WELCOME

CERN Courier – digital edition

Welcome to the digital edition of the October 2013 issue of *CERN Courier*.

Particle-physics experiments take place in all kinds of places. Out in space, the AMS-02 experiment on the International Space Station has worked flawlessly for more than two years, collecting data on 36.5×10^9 cosmic rays. Eagerly awaited results were presented at this year's major cosmic-ray conference. Deep under a mountain, in the Gran Sasso National Laboratory, the XENON100 experiment searches for dark matter and has new stringent limits. Nearer to the Earth's surface, the current shutdown at CERN is providing the opportunity for improvements to detectors – in this issue the focus is on ATLAS – as well as time to review results from the first long run, as ALICE does here. All this and more were topics for EPS-HEP 2013, the major summer conference that was held in Stockholm.

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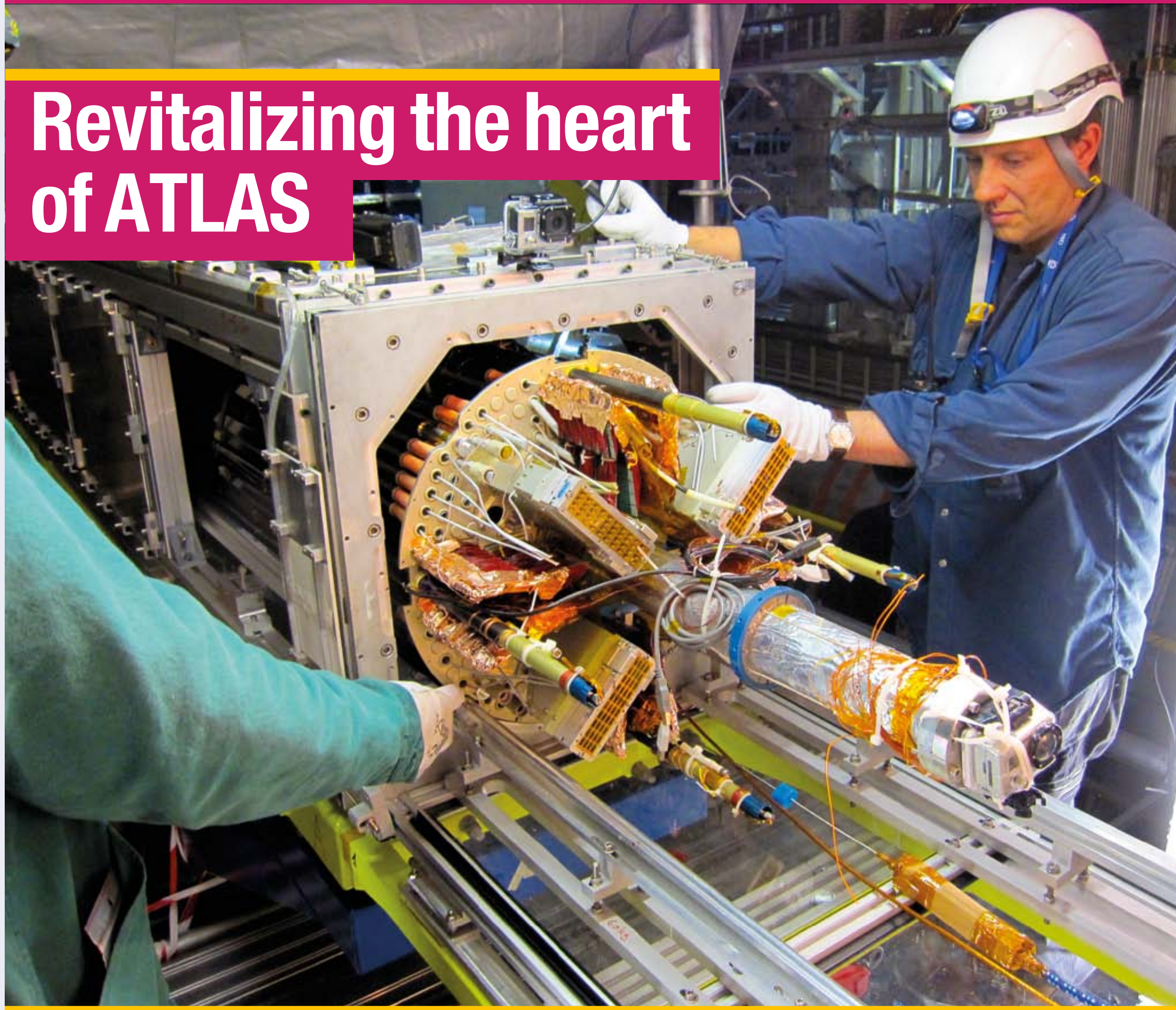
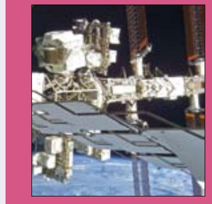
CERN COURIER

VOLUME 53 NUMBER 8 OCTOBER 2013

Revitalizing the heart of ATLAS

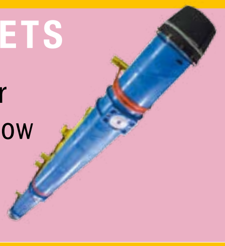




AMS-02

Results from the first two years on board the ISS
p22

LHC MAGNETS



First missions for long shutdown now accomplished
p5

EPS-HