, a pre-press version with 1236 contributions was published five days after the conference. The final version was published on the site just three weeks after the conference – yet another impressive record set by the JACoW collaboration.

IPAC'12 will be the third conference in the new IPAC series that resulted from the combining of the previous regional accelerator conferences held in North America, Asia and Europe. It will be the first IPAC to take place in the US and will be held at the Ernest N Morial Convention Center, New Orleans, on 20–25 May. Registration began on 1 November and early registration (with the best rates) ends on 31 March. The deadline for submission of abstracts is 7 December.
● *For further information, see www.ipac12.org.*

Résumé

IPAC'11 réuni à Saint-Sébastien

Tous les trois ans, c'est l'Europe qui accueille la Conférence internationale sur les accélérateurs de particules (IPAC), qui a lieu tous les ans ; l'Asie et l'Amérique prennent le relais les autres années. IPAC'11, deuxième conférence de la série, a attiré quelque 1100 participants d'environ 30 pays, dont environ la moitié venait d'Europe et la moitié d'Asie et d'Amérique du Nord. À cette occasion, ils ont pu échanger sur différents sujets, tels que les sources de lumière synchrotron, les lasers à électron libre, les accélérateurs de hadrons, les collisionneurs et les applications des accélérateurs.

Christine Sutton, CERN.

SQM 2011

Strangeness and heavy flavours in Krakow

Participants at the recent Strangeness in Quark Matter conference heard all of the latest news from the heavy-ion collisions field – during a meeting with a jubilee touch.

The 13th international conference on Strangeness in Quark Matter (SQM 2011) took place in Krakow on 18–24 September. Organized by the Polish Academy of Arts and Sciences (Polska Akademia Umiejętności, PAU), it attracted more than 160 participants from 20 countries. The emphasis was on new data on the production of strangeness and heavy flavours in heavy-ion and hadronic collisions, in particular the new results from the LHC at CERN and the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. With the new high-quality data on identified particles, SQM 2011 in a sense supplemented the Quark Matter conference that was held in Annecy in May (*CERN Courier* September p23).

Summary talks during the first two morning sessions introduced the experimental highlights for the main heavy-ion experiments currently in operation. They included data at energies ranging from the Heavy Ion Synchrotron (SIS) at GSI (the HADES and FOPI experiments), through the Super Proton Synchrotron at CERN (NA49 and NA61) and RHIC (PHENIX and STAR), up to the LHC (ALICE, ATLAS and CMS), as well as prospects for new or future facilities, such as the Facility for Antiproton and Ion Research (FAIR) and the Nuclotron-based Ion Collider Facility (NICA).

In this report we can cover only a small selection of the impressive wealth of new results and information presented at the conference. The following highlights illustrate some of the most recent measurements in nucleus–nucleus collisions at the LHC and in the Beam Energy Scan programme at RHIC. All of them focus on results obtained in the sectors of strange and heavy quarks, which traditionally form the major part of the discussions at SQM conferences.

Experimental results

Maria Nicassio of the University and INFN Bari for the ALICE collaboration presented preliminary results on the production of the charged multi-strange hadrons Ξ^- and Ω^- and their antiparticles, from peripheral to the most central lead–lead collisions at the current maximum centre-of-mass energy of 2.76 TeV per equivalent nucleon–nucleon (p8). The enhancement of these particle yields normalized to the number of nucleons participating in the collision and compared with proton–proton (pp) production was shown for the first time (figure 1). As already found in heavy-ion collisions at the SPS and RHIC, the yields at the LHC cannot be achieved in a hadronic phase only, but require a fast equilibration and a large correlation volume. For these reasons, the enhanced production of multi-strange baryons is regarded as one of the signals for the phase transition from ordinary hadronic matter to the quark–gluon plasma (QGP). It was also stressed that, although the absolute production of hyperons increases with energy from RHIC to the LHC, both in heavy-ion and in pp collisions, the relative enhancement decreases as a result of a significant increase in pp yields at the LHC.

The yields at the LHC cannot be achieved in a hadronic phase only.

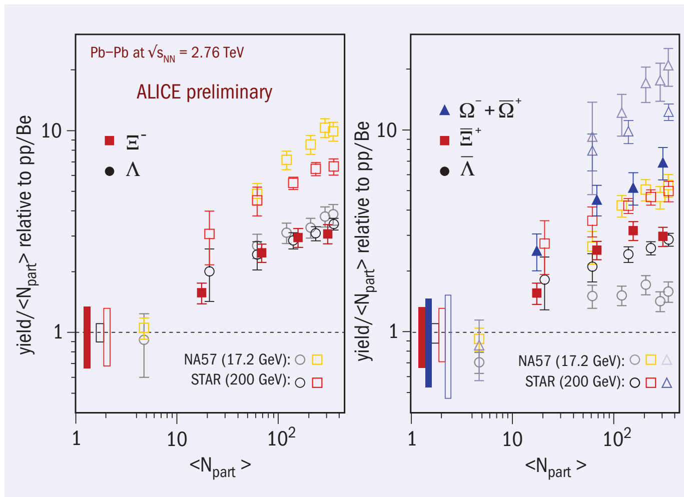


Fig. 1. Enhancement of the multi-strange baryon yields in lead–lead collisions at the LHC, as a function of the number of participants and compared with pp, together with similar measurements at the SPS (compared with pBe collisions) and RHIC.

Using the Beam Energy Scan at RHIC, the STAR collaboration has progressed significantly with tackling the evolution of the collective effects observed in heavy-ion (Au–Au) collisions between $\sqrt{s_{NN}}$=7.7 GeV and 62.4 GeV, as Shusu Shi of Central China Normal

University showed. While studying the excitation function of the second harmonic v_2 in the azimuthal distribution of particle (π, K, p and Λ) production, the collaboration identified a significant difference in the behaviour of particles and antiparticles for 0–80% central Au–Au reactions (figure 2). The increasing deviation in v_2 between particles and antiparticles, observed with decreasing $\sqrt{s_{NN}}$, is more pronounced for baryons, such as protons and Λs, than for mesons (charged π and K). However, it must be noted that above 39 GeV, the difference in v_2 between particles and antiparticles remains almost constant to higher energies at about 5–10%. The large difference between particle and antiparticle v_2 at lower energies could thus be related to an increased amount of transported quarks to mid-rapidity or it could indicate that hadronic interactions become dominant below 11.5 GeV. In the latter case, the difference in v_2 could be attributed to different interaction cross-sections of particles and antiparticles in hadronic matter of high baryon density.

The ALICE collaboration also presented preliminary results on the azimuthal anisotropy (v_2) of charm production in non-central lead–lead collisions at the LHC, in a talk by Chiara Bianchin of the University and INFN Padova. Such a measurement was highly anticipated, after the observation of a large suppression of charmed-meson yields in nucleus–nucleus collisions, which implies strong quenching of charm quarks in dense QGP (*CERN Courier* July/August 2011 p7). The study of charm anisotropy would provide insight on the degree of thermalization of the quenched charm quarks within QGP. Figure 3 shows the v_2 parameter of D^0 mesons, reconstructed in the $K^-\pi^+$ channel, as a function of transverse momentum (in red), compared with that of charged hadrons (in black). This measurement, though statistically limited, hints at a non-zero charm v_2 at low momentum and bodes well for the continuation of the study with the higher-luminosity lead run in 2011.

Theoretical discussions

The conference witnessed a lively debate on theoretical issues. In the theoretical summary talk, Giorgio Torrieri of the Goethe University, Frankfurt, pointed to various differences in the interpretation of heavy-ion data (e.g. equilibrated vs non-equilibrated hadron gas; statistical vs non-statistical production in small systems). Probably everyone connected with the SQM conferences is enthusiastic about the fact that statistical models do an excellent job in describing hadron production in heavy-ion and hadronic collisions, with the key role being played by the fast strange-quark thermalization. Perhaps, this attitude just defines the SQM community. On the other hand, there exist differences in the approaches and interpretations that should be resolved if the community is to gain a better understanding of hadron production processes. The relatively low proton-to-pion production ratio measured recently by ALICE, presented by Alexander Kalweit of the Technische Universität Darmstadt, will trigger such attempts.

The analysis of the data has led to a physical picture that may be regarded as a kind of standard model of relativistic heavy-ion collisions. This model is based on the application of relativistic hydrodynamics combined with the modelling of the initial state on one side, supplemented by the kinetic simulations of freeze-out on the other side. From the theoretical point of view, it is not completely clear how strange particles may be accommodated into this picture, both at RHIC and at the LHC. The results obtained from 2+1 dissipative hydrodynamics, presented by Piotr Bozek of the Institute of Nuclear Physics, Krakow, indicate that the multi-strange particle spectra measured at the LHC cannot be simply reproduced in hydrodynamic calculations that are constructed to describe ordinary hadrons, such as pions, kaons and protons. The new LHC measurement of the elliptic flow of D^0 mesons shown in figure 3 will be another important input for hydrodynamic and energy-loss models. As Christoph Blume of the University of Heidelberg indicated, the general concept that strange particles are ▷

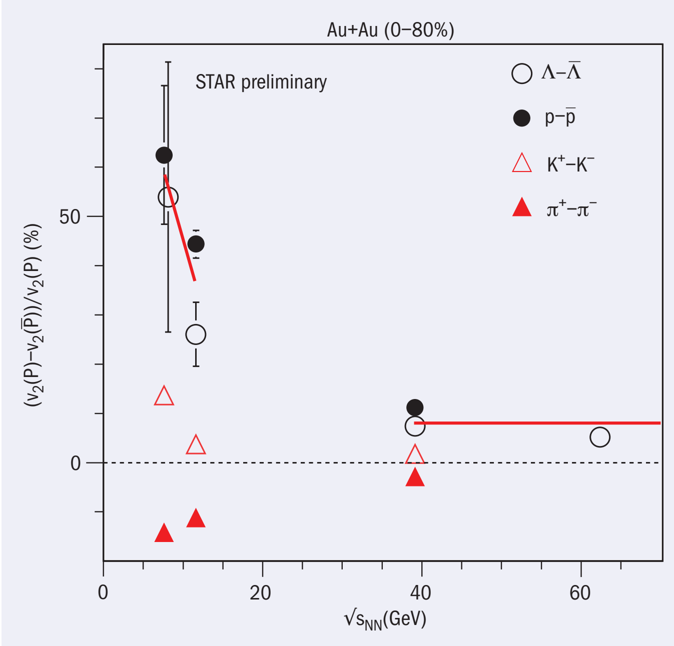


Fig. 2. Integrated v_2 difference between particles (p) and their corresponding antiparticles ($\bar{p}$), normalized to the integrated particle v_2 as a function of the collision energy per nucleon pair for 0–80% central Au–Au reactions.

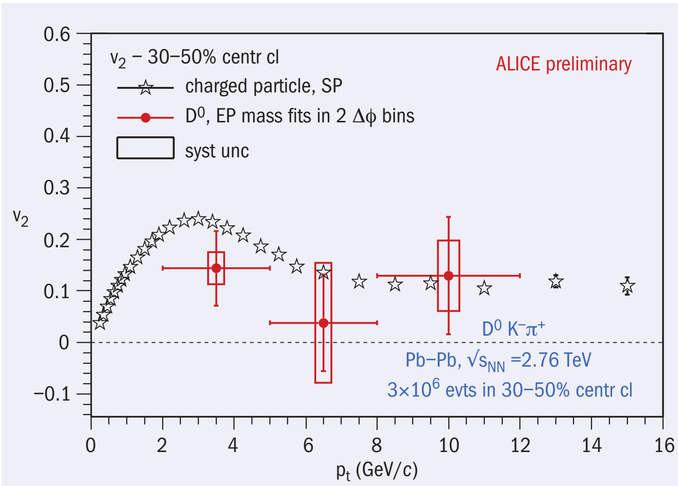


Fig. 3. Azimuthal anisotropy (v_2) for D^0 mesons, reconstructed in the $K^-\pi^+$ channel, in non-central lead–lead collisions at the LHC.

SQM 2011

Jubilee time

The Jubilee Session held during the conference was organized to celebrate the 60th birthday of Johann Rafelski, one of the founders of the SQM series and a leading player of the quark–gluon plasma hunting community. His seminal paper "Strangeness Production in the Quark–Gluon Plasma", written together with Berndt Mueller in 1982, triggered worldwide interest in physical observables connected with strangeness.

There was a good reason to celebrate Rafelski's birthday during SQM 2011, since he was born in Krakow. The Jubilee Session included talks given by Andrzej Bialas, Berndt Mueller, Emanuele Quercigh, Joe Kapusta, Marek Gazdzicki, George Stephans, Laszlo Csernai, Tamas Biro and Giorgio Torrieri, and ended with a talk by Rafelski himself.

Johann Rafelski (right) wearing the traditional Krakow hat presented to him by Andrzej Bialas, the President of the Polish Academy of Arts and Sciences. (Image credit: Andrzej Kobos.)

emitted much earlier than other more abundant hadrons may be challenged in attempts to achieve a uniform description of several observables simultaneously.

Another theoretical activity presented at SQM 2011 was triggered by low-energy experiments aimed at finding the critical point of QCD (RHIC Beam Energy Scan, NA61, FAIR, NICA). This critical point marks the end of the alleged first-order phase transition in the QCD phase diagram. Its position is suggested by the effective models of QCD and lattice QCD simulations. These two approaches suffer from fundamental problems but, nevertheless, deliver useful physical insights. For example, as Christian Schmidt of the Frankfurt Institute for Advanced Studies showed, the lattice QCD calculations suggest that the curvature of the chiral phase-transition line is smaller than that of the freeze-out curve. Moreover, the lattice results are in agreement with the STAR data on net-proton fluctuations. As Krzysztof Redlich of the University of Wroclaw pointed out, theoretical probability distributions of conserved charges may be compared directly with the distributions measured by STAR to probe the critical behaviour.

The analysis has led to a kind of standard model of relativisitic heavy-ion collisions.

The last day of the meeting was the occasion for more experimental highlights, presented in the summary talk by Karel Safarik of CERN. The conference ended with a presentation by Orlando Villalobos-Baillie of the next SQM meeting, which will be held in Birmingham, UK, in 2013.

● For the full programme of Strangeness in Quark Matter 2011 (SQM 2011), see indico.ujk.edu.pl/conferenceDisplay.py?confId=0. Andrzej Bialas, the founder and the leader of the high-energy physics theoretical group in Krakow, who is currently the president of PAU, was the honorary chair of the conference. The organization chairs were Wojtek Broniowski and Wojtek Florkowski of Jan Kochanowski University, Kielce, and the Institute of Nuclear Physics, Krakow.

Résumé

Étranges rencontres à Cracovie

La 13^e édition de la conférence Strangeness in Quark Matter *a eu lieu à l'Académie polonaise des arts et des sciences à Cracovie du 18 au 24 septembre. Cette conférence, qui a pour tradition de mettre l'accent sur les signatures du plasma de quarks et de gluons (QGP) liées à l'étrangeté et aux saveurs lourdes, a permis de passer en revue les résultats obtenus en la matière avec les premières collisions d'ions lourds auprès du LHC et de les comparer aux mesures effectuées au Supersynchrotron à protons (SPS) et au collisionneur d'ions lourds relativistes (RHIC) de Brookhaven. À cette occasion, on a également célébré simultanément les 20 ans de la découverte de l'accroissement de l'étrangeté comme manifestation du QGP et les 60 ans de Johann Rafelski, l'un de ceux qui avaient prédit cette observation, par ailleurs initiateur de cette série de conférences.*

Wojtek Florkowski, Jan Kochanowski University/Institute of Nuclear Physics, Krakow, and **Boris Hippolyte**, Institut Pluridisciplinaire Hubert Curien/University of Strasbourg.

Two years of LHC physics: ATLAS takes stock

From the first paper to the dozens of ground-breaking results presented over recent months, the first two years of ATLAS physics have been a hugely productive time.

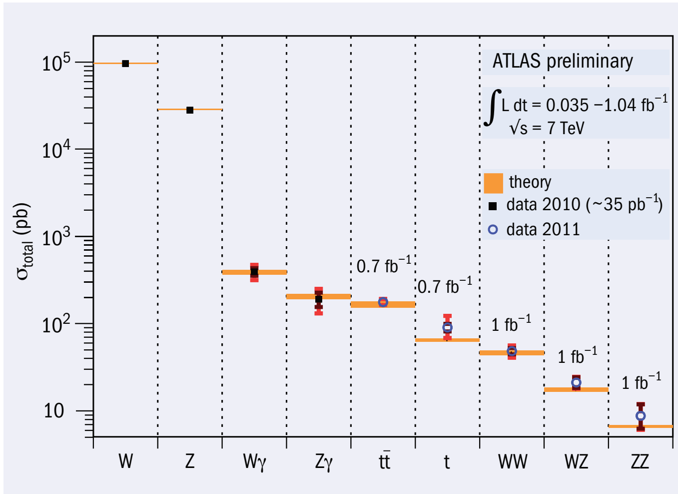


Fig. 1. Total production cross-section measurements compared to the Standard Model expectations (calculated at NLO or higher). The dark error bar shows the statistical uncertainty, the red error bar the full uncertainty, including systematic and luminosity uncertainties.

Since the first LHC collisions about two years ago, the ATLAS experiment has performed superbly – collecting quality data with high efficiency, processing the data in a timely way and preparing and publishing many new physics results. During this time the LHC has delivered more than 5 fb^{-1} of proton–proton collision data at $\sqrt{s}$=7 TeV. Using a good fraction of these data, the collaboration has carried out Higgs-boson searches, as well as searches beyond the Standard Model. While no new physics has been observed, ATLAS is setting stringent limits on the production cross-sections of new particles, including – but not limited to – the Higgs boson predicted by the Standard Model. Accurate measurements of Standard Model physics quantities have been performed covering many orders of magnitude in cross-section, with a precision often comparable to or exceeding that of the predictions.

These accomplishments have not been as easy as they may appear. Built on the tremendous success of the LHC, they are also the product of the strength and hard work of the 3000-member ATLAS collaboration. This article recounts the story of the first two years of the ATLAS physics programme, with an eye to some of the special occurrences and accomplishments along the way. However, it represents only the tip of the iceberg as far as the reach of the LHC physics programme is concerned. So far, ATLAS has collected just a small percentage of the total luminosity expected over the lifetime of the LHC.

Major progress

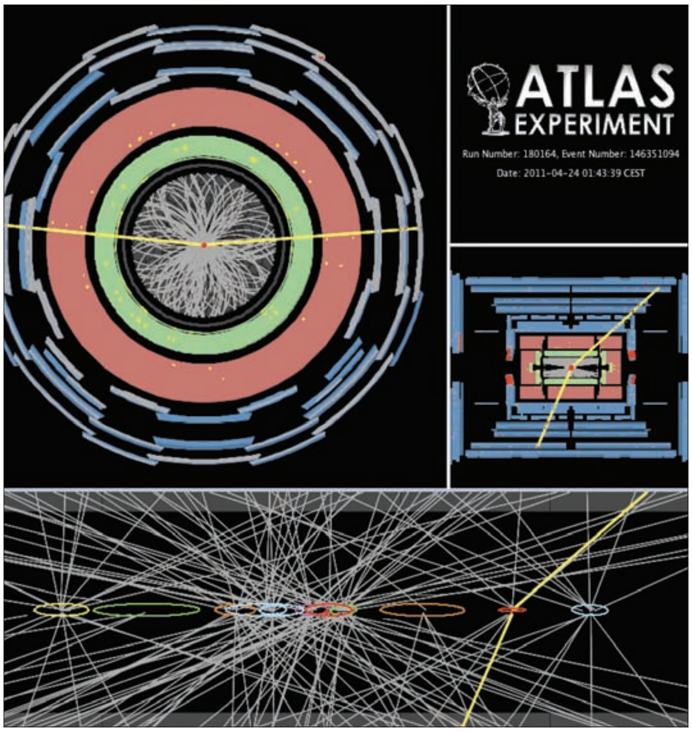
Before any physics analysis can be carried out, many members of the ATLAS collaboration work tirelessly to ready and tune the detectors, data acquisition, and trigger, to collect and reconstruct the data, and to check the quality of the data. Other members work to understand and characterize the various reconstructed objects seen in the detector. These are electrons, muons, τ leptons, photons, jets, missing transverse energy and identified heavy flavour. In two years ATLAS has gone from beginning to understand charged particles in the inner detector to using complex neural networks for flavour tagging. Algorithms have also progressed, for example from simple calorimeter-based definitions of missing transverse energy to more sophisticated definitions correcting for the calibrations and energies of the various objects.

The general complexity of the ATLAS results has followed a similar progression, from counting events for processes with large cross-sections, through using advanced analysis techniques to extract small signals from large backgrounds. Some analyses used complex unfolding techniques to compare measurements in the best way to parton-level predictions, and some have used modern statistical tools that allow the combination of many different channels into a single physics interpretation.

Accurate measurements of Standard Model quantities have been performed covering many orders of magnitude in cross-section.

Figure 1 summarizes the production cross-sections for the main Standard Model processes and shows the luminosity used to measure these ▷

ATLAS physics



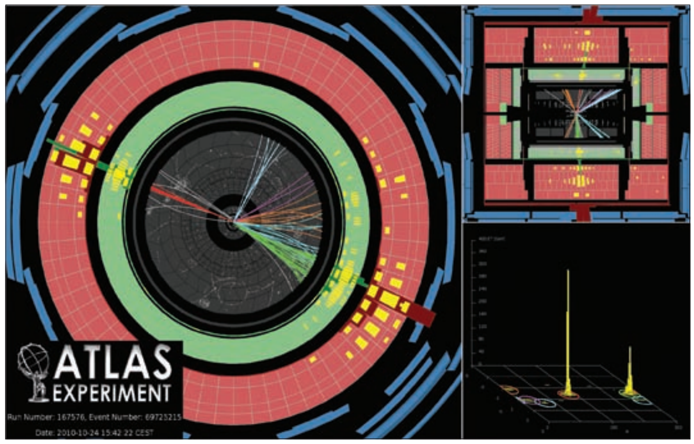


Fig. 2. Left: A candidate Z→μμ event with 11 reconstructed vertices. Recorded in April 2011, it is typical for high pile-up in 2011. The vertices shown are reconstructed using tracks with p_T greater than 0.4 GeV.

Fig. 3. Above: The highest mass central dijet event and the highest-p_T jet collected by the ATLAS detector by the end of October 2010. The two central high-p_T jets have an invariant mass of 2.6 TeV, and the highest p_T jet has a transverse momentum of 1.3 TeV.

processes. The W and Z inclusive cross-sections and the Wγ and Zγ cross-sections were measured with the approximately 35 pb^{-1} from 2010. The $t\bar{t}$ cross-section is based on a statistical combination of measurements using dilepton final states with 0.70 fb^{-1} of data and single-lepton final states with 35 pb^{-1}. The other measurements were made with the 2011 dataset. After only two years of running ATLAS can now measure processes with cross-section times branching ratio down to around 10 pb.

One of the by-products of the excellent LHC performance is another increase in complexity: the presence of multiple interactions within the same bunch crossing (pile-up). The 40 pb^{-1} of data recorded in 2010 had an average of 3 interactions per bunch crossing (<μ>), allowing good quality measurements in a relatively clean environment. The LHC run in 2011 was characterized by a rapid increase in instantaneous luminosity from the beginning of the machine operations in March, reaching <μ> of 10 in August. Figure 2 shows the complexity of an event with a Z→μμ candidate produced in a bunch crossing with 11 reconstructed proton–proton interaction vertices. The time for the integrated luminosity to double at the beginning of the run was less than one week. Since the end of May this year, the machine has regularly delivered more luminosity in one day than the total delivered in 2010.

First results

In the beginning, analyses focused mostly on understanding and measuring properties using single detectors. The first ATLAS publication on collisions reported the charged-particle multiplicities and distributions as a function of the transverse momentum p_T and pseudo-rapidity η, analysing the data taken in December 2009 ($\sqrt{s}$=0.9 TeV). This allowed validation of the charged-particle reconstruction, providing important feedback on the modelling of the alignment of the detector as well as on the distribution of the material. These results, and those from a more detailed later study, were also used to tune the parameters of the Monte Carlo modelling of non-perturbative processes, which is now used to model the effect of the multiple interactions for the latest data.

Using only 17 nb^{-1} of recorded data, the production cross-sections of inclusive jets and dijets have been measured over a range of jet transverse-momenta, up to 0.6 TeV. Figure 3 shows the event with the highest central dijet-mass recorded by ATLAS in 2010. These measurements allowed the first accurate tests of QCD at the LHC. The differential cross-sections showed a remarkably good agreement with next-to-leading (NLO) perturbative QCD (pQCD) calculations, corrected for non-perturbative effects, in this unexplored kinematic regime. Given the good agreement of data and the Standard Model predictions, the study of dijet final states was used to set limits on the mass of new physics objects such as excited quarks Q*: excluding $0.30<m_{Q*}<1.26$ TeV at 95% confidence level (CL).

The first few hundred inverse nanobarns of data allowed early searches for new physics, looking for quark-contact interactions in dijet final-state events by studying the χ variable associated with a jet pair, where $\chi=\exp|y^*|$ and y* is the scattering rapidity evaluated in the centre-of-mass frame. The data were fully consistent with Standard Model expectations and allowed quark-contact interactions to be excluded at 95% CL with a compositeness scale Λ=3.4 TeV. Using about 100 times more data than the first jet results, ATLAS studied more complex multi-jet production, with up to six jets per event in the kinematic region of p_T^{jet}>60 GeV.

ATLAS was soon able to combine measurements from many detector components and reconstruct more of the Standard Model particles. A study of Standard Model production of gauge bosons ($W^{\pm}$ and Z^0/γ^*) was performed with the first 330 nb^{-1} of data,

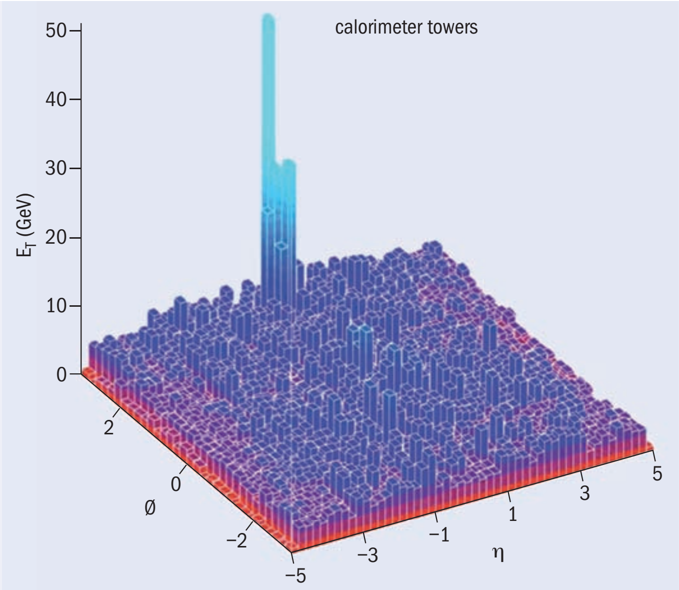


Fig. 4. Event display for a highly asymmetric heavy-ion dijet event, with only one reconstructed jet at a transverse energy E_T > 100 GeV. In the opposite azimuthal region, there is some hadronic activity in the calorimeter cells, but no reconstructed jets.

in the lν and ll final states (l=e or μ). Both the measurements of the inclusive production cross-section times branching fraction $\sigma_{W,Z} \times BR(W,Z \rightarrow l\nu, ll)$ and the ratio of the two agree well with next-to-NLO calculations (NNLO) within experimental and theoretical uncertainties.

By combining measurements from the calorimeters and the central inner tracker, ATLAS was able to analyse the production of inclusive high-p_T photons and perform extensive QCD studies. For this, additional complexity resides in the need to model and understand significant background contributions. These were estimated for this analysis from data, based on the observed distribution of the transverse isolation energy around the photon candidate. A comparison of results to predictions from NLO pQCD calculations again showed remarkable agreement.

An initial measurement of the production cross-section for top-quark pairs was already possible with just a small fraction of the 2010 data. Combining information from almost all detector systems, events were selected with either a single lepton produced together with at least four high-p_T jets plus large transverse missing energy, or two leptons in association with at least two high-p_T jets and large transverse missing energy. In this analysis ATLAS used b-jet identification algorithms for the first time – crucial for the rejection of the large backgrounds that do not contain b-quarks. A total of 37 single-lepton and 9 dilepton events were selected, in good agreement with Standard Model predictions.

The use of all of the 2010 data allowed ATLAS to study more complex quantities and distributions. For example, the W and Z differential cross-sections were measured as functions of the boson transverse-momentum, allowing more extensive tests of pQCD. Using the ratio of the difference between the number of the positive and the negative Ws to their sum, ATLAS measured the W charge-asymmetry as a function of the boson pseudo-rapidity. These results provided the first input from ATLAS on the fractions of u and d quark momentum of the proton.

At this stage, the analysis of $W \rightarrow \tau\nu$ and $Z \rightarrow \tau\tau$ represented an important step in commissioning the selection of hadronic τ final states that are crucial in searches for new physics as well as for the Higgs boson. More accurate studies of top physics were also performed, from the inclusive cross-section for $t\bar{t}$ pairs to a preliminary measurement of the top quark's mass.

New experiences

The full 2010 dataset also offered the first concrete possibility to look for physics signals beyond the Standard Model over a wide spectrum of final states. Events with high-p_T jets or leptons and with large missing transverse momentum were studied extensively to search for supersymmetric (SUSY) particles. Here, more complex variables were used, such as the "effective mass" (the sum of the transverse momentum of selected jets, leptons and missing transverse energy), which is sensitive to the production of new particles. No significant excess of events was found in the data and limits were set on the mass of squarks and gluinos, $m_{\tilde{q}}$ and $m_{\tilde{g}}$, assuming simplified SUSY models. If $m_{\tilde{q}} = m_{\tilde{g}}$ and the mass of the lightest stable SUSY particle is $m_{\chi_1^0}$=0, then the limit is about 850 GeV at 95% CL. Limits have been placed assuming other SUSY interpretations, such as minimal supergravity grand unification (MSUGRA) and the constrained minimal supersymmetric extension of the Standard Model (CMSSM).

The 2010 run ended with a short period in November dedicated to lead-ion collisions with a centre-of-mass energy per nucleon $\sqrt{s_{NN}}$ = 2.76 TeV. This was certainly one of the most amazing experiences for ATLAS during the first two years of collisions at the LHC. As the online event display in the ATLAS control room brought up the first event images, the calorimeter plot showed many events where a narrow cluster of calorimeter cells with high-energy deposits (a jet) were poorly – or not at all – balanced in the transverse plane by equivalent activity in the back-to-back region (figure 4). The gut feeling was clear: this was the first direct observation of jet-quenching in heavy-ion collisions. A detailed analysis of the early lead-collision data studied the dijet asymmetry – defined as $A_j = (E_T^{j1} - E_T^{j2})/(E_T^{j1} + E_T^{j2})$, where E_T^{ji} is the transverse jet energy calibrated at the hadronic scale – as a function of the event "centrality". This showed that the transverse energies of dijets in opposite hemispheres become systematically more unbalanced with increasing event "centrality", leading to a large number of events that contain highly asymmetric dijets. Such an effect was not observed in proton–proton collisions, pointing to an interpretation in terms of strong jet-energy loss in a hot, dense medium.

The early part of data-taking in 2011 was an extremely intense period. Already in June, ATLAS presented the first preliminary results on eight analyses using about 300 pb^{-1} of data, almost 10 times the integrated luminosity of 2010. This allowed more stringent limits to be placed on SUSY particles, heavy bosons W' and Z', new particles decaying to $t\bar{t}$ pairs, and on the production cross-section of a Standard Model Higgs boson decaying to photon-pair final states. It also allowed the first limits on particles with masses above 1 TeV.

Using a similar dataset ATLAS reported preliminary results ▷

ATLAS physics

on the production of single top at the LHC, looking in particular to the t-channel process, where a b-quark from the sea scatters with a valence quark. This process is particularly important, as any deviation from QCD predictions may indicate the presence of new physics beyond the Standard Model. The analysis is extremely difficult as the signal is hidden under a large non-reducible background from W+jets. It requires complex methods that make use of the full kinematic information of the events, looking simultaneously at many different distributions.

Extending the search with 1 fb^{-1}

While ATLAS was carrying out these analyses, the LHC completed delivery of the first inverse femtobarn, opening up a number of new physics channels. The collaboration quickly released results on a total of 35 physics analyses with these data, most of them having to deal with the increased level of pile-up.

Preliminary WW, WZ and ZZ diboson production cross-section measurements show an overall precision of about 15% (WW and WZ) or 30% (ZZ). These measurements, all consistent with the Standard Model predictions, represent an important foundation for searches for the Standard Model Higgs boson. Triple-gauge couplings have been studied and found to be in agreement with the Standard Model, allowing limits to be placed on the size of anomalous couplings of this kind.

The 2011 data allowed more sensitive searches for SUSY particles, using similar or more complex distributions than in 2010. Once more, the results are in good agreement with the Standard Model expectations and have again been interpreted in the MSUGRA/CMSSM models as well as in simplified models. These studies exclude squarks and gluinos in simplified models with masses less than about 1.08 TeV at 95% CL.

ATLAS has also performed searches for dijet, lepton–neutrino and lepton–lepton resonances. Figure 5 shows the invariant mass distribution for an electron and missing transverse-energy. These searches have placed limits on new heavy-quark masses, $m_{Q^*} > 1.92$ TeV, and on the mass of W' and Z' predicted by a number of different models, $m_{W'} > 2.15$ TeV and $m_{Z'} > 1.83$ TeV, all at the 95% CL.

The 2011 data began to open up the search for the Standard Model Higgs boson. To cover the entire mass range, from about 110 GeV (the limit from the Large Electron Positron collider is 114.4 GeV at 95% CL) to the highest possible values (around 600 GeV), this exploration was conducted in several final states: $H\rightarrow\gamma\gamma$; $\tau\tau$; $WW^{(*)}\rightarrow l\nu l\nu$, $l\nu qq$; $ZZ^{(*)}\rightarrow llll$, $ll\nu\nu$, $llqq$ as well as $H\rightarrow b\bar{b}$ produced in association with a W or Z.

In the analysis dedicated to the search for $H\rightarrow\gamma\gamma$ processes, events with pairs of high-p_T photons were selected and the photons combined to reconstruct the invariant mass. The accurate measurement of the direction of flight of the photons is crucial for obtaining high mass-resolution and hence a strong rejection of background processes, in particular, QCD diphoton production. This is possible in ATLAS thanks to the longitudinal segmentation of the electromagnetic calorimeter, which in addition allows a strong rejection of fake photons produced by QCD jets. This channel alone allowed exclusion at the level of about three times the cross-section predicted by the Standard Model.

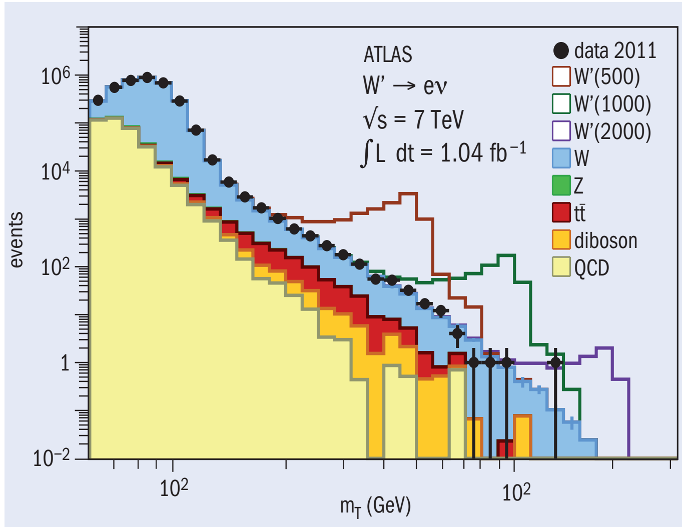


Fig. 5. Transverse mass distribution for the eν channel after event selection. The filled histograms show backgrounds; open histograms are W'→eν signals added to the background with different masses. The signal and other background samples are normalized using the integrated luminosity of the data and the NNLO (approximate-NNLO for $t\bar{t}$) cross-section predictions.

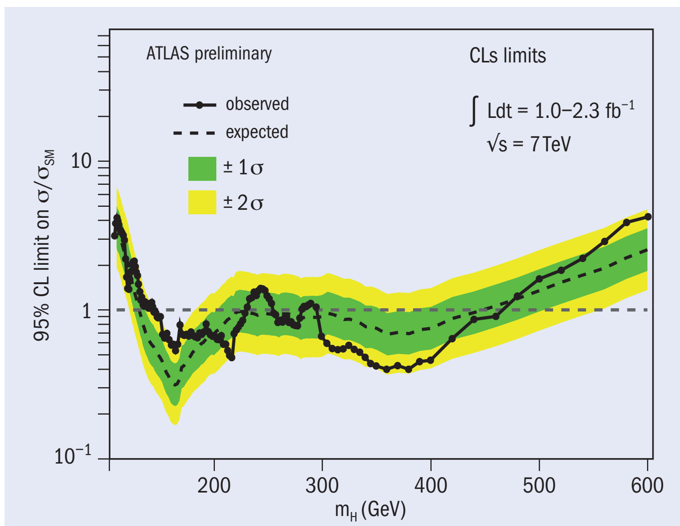


Fig. 6. The Higgs boson production cross-section excluded at 95% CL by ATLAS, in terms of the Standard Model expectation at that mass. The solid black line shows the limit observed; the dashed black line shows the median expected limit in the absence of the Higgs boson. The green and yellow bands indicate the uncertainty of the predicted values. If the solid black line dips below 1, then production of the Standard Model Higgs is excluded at 95% CL at that mass.

The analysis dedicated to the search for $H\rightarrow WW^*\rightarrow l\nu l\nu$ was based on the selection of high-p_T lepton pairs, electrons and muons, produced in association with large transverse missing energy. Two independent final-state classes were considered, depending on whether 0 or 1 high-p_T jets were reconstructed in the same event. The analysis revealed no excess events, excluding

ATLAS physics

the production of a Standard Model Higgs boson with mass in the interval $154<m_H<186$ GeV at 95% CL and thereby enlarging the mass region already excluded by the Tevatron.

The golden channel $H\rightarrow ZZ^{(*)}\rightarrow 4l$ is based on a conceptually simple analysis: the selection of events with isolated dimuon or di-electron pairs, associated to the same hard-scattering proton–proton vertex. ATLAS found the rate of 4-lepton events to be fully consistent with the expectations from background; the analysis excludes a Higgs boson produced with a cross-section close to that predicted by the Standard Model throughout nearly the entire mass interval from 200 to 400 GeV. No evidence for an excess of events has been found in all other analysed channels, allowing 95% CL exclusion limits to be placed for each of them.

Last, ATLAS used complex statistical methods to combine the information from all of these Higgs decay channels into a single limit. While the Standard Model does not predict the mass of the Higgs boson, it does predict the production cross-section and branching ratios once the mass is known. Figure 6 shows, as a function of the Higgs mass, the Higgs boson production cross-section excluded at 95% CL by ATLAS, in terms of the Standard Model cross-section. If the solid black line (the observed limit) dips below 1, then the data exclude the production of the Standard Model Higgs at 95% CL at that mass. If the solid black line is above 1, the production of a Standard Model Higgs cannot be excluded at that mass. As figure 6 shows, the data exclude the Standard Model Higgs boson in the mass range $146<m_H<466$ GeV at 95% CL, with the exception of the mass intervals $232<m_H<256$ GeV and $282<m_H<296$ GeV.

This article has been able to present only a few of the ATLAS results using up to the first inverse femtobarn of data. In 2011 the experiment collected more than 5 fb^{-1}, so the collaboration is working hard on the analysis of the new data in time for presentation of new results at the "winter" conferences early in 2012 . The first results presented here represent only a few per cent of the total data ultimately expected from the LHC. We look forward to many more exciting and impressive years.

For information about all these results and more, see https://twiki.cern.ch/twiki/bin/view/AtlasPublic.

Résumé

Deux ans de physique au LHC : ATLAS continue à engranger

Depuis les premières collisions au LHC, en 2009, l'expérience ATLAS a fonctionné de façon remarquable : des données de qualité ont été recueillies avec une grande efficacité, traitées très rapidement, et de nombreux résultats ont été publiés. Ces réalisations ne sont pas aussi simples qu'il paraît. Elles sont le fruit, d'abord, de la grande réussite de l'exploitation du LHC, mais aussi de la compétence et du travail acharné des 3000 membres de la collaboration ATLAS. L'article retrace l'histoire des deux premières années du programme de physique d'ATLAS, depuis le tout premier article jusqu'aux dizaines de résultats marquants présentés ces derniers mois.

Aleandro Nisati, University/INFN Rome I, and **Alison Lister**, University of Geneva, on behalf of the ATLAS collaboration.

Zehui He: following a different road

A look at the life of a physicist who worked in Berlin and Paris in the 1930–1940s and later helped establish nuclear and particle physics in her home country, China.

Zehui He 1914–2011. (Image credit: Jian-she Zhang.)

Two roads diverged in a wood, and I –
I took the one less travelled by,
And that has made all the difference.
Robert Frost (1874–1963)

This year marks the 100th anniversary of the first International Women's Day and, appropriately, the awarding in December 1911 of a second Nobel prize to Marie Curie (*CERN Courier* March 2011 p33). No other woman physicist has achieved such worldwide acclaim, and although there have been a number of high-flyers they remain relatively unknown. One such person is Zehui He (Zah-Wei Ho), who worked at the Curie Institute in Paris in the 1940s before becoming a leading figure in nuclear physics in her own country of China.

Zehui was born in 1914 in Suzhou, on the lower reaches of the Yangtze River, into a family of eight children where culture and learning were as important for the girls as for the boys. After studying at a school for girls (which had been established by her maternal grandmother) and succeeding in a national competition, she was admitted to the physics department of the Tsinghua University, Peking (now Beijing), in 1932. In a class of 28 there were 10 women, and the head of the department strongly discouraged all of them from pursuing a career in physics, a common habit at the time (not only in China). However, he did not succeed with Zehui, and she came out top of the 10 students – including two other women – who graduated in 1936.

Some of the professors, Zehui later recalled, did appreciate her talent and pushed her towards a stimulating final research project on "A voltage stabilizer of electric current used in laboratories". Yet, afterwards, like the other female graduates she was offered no support when looking for somewhere to continue her studies or to work. It was thanks again to her persistence, as well as to a fund granted by her native Shanxi Province, that she was able to go to Germany to pursue a doctoral degree at the Technical Physics Department of the Technische Hochschule in Berlin. Sanqiang Qian (San-Tsiang Tsien), who was also at the top of Zehui's class in 1936, after working in the institute of physics in Peking for a year, went to Paris in 1937 to the laboratory of Irène Curie (Marie's daughter) and her husband Frédéric Joliot. He obtained his doctorate there in 1940 with a thesis on "Étude des collisions des particules α avec les noyaux d'hydrogène" supervised by the Joliot-Curies.

In Berlin, meanwhile, Zehui pursued a doctorate in experimental ballistics with a thesis on "A new precise and simple method of ▷

Women in physics

measuring the speed of flying bullets". By then it was 1940 and the Second World War had begun. Zehui was stuck in Germany, but she found work in Berlin with the Siemens Company and did research on magnetic materials from 1940 to 1942. However, during her studies Zehui had stayed at the home of Friedrich Paschen, well known for spectroscopy and the eponymous hydrogen series and line-splitting in a strong magnetic field. The Paschen family loved Zehui as one of their own, and Paschen introduced her to his friend Walther Bothe, director of the Physics Institute of the Kaiser Wilhelm Institute for Medical Research in Heidelberg. There, Zehui converted to basic research in nuclear physics.

Given the time (1943) and the place (soon to be not far from the war's front line), it was an improbable scenario. Bothe, one of the principals of the German Uranium Project, had returned to basic research in Heidelberg, where in December 1943 the 10 MeV cyclotron came into operation – the first in Germany. While Bothe used counters and electronics to study cosmic rays and radioactive nuclei, his colleague Heinz Maier-Leibnitz built a cloud chamber and, together with Bothe and Wolfgang Gentner, in 1940 published the *Atlas of Typical Cloud Chamber Images* – a reference for identifying scattered particles.

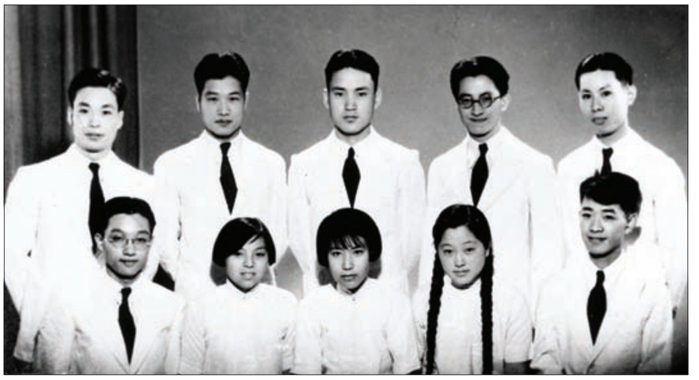
Zehui worked with Maier-Leibnitz on building a second cloud chamber to study positron–electron collisions, using positrons from the decays of artificially produced radioactive isotopes, with a view to checking the validity of Homi Bhabha's and Bothe's calculations based on Paul Dirac's theory. The advantage with respect to electron–electron elastic collisions was the lack of ambiguity between recoil and scattered particles, allowing a separation between events of large and small energy-exchange. The experiment, which used positrons from a source of ^{52}Mn, also allowed a cross-check of Hans Bethe's calculation of the ratio of annihilation to elastic cross-sections.

Breakthrough

The first ever picture of a positron–electron scatter was shown at the cosmic-ray conference in Bristol in September 1945 and mentioned in a report on the meeting published in November (*Nature* 1945). In all, Zehui measured 178 elastic collisions from 2774 positrons and found that: "In the first approximation, there is a general agreement between the theoretical and the experimental curves [for the number of collisions]. But it seems that in the case of strong energy exchange (A>0.6), for which the measurements are more precise, the experimental values are higher than the theoretical ones" (Ho 1947). She also observed three annihilation events, as expected from Bethe's calculations.

The results were widely disseminated. On 5 April 1946, a paper on the measurements was read by R W Pohl in Gottingen, then on 15 April by Joliot in Paris. In July 1946, Sanqiang Qian presented the work at the International Conference on Fundamental Particles and Low Temperatures in Cambridge; and a letter, sent at around the same time to *Physical Review*, was published in August that year (Ho 1946).

Meanwhile, Zehui had moved from Heidelberg to Paris, where she rejoined her classmate Sanqiang, marrying him in the spring of 1946. From 1946 to 1948 she worked at the Nuclear Chemistry Laboratory of Collège de France and the Curie Laboratory of the Institut du Radium. Continuing the research she had started in Germany and using a cloud chamber with a long time sensitivity, as developed by Joliot, Zehui measured the spectrum of positrons and gammas from the decays of ^{34}Cl and ^{18}F, and also confirmed her previous result on positron–electron collisions. However, the discrepancy with the theory at large-energy transfer was not observed by others.



The 1936 graduation class of the physics department at Tsinghua University. Zehui He is at the front, second from right; Sanqiang Qian is at the back, far left. (Image credit: Qian family.)

Sanqiang and Zehui, second and third from right, were the only experimental nuclear physicists among the Chinese participants at the International Conference on Fundamental Particles and Low Temperatures held in Cambridge in July 1946. (Image credit: Qian family.)

Working with Sanqiang and two PhD students – R Chastel and L Vigneron – Zehui went on to study the fission processes induced by slow neutrons, using nuclear emulsions loaded with uranium. After the discovery of fission in 1938 it was generally believed that the nucleus of a heavy atom splits into two lighter nuclei. However, with these experiments Sanqiang and Zehui proved the existence of ternary fission from the measurement of fission traces; they also explained the mecha-

Zehui worked on building a second cloud chamber to study positron–electron collisions.

nism of such a reaction and predicted the mass spectrum of the fragments (Tsien *et al*. 1947). Zehui also made the first observation of quaternary fission in November 1946. Ternary fission was not understood by the physics community until the late 1960s, and multifission not verified until the 1970s.

In May 1948 Zehui returned to China with her husband and their six-month-old daughter. (A second daughter was born in 1949 and a son in 1951.) The couple's involvement in science became deeply intertwined with the history of their country, echoing the farewell advice of the Joliot-Curies that they should "serve science, but science must serve the people".

Zehui was immediately recruited as the only full-time research fellow in the Atomic Research Institute of the National Peking Research Academy. After the founding of the People's Republic of China in 1949 she became a research fellow (1950–1958) at the Modern Physics Institute of the Chinese Academy of Sciences (CAS) and then research fellow (1958–1973) and deputy director (1963–1973) of the Atomic Energy Institute. Following the establishment of the Institute of High-Energy Physics (IHEP) at the CAS in 1973, she moved there as a research fellow and deputy director (1973–1984). She was elected a member of the academy in the Mathematics and Physics Division in 1980 and was also a standing member of the Chinese Space-Science Society.

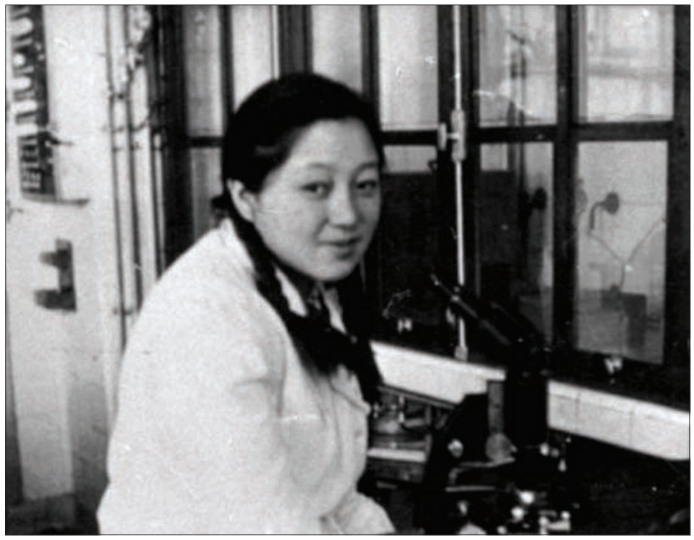
Focusing on nuclear research

In all of her administrative positions, Zehui's constant preoccupation was to develop her country's nuclear research, almost from scratch to the current achievements. In 1956, for example, her group succeeded in making nuclear emulsions of a quality comparable to the most advanced in the world, mainly with respect to the ones sensitive to protons, alpha particles and fission fragments.

An important change took place in 1955 when the Chinese government decided to move into nuclear energy. Sanqiang took on major responsibilities in setting up a nuclear industry and by 1958, with help from the Soviet Union, the first Chinese nuclear reactor and a cyclotron had started operation. Zehui led the Neutron Physics Research Division of the Modern Physics Institute (later renamed Atomic Energy Institute) and made important contributions to the establishment of basic laboratory infrastructure, the design and manufacture of measuring instruments, and the development of various types of equipment.

Around 1966, Zehui disappeared from public view as a result of the Cultural Revolution. This was over by 1978, when for the first time in more than 30 years she visited Germany as a member of a government delegation. Around the same time, Sanqiang led a Chinese delegation to visit CERN – where the Super Proton Synchrotron had recently become operational – and later to the US and many other countries, working hard to promote international scientific collaboration.

In the wake of that effort, the Beijing Electron–Positron Collider was initiated, achieving its first collisions on 16 October 1988. Meanwhile, Zehui, in charge of the Cosmic Ray and Astrophysics Division of IHEP, promoted research in these fields. Under her initiation and fostering, the former cosmic-ray research division of IHEP built – through domestic and international collaborations – nuclear emulsion chambers installed at the highest altitude in



Zehui in the Paris laboratory in 1946 where she studied nuclear ternary and quaternary fission. (Image credit: Qian family.)

the world (5500 m) on Kam-Pala mountain in Tibet. Also, starting from scratch, the division launched scientific balloons of increasing size near Beijing. In parallel, following the launch of the first Chinese satellite in 1970, the technology was developed to detect hard X-rays in space. As before, under Zehui's direction and influence, generations of young researchers rapidly grew up to become the key figures in nuclear and space science in China.

Zehui He died in June 2011, nearly 20 years after Sanqiang Qian (1913–1992). She had continued to work full time until late in life, maintaining the high standards that she had always cherished. She loved her country and science; to both she is now an icon.

• Further reading

1945 *Nature* **156** 543.
Zah-Wei Ho 1946 *Phys. Rev.* **70** 224.
Zah-Wei Ho 1947 *Report of an International Conference on Fundamental Particles and Low Temperatures* **1** 78 .
San-Tsiang Tsien *et al.* 1947 *J. Phys. Radium* **8** 165 and 200.

Résumé

Zehui He: une autre voie

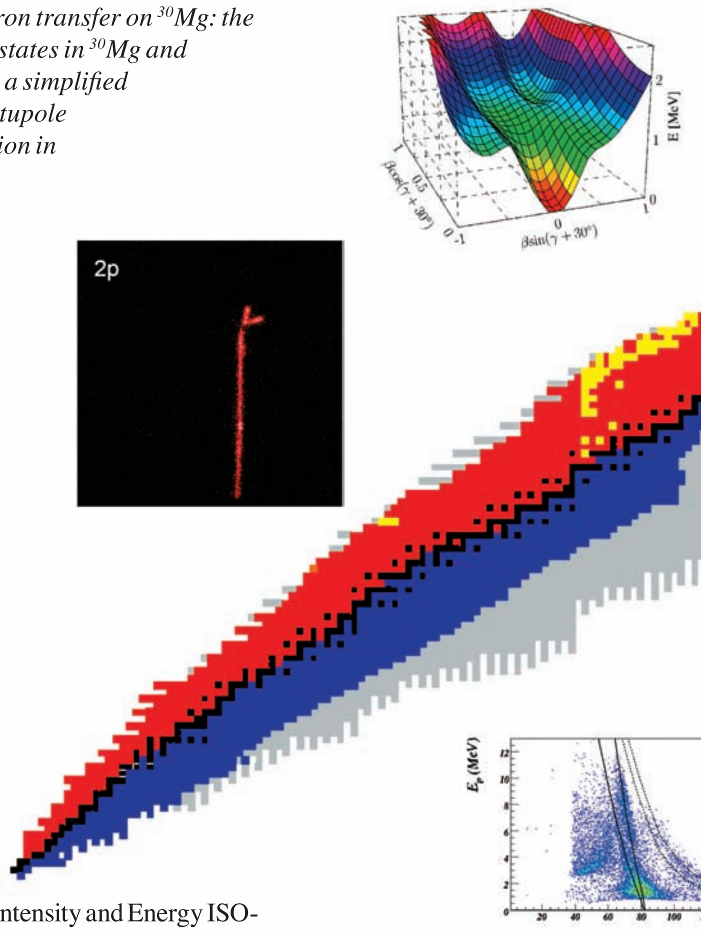
Cette année marque le centenaire de la Journée internationale de la femme, et aussi, heureuse coïncidence, celui de l'attribution d'un deuxième prix Nobel à Marie Curie. Aucune physicienne n'a obtenu une telle reconnaissance internationale ; plusieurs autres femmes ayant occupé une place éminente dans la physique sont restées relativement dans l'ombre. C'est le cas de Zehui He, décédée en juin dernier. Arrivée en tête d'une promotion de dix étudiants de physique à l'Université de Tsighua en 1936, elle a réalisé à Berlin et à Paris des travaux pionniers sur la diffusion électron-positon et la fission, avant de devenir, dans sa Chine natale, une figure marquante de la physique nucléaire.

Maria Fidecaro and **Christine Sutton**, CERN, based on several sources, including information kindly supplied by Sijin Qian.

ARIS 2011 charts the

A report on the first meeting in a conference series on Advances in Radioactive Isotope Science provides the occasion for a review of the field in light of the latest results.

Fig. 1. The chart of known stable (black) and radioactive isotopes with examples of recent studies. Top, left to right: Two-proton decay of ^{48}Ni; minima in the potential-energy surface reveal shape co-existence in ^{186}Pb; resonance spectrum of ^{253}No measured in a Penning trap. Bottom, left to right: Few-nucleon transfer on ^{20}O showing the proton energy as a function of laboratory angle; two-neutron transfer on ^{30}Mg: the essential states in ^{30}Mg and ^{32}Mg with a simplified shape; octupole deformation in ^{225}Ra.



The roots of the first conference on Advances in Radioactive Isotope Science, ARIS 2011, go back to CERN in 1964, when the then director-general Victor Weisskopf called for proposals for on-line experiments to study radioactive nuclei at the 600 MeV synchrocyclotron. Why this should be done – and how – became the subject of a conference held in Lysekil, Sweden, in 1966 and a year later experiments began at ISOLDE, CERN's Isotope Separator On Line (*CERN Courier* December 2004 p16). Following this successful start, in 1970 CERN organized a first meeting on nuclei far from stability in Leysin, Switzerland.

Since then there have been regular conferences within the field, with more specialized meetings arising hand in hand with increasingly sophisticated technical developments (see box, p34). Three years ago the community felt that the time was ripe to streamline the conferences by merging all of the physics into a single meeting held every three years. The result was that at the end of May this year some 300 physicists met in the beautiful medieval town of Leuven in Belgium to attend ARIS 2011. The success of the meeting, with its excellent scientific programme, indicates that this was the perfect decision.

Over the past two decades the experimental possibilities for studying exotic nuclear systems have increased dramatically thanks to impressive technical developments for the production of rare nuclear species, both at rest and as energetic beams. New sophisticated detection methods and data-acquisition techniques with on- and off-line analysis methods have also been developed. The two basic techniques now used at laboratories worldwide are the isotope separator on-line (ISOL) and in-flight production methods, with several variations.

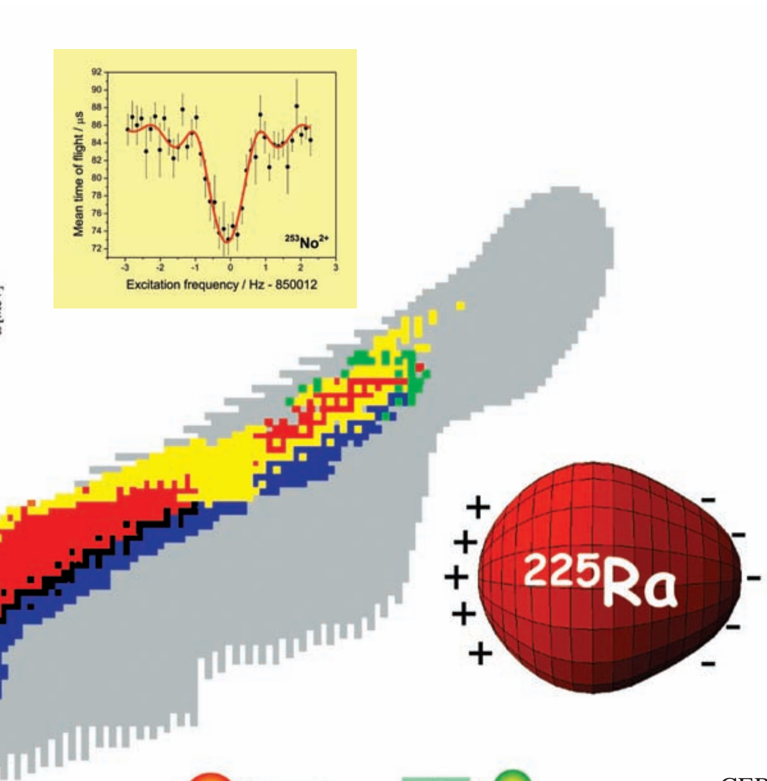
Conference highlights

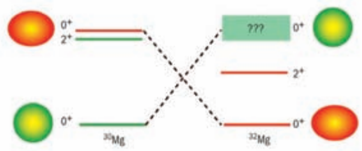
The conference heard the latest news about plans to make major improvements to existing facilities or to build new facilities, offering new research opportunities. The review of the first results from the new major in-flight facility, the Radioactive Isotope Beam Factory at the RIKEN research institute in Japan, was particularly exciting. The production of 45 new neutron-rich isotopes together with results from the Zero-Degree Spectrometer and the radioactive-ion beam separator, BigRIPS, gave a glimpse of the facility's quality. Future installations, such as the Facility for Antiproton and Ion Research (FAIR) at GSI, SPIRAL2 at the GANIL laboratory, the High Intensity and Energy ISOLDE at CERN, the Facility for Rare Isotope Beams at Michigan State University (MSU) and the Advanced Rare Isotope Laboratory at TRIUMF were also discussed, together with the advanced plans to build EURISOL, a major new European facility complementary to FAIR.

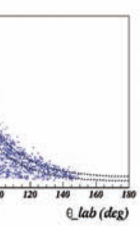
The nuclear mass is arguably the most basic information to be gained for an isotope. Its measurement has involved various techniques, but a paradigm shift came with the development of mass spectrometers based on Penning traps and such devices are now coupled to the majority of radioactive-beam facilities. This has led to mass-determinations of unprecedented precision for isotopes in all regions of the nuclear chart, making it possible in effect to walk round the mass "landscape" and scrutinize its details (figure 3, p34).

Recent results from the ISOLTRAP mass spectrometer at

e nuclear landscape







CERN, which has been in operation for more than 20 years, have a precision in the order of 10^{-8} for the masses of isotopes with half-lives down to milliseconds. The first determination of masses of neutron-rich francium isotopes, where the mass of ^{228}Fr ($T_{1/2} = 39$ s) is a notable example, were presented at ARIS 2011. The JYFLTRAP group, using the IGISOL facility at the physics department of the University of Jyväskylä (JYFL), presented masses for about 40 neutron-rich isotopes in the medium-mass region. The SHIPTRAP spectrometer at GSI has made measurements of masses towards the region of super-heavy elements; ^{256}Lr, produced at a rate of only two atoms a minute, is the heaviest element studied so far. The TRISTAN spectrometer at TRIUMF has boosted precision by "breeding" isotopes to higher charge-states – for example, in a new measurement of the mass of the super-allowed β-emitter ^{74}Rb, which is relevant to the unitarity of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. Results from isochronous mass-spectroscopy with the CSRe storage ring at the National Laboratory of Heavy Ion Research in Lanzhou were also presented. Ion-traps are now routinely used as a key instrument for cooling and bunching the radioactive beams. This gives an improvement of several orders of magnitude in the peak-to-background ratio in laser spectroscopy experiments, or can be used prior to post-acceleration.

The determination of nuclear matter and charge radii has been important to the progress of radioactive-beam physics. The observation of shape co-existence in mercury isotopes at ISOLDE was the starting point for impressive developments, with lasers playing the key role. The most recent results from the same area of the nuclear chart are measurements using the Resonance Ionization Laser Ion Source at ISOLDE of isotope shifts and charge radii for the isotope chain $^{191-218}$Po. Another demonstration of the state of the art was shown in the determination of the charge radius of ^{12}Be using collinear laser spectroscopy based on a frequency comb together with a photon-ion coincidence technique. Electron scattering from radioactive beams will be the next step for investigating nuclear shapes; the ELISe project at GSI and SCRIT at RIKEN are examples of such plans.

The determination of matter radii by transmission techniques, pioneered at Berkeley in the mid-1980s, led to the discovery of halo states in nuclei. These are well known today but the main data are limited to the lightest region of the nuclear chart. A step towards heavier cases was presented at ARIS in new data from RIKEN, where results from RIPS and BigRIPS indicate a halo state for ^{22}C and ^{31}Ne and maybe also for ^{37}Mg.

The use of laser spectroscopy in measuring charge radii, nuclear spins, magnetic moments and electric quadrupole moments has been extremely successful over the years. New results from the IGISOL facility – mapping the sudden onset of deformation at $N = 60$ – and from the ISOLDE cooler/buncher ISCOOL – for copper and gallium isotopes – were highlighted at the conference. The two-neutron halo nucleus ^{11}Li continues to attract interest both theoretically and experimentally, where a better determination of the ratio of the electric quadrupole moments between mass 11 and 9 was needed. Now a measurement at TRIUMF based on a β-detected nuclear-quadrupole resonance technique ▷

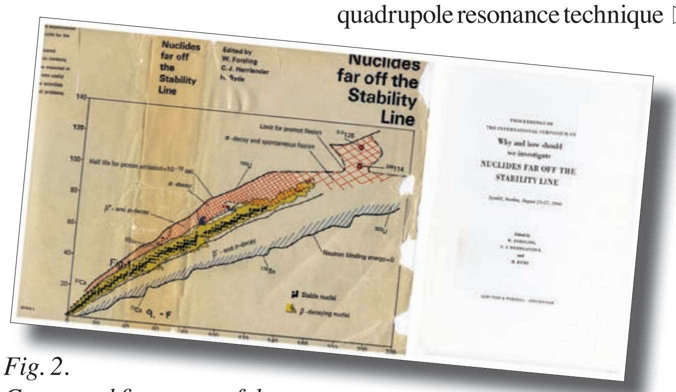


Fig. 2. Cover and first page of the symposium in Lysekil in 1966 on "Why and how we should investigate nuclides far off the stability line".

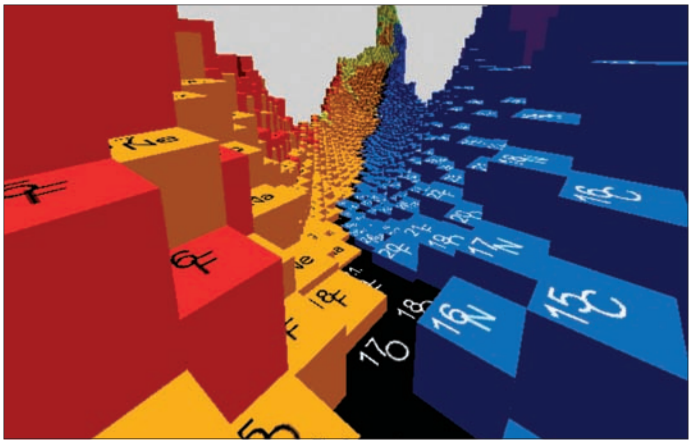


Fig. 3. Plotting mass excess in a third dimension turns the nuclear chart into a "landscape". (Image credit: David Lunney/CSNSM/IN2P3.)

has yielded a value of $Q(^{11}Li)/Q(^{9}Li) = 1.077(1)$. Here, the cross-fertilization between beam and detector developments has led to laser-resonant ionization becoming an essential ingredient in the production cycle of pure radioactive, sometimes isomeric, beams.

Nuclear-structure studies of exotic nuclei were the topic of many contributions at ARIS. There is progress on the theoretical side with large-scale shell model calculations in the vicinity of ^{78}Ni leading to a unified description of neutron-rich nuclei between $N=40$ and $N=50$. The evolution of collectivity for the $N=40$ isotopes has provided many interesting experimental results. From the strongly deformed $N=Z$ nucleus ^{80}Zr, collectivity is rapidly decreasing to ^{68}Ni with a high-lying 2^+ state at 2.03 MeV, suggesting a doubly magic character. Going to ^{64}Cr, there is a new deformed region illustrated by a 2^+ state at 470 keV, and research at the National Superconducting Cyclotron Laboratory at MSU has found an enhanced collectivity for ^{78}Sr, with a quadrupole deformation parameter of $\beta_2=0.44$.

Many of the talks at ARIS addressed the "island of inversion". A recent result from REX-ISOLDE identifies an excited 0^+ state in ^{32}Mg, illustrating shape coexistence at the borders of the island (*CERN Courier*, September 2011 p39). Many new results – a rotational band in ^{38}Mg observed by BigRIPS, isotope shifts for $^{21-32}$Mg measured at ISOLDE, β-decay for chromium isotopes from Berkeley and shape-coexistence in ^{34}Si and ^{44}S – add to the understanding of this interesting region of the nuclear chart. A new island of inversion, indicated by data for $^{80-84}$Ga from the ALTO facility in Orsay, was also discussed.

Continuing with nuclear structure, data from GANIL and its MUST 2 array on $d(^{68}Ni, p)^{69}Ni$ give access to the $d_{5/2}$ orbital, which is crucial for understanding shell structure and deformation in this mass region. The reaction $d(^{34}Si, p)^{35}Si$ shows a density dependence of the spin-orbit splitting leading to a depletion of the nuclear matter density and resulting in a "bubble nucleus" – a topic also discussed in a theory talk.

The doubly magic nucleus ^{24}O has attracted interest for a decade, from experimental and theoretical viewpoints. At ARIS, the coupled-cluster approach was presented as an ideal compromise between computational costs and numerical accuracy in theoretical models, while the absence of bound oxygen isotopes up to the classically expected doubly magic nucleus ^{28}O presents a theoretical challenge.

Experimentally, there is an impressive series of data – over a wide range of elements – from the MINIBALL array at ISOLDE. One of the highlights here was the observation of shape coexistence in the lead region. A theory talk pointed out that the nuclear energy-density functional approach, both for mean-field and beyond-mean-field applications, is an efficient tool for calculations on medium-mass and heavy nuclei.

Early experiments with radioactive beams revealed exotic decay-modes such as β-delayed particle emission. Today these processes are well understood and used as workhorses to learn about the structure of exotic nuclei. The study of β-delayed three-proton emission from ^{43}Cr and two-proton radioactivity from ^{48}Ni using an Optical Time Projection Chamber at MSU was also presented at ARIS. Here it is clear that in future the study of the most exotic

The rise of ARIS

Scientists from 26 countries participated in the first Advances in Radioactive Isotope Science (ARIS) conference, which was held in Leuven, Belgium, on 29 May – 3 June and organized jointly by the universities of Leuven (KU Leuven) and Brussels (ULB). ARIS 2011 attracted more than 300 participants, with more than 50% made up of doctoral students and post-docs, and it offered some 300 oral and poster presentations.

This new series is a result of a merger between the International Conference on Exotic Nuclei and Atomic Masses (ENAM) and the International Conference on Radioactive Nuclear Beams (RNB). It dates from the 1950s and 1960s when the conference series on Nuclei Far From Stability and the Atomic Mass and Fundamental Constants were initiated. The former dealt mainly with the decay properties and laser-spectroscopy studies of highly unstable nuclei, while the latter concerned, among other topics, the mass of the nucleus. These two conferences were jointly organized in 1992 and merged in 1995 as the first ENAM conference (in Arles, France). ENAM conferences then took place in Bellaire, US (1998), in Hämeenlinna, Finland (2001), in Callaway Gardens – Pine Mountain, US (2004) and in Ryn, Poland (2008). The RNB series was initiated when results using energetic radioactive beams emerged. The first event was organized in Berkeley (1989) and the series continued in Louvain la Neuve, Belgium (1991), East Lansing, US (1993), Ohmiya, Japan (1996), Divonne-les-Bains, France (2000), Argonne, US (2003), Cortina d'Ampezzo, Italy (2006) and Grand Rapids, US (2009).

Because the ENAM and RNB conferences dealt with radioactive-ion-beam research and discussed the same physics questions, the decision was taken to merge the two series and so ARIS was born. This new series will focus on the physics results, while the established conference series on Electromagnetic Isotope Separators (EMIS) will continue to discuss beam development and instrumentation. ARIS and EMIS together with the International Nuclear Physics Conference will offer the field of radioactive-ion-beam research an excellent forum to exchange information, discuss progress and initiate new collaborations.

The next ARIS conference will take place in 2014 in Tokyo and be hosted by the RIKEN Nishina Center and the University of Tokyo (Center for Nuclear Study).

decay modes will use active targets, such as in the Maya detector developed at GANIL and the ACTAR-TPC project being planned by GANIL together with MSU. An interesting new result concerns the observation of β-delayed fission-precursors in the Hg-Tl region, where an unexpected asymmetric fragment-distribution has been observed for the β-delayed fission of ^{180}Tl.

Unbound nuclei or resonance states are sometimes debated as "ghosts" without any physics significance. However, developments over the past 5–10 years have provided a huge amount of data, so that most of the previously empty spots on the nuclear chart for the light elements are now filled. The production of ^{10}He and ^{12,13}Li from proton-knockout reactions from ^{11}Li and ^{14}Be, respectively, is a particularly spectacular case. The knockout of a strongly bound proton from the almost unbound nucleus ^{14}Be results in a ^{11}Li nucleus that together with two neutrons shows features that can only be attributed to an unbound ^{13}Li nucleus. Many of the resonance states might be populated in transfer reactions in inverse kinematics, in which the exotic nuclei are used as an energetic beam directed towards a target that was earlier used as the beam. The HELIOS spectrometer, which will use neutron-rich beams from the CARIBU injector at the Argonne Tandem Linear Accelerator System, is a model for what might develop at many facilities in the future.

The super-heavy-element community was represented in several talks at ARIS. Having produced all elements up to Z = 118, the next step is to tackle the Z = 120 barrier, an exciting goal that could become a reality with reactions such as ^{54}Cr+^{248}Cm. Nuclear spectroscopy is also climbing towards ever higher mass numbers and elements, as demonstrated by data from JYFL for ^{254}No. One exciting talk concerned the chemical identification of isotopes of element 114 (^{287,288}Uuq), which is found to belong to group 14 (in modern notation) in the periodic table – the group that contains lead, tin, germanium, silicon and carbon.

The acquisition of data pertinent to nuclear astrophysics has grown tremendously thanks to the access to nuclei in relevant regions of the nuclear chart. Results include the study at JYFL and at the Nuclear-physics Accelerator Institute (KVI), Groningen, of β-decay of ^{8}B for the solar-neutrino problem and the work at ISOLDE, JYFL and KVI on β-decays of ^{12}N and ^{12}B, which are important for the production of ^{12}C in astrophysical environments. Data from ISOLDE and JYFL on the neutron-deficient nuclei ^{31}Ar and ^{23}Al, relevant for explosive hydrogen burning, were also discussed, as were results from MSU relating to the hot carbon–nitrogen–oxygen cycle and the αp-, rp- and r-processes in nucleosynthesis. GANIL has results on the reaction d(^{60}Fe,p)^{61}Fe, which is relevant for type II supernovae, while the Radioactive Ion Beam Facility in Brazil in São Paulo has data on the p(^{8}Li,α)^{5}He reaction. Calculations for proton scattering on ^{7}Be in a many-body approach, combining the resonating-group method with the *ab initio* no-core shell model, were also described at the conference.

Exotic nuclei can also provide information about fundamental symmetries and interactions. The painstaking collection of data over decades has provided an extremely sensitive test of the unitarity of the top row of the CKM matrix. Today there are precise data for 13 super-allowed β-emitters, which give a value of 0.99990(60) for this quantity. In this context, there are plans for measurements with the Magneto Optical Trap at Argonne of β-neutrino correlations for ^{6}He and the electric dipole moment for ^{225}Ra. The high-precision set-ups – WITCH at CERN, LPC Trap at GANIL and WIRED at the Weizmann Institute – were also discussed at the conference. The claim is that this kind of experiment – the high-precision frontier – will to some extent complement the high-energy frontier in understanding the deepest secrets of nature.

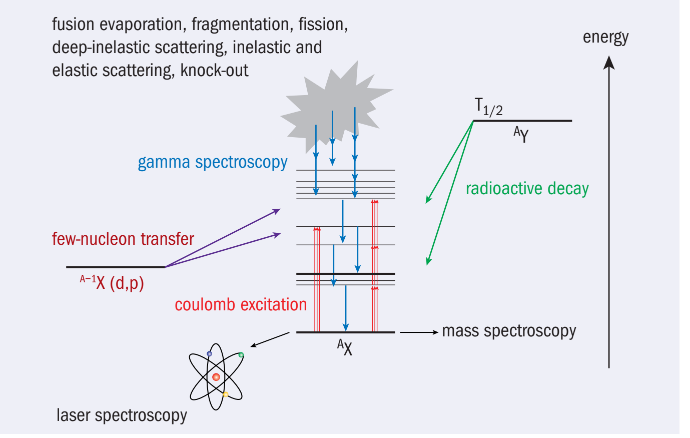


Fig. 4. A nuclear energy-level diagram serves to illustrate all of the processes that can be studied with radioactive beams.

Finally, a review of the different techniques using radioactive isotopes in solid-state physics presented the current state of the art, together with some recent results. This work was pioneered at CERN and has over the years become an important ingredient at many facilities.

In summary, ARIS 2011 turned out to be a successful merger of the former ENAM and RNB conferences (see box). The talks, supported by an excellent poster show, covered the field perfectly. The talks are available on the conference website and the organizers had the excellent idea of putting the posters there too – this is "a first", to be followed in future.

• Further reading

For all of the talks and posters, see http://iks32.fys.kuleuven.be/aris2011/.

Résumé

ARIS2011 établit une cartographie des noyaux

Au cours des 10 à 20 dernières années, les possibilités d'expérimentation pour l'étude des noyaux exotiques se sont beaucoup développées, grâce à des progrès techniques impressionnants permettant la production d'espèces nucléaires rares, aussi bien au repos que dans des faisceaux énergétiques. ARIS2011, la première d'une série de conférences sur le thème des avancées de la science des isotopes radioactifs, a été l'occasion de passer en revue ce domaine et d'examiner les résultats les plus récents. Ce nouveau rendez-vous pour les physiciens résulte de la fusion de deux conférences internationales, consacrées respectivement aux noyaux exotiques et masses atomiques et aux faisceaux nucléaires radioactifs, qui existaient depuis les années 1960.

Björn Jonson, Chalmers University of Technology.

A wide-angle view of a treatment room at the Heidelberg Ion Therapy Centre. (Image credit: GSI/HIT/Siemens.)

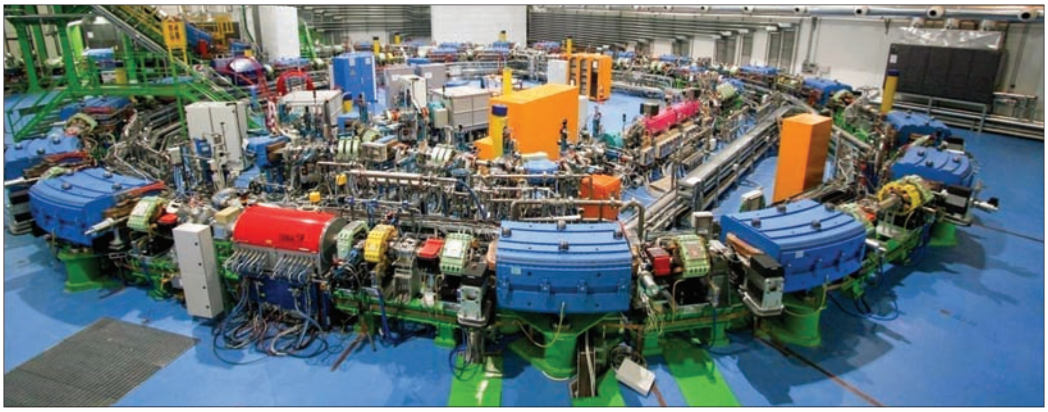
Hadron therapy: collaborating for the future

Hadron therapy now faces the challenge of delivering a cost-effective, high-precision cancer treatment. More than ever, particle physics and medicine will benefit from mutual collaboration. **Manuela Cirilli** explains.

In 1946, accelerator pioneer Robert Wilson laid the foundation for hadron therapy with his article in *Radiology* about the therapeutic interest of protons for treating cancer (*CERN Courier* December 2006 p24). Sixty-five years later, proton therapy has grown into a mainstream clinical modality. More than 60 000 patients worldwide have been treated since the establishment of the first hospital-based treatment centre in Loma Linda, California, in 1990 and various companies are now offering turn-key solutions for medical centres. Moreover, encouraging studies with other types of hadrons have resulted in the creation and planning of various dedicated facilities.

Hadron therapy is the epitome of a multidisciplinary and transnational venture: its full development requires the competences of physicists, physicians, radiobiologists, engineers and IT experts, as well as collaboration between research and industrial partners. The translational aspects are extremely relevant because the ▷

Medical physics



The synchrotron at the CNAO facility in Pavia. (Image credit: CNAO.)

communities involved are traditionally separate and they have to learn to speak the same "language". Ions that are considered "light" by physicists, such as carbon, are "heavy" for radiobiologists – and this is just one of many examples.

Although state-of-the-art techniques borrowed from particle accelerators and detectors are increasingly being used in the medical field for the early diagnosis and treatment of tumours and other diseases, medical doctors and physicists lack occasions to get together and discuss global strategies. The first Physics for Health (PHE) workshop was organized in 2010 at CERN exactly to develop synergies between these diverse communities. Preparations are now underway for a follow-up workshop, which will join forces with the International Conference on Translational Research in Radiation Oncology (ICTR). The ICTR-PHE 2012 conference will be held in Geneva on 27 February – 2 March. The aim is to catalyse and enhance further exchanges and interactions between experts in this multidisciplinary field where medicine, biology and physics intersect.

The advantages of hadron therapy

The clinical interest in hadron therapy resides in the fact that it delivers precision treatment of tumours, exploiting the characteristic shape of the Bragg curve for hadrons, i.e. the dose deposition as a function of the depth of matter traversed. While X-rays lose energy slowly and mainly exponentially as they penetrate tissue, hadrons deposit almost all of their energy in a sharp peak – the Bragg peak – at the very end of their path.

The Bragg peak makes it possible to target a well defined cancerous region at a depth in the body that can be tuned by adjusting the energy of the incident particle beam, with reduced damage to the surrounding healthy tissues. The dose deposition is so sharp that new techniques had to be developed to treat the whole target. These fall under the categories of passive scattering, where one or more scatterers are used to spread the beam, and spot scanning, where a thin, pencil-like beam covers the target volume in 3D under the control of sweeping magnets coupled to energy variations.

While the advantages of protons over photons are quantitative in terms of the amount and distribution of the delivered dose, several studies show evidence that carbon ions damage cancer cells in a way that the cells cannot repair themselves. Carbon therapy may be the optimal choice to tackle radio-resistant tumours; other light ions, such as helium, are also being investigated.

Although hadron therapy has largely shown its potential scientifically, the relative complexity of the required infrastructures limits its exploitation. "Hadron therapy is not a replacement for conventional radiotherapy or surgery, but is an additional tool in the toolbox of the oncologists," confirms Robert Miller of the Mayo Clinic in the US, which just embarked on the construction of two proton-therapy facilities. Indeed, hadron therapy is mostly used for treating tumours that are located close to vital organs that would be unacceptably damaged by X-rays, or in paediatric oncology, where quality of life and late side effects are a major concern.

At present, the world map of hadron therapy is divided into three distinct regions: Asia (mainly Japan), the US and Europe. In addition, three proton-therapy facilities are operational in Russia and one in South Africa.

Japan is the uncontested leader in treatment and clinical studies with carbon ions (*CERN Courier* June 2010 p22). By the end of 2010, its two major facilities – the Heavy-Ion Medical Accelerator in Chiba (HIMAC) and the Hyogo Ion Beam Medical Center – had treated more than 90% of the 6600 world total of patients irradiated with carbon ions. Clinical experience in the Japanese centres has not only demonstrated that carbon therapy is more effective than conventional photon radiotherapy on certain types of tumours but also that, with respect to both protons and photons, a significant reduction of the overall treatment time and the number of irradiation sessions can be achieved. In addition to the existing facilities, Japan is planning the construction of two more centres for carbon-ion therapy and two more for proton therapy. Following this lead, China and other countries in Asia have constructed or are planning several carbon-ion and proton-therapy facilities.

In the US alone more than 30 000 patients have already been treated with protons over the past 20 years, half of them at Loma Linda. There are currently six active proton facilities, three more under construction and a number of centres announced or planned in the near future. When hadron therapy was still confined to facilities operating within particle-physics laboratories, the US pioneered the use not only of protons but also of other ions: between 1957 and 1992, the Bevalac in Berkeley treated about 2500 cancer patients with particles including neon, carbon, silicon and argon. Today, there is no therapy centre delivering ions other than protons in America. Plans for the future include only an R&D facility in the San Francisco Bay area called SPARC, which would be a joint effort between Stanford/SLAC and Lawrence Berkeley National

Laboratory/University of California San Francisco, and a carbon and helium facility at the Mayo Clinic.

Europe has 10 active proton facilities, with five more planned or under construction. Capitalizing on the experience gained from the carbon-therapy programme at GSI in Darmstadt and at Heidelberg, Europe is now witnessing the birth of "dual" centres that are capable of delivering beams of both protons and carbon ions. Two major centres were recently completed: Heidelberg Ion Therapy Centre (HIT), which started treatments at the end of 2009 and has irradiated about 500 patients with carbon ions to date; and the Centro Nazionale di Adroterapia Oncologica (CNAO) in Pavia, which started treating the first patient with protons in September and will launch the preclinical phase with carbon ions in the coming months. The *Med*Austron dual facility in Wiener Neustadt is currently under construction (*CERN Courier* October 2011 p33) and more centres of a similar nature are at different stages in planning and implementation in France and Germany.

HIT is the first facility in the world to be equipped with a gantry for carbon ions, i.e. a structure to rotate the particle beam and guide it to the patient at a chosen angle. Using the gantry, radio-oncologists can select the optimal beam direction to minimize the amount of healthy tissue traversed by the hadrons before reaching the tumour. They can also irradiate the target from multiple angles – a technique that, thanks to the overlapping beams, delivers to the target a total dose that is much higher than in the surrounding normal tissues. CNAO relies on an accelerator design implemented by Terapia con Radiazion Adroniche Foundation based on the results of the Proton Ion Medical Machine Study hosted at CERN from 1996 to 1999. The CNAO facility will deliver horizontal and vertical beams and a gantry will be added at a later stage.

Co-ordination and training

With the blossoming of carbon therapy in Europe, the European Network for Light Ion Therapy (ENLIGHT) considered that the time was right to leverage the experience at the various facilities, as well as the wealth of advances in beam delivery for conventional radiation therapy, and improve the technology with the aim of more effective and affordable cancer treatments with particles. While developing and optimizing the next-generation facilities remains the community's primary goal, it is also of paramount importance that the existing centres collaborate intensively and that researchers, clinicians and patients have protocols to access these structures. Within this framework, the Union of Light Ion Centres in Europe (ULICE) project was launched in September 2009, funded by the European Commission.

ULICE is a collaboration of 20 partners led by Roberto Orecchia, scientific director of CNAO. The project involves all of the existing and planned European carbon-therapy facilities, including the two leading European companies in the hadron-therapy sector, IBA and Siemens. The participation of private companies ensures that specific issues related to possible future industrial production are addressed. IBA has designed and installed the majority of clinically operating proton-therapy facilities in the world and is developing innovative and more affordable single-room proton systems, as well as superconducting cyclotron solutions for carbon. Siemens Healthcare is one of the world's largest providers of medical solutions and was the first company outside of Asia to enter the carbon-ion therapy market. The company delivered the complete patient environment at HIT and the treatment-planning system at CNAO.

ULICE is a four-year project built around three pillars: Joint Research Activities that focus on development of instruments and protocols; Networking, to increase co-operation between facilities and research communities wanting to work with the research infrastructure; and Transnational Access, which aims at allowing researchers to use the facilities and for radiobiological and physics experiments to take place.

At the recent mid-term review meeting in Marburg, Richard Pötter, a radiation oncologist at the University of Vienna and co-ordinator of the Joint Research Activities of ULICE, confirmed that the first achievements of the research work are extremely encouraging. The existing clinical-study protocols worldwide have been reviewed to start defining common guidelines for patient selection. Specific studies have focused on setting up appropriate structures for a comprehensive and prospective multicentre clinical-research programme and the development of a dosimetry protocol. Important steps forward have also been made in defining uniform methods and concepts for irradiation doses and tumour volumes in radio-oncology, to create a common language not only within the consortium but across all of the communities involved in different forms of radiotherapy. The ULICE consortium is working hard to develop new concepts for more compact and affordable gantries: the HIT gantry is a steel giant of 25 m in length and 13 m in height, and alternative designs are clearly needed.

It is of paramount importance that the existing centres collaborate intensively.

Within the activities of Transnational Access, the ULICE partners are examining the complex task of setting up a structure to allow access to the existing European facilities for patients, clinical and experimental research, as well as for clinical training and education. Japan is once again an example to follow, with the International Open Laboratory (IOL) programme of the National Institute of Radiological Sciences launched in 2008 to grant beam time at HIMAC to external researchers. There are currently four active IOLs with Columbia University, Colorado State University, the University of Sussex, Karolinska Institutet and GSI. As of summer 2011, researchers from eligible countries can apply to take part in research activities or submit experimental proposals in the clinical, radiobiological and physical field at the University Hospital of Heidelberg and at CNAO. In the words of Jürgen Debus, medical director of the Department of Radiation Oncology and Radiation Therapy of Heidelberg University Hospital and co-ordinator of the ULICE Transnational Access: "A technology has worth in the medical field only if it is spread and if everyone can participate to its evolution with their experience and feedback." Applications for participation in the Transnational Access programme will be reviewed by a multicentre scientific committee and successful applicants will be granted free access thanks to the European Union Transnational Access funding. ▷

Medical physics

The ENLIGHT community at its 2011 annual meeting in Marburg. (Image credit: Nathalie Hospital for ENLIGHT.)

In the same framework, ULICE is also developing an international web-based documentation and data-management system, which will be an essential tool for transnational and multicentre clinical studies in particle therapy.

In the coming years, the project will focus on expanding and consolidating the transnational access and on developing innovative gantry designs. The support of ENLIGHT will be instrumental to dissemination, communication and networking, which will help it reach out to the widest possible community.

ENLIGHT also actively supports the creation of the next generation of the necessary highly specialized experts through the Particle Training Network for European Radiotherapy (PARTNER), funded by the European Commission under the Marie Curie Initial Training Network programme (*CERN Courier* March 2010 p27). Both ENLIGHT and PARTNER are co-ordinated by Manjit Dosanjh at CERN. PARTNER is offering research and training opportunities in leading European institutions and companies to 25 young researchers who are mostly involved in PhD studies at the same time. At the recent annual meeting in Marburg, the presentations of the individual projects displayed clearly the variety of topics being addressed and the quality of the research. PARTNER is now in its fourth and final year, and in a few months it will be time to review the results that have been achieved.

- For more about ULICE, see http://cern.ch/ULICE.

Résumé

Thérapie hadronique : collaborer pour l'avenir

L'utilisation des hadrons, sous la forme de protons et d'ions légers, en particulier de carbone, pour traiter certains cancers s'est généralisée au cours des 20 dernières années. On trouve maintenant des équipements aux États-Unis, au Japon et en Europe. Ce domaine se caractérise par son aspect multidisciplinaire et international: il fait appel aux compétences de physiciens, de médecins, de radiobiologistes, d'ingénieurs et d'informaticiens, et implique également une collaboration entre chercheurs et partenaires industriels. À présent, les recherches visent à permettre de disposer d'un traitement contre le cancer de haute précision pour un coût acceptable. Plus que jamais, la collaboration entre physique des particules et médecine s'avère fructueuse.

Manuela Cirilli, CERN.

NA61/SHINE: more precision for neutrino beams

An experiment at CERN is making use of detectors designed for heavy-ion studies to gain a more precise knowledge of neutrino production at accelerators.

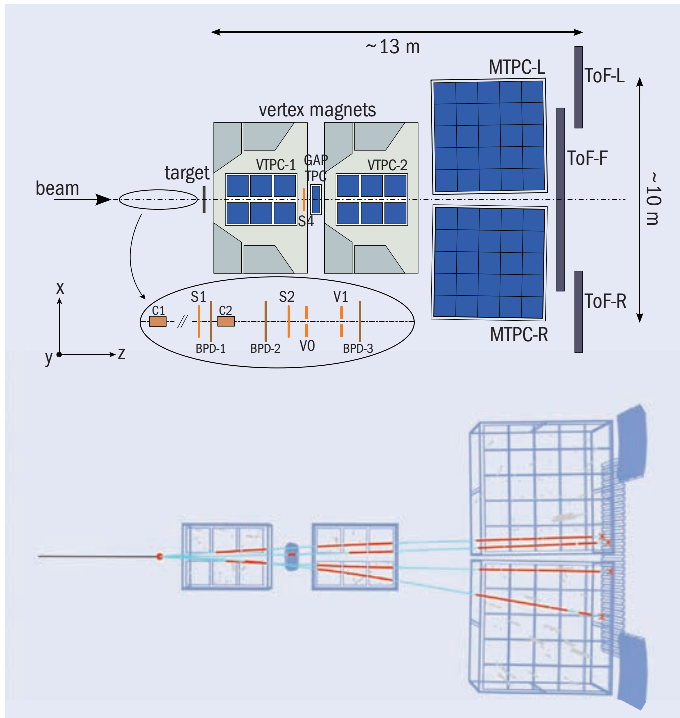


Fig. 1. Top: NA61/SHINE, with the TPCs and TOF detectors. Bottom: a 30 GeV proton interaction in a carbon target.

Accelerator neutrino beams are currently the object of intense discussion and development. They provide a necessary tool for the detailed study of neutrino oscillations and in particular the observation of potential CP-violating effects that are born from the interference of transitions among the three known species of neutrino. Neutrino interaction cross-sections are tiny, so the challenge in studying their properties has been to produce ever increasing beam intensities. The next challenge in neutrino physics will be to establish precisely the parameters of the oscillations and then compare the oscillations of neutrinos with anti-neutrinos (or the oscillation probability as a function of neutrino energy) to search for CP-violation. This will require precise measurements of the transitions of neutrinos into each other, which will in turn demand a much better knowledge of the neutrino beams.

At present – and probably for the next decade – neutrino beams are generated by the conventional technique: a beam of multi-giga-electron-volt protons, as powerful as possible (up to around 500 kW beam power), is directed at a target to produce a large number (10^{12} or more) of hadrons, mainly pions with a small admixture (5–10%) of kaons. These are then focused in the direction desired for the neutrino beam and they decay – producing neutrinos – in a decay tunnel.

In the absence of a good theory of hadronic interactions, a precise prediction of the properties of such neutrino beams requires measurements of particle production at an unprecedented level of precision. The role of the NA61/SHINE experiment at CERN's Super Proton Synchrotron (SPS) is to perform these hadron production measurements. More specifically, it has taken data for the T2K experiment in Japan, both with a thin carbon target and a full replica of the target used in T2K (*CERN Courier* July/August 2008 p19). These data have already proved important for the extraction of the first results on electron-neutrino appearance and muon-neutrino disappearance in T2K (*CERN Courier* September 2011 p6, Abe *et al*. 2011). As statistics increase in T2K, they will become more and more essential.

The collaboration behind the SPS Heavy Ion and Neutrino Experiment (SHINE, approved at CERN as NA61) is an unlikely marriage between aficionados of the heaviest and lightest beams on offer. Ions as heavy as lead nuclei have been accelerated in the SPS, while neutrinos have the lightest mass (now famously non-zero) of all particles apart from photons. So what is the unifying concept between these communities that are *a priori* so different?

The NA49 detector in CERN's North Area offers excellent tracking with its immense set of time-projection chambers (TPCs), time-of-flight (TOF) detectors and flexible beamline. To perform systematic measurements at energies at the onset of quark–gluon plasma creation, the heavy-ion physicists were interested in upgrading the detector to allow higher event statistics and lower systematic uncertainties. At the same time, neutrino physicists, attracted by the extensive coverage of the detector, were interested in running it in a simple configuration, but also with high statistics, so as to have the first data ready in time for the start of T2K.

The main upgrades relevant for all of the NA61/SHINE physics programmes concerned the TPC read-out, an extension of the ▷

Neutrinos

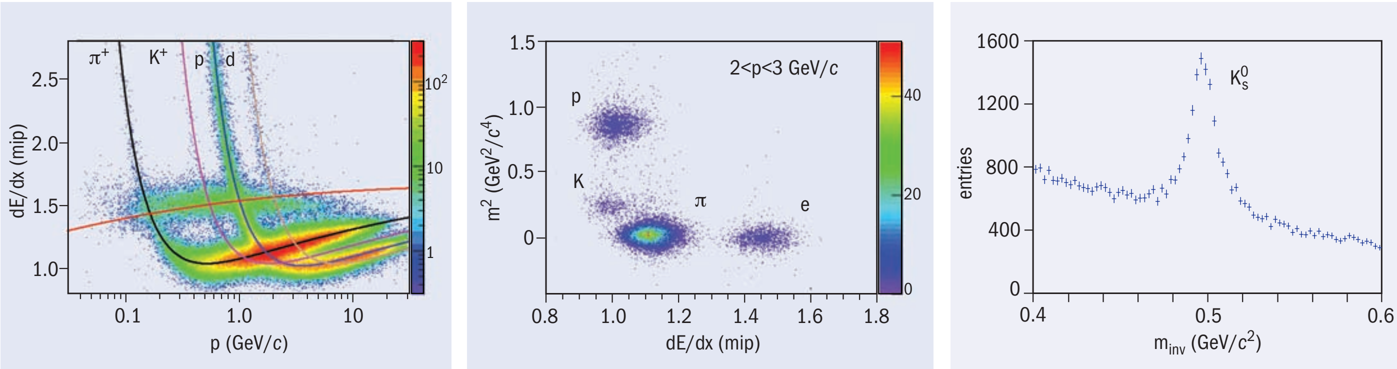


Fig. 2. Particle identification in NA61/SHINE. Left: The dE/dx measurement in the TPCs; centre, the combination of dE/dx with the TOF allows quasi-perfect separation of charged pions, protons, kaons and electrons/positrons up to at least 5 GeV/c; right: reconstruction of V^0-like vertices allow measurements of neutral-kaon production.

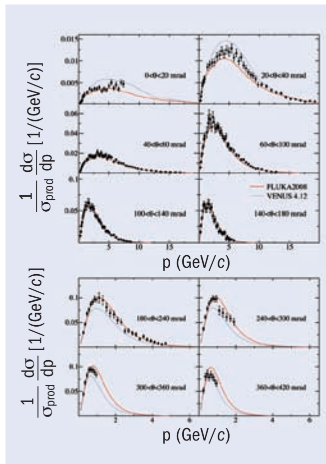
TOF detectors and an upgrade of the trigger and data-acquisition system. Figure 1 (p41) shows the upgraded detector. Its acceptance fully covers the kinematic region of interest for T2K.

The NA61/SHINE experiment was approved in April 2007 and took data in a pilot run the following September, with 600 000 triggers on the thin carbon target and 200 000 triggers on the replica (long) T2K target. More extensive data-taking for the T2K physics programme took place in 2009 and 2010, both with thin (6 million triggers in 2009) and long targets (10 million triggers in 2010). In parallel, data were recorded for the NA61/SHINE heavy-ion and cosmic-ray programmes.

As a first priority, the cross-sections for producing charged pions from 30 GeV protons on carbon were measured with the thin-target data taken in 2007 (Abgrall *et al*. 2011). The systematic errors are typically in the range of 5–10% and smaller than the statistical errors. These data have already been used for an improved prediction of the neutrino flux in T2K (Abe *et al*. 2011). Furthermore, they also provide important input to improve the hadron-production models needed for the interpretation of air showers initiated by ultra-high-energy cosmic rays.

However, these first NA61/SHINE measurements provide only a part of what is needed to predict the neutrino flux in T2K. A substantial fraction of the high-energy flux, and in particular the electron-neutrino contamination, originates from the decay of kaons. Charged kaons are readily identified in NA61/SHINE from the suite of particle-identification techniques – dE/dx in the TPC and the TOF in the upgraded detector (see figure 2) – and a first set of cross-sections has been produced already. Neutral kaons can be reconstructed using the V^0-like topology of $K^0_S \rightarrow \pi^+\pi^-$ decays.

A large fraction (up to 40%) of the neutrinos originates from particles produced by re-interactions of secondary particles in the target, which for T2K is 90 cm long. This is difficult to calculate precisely and it motivates a careful analysis of the data taken with the long target. Long-target data are notoriously more difficult to reconstruct and analyse but they provide much more directly the information needed for extracting the neutrino flux. The NA61/SHINE collaboration presented a pilot analysis at the NUFACT meeting at CERN in early August (Abgrall 2011). The ultimate precision will come from the full analysis of the long-target data taken in 2010. The collaboration is working hard to complete these



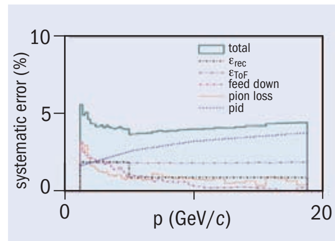


Fig. 3. Left: Measured spectra of positively charged pions and comparison with existing models. Top: The systematic errors (below 5%) in one of the bins and their decomposition into correlated sources.

analyses in time for the high-statistics measurements that will become possible in T2K when the experiment resumes data-taking after recovering from damage in the massive earthquake in north-eastern Japan that occurred in March this year.

Further reading

K Abe *et al.* (T2K collaboration) 2011 *Phys. Rev. Lett.* **107** 041801.
N Abgrall *et al.* (NA61/SHINE collaboration) 2011 *Phys. Rev. C* **84** 034604.
N Abgrall (for the NA61/SHINE collaboration) 2011 arXiv:1110.1966 [hep-ex].

Résumé

NA61/SHINE: une étape vers des faisceaux de neutrinos de précision.

La physique des neutrinos réclame de plus en plus de précision, pour déterminer en particulier la violation de CP dans les oscillations. NA61/SHINE au CERN rassemble expérimentateurs des ions lourds et des neutrinos, pour mesurer la production de hadrons dans la cible du faisceau de l'expérience T2K au Japon. SHINE a produit les premieres données prises en 2007 à temps pour les premiers résultats de T2K; les données acquises depuis permettront une précision de l'ordre de 5% sur le flux.

Alain Blondel, University of Geneva, and **Boris Popov**, JINR, Dubna, and LPNHE, Paris, on behalf of the NA61/SHINE collaboration.

Faces & Places

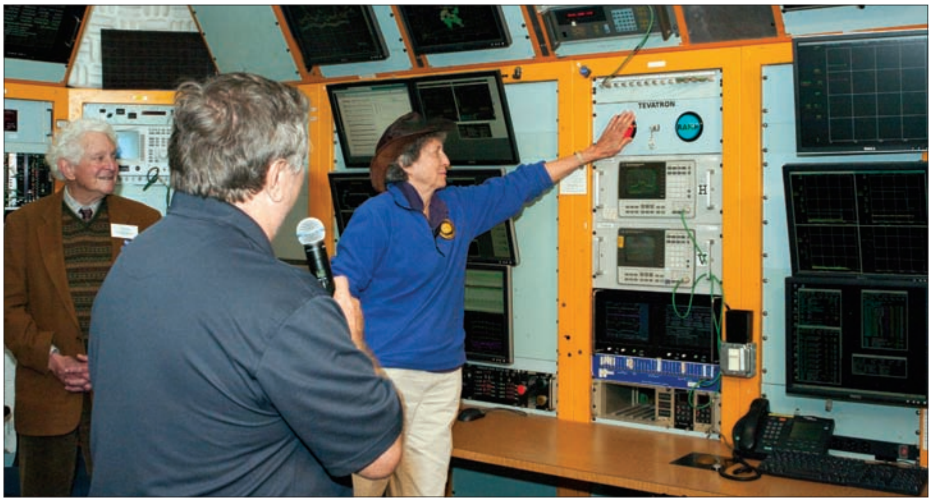
FERMILAB

The Tevatron shuts down for the last time

Thousands of staff members and scientific collaborators flooded Fermilab and watched remotely online from across the globe to see the Tevatron power down one final time on 30 September. Following the shutdown, everyone joined in to celebrate nearly three decades of scientific and technological achievements that have changed the way we understand the world (*CERN Courier* October 2011 p20).

"The Tevatron exceeded every expectation ever set for it," said Fermilab director Pier Oddone, as the 40-minute shutdown procedure began. "As of this moment, the two detectors, CDF and DØ, have recorded nearly 12 inverse femtobarns of data. The collider has reached peak luminosities of $4\times10^{32}/cm^2/s$, producing several million collisions per second. These numbers were considered totally impossible by scientists and engineers back in the eighties when the machine first came online."

The Tevatron was the world's first superconducting synchrotron, delivering beams to fixed-target experiments until 2000 (*CERN Courier* November 2011 p28). In operating as a proton–antiproton collider from 1987 onwards, it required the development of the world's most intense, consistent source of antiprotons and eventually operated 300 times beyond its original design capabilities. The creativity and tools needed for these achievements generated a globally competitive workforce that has gone on to help design the LHC and countless physics experiments.



From left: Leon Lederman, former director of Fermilab; Robert Mau, former head of Fermilab Accelerator Operations; and Helen Edwards, former head of the Accelerator Division, abort colliding beams in the Tevatron for the last time. (Image credit: Fermilab Visual Media Services/Marty Murphy.)

The discovery of the τ neutrino by the fixed-target programme was one of the main achievements in neutrino physics worldwide. In the collider runs, the discoveries made by the CDF and DØ experiments include the top quark and a whole new family of baryons. The subsequent precision measurements of the top quark as well as those of the W boson mass have laid the groundwork for the search for the Higgs boson.

Shutting the Tevatron down was a bittersweet time for employees and users, many of whom had spent most of their careers making the machine one of the most productive sources of physics research in the world. CDF and DØ will continue to deliver analyses from Tevatron data at an average rate of one scientific paper a week for at least two more years.

● Extracted from an article in *Fermilab Today*, where daily news about Fermilab's activities can be found at www.fnal.gov/pub/today/.

APPOINTMENT

Ferroni takes the reins at INFN

Fernando Ferroni has been appointed as the president of the Italian National Institute for Nuclear Physics (INFN), by a ministerial decree announced on 26 October. He replaces Roberto Petronzio who has guided INFN for seven years.

Born in Rome in 1952, Ferroni obtained his physics degree in 1975 at the University La Sapienza of Rome where he is currently professor. A particle physicist, he worked at CERN first in the 1980s on neutrino experiments and then on the L3 experiment at the Large Electron–Positron collider. At the beginning of the 1990s he began collaboration with the BaBar experiment at SLAC in studying CP violation in the b quark decay.

Fernando Ferroni. (Image credit: INFN.)

Ferroni is currently working at the INFN's Gran Sasso National Laboratory on research into neutrinoless double β-decay with the Cryogenic Underground Observatory for Rare Events (CUORE). He is also involved with LUCIFER, a project financed by the European Research Council to build a background-free detector for neutrinoless double β-decay. The author of more than 700 scientific papers, he has been involved in many international committees on high-energy physics.

Appointment

Womersley takes over at STFC

John Womersley has been appointed Chief Executive Officer of the UK's Science and Technology Facilities Council (STFC) for four years from 1 November 2011.

A graduate of Cambridge and Oxford, he has played a leading role in particle physics both in Europe and the US. He worked at the Florida State University and Fermilab, where he was spokesperson for the DØ experiment, before becoming a scientific advisor to the Department of Energy in the US. He returned to the UK in 2005 to become Director of the Particle Physics Department at the STFC Rutherford Appleton Laboratory at a time when it was building and delivering vital components to CERN's Large Hadron Collider.

John Womersley. (Image credit: STFC.)

In 2007, Womersley took on a broader role at STFC, managing the Science Programmes Office – which oversees the STFC's science and technology strategy, science operations and planning, including the STFC's processes for peer review and research grants, as well as STFC's programmes in education, training and public outreach. He represents the UK in a number of international forums including the Council of the European Southern Observatory and the European Strategy Forum on Research Infrastructures.

Schools

CAS spreads the word on accelerators

Participants of the specialized school in Bilbao. (Image credit: Domi Alonso Crespo.)

By the sea in Chios, participants at the intermediate-level school. (Image credit: M Moutafis.)

The CERN Accelerator School (CAS) held two courses on accelerators and their physics this summer – one in Spain and one in Greece.

The first, in early summer, was a specialized course on high-power hadron machines. This was organized jointly with ESS-Bilbao and held on 24 May – 2 June. After some lectures recapitulating essential accelerator physics and reviewing different types of accelerator, the course focused on the challenges faced when designing and operating high-power facilities. In addition to the academic programme, participants could take part in a one-day excursion, which included time to visit the famous Guggenheim Museum. The school attracted 69 participants representing 22 nationalities and feedback was extremely positive.

Later in the summer, a course on intermediate-level accelerator physics took place in Chios on 19–30 September, this time organized jointly with the University of the Aegean. This followed the established format of the intermediate schools, with lectures in the mornings and specialized courses in the afternoons. The latter provided "hands-on" education and experience in three topics: "RF measurement techniques", "Beam instrumentation and diagnostics" and "Optics design and correction". Participants selected one of the three courses and followed the chosen topic throughout the school. Guided studies and tutorials on core subjects, seminars and a poster session completed the programme.

This school attracted a lot of interest and participation had to be limited, with 74 students of 22 nationalities attending. The feedback was again positive, with lecturers noting the high standard and motivation of the students. An excursion included visits to the Nea Moni monastery and two medieval villages, Pyrgi and Mesta, followed by a typical Greek meal in the port of Limena Meston. A small exhibition on CERN was arranged at the Homerion Cultural Centre in Chios and opened by CERN's director-general, Rolf Heuer.

● The next specialized CAS course, on ion sources, will take place in Senec, Slovakia, on 29 May – 8 June 2012. For more information about this next specialized course, see www.cern.ch/schools/CAS.

Prizes galore: from the Standard Model to the FEL

The American Physical Society (APS) has announced many awards for 2012, which include major awards in particle physics and related fields.

Starting with the theoretical side, the 2012 J J Sakurai Prize for Theoretical Particle Physics, which recognizes and encourages outstanding achievement in particle theory, goes to three Europeans: Bryan Webber of the University of Cambridge, Guido Altarelli of Universita di Roma Tre (and formerly a CERN theorist) and Torbjörn Sjöstrand of Lund University. They are rewarded for "key ideas leading to the detailed confirmation of the Standard Model of particle physics, enabling high-energy experiments to extract precise information about quantum chromodynamics, electroweak interactions and possible new physics."

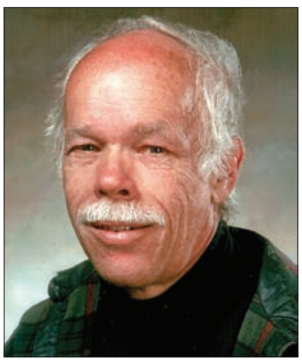
The Dannie Heineman Prize for Mathematical Physics is to recognize outstanding publications in the field of mathematical physics. For 2012 this encompasses particle theory with the award of the prize to Giovanni Jona-Lasinio of the University of Rome "for contributions to the interaction between statistical mechanics, field theory and the theory of elementary particles, including spontaneous symmetry breaking, critical phenomena and a general theory of dissipative systems."

Symmetry also features in the award of the 2012 Julius Edgar Lilienfeld Prize in recognition of a most outstanding contribution to physics. This goes to Gordon Kane of the University of Michigan "for important contributions to the phenomenology of elementary particle physics, especially supersymmetry, and for his accomplished record as a popularizer of science." The 2012 Henry Primakoff Award for Early-Career Particle Physics also recognizes theoretical work of this kind. The recipient is Daniel Jafferis of Harvard University for "the construction and study of three-dimensional supersymmetric quantum field theories." This award is for outstanding elementary particle-physics research performed by a physicist who has not held a PhD for more than seven years.

Theoretical work is also the subject of the 2012 Tom W Bonner Prize in Nuclear Physics. Witold Nazarewicz of the University of Tennessee receives this award "for his foundational work in developing and applying nuclear density functional theory, motivating experiments and interpreting their results, and implementing a comprehensive theoretical framework for the physics of exotic nuclei".



Winners of the 2012 J J Sakurai Prize, left to right: Bryan Webber, Guido Altarelli and Torbjörn Sjöstrand. (Image credits: left, University of Cambridge; right University of Lund.)




Left, Bill Attwood and Lillian Hoddeson were among other APS prize-winners for 2012. (Image credits: UC Santa Cruz, far left, and University of Illinois/L Brian Stauffer.)

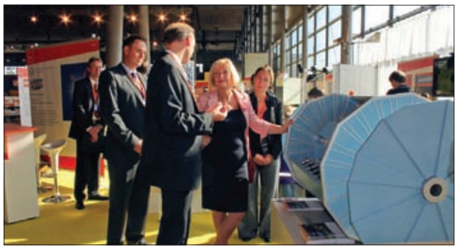
In experimental physics the Robert R Wilson Prize for Achievement in the Physics of Particle Accelerators this year looks to what has become a major application of accelerators worldwide. John Madey of the University of Hawaii, Manoa, receives the 2012 prize for "the invention and first experimental demonstration of the free-electron laser and important contributions to its conceptual development". The free-electron laser, or FEL, is a vital tool for producing intense short-wavelength laser light for use in many areas of science (*CERN Courier* December 2010 p17).

The crossover between particle physics and astronomy and cosmology has become increasingly significant in recent years and is recognized in the award of the 2012 W K H Panofsky Prize in Experimental Particle Physics to William B Atwood of the University of California, Santa Cruz. He receives the prize, which recognizes and encourages outstanding achievements in experimental particle physics, "for his leading work on the design, construction, and use of the Large Area Telescope (LAT) on the Fermi Gamma-ray Space Telescope, enabling numerous new results in gamma-ray astrophysics and fundamental physics." Attwood was an experimental particle physicist at SLAC for many years and with Peter Michelson of Stanford proposed the concept for a satellite-borne gamma-ray detector that became the LAT.

Finally, a science historian well known to particle physicists, Lillian Hoddeson of the University of Illinois, has been awarded the 2012 Abraham Pais Prize for History of Physics in recognition of outstanding scholarly achievements. As well as co-editing a three-volume series on the rise of particle physics, she has co-authored books on the atomic bomb and on Fermilab, among others. She is currently completing a co-authored history of the Superconducting Super Collider.

OUTREACH

Particle physics is a hit in Hanover



Left: Johanna Wanka, minister of science in Lower Saxony, at the ATLAS exhibit at the IdeenExpo. Right: Science-slam winner, Boris Lemmer, centre, with the minister and Dirk Schulte, Salzgitter Service und Technik GmbH, far left, and representatives of the Kurt-Alten Foundation, which supports gifted students and provided the prize money.(Image credit: IdeenExpo.)

Hanover was the place to be for young Germans interested in science, when the IdeenExpo 2011 for young people took place on 27 August – 4 September. Its aim is to inspire teenagers and young adults, with an aim to redressing the lack of qualified personnel in German science and technology.

With more than 310 000 visitors over the nine days, the exhibition achieved a new record and also provided a showcase for particle physics. At the core of the IdeenExpo were exhibits that give a sense of adventure, provided by companies, universities and research institutes from Lower Saxony as well as the rest Germany.

The visitors not only received information about starting technical professions but numerous workshops allowed small groups to dive into scientific and technological topics in detail. Finally, a broad programme of science shows, talks, a fun area and evening entertainment with popular bands completed the event.

Students and scientists of the University of Göttingen introduced the curious visitors to the world of elementary particle physics. With the help of Anne Glück (TU Dresden), co-ordinator of the particle-physics network, Gerrit Hörentrup (DESY), co-ordinator of the mobile exhibition "Weltmaschine", and the company PHYWE, a provider of school and university lab equipment, they explained ideas with the help of many objects, from TV sets and linear accelerators to a 1:25 model of the ATLAS detector and a diffusion cloud chamber. There were also presentations on the LHC, advice on physics career paths, masterclasses with ATLAS events and a live video conference to CERN, Fermilab and KEK.

The "science slam" finals were clearly the highlight of the entire event. Six scientists from a range of research fields entered the competition to entertain and inspire a semi-professional audience for 10 minutes with their personal research activities. As expected, the audience not only awarded points for exciting research, but also recognized the high entertainment value in several presentations. As in several earlier national competitions, Boris Lemmer, a PhD student at the Georg-August-Universität Göttingen on the ATLAS experiment, won the competition in front of 1000 spectators with an amazing 99 out of 100 points. The audience was thrilled by his presentation about particle accelerators and in particular the LHC.

● For more about the exhibition and science slam, see www.ideenexpo.de.

WORKSHOP

EPIC days in Bari

Light shines on the participants at the EPIC@LHC 2011 workshop in Giovinazzo, Bari. (Image credit: Domenico Elia/INFN).

The International Workshop on Early Physics with heavy-Ion Collisions at the LHC (EPIC 2011) took place on 6–8 July in Giovinazzo, a resort by the sea a few kilometres from the centre of Bari. Hosted by the Italian National Institute for Nuclear and Particle Physics (INFN), the meeting attracted about 60 participants from all over the world. The workshop brought experimentalists and theorists together in an enthusiastic and friendly atmosphere to discuss results from the first heavy-ion collisions provided by the LHC at the end of 2010.

A few introductory overview talks set the scene. CERN's Urs Wiedemann opened the first session with his view of the "theory perspective on a small subset of data from the first LHC heavy-ion run", followed by Helen Caines from Yale, who reported on the latest results from the Relativistic Heavy Ion Collider (RHIC). The main experimental results at the LHC were then illustrated by John Harris (ALICE), Sebastian White (ATLAS) and Bolek Wyslouch (CMS).

A total of about 40 presentations, both on theory and experiment, were spread over the three days of the workshop in plenary sessions on five topics (global event properties, correlations and fluctuations, baryon and strangeness, heavy flavour and di-leptons, as well as jets and photons). Even if most of the reports naturally focused on results from the three LHC experiments participating in the heavy-ion programme, there were also presentations from the PHENIX and STAR collaborations, emphasizing in particular the outcome of the recent beam energy-scan programme at RHIC. A talk by Marek Gazdzicki from Frankfurt and Kielce, on "the SPS ion programme and the first LHC data", suitably contributed to the discussion on understanding of the heavy-ion data that now cover two orders of magnitude in centre-of-mass energy.

On the last day the overall discussion was enlivened by the contribution of Itzhak Tserruya of the Weizmann Institute ("From RHIC to LHC: first lessons") and the summary talk by CERN's Karel Šafařík ("Heavy ions in LHC: experimental achievements and prospects"). As well as the inspiring talks and in-depth discussions, the beautiful venue, the Italian food, the excursion to the famous 13th-century Castel del Monte built by the Holy Roman Emperor Frederick II and the memorable conference party with a live performance by a group of musicians all contributed to making this workshop exceed the expectations of participants and organizers.

- EPIC 2011, chaired by Domenico Elia (INFN Bari), was organized by INFN and supported by Dipartimento Interateneo di Fisica Bari, the University of Bari and Fondazione Cassa di Risparmio di Puglia. For the programme and presentations, see www.ba.infn.it/EPIC.

Visits

The Indian president, **Pratibha Devising Patil**, visited CERN on 1 October. During her tour she saw, top right, the ALICE experiment (with from left to right Paolo Giubellino, ALICE spokesperson, Chitra Narayanan, Indian Ambassador to Switzerland, Rolf Heuer, CERN's director-general, Christy Fernandez, secretary to the president, Rajeev Shukla, Indian minister of state for parliamentary affairs, Tapan Nayak, ALICE and VECC, and Felicitas Pauss, CERN's head of international relations); top left, went underground with Vinod Chohan, from the Accelerator Beam Lines & Areas group, far left, and (back to camera) Steve Myers, director of accelerators and technology at CERN; bottom left, greeted Indian physicists at CERN; finally posing with Indian members of the ALICE and CMS collaborations and Indian officials.

Austrian state secretary for foreign affairs, **Wolfgang Waldner**, left, was welcomed to CERN by **Felicitas Pauss**, head of international relations at CERN, on 19 September. While at CERN, he toured the CMS control room and underground experimental service cavern, the LHC superconducting magnet test hall, and the *Universe of Particles* exhibition in the Globe of Science and Innovation.

Steven E Koonin, US under-secretary for science for the Department of Energy, centre, visited CERN on 14 and 15 September. During his tour of the LHC superconducting magnet test hall he saw one of the superconducting inner-triplet magnets contributed by Fermilab to the LHC. His visit also included the CMS, ATLAS and ALICE experiments as well as the CERN Control Centre.

On 5 October the directorate of the Vienna Science and Technology Fund (WWTF) and other high-ranking Austrian officials visited CERN. Here **Michael Häupl**, the Lord Mayor and governor of Vienna and president of WWTF is seen in front of a photo of CMS together with **Renate Brauner**, Deputy Mayor of Vienna. (Image credit: M Hoch for CERN.)

Faces & Places

Workshop

Quantum field theory meets collider physics on the Black Sea

Participants at the workshop pose for the traditional photo, with a life buoy to symbolize help for basic research worldwide. (Image credit: SINP, MSU.)

The international workshop "Quantum Field Theory and High Energy Physics 2011" was held on the shore of the Black Sea in the Russian resort Sochi on 24 September – 1 October. It was the 20th in the series of workshops started in 1985 by the Skobeltsyn Institute of Nuclear Physics (SINP) of Lomonosov Moscow State University, with the purpose of presenting topics of current interest to young scientists and providing them with a stimulating environment for scientific discussions on new developments in theoretical and experimental high-energy physics and programmes of physics for future colliders. This year's workshop, QFTHEP'2011, was jointly organized by the SINP and the Southern Federal University (Rostov-on-Don) and was attended by 87 participants from 11 countries.

The scientific programme included 62 talks divided between plenary and parallel sessions, almost a third given by young scientists. The major focus was on the presentation of new data from the LHC together with an overview of other important results in experimental high-energy physics. The latest results on the apparent superluminal neutrinos detected by the OPERA collaboration were a particular highlight and were eagerly discussed both in the sessions and discussions. At the end of the workshop there was a special talk summarising the work of the Tevatron by Maxim Perfilov of the SINP on behalf of both the DØ and CDF collaborations. This was dedicated to the closing down of the Tevatron on 30 September.

The talks also covered a range of modern theoretical ideas in high-energy physics and field theory. In particular, Lev Lipatov of Saint Petersburg Nuclear Physics Institute drew a parallel between high-energy scattering in QCD and in gravity theory, and constructed an effective action for reggeized gravitons. The gap between the theoretical and the experimental sides was bridged by Kirill Melnikov of Johns Hopkins University, who reviewed the latest results in next-to-leading-order QCD calculations and their relevance for collider phenomenology.

On the rest-day the participants were given an opportunity to visit the ski resort of Krasnaya Polyana, where the mountain events of the 2014 Winter Olympics will take place, as well as other places of interest around Sochi.

● For further information, see http://qfthep.sinp.msu.ru.

Conference

Particle and nuclear physics convene at MIT

Attendees at the PANIC11 Rutherford Centennial meeting at MIT. (Image credit: J Knight.)

The first Particles and Nuclei International Conference in the LHC era, PANIC11, brought 539 participants to the Massachusetts Institute of Technology (MIT) on 24–29 July. The latest in a triennial series that showcases recent progress worldwide in particle and nuclear physics, PANIC11 took place in the year that not only celebrated the 150th anniversary of the founding of MIT and the century of Ernest Rutherford's seminal paper on the discovery of the atomic nucleus, but also the 65th anniversary of MIT's Laboratory for Nuclear Science, which hosted the conference. With strong backing from the US Department of Energy, many national laboratories worldwide, industrial sponsors and MIT, the conference supported the attendance of many young scientists, students and post-docs, who formed the majority of participants and made for a lively conference. Broad international participation was enhanced by support from the International Union of Pure and Applied Physics for scientists from developing countries.

The conference programme was developed around 12 major themes: quarks and gluons in hot and dense matter; quarks and gluons in hadrons; neutrino physics and astrophysics; dark matter and cosmology; nuclear and particle astrophysics; Standard Model physics at the tera-electron-volt scale; Tevatron and LHC physics beyond the Standard Model; heavy-flavour physics within and beyond the standard model; tests of symmetries and conservation laws; kaons, hypernuclei, hadron spectroscopy and exotics; applied string theory; and accelerator physics.

The programme consisted of 24 plenary talks and 304 parallel session talks, as well as a poster session. In addition, there was a plenary presentation on the effects of the 11 March earthquake on nuclear and particle-physics facilities in Japan. There were also well attended public lectures by Brian Cathcart entitled, "Glimpsing the Fly in the Cathedral: Ernest Rutherford and the Atomic Nucleus" and by Jerome Friedman entitled, "Rutherford's Legacy in Particle Physics: Exploring the Proton". On the day before the start of the conference, nine pedagogical lectures, directed at the level of the beginning graduate student, were presented by young researchers, covering the major thrusts in subatomic physics as well as recent advances in accelerators and detectors.

● The proceedings of PANIC11 will be published by the American Institute of Physics early in 2012. Through generous support by the National Science Foundation, in an initiative to make such conferences available to a broad, world audience, video recordings of all pedagogical, plenary and public lectures are available on MIT's Tech TV website at http://techtv.mit.edu/collections/panic11_/videos. The next conference will be hosted by the DESY Laboratory in Hamburg in 2014.

On 13 September, physicists from around the world joined John Ellis, left, at a colloquium to celebrate his 65th birthday, and as he ended his long career as a distinguished CERN staff member and joins King's College London. Here he is in the audience with fellow theorists, Nobel laureate Gerard 't Hooft, front centre, and Chris Llewellyn Smith, former director-general of CERN, front right.

CELEBRATION

Steinberger at 90

When Jack Steinberger won the Nobel Prize in Physics in 1988 together with Melvin Schwartz and Leon Lederman for demonstrating the existence of two types of neutrino in 1962, he commented that the way to win the prize was to do a good experiment while young and then live for a long time. Earlier this year he turned 90, and can look back on a long lifetime of good experiments.

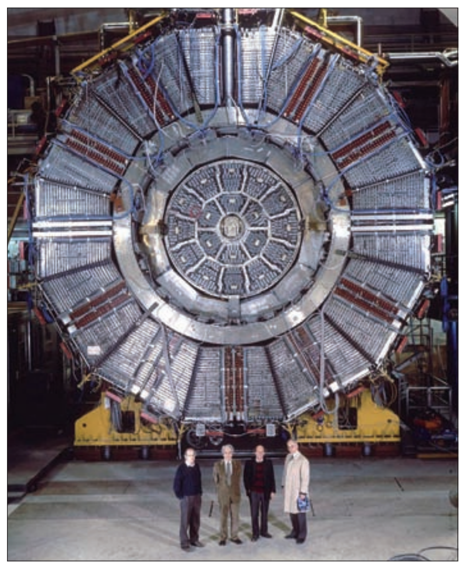
Jack has spent more than half of his life associated with CERN, where he is still a familiar sight. (He joined the laboratory in 1968, but had already been to do experiments at the Proton Synchrotron.) After many years of cycling the 10 km to the lab, he now takes the first bus of the day and logs in to the computer in his office at about 6.30 am. His task is to look through the latest preprints in astrophysics on the arXiv server and print out the handful that catches his eye out of the tens that have appeared since the previous day. His aim still is to learn, something that has characterized his attitude to science throughout his life.

His scientific career in physics began in 1946-8, when he joined the graduate school at Chicago University, at the end of the Second World War. There he learned from a true master, his thesis advisor Enrico Fermi. It was a time when there was much to learn about the new world of particle physics, which was being opened up by experiments with cosmic rays and at the newly developed particle accelerators. His immersion in particle physics continued for nearly 50 years, until the early 1990s. In 1990 he stepped down as spokesperson for the ALEPH Collaboration, which he had led since 1983. At the time ALEPH and the other experiments at CERN's Large Electron-Positron collider were reinforcing the Standard Model of particle physics with great precision, but it was clear that progress in particle physics had become far more difficult than in the days of his thesis experiment.

So Jack turned to learning about other areas of physics and in particular became fascinated by the challenges of cosmology, in particular in the wake of the beautiful measurements of the inhomogeneities of the cosmic background radiation by the Cosmic Microwave Background Explorer in 1992. This took him into physics that he had not needed in particle physics, such as general relativity, hydrodynamics, magneto hydrodynamics. This interest in cosmology and astrophysics continues today, as do his concerns about society, in particular in relation to energy and climate change.

● For more about Jack's life in particle physics, see *Learning About Particles: 50 Privileged Years* (Springer 2005).

Speaking at the CERN colloquium "From the PS to the LHC: 50 years of Nobel Memories in High-Energy Physics" in December 2009.



The ALEPH detector had at its core a time projection chamber, for years the world's largest. In the foreground from the left, Jacques Lefrancois, Jack Steinberger, Lorenzo Foa and Pierre Lazeyras.

Faces & Places

AWARDS

Letwyler and Gershtein receive Pomeranchuk Prize

Heinrich Leutwyler, left, and Semion Gershtein. (Image credit: ITEP.)

Heinrich Leutwyler and Semion Gershtein were awarded the Pomeranchuk Prize for 2011 in a ceremony at the Institute for Theoretical and Experimental Physics (ITEP), Moscow, on 29 September. The prize, established by ITEP in 1998 in memory of Isaak Pomeranchuk, is awarded annually to one foreign and one Russian theoretician for outstanding achievements.

Leutwyler, of the Albert Einstein Center for Fundamental Physics at the University of Bern, is recognized for major contributions to the foundation of QCD and the development of chiral perturbation theory. In one of his first theoretical papers, Leutwyler, with Murray Gell-Mann and Harald Fritsch, formulated QCD in 1973. A decade later, in 1984–1985, he suggested together with Jürg Gasser a new approach to QCD at low energies, i.e. chiral perturbation theory.

Gershtein, of the Institute for High Energy Physics, Protvino, received the award for the discovery of vector-current conservation (CVC) and basic work that connects particle physics with cosmology and astrophysics. In 1955, Gershtein and Ya B Zeldovich pointed out that in the vector interaction the β-decay constant is not renormalized by strong interactions. This phenomenon of CVC was the first demonstration of the unified nature of the electromagnetic and weak interactions. In 1966, in one of the first papers to open a new field bridging particle physics and cosmology, they obtained the limit for the sum of stable neutrino masses from the lifetime of the universe.

CORRECTIONS

The article on the early days of the LHC in the November 2011 issue of *CERN Courier* (p21) unfortunately lost a sentence in the first paragraph. It should have read: *Fermilab's project, however, became a reality as the Tevatron. Based on 800 superconducting dipole magnets with a field in excess of 4 T, it involved the first ever mass-production of superconductor and represented a real breakthrough in accelerator technology.*

Also, the picture on p17 in the article about the discovery of type II superconductivity was wrongly captioned. The picture shows, clockwise from top left: L V Shubnikov; V I Khotkevich; Yu N Rjabinin; G D Shepelev.

Many apologies to all concerned.

LETTER

Targeting the proton

It is great that TOTEM is able to see the dip in proton-proton collisions at 7 TeV at the LHC, after it was seen only at the ISR with a maximum energy of 60 GeV, and also to see that the dip moves towards smaller |t| (*CERN Courier* October 2011 p7). This was indeed what was expected from various models. I find the comments on the failure of the models to reproduce the data a little severe, since Bourrely-Soffer-Wu and Petrov predict the dip at the right place, but are off by less than a factor of 2 from the data.

However the main reason for writing is that I see that only 5 lines of a column are devoted to the results obtained by the $p\bar{p}$ colliders, at CERN and at Fermilab in a 3-page article. It is true that TOTEM (and soon other experiments) has taken a big step, but we must remember that $p\bar{p}$ experiments also made a big step at the time, already showing that the proton becomes "larger". They also showed that the proton becomes darker. The UA4/2 experiment, using a measurement of the real part of the scattering amplitude made a fit that favours a log s^2 dependence for the high-energy cross-section. They predict at 7 TeV, σ_{total} = 92+/–3 mb. We shall see soon if this is confirmed by present experiments.

To end I would like to say that we are in an exciting period where, while the Higgs appears and disappears, tremendous progress is made by all groups, TOTEM, CMS, ATLAS, ATLAS-ALFA on elastic and inelastic proton-proton scattering The forthcoming "Blois" meeting in Vietnam, at the end of the year, should be extremely exciting.

● *André Martin, CERN.*

NEW PRODUCTS

Maxon Motor has announced the ESCON 36/2 DC, the first in a new servo controller range. The extremely compact, powerful 4-quadrant PWM offers efficient control of brushed permanent-magnet activated DC motors up to about 72 W. For details, contact Barbara Schlup, tel +41 41 662 43 89, fax +41 41 666 1676, e-mail Barbara.Schlup@maxonmotor.com, or see www.maxonmotor.com.

Datel, a business unit of **Murata Power Solutions**, has introduced the DAC-12100 series of low power 12-bit current output digital-to-analogue converters with TTL/CMOS compatible inputs. With a 100 MHz conversion rate, these devices suit speed-critical applications. With an extremely low-glitch energy characteristic of 3.0 pV-s compared to the industry norm of 100 pV-s, the DAC-12100 generates little switching noise. Murata Power Solutions has also announced the 6000A and 6000B series of surface-mount power inductors. Both series can accommodate high-current throughput and offer a wide range of inductance values. For more information, contact Sarah Smith, e-mail sarah.smith@murata-ps.com, or visit www.datel.com and www.murata-ps.com.

Specialised Imaging Ltd has announced a new range of high-power xenon flash units optimized for use with ultra-high-speed cameras. The SI-IMS300 flash unit offers a high-intensity source with a short duration making it ideal for processes that occur over a short time window. The SI-MSFH500 flash system offers the flexibility of four controllable high-intensity flash lights for use in scientific and industrial environments. For further details, tel +44 1442 827 728, e-mail info@specialised-imaging.com, or see www.specialised-imaging.com/products.php.

XP Power has introduced the JHM10 series of board-mounted compact isolated 10 W DC/DC converters. With a maximum leakage current of 2 μA, the converters have reinforced input-to-output insulation at a working voltage of 250 VAC and provide an isolation of up to 4000 VAC for up to 1 minute, and up to 5000 VAC for up to 10 ms. For more information, contact Steve Head, tel +44 118 984 5515, e-mail shead@xppower.com, or visit www.xppower.com.

Recruitment

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Please contact us for information about rates, colour options, publication dates and deadlines.

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We're people like you from a research lab who became the leading specialized control system integrator for accelerators worldwide, working also on other large projects like ITER and ALMA. Our customers are satisfied with us, since they continue the collaboration with us.

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○ Postdoctoral Fellows ○ Distinguished Postdoctoral Fellows ○ Assistant Professors ○ Associate and Full Professors

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

The "Institute for the Physics and Mathematics of the Universe" (IPMU) is a new 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 to interact with people from other subfields.

We intend to appoint the four positions listed above. 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 initial focus of 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 underground experiments. We are leading efforts on the XMASS dark matter experiment, the HyperSuprimeCam project for weak lensing surveys at the Subaru telescope, GADZOOKS! at Super-Kamiokande, the Xe-based double beta-decay search in KamLAND, and R&D for future large neutrino detectors. IPMU is a full institutional member in SDSS-III.

The search is open until filled, but for full considerations please submit the applications and letters by Dec 1, 2011.

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

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

LA^{3}NET

Open Positions with the LA^{3}NET Project

Lasers have become increasingly important for the successful operation and continuous optimization of particle accelerators.

Laser-based particle sources are well suited for delivering the highest quality ion and electron beams, laser acceleration has demonstrated unprecedented accelerating gradients and might be an alternative for conventional particle accelerators in the future, and without laser-based beam diagnostics it would not be possible to unravel the characteristics of many complex particle beams. Within LA^{3}NET, laser applications for particle accelerators will be developed within an international network.

The network is currently aiming to recruit a pool of talented, energetic, strongly motivated, early stage researchers with a degree in physics or a closely related field. Possibilities for enrolling into a PhD program exist. Women are especially encouraged to apply.

Each researcher will benefit from a wide ranging training program that will take advantage of both local and network-wide activities, as well as of schools, conferences, and workshops. Excellent salaries will be offered. Most positions are for starting in spring 2012.

Application deadline:
January 6th 2012

You will find more information about LA^{3}NET, all research projects and the application details at:
http://www.liv.ac.uk/la3net

Contact and further detail:
Carsten P. Welsch
Cockcroft Institute of Accelerator Science and Technology
University of Liverpool
Department of Physics
L69 7ZE Liverpool, UK
carsten.welsch@quasar-group.org

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

PARTICLE PHYSICS.

DESY, Hamburg location, is seeking:
Physicist (m/f)

DESY
DESY is one of the world's leading centres for the investigation of the structure of matter. DESY develops, runs and uses accelerators and detectors for photon science and particle physics.

DESY has a long-standing and strong expertise in the development of technologies for experiments in particle physics. To expand this expertise we are looking for a scientist in the area of detector development. The position is located within a group developing novel technologies for particle physics and beyond. The group is involved centrally in the CALICE collaboration, which studies calorimeters for future accelerator based experiments, and more generally contributes to the experimental program at future facilities like the International Linear Collider, ILC.

The position
We are looking for an experienced physicist contributing to state of the art detector systems and technology, with a background in hardware and in software developments. The initial focus of the position will be
- Development of advanced calorimeters for experiments at high energy colliders within the CALICE collaboration
- Participation in the general program of detector development for particle physics at DESY
- Integration of large scale detector systems
- Supervision of scientific and technical personnel in the area of detector development

Requirements
- PhD in experimental particle physics
- Several years of experience as a postdoc with a focus on detector science, preferably in the context of a large particle physics collaboration
- Excellent communication skills in English; knowledge of the German language is an advantage
- Capacity for teamwork

For further information please contact Dr. Ties Behnke +49 40 8998-4918, ties.behnke@desy.de.

Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is an bilingual kindergarten on the DESY site.

Please send your application quoting the reference code, also by e-mail to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: 147/2011
Notkestraße 85 | 22607 Hamburg | Germany
Phone: +49 40 8998-1589 | E-mail: personal.abteilung@desy.de
Deadline for applications: December 31st, 2011
www.desy.de

The Helmholtz Association is Germany's largest scientific organisation.
www.helmholtz.de

HELMHOLTZ | GEMEINSCHAFT

The Institute of Particle Physics Research Scientist

Applications are invited for a position as a Research Scientist with the Institute of Particle Physics in Canada, IPP (**http://www.ipp.ca**). Candidates should preferably have at least three years of postdoctoral experience and a demonstrated record of accomplishment in experimental particle physics. The Research Scientist appointment is associated with an academic research position at a Canadian university and includes the right to hold research grants and to supervise graduate students. Such an appointment may be made permanent following a review after three years of employment.

The current program of IPP includes the following experiments:

p-p collisions at the LHC (ATLAS);
Long baseline neutrino studies at JPARC (T2K);
Double-beta-decay searches with the SNO+ and EXO detectors;
Dark Matter searches with the DEAP and PICASSO experiments;
Precision pion decay studies at TRIUMF (PiENu);
Very-high-energy gamma-ray astronomy (VERITAS).

The choice of experiment and university affiliation will be determined by mutual agreement between the candidate and the IPP. The position will be available as early as September 1, 2012.

Send curriculum vitae, statement of research interests and arrange for letters of recommendation from at least three referees, to be received by February 3, 2012 at:

Prof. W.Trischuk, Director
Institute of Particle Physics
Department of Physics
University of Toronto
60 Saint George Street,
Toronto, ON M5S 1A7
Canada
email: william@physics.utoronto.ca

INSTITUTE OF PARTICLE PHYSICS

All qualified candidates are encouraged to apply, however, in accordance with immigration regulations, Canadians and permanent residents will be given priority.

Faculty Position in Theoretical High Energy Physics

University of Wisconsin–Madison
Department of Physics

The Department of Physics at the University of Wisconsin, Madison invites applications for an assistant professor position in high energy theory, beginning August, 2012. We welcome all applicants who can strengthen the Department's program in theoretical high energy physics, including candidates with a strong interest in particle physics phenomenology.

The successful candidate will be expected to perform high-impact scholarly research, teaching duties at the undergraduate and graduate levels, and service duties. Classroom and individual instruction and supervision of graduate and undergraduate thesis research are required.

Interested candidates should apply with a CV, publications list, research statement, teaching statement, and at least 3 letters of reference at http://www.physics.wisc.edu/apply/theory-2011/
(Paper Submissions are strongly discouraged.)

To ensure consideration please submit application materials by December 31, 2011. Please email info@physics.wisc.edu to see if applications are still being accepted after the deadline.

The University of Wisconsin–Madison is an equal opportunity/affirmative action employer, and especially encourages women and underrepresented minorities to apply. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality. A criminal background check may be required prior to employment.

For further information email info@physics.wisc.edu.
University of Wisconsin-Madison Position Vacancy Listing PVL# 71965.

WISCONSIN

ELEKTA

Elekta is a human care company pioneering significant innovations and clinical solutions for treating cancer and brain disorders. The company develops sophisticated state of the art tools and treatment planning systems for radiation therapy and radiosurgery, as well as workflow enhancing software systems across the spectrum of cancer care.

We have a number of vacancies for **Physicists** to join our R&D Physics group in Crawley. The Physics group is responsible for providing support to the business and contribute with designs and measurements in the following areas: Physics of Radiotherapy Systems, including beam generation and dosimetry (electron beams, MV and kV photon beams), general Radiation Physics, Monte Carlo simulations and other computational modelling methods, Control Systems for experiments, Microwave components and theory, Waveguide testing and tuning, Optics, Physics of Detectors and Imaging Systems.

Successful applicants will take a leading role in supporting the development of new products and will be involved on a number of projects including both computational and experimental activities. Ideally candidates will have experience of medical accelerator systems and the ability to contribute in several of the areas that the Physics group is responsible for. Projects will often offer interaction with Research Hospitals and other Institutions, therefore exceptional written and spoken communication skills will be required. Our preference is for candidates to be educated to MSc or PhD level or equivalent. The ability to work to tight deadlines and within a successful team is also essential for these roles.

Current vacancies include:

- **Radiotherapy System Physicist**: You will take a leading role in designing, planning, implementing and managing test programmes in order to produce performance data for Elekta Linac systems. You will be involved in a variety of R&D projects. You will ideally have an MSc or a PhD degree in Medical Physics, Radiation Physics or closely related discipline and experience working within the Medical Devices industry or a Radiotherapy Hospital department (although experience as a Radiation Physicist in another area will be considered). Experience with international compliance standards and/or Physics QA programmes will be an advantage.

- **Accelerator Physicist**: You will provide the business with technical support of Elekta RF electron linear accelerators and associated developments, with particular focus on beam generation, transport, control and monitoring. This role will require an understanding of periodic accelerating structures, particle-in cell modelling, electron sources, RF sources and electron beam dynamics. Ideal candidates will have a PhD degree in Physics, Accelerator Physics, Particle Beam Physics or closely related discipline. Candidates will have experience as an accelerator physicist, involved with modelling aspects of accelerating structures as well as beam experiments, either in a research or industrial environment. However applicants with less experience yet exceptional skills will also be considered.

- **Imaging Physicist**: The aim of this position is to provide physics support for the research and development of Elekta systems for Image Guided Radiotherapy. The Imaging Physicist contributes to the design and experimental evaluation of new developments of kV and MV imaging systems, define technical specifications and address issues related to acceptance, quality assurance and regulatory requirements. The role involves both computational and experimental tasks.

To be successful in this role a thorough understanding of the physics of X-ray imaging, X-ray sources and detectors is required. Candidates should have an MSc or preferably a PhD in Physics, Medical Physics, Radiation Physics, Medical Imaging or closely related discipline. Candidates will be expected to have experience as an X-ray Imaging Physicist, either in an industrial, research or clinical environment, having developed significant knowledge in several of the following areas: design and evaluation of planar or tomographic X-ray imaging systems, imaging detector electronics, image reconstruction algorithms, scatter correction methods, modelling of imaging systems, dosimetry of kV and MV photon beams.

To apply for these vacancies please visit our website **www.elekta.com** and apply via the careers section.

brightrecruits.com

New career video just added

Careers at IMT Institute for Advanced Studies

Watch it online now

youtube.com/brightrecruitsTV

Tenure Track Faculty Position in Experimental Astroparticle Physics in the Department of Physics

Unversity of Wisconsin–Madison
Department of Physics
WISCONSIN

The Department of Physics at the University of Wisconsin-Madison invites applications for a tenure-track assistant professor position in experimental astroparticle physics beginning August, 2012.

The successful candidate will be expected to develop a strong, independent, high-impact research program that enhances or complements efforts in experimental astroparticle physics, including areas such as neutrino physics, neutrino and ground-based gamma ray astronomy and the search for dark matter. UW-Madison is the lead institution for IceCube and also participates in the Askaryan Radio Array, the High Altitude Water Cherenkov experiment, the DM-Ice experiment as well as other neutrino and dark matter experiments.

Classroom and individual instruction and supervision of graduate and undergraduate thesis research are required, as are service duties.

Each candidate should submit a CV, publications list, research statement, teaching statement, and at least 3 letters of reference at: https://www.physics.wisc.edu/apply/astroparticle-2011/

The material submitted should provide evidence of teaching skills and the ability to carry out an independent research program.

(Paper Submissions are strongly discouraged.)

To ensure consideration please submit application materials by January 15, 2012. Please email info@physics.wisc.edu to see if applications are still being accepted after the deadline.

The University of Wisconsin–Madison is an equal opportunity/affirmative action employer, and especially encourages women and underrepresented minorities to apply. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality.

For further information email info@physics.wisc.edu or contact Professor Francis Halzen (halzen@physics.wisc.edu).
University of Wisconsin-Madison Position Vacancy Listing PVL#72173.

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

DESY

PETRA III EXPERIMENTS .

DESY, Hamburg location, is seeking:
Beamline Scientist (m/f)

DESY

DESY is one of the world's leading centres for the investigation of the structure of matter. DESY develops, runs and uses accelerators and detectors for photon science and particle physics.

DESY looks back on a long tradition in synchrotron radiation experiments in a wide range of applications and has developed into one of the leading centers in this field worldwide. For high end synchrotron radiation applications, the 3rd generation source PETRA III is available since 2009 as one of the most brilliant hard X-ray sources worldwide. The Hard X-ray Micro/Nano-Probe Beamline (P06) at PETRA III is designed for two-dimensional mapping and scanning tomography. It supports microscopy using X-ray fluorescence, absorption spectroscopy and (coherent) diffraction contrast, yielding elemental and structural information from inside the sample.

The position

- Pursuing an own research profile utilising nanobeam based X-ray imaging
- Supporting users at the beamline
- Developing and commissioning of the beamline

Requirements

- PhD in physics, chemistry or equivalent qualification
- Sound working experience at a third generation synchrotron radiation source
- Profound knowledge in x-ray absorption spectroscopy or X-ray diffraction methods
- Experimental and IT-based skills

For further information please contact Hermann Franz, +4940 8998 -4534, hermann.franz@desy.de, or Gerald Falkenberg, +4940 8998 -2933, gerald.falkenberg@desy.de

The position is limited to 3 years
Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is an bilingual kindergarten on the DESY site.

Please send your application quoting the reference code,
also by E-Mail to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: 163/2011
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-1589 |
E-Mail: personal.abteilung@desy.de
Deadline for applications: 16 December 11
www.desy.de

The Helmholtz Association is Germany's
largest scientific organisation.
www.helmholtz.de

HELMHOLTZ | ASSOCIATION

Massachusetts Institute of Technology

Come work with us!

Professor

The MIT Nuclear Science and Engineering Department invites applications for a tenure-track or tenured faculty position.

The Department is a world leader in the engineering and application of nuclear and radiation systems. Its faculty teach and conduct research in fields from fundamental nuclear science to practical applications of nuclear technology in energy, security and other fields. An area of particular interest is in the broad field of nuclear science and technology for security; for example applied accelerator technology, radiation generation, detection and imaging, and system-level design and analysis.

Outstanding applicants in the Department's other fields of research and education will also be considered. These include advanced modeling, simulation, theory, and experimentation in fission reactor systems, the nuclear fuel cycle, plasma physics and fusion technology, advanced materials for extreme environments, and radiation science and technology. [See http://web.mit.edu/nse/]

Applicants must have a doctorate in a relevant engineering or scientific field by the beginning of the appointment period, and must have demonstrated excellence in research and scholarship in a relevant technical field. A commitment to excel in teaching in one of the subfields of nuclear science and engineering is essential. Faculty duties will include teaching at the graduate and undergraduate levels, research, and supervision of graduate students.

To apply, submit a curriculum vitae, description of research interests, and the names of three references online at http://nse-search.mit.edu/ for consideration. Applications received before January 31, 2012 will be given priority.

MIT is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

http://web.mit.edu

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University of Central Lancashire

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PGDip Nuclear Safety and Security
PGCert Nuclear Safety
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Bookshelf

Festive Bookshelf

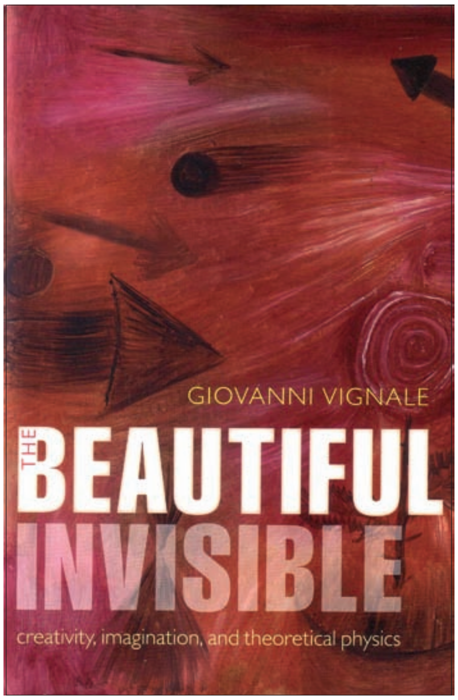
Once again, it will soon be time for many of us to spend some time with friends and family, probably after a few hectic hours of searching for presents in this festive season. To help with the shopping, this edition of Bookshelf includes some books that aim to take particle physics and related areas of science to a wider audience, together with one or two that you may want to add to your own wish list.

The Beautiful Invisible: Creativity, Imagination, and Theoretical Physics

By Giovanni Vignale
Oxford University Press
Hardback: £16.99 $22

Most things in life are not "invariants". Consider two identical glasses of good wine. A thirsty person quickly drinks the first one and then complains about the ensuing headache. The other glass has its aromas and textures slowly appreciated, mixed with the whispering sounds of waves breaking on a nearby shore, dimly illuminated by the crimson shades of the late afternoon sun – still bright but so tired from the long day's journey that its descent behind the shallow mountains can be directly followed, triggering an everlasting memory associating the wine's flavours with a pleasant feeling. *The Beautiful Invisible* is a truly remarkable opus, better appreciated if read in a slow and relaxed mood, savouring each sentence, each paragraph. I wonder if I have ever read another book with so few misprints, unclear sentences, or misplaced arguments. Each word is the right word, in the right place. And yet, as if to disturb the poet Stefan Mallarmé ("We do not write poems with ideas, but with words"), the continuum of great ideas is, at least for physicists, what makes this book such a wonderful "poem".

Giovanni Vignale, besides being a professor at the University of Missouri and a condensed-matter theorist, is a connoisseur of literature, art, theatre and cinema, and seems to have spent plenty of time in transatlantic flights to conceive this "travel guide". It takes the interested reader through a journey of invisible fields and virtual characters, intertwined with the reality of surreal but beautiful landscapes, surpassing the most imaginative creations of the human mind. As every condensed-matter theorist knows, "more is different", and if you dive into this book, your mind will be filled with



much more than just physics. Saint-Exupery, Musil, Bulgakov, Borges, García Márquez, Elliot, Poe, Shakespeare, Magritte, Vermeer and many others will walk along with you on this path to enlightenment. Some of the scenery is impressive and breathtaking. Maxwell's discovery of electromagnetic waves by a purely theoretical argument, Dirac's bringing together of quantum mechanics and special relativity, and other magnificent viewpoints welcome you along this incredible journey, which connects mechanics, thermodynamics, relativity, electrodynamics and quantum mechanics and ends on superconductivity – "one of the highest achievements of the physics of the 20th century" – a natural stop for a book published in 2011.

Along the way, casually dropped here and there by the side of the path, you might find some pearls of wisdom: "we must already know what we are looking for, in order to see it"; "theory grows at the confluence of fantasy and truth"; "there is no better way to test a theory than to apply it to a scenario different from the one that initially prompted its development". We are also reminded of the fascinating and paradoxical mysteries of quantum mechanics: "there is nothing I can say to demystify it, words attempt the task and come back defeated". And we are given some good advice: "complex calculations often simplify dramatically when approached from the right angle"; "different representations stimulate our imagination in different ways, producing vastly different results"; certain issues are "ignorable in the limit of interest". At the end, after almost 300 pages, the pilgrim is offered some final take-home souvenirs: "there are no final truths at the frontier, only an inexhaustible activity that creates and continuously destroys its own creations", "the search for the truth has more value than the truth itself".

Vignale shows, convincingly, that no one should think that physicists are any less imaginative than novelists or poets. In summary, this book is the best Christmas reading for physicists this year (even better than *Dirac's Principles of Quantum Mechanics*), at least for physicists who manage to relax for a week or two. I will surely enjoy reading it again, some day. But first I would like to follow up some of the many "suggestions for further reading". Maybe I will start by reminding myself of Le Petit Prince: "anything essential is invisible to the eye and one sees clearly only with the heart".

● *Carlos Lourenço, CERN.*

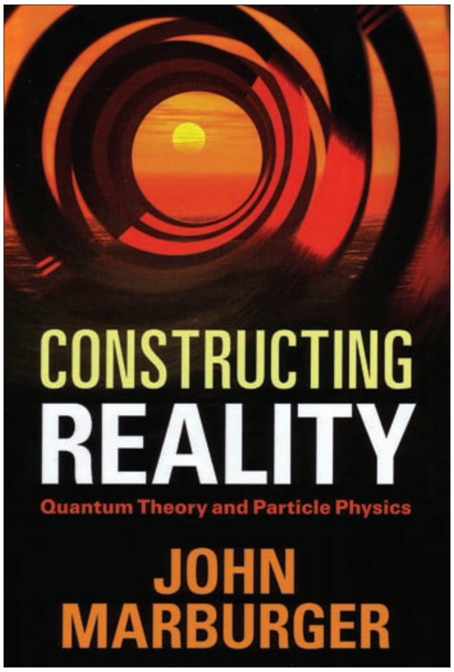
LHC

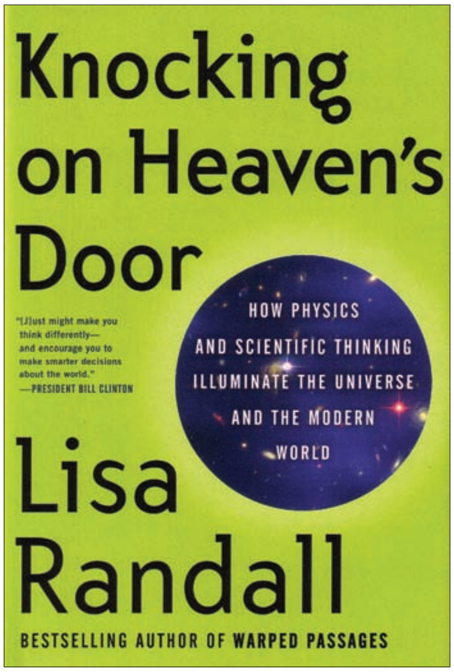
By Peter Ginter, Rolf-Dieter Heuer, Franzobel
Edition Lammerhuber
Hardback: €64

This large-format, lavishly produced volume in its psychedelic slipcase is a fitting celebration of the "world machine" that is the LHC. To describe it as a coffee-table book is to demean it. Long after the LHC has been superseded, it will remain as a beautiful record of the astonishing complexity and achievement of what currently hums and whirls beneath placid Swiss and French fields.

LHC is built around the photographs of

Bookshelf





Peter Ginter, master of the demanding craft – and art – of photographing technology and industry. The pictures are complemented by an interview with Rolf-Dieter Heuer, director-general of CERN, and an essay by Franzobel (pseudonym of the Austrian writer Stefan Griebl). Together with the explanatory picture captions, the text (in English, German and French) builds up to provide an excellent layperson's introduction to the LHC, how it works and what it aims to achieve.

The book divides into sections on the collider, the four big detectors (ALICE, ATLAS, CMS, LHCb), event displays and computing ("from www to grid"), together with a brief history of CERN and the LHC project.

The photographs are magnificent. To any child or adult unfamiliar with particle physics, and even to people who visit CERN frequently or work there every day, they reveal the LHC and its detectors as a soaring pinnacle of research, built with the precision, coordination and search for truth that informed the great medieval cathedrals, updated to the 21st century.

One photograph shows four Russian workmen perched on a mound of artillery shell casings; a second shows the brass from the casings turned into a wheel of giant golden segments arranged like the iris diaphragm of a camera; and a third shows this huge "wheel" – designed to cause showers of secondary particles after an initial collision – being installed as one of the elements of the CMS detector.

And there is more. A physicist abseils into the gleaming innards of LHCb, like a mountaineer into a crevasse. Pakistani workmen pose beside one of the "feet" on which the 14 000 tonne CMS will sit. Engineers are dwarfed as one of the giant coils of the ATLAS toroid is manoeuvred into position. ALICE's innermost detector gleams with myriad silicon faces like a futuristic Fabergé egg.

This book is a great photographic feat by Ginter; the result of endless visits to CERN over many years. Each picture has been planned, negotiated, composed and lit, representing many hours of work and inspiration.

Edition Lammerhuber has produced a magnificent volume to the highest publishing standards. Everyone concerned with or interested in CERN should have a copy. I also urge the publishers to produce an e-book version that could reach a mass audience worldwide. These pictures would look glorious on a tablet computer.

● *Michael Marten, Science Photo Library.*

Constructing Reality: Quantum Theory and Particle Physics

By John Marburger

Cambridge University Press

Hardback: £17.99 $29

E-book: $23

This is easily the best introduction to quantum theory and particle physics that I have ever seen. The book is remarkable both for what it covers and for what it does not. Unlike many recent popular books, this one avoids references to unproven hypotheses such as grand unification, supersymmetry, strings and extra dimensions. The total space devoted to these ideas is under two pages. Rather, the book describes the story of the development of physical theory from Newtonian mechanics through the changes that were required by relativity and quantum mechanics. It continues all the way through to a lucid description of the Standard Model, nuclear physics and the periodic table and conveys tremendous excitement at how far physics has advanced while sticking to what is really known. It presents a clear and deep account of the physicist's view of the basic bits that make up the world and how they interact.

The author provides a great deal of mathematical detail, but this never requires anything beyond what would be expected of a high-school student or first-year university undergraduate. Even concepts such as complex numbers, vectors, matrices and Hilbert space are introduced just enough to make the basic ideas clear without getting bogged down in detail. If I hadn't just read the book, I would have doubted that such a presentation would even be possible.

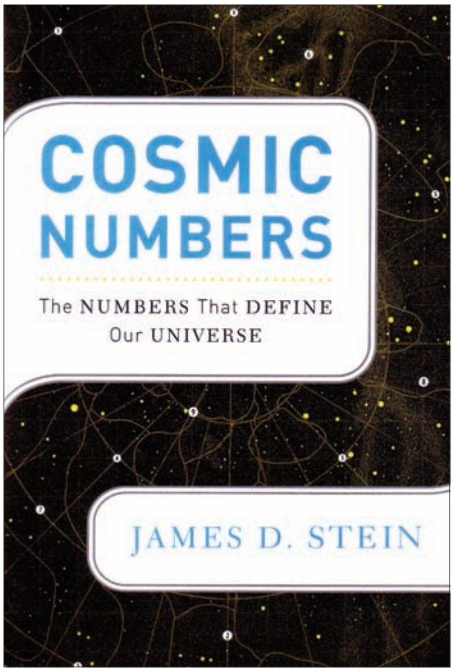
Each chapter has detailed notes and references at the end. These could easily lead a serious reader a good way into an undergraduate physics education. Without "dumbing things down", the mathematical concepts are presented with clear physical insight and motivated by their necessity to understand observed reality.

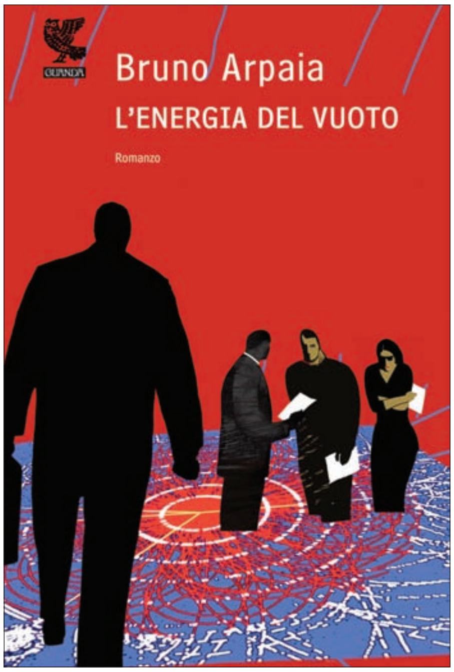
One caveat is that there is little detail on experiments, but I think this sacrifice is worthwhile to maintain focus and keep the book to under 300 readable pages. Certainly the key role played by experiments in physics is made extremely clear. Perhaps the best single overall feature of the book from the view of a practicing particle physicist, is that you can give it to any bright person to give them a good idea of the field and not have them wondering which parts correspond to tested ideas and which are purely speculative.

Many friends and colleagues have asked me to point them to something that could give them a clear picture of what's actually known and this is, in every way, just the sort of book I've wanted. Sadly, the author died this past July after having been director of Brookhaven National Laboratory and also director of the Office of Science and Technology Policy under US President George W Bush. I'd like to think of the book as a parting gift to those he left behind. He has done a real service to all of us in the field and I recommend the book heartily to everyone. I'll certainly be buying quite a few for Christmas.

● *John Swain, Northeastern University.*

Bookshelf





Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World

By Lisa Randall
HarperCollins
Hardback: $29.99
E-book: $14.99

Lisa Randall's new book *Knocking on Heaven's Door* has an interesting choreography. It reads almost as though it started out as a conversation with the author at, say, a dinner party that turned into a tour of CERN and the LHC. With many personal references and anecdotes thrown in, it certainly isn't your standard popular-science volume about the LHC and the current state of particle physics.

For example, Randall, well known role-model theorist and media darling (this is meant in a good way), doesn't start with the theory. Instead, she ends with it, explaining the open questions of the Higgs or missing antimatter, delving deeply into string theory and dark matter before she closes with an aside on theoretical methods and the notions of science as a quest, scientific genius and patience, thus giving a nice insight into the proverbial question: "What do theorists do all day?"

So why does it read as though it started out as a dinner conversation? Because the first quarter of the book is dedicated to the explanation of what science is all about, i.e. that is it guided by evidence, proof and experiment, and that these sometimes lead to readjustments in theories but rarely to complete revolutions. Doesn't this sound like a question somebody might ask at a dinner table? Or the famous question of how science and religion can survive side by side, a topic that is hinted at in the book's title.

After an evening of explanations and justification, the next natural step would be to invite the interrogator for a tour, which is what follows. Randall gives a quick introduction to CERN and a longer one on the LHC, and then while making her way to detector technologies there's an aside on black holes, cost-benefit analysis and ecological arguments. The grand finale of the tour takes place in the cafeteria, where the really interested visitors are treated to the whole state of theoretical thinking.

Knocking on Heaven's Door may not be the most stringent introduction to particle physics and its problems today, but it offers a fascinating insight into the world of science and manages to get across the excitement that the whole field, theorists and experimentalists alike, feels at the brink of discoveries to come from the LHC.

● *Barbara Warmbein, DESY.*

Cosmic Numbers: The Numbers That Define Our Universe

By James D Stein
Basic Books
Hardback: £17.99 $25

Numbers are much better than words at conveying the immensity of our universe and the smallness of its components. We appear to sit uneasily on a fragile perch somewhere in the middle, using mighty telescopes to look outwards and hi-tech microscope devices to peer inwards. However, to make them digestible, these huge numbers still need words, imagination and humility.

Martin Rees' commendable book *Just Six Numbers: The deep forces that shape the Universe* examined a selection of numbers, mostly large ones, which miraculously ensure that the universe as we know it is possible. If the dial that set these numbers had been tuned otherwise, even slightly, any outcome would have been unrecognizable.

Rees' book was published by Basic Books in 2001. Ten years later, the same publisher now offers another book on numbers, and author Stein acknowledges this pedigree. His book takes a few of the numbers already looked at by Rees and adds some more.

Each number gets its own chapter and most of the headings are instantly recognizable: the gravitational constant, the speed of light, the ideal gas constant, absolute zero, Avogadro's number, the Boltzmann constant, the Planck constant, the Schwarzschild radius, the Chandrasekhar limit and the Hubble constant. Some require further explanation: electricity and the proportionality constant, and the efficiency of hydrogen fusion.

Most impenetrable of all is the cryptic "omega" of the final chapter, which looks at matter density in the universe. Here, new supernova measurements show that the expansion of the universe is accelerating. This new Copernican revolution with its mysterious dark energy earned the 2011 Nobel Prize in Physics.

In "omega", Stein applauds his own scientific judgement and regrets not having been able to bet on the demise of some recent tenuous theories. This emboldened him to scorn the value of the supernova finding: "It just somehow seems wrong to me." However, this apparently did not carry much weight in Stockholm. Any betting odds must now have lengthened considerably.

● *Gordon Fraser, Divonne-les-Bains.*

L'Energia del Vuoto (Vacuum's Energy)

By Bruno Arpaia
Guanda
Paperback: €16.50

Another thriller based at CERN, but this time far removed from the science fiction of *Angels & Demons*. In *L'Energia del Vuoto*, the science plays a major role, not only because the whole action takes place around the LHC, but also because the book is full of well written pages explaining the science of elementary particles and the Big Bang. Probably the weakest part of this book is the thriller plot itself.

The story is about a group of fundamentalist techno-terrorists who plan to corrupt the data of one of the large LHC experiments to provide fake evidence for a

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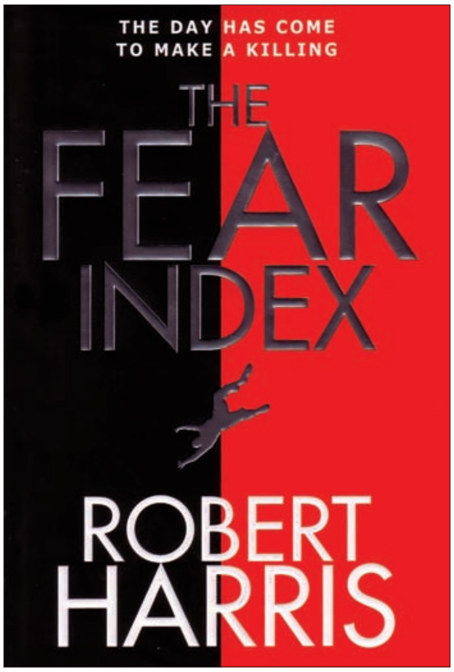
discovery, causing a great deal of confusion in the whole field of high-energy physics. The idea is original and it is intriguing from the point of view of scientists involved with "big science" experiments. It is indeed a scientist's nightmare to make a false discovery or to lose a major discovery in an experiment that took 20 years to build and will not be possible to repeat. However, this aspect is not likely to interest most readers.

The narrative centres on Emilia and Pietro, a couple heading for a deep crisis. On one side there is Emilia's total commitment as the leader of one of the large LHC collaborations: on the other, the normal lives of Pietro and their son Nico. One day Emilia does not return home and Pietro and Nico have to make a get-away, avoiding strange people who are trying to capture them.

In a parallel story, Nuria Moreno, a fascinating Hispanic journalist in charge of writing an article about CERN, is trained in the subtleties of modern physics. These pages on science are the best part of the book; dense but terse, understandable, entertaining, but possibly too much for a thriller. *Angels & Demons* also has long passages devoted to philosophy, science, religion and history, but there they are a mixture of science and fiction cleverly conceived to capture the reader's attention. For Dan Brown, adherence to scientific or historical truth is not an issue. This is why *Angels & Demons* is a "bad" educational book but a successfully entertaining story. In *L'Energia del Vuoto*, Arpaia instead tries his best to mix true science with a fictional story, hoping that the fascinating science of the beginning of time and of infinitesimally small things will capture the reader's imagination. The success of his attempt, however, is somewhat limited.

On the other hand, for anyone who knows CERN a little, this book has another interesting aspect: almost all of the fictional characters have clear correspondences with real people. There are no secrets about this – looking at the acknowledgment page it is easy to find the names of the scientists who helped Arpaia during his stay at CERN and to identify the main figures. For the CERN-based audience this could be definitely an amusing part of the reading.

● *Roberto Battiston, University of Perugia.*



The Fear Index

By Robert Harris
Hutchinson
Hardback: £18.99
E-book: £19.81

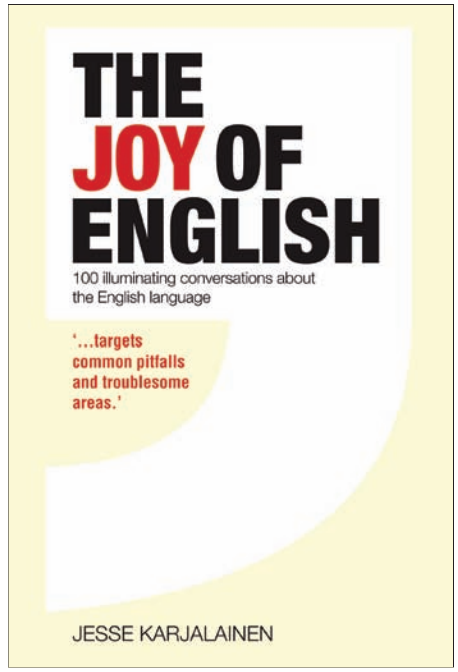
When Robert Harris came to CERN to research a new novel inspired by the financial crisis, I wondered whether we were in for a tale of scientists too clever for their own good – and ours – bringing down the global financial system. Instead, what we've got is a tight, well researched and fast-paced thriller in which CERN serves as a sort of "UN with Asperger's": a home for the smart but socially challenged.

As always, Harris's attention to detail is impressive, and for anyone who knows Geneva well, some things are bound to raise a smile: the plague of independent financial advisors, for example, who cleverly persuade people to part with their money, only for them to see it halve in value, or the phalanx of locals standing by the kerb of an empty street waiting for the lights to change. However, as with any story that's big on detail, to anyone who really knows the lie of the land, some things don't quite gel: surely you couldn't get from A to B that fast, even at the crack of dawn, and CERN's main building seems to be confused with the lab's reception. When the last page is turned, however, these things don't matter, because the plot carries you through with consummate ease.

Alex Hoffman is an ex-CERN scientist and computer whizz who has made a successful move into finance. His clever software has generated unimaginable wealth for his clients, his staff and himself, and it seems that someone is jealous enough to want him dead. Without giving anything away, the plot keeps you guessing and drives relentlessly on to a rather surprising conclusion.

The Fear Index is almost a foray into sci-fi, extrapolating reality only slightly into the realms of the unknown to tell a cautionary tale. Harris's warning concerns what might happen when mathematical wizardry meets a global financial system built on gambling and an unhealthy dose of human naivety and greed. The shocking speed of transactions, with people holding positions for fractions of second before taking multimillion dollar decisions, is truly terrifying, leaving this reader with the feeling that current financial reforms might only be scratching the surface and that the next time we plunge into crisis it won't be the clever scientists who are at fault. In *The Fear Index*, Alex Hoffman is as much a victim as the rest of us.

● *James Gillies, CERN.*



The Joy of English: 100 illuminating conversations about the English language

By Jesse Karjalainen
How To Books
Hardback: £12.99

Those who have been put off improving their use of the English language by pedants and coma-inducing teachers who talked of gerunds and genitive forms have nothing to fear from this book and everything to learn. As its title suggests, the English language is a joy, and the author's enthusiasm to enable the reader to share in this is apparent from the start. There is nothing here of the chalk-tossing Latin master; this book feels like a conversation between equals, one that the reader can engage with and learn from right away.

The book is structured around a hundred common mistakes, tips and discussion points

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applicable to both British and American English, ranging from the truth about split infinitives to the importance of proofreading and checking over your writing. The emphasis is on style, with an examination of what works well and why, not merely on what is correct. Each point is discussed and explained in a variety of ways that suit a variety of learning styles and situations. Quick reference is aided by clearly typeset "right" and "wrong" examples that are easy to scan, for instance, while (I was tempted, by habit, to write "whilst" here!) section subheadings are designed to help you remember the core message: the subheading for the section on sentence structure, for example, is simply "Somebody did something". Karjalainen does not shy away from plain didactic advice, either, but he offers it without sounding smug or superior.

This book is much more than a reference book. While it is entirely suited as such, it invites deeper engagement and reflection. Karjalainen should be commended for infusing it with an infectious sense of joy that leaves the reader wanting to strive towards the improvement of his or her own use of the English language.

A free sample PDF is available for download at www.thejoyofenglish.com

● *Dan Noyes, CERN.*

Books received

Les Nobel juifs de chimie : Le partage du savoir au XXe siècle
By Isaac Benguigui
Editions Slatkine
Paperback: SwFr35

This year, the International Year of Chemistry, provided the opportunity to highlight the fascinating stories of the people who have contributed to the field. In this book Isaac Benguigui focuses on a particular group – those Jewish chemists who went on to win the Nobel Prize during the 20th century. He tells the stories of 23 Nobel laureates, whose lives spanned more than a century and several continents, from Adolf Von Bayer born in Berlin in 1835 (Nobel prize 1905) to Alan J Heeger (Nobel prize 2000), the son of Russian immigrants to the US. It is not only a tale of scientific discovery but one that also highlights the turbulent times of the Jewish people, particularly during the first half of the 20th century in Europe.

A Scientific Autobiography: S Chandrasekhar
By Kameshwar C Wali (ed.)
World Scientific
Hardback: £55 $85
Paperback: £27 $42
E-book: $111

Subrahmanyan "Chandra" Chandrasekhar was one of the foremost scientists of the 20th century. He died in 1995, but during his life he kept a journal of his scientific activities, which he gave to Kameshwar Wali, saying that if his wife Lalitha and Wali thought it worthwhile, it could be published after his death. The result is an intriguing scientific autobiography published as an appropriate tribute to mark the centenary of Chandra's birth in 2010. It begins in late 1943 and continues until a few months before his death. As Chandra elucidates in the preface, it describes "in detail the evolution of my scientific work during the past 40 years and records each investigation, describing the doubts and the successes, the trials and the tribulations". He also details the parts his associates and assistants played in the completion of the different investigations. It is indeed a remarkable document.

Viewpoint

Trends in isotope discovery

Michael Thoennessen did not realize where documenting the discovery of isotopes would lead.

It all started innocently enough with a review article I wrote in 2004 about the nuclear driplines, which described the exploration of the most neutron- and proton-rich isotopes (Thoennessen 2004). The article included tables listing the first observation of each isotope along the proton- and neutron-dripline. The idea to expand this list to cover all isotopes lingered for a few years until in 2007 I mentioned it to an undergraduate student as a possible research project. At the beginning we did not appreciate the magnitude of the project; after all, there are more than 3000 isotopes presently known. However, with the help of many undergraduate students performing elaborate literature searches and carefully judging the merits of the individual papers we continued, even though we extrapolated that the project would take about 10 years to reach completion.

We have described details of the discovery of each isotope in short paragraphs, arranged by elements, which are published in a series of articles in *Atomic Data and Nuclear Data Tables*. In a summary table, the first author, year, journal, laboratory, country and method of discovery are presented. Now, only four years after we started, the project is almost completed. We finished the initial discovery assignment for all isotopes and are currently finalizing the paragraphs for the last four elements: actinium, thorium, protactinium and uranium.

The master table of all elements is a rich source of interesting information. Along the way it has been fascinating to see how not only the physics and technology changed over time, but also the style of the papers. For example, the average number of authors per article increased from 1.1 in 1930 to 16.4 in 2000.

One piece of information – the number of isotopes discovered by the different laboratories around the world as a function of time – was recently highlighted by a *Nature News* article and has drawn a lot of attention over the past few weeks (Samuel Reich 2011). The article reveals the labs and individuals that have discovered the largest number of new isotopes. The results show that while Lawrence Berkeley National Laboratory leads by almost a factor of two, other laboratories in Japan and Europe – most notably GSI in Germany – have made most of the new discoveries in the past couple of decades. A graph displaying the number of isotopes discovered per laboratory as a function of time was featured as the "Trendwatch" in a recent issue of *Nature* (Trendwatch 2011). The graph seems to indicate that the top five laboratories are Berkeley, Cavendish, GSI, RIKEN, and JINR in Dubna; however, RIKEN was included only because of the large number of recent discoveries. But in reality, CERN's ISOLDE has played a pioneering role in the discovery of isotopes, especially with the "isotope-online" technique, and ranks number five on the list.

Michael Thoennessen. (Image credit: MSU.)

Now why is the information contained in the database significant? The discovery of isotopes has a long history beginning with the discovery of radioactivity of uranium (later identified as ^{238}U) by Becquerel in 1896. The discovery of new isotopes is closely linked to developments of new techniques and new accelerators (Thoennessen and Sherrill 2011). Creating and detecting new isotopes is the first prerequisite to being able to study them, automatically putting the laboratories that produce the most exotic isotopes in the best position for doing the most exciting science with these isotopes. The techniques to produce, separate and identify these isotopes are also critical to make and deliver clean beams of less exotic isotopes at higher intensities, which can then be used to explore the properties of these nuclei. The recent conference on Advances in Radioactive Isotope Science, ARIS 2011, highlighted not only the tremendous interest in the field and the most recent advances in physics but also the technical developments making these experiments with exotic isotopes possible (p32).

The data presented in the Trendwatch indicate that the balance of power pushing the field forward has shifted away from the US. The article did not stress that 2010 was the most productive year for the discovery of isotopes. For the first time more than 100 isotopes were discovered in a single year. This points to a renaissance of the field, which is driven by the start of a new accelerator system in RIKEN, Japan, and new technical developments at GSI. During the past 20 years, most new isotopes were discovered at projectile fragmentation facilities, thus the next major step will be the new accelerators currently being designed at the Facility for Antiprotons and Ion Research (FAIR) at GSI and the Facility for Rare Isotope Beams (FRIB) at Michigan State University in the US. FRIB is absolutely critical for the US to play a leading role in nuclear physics in the future.

● Further reading

M Thoennessen 2004 *Rep. Prog. Phys.* **67** 1187.
M Thoennessen and B M Sherrill 2011 *Nature* **473** 25.
Trendwatch 2011 *Nature* **478** 161.
E Samuel Reich 2011 *Nature News* doi:10.1038/new.2011.571.

● *Michael Thoennessen, Department of Physics and Astronomy and NSCL, Michigan State University.*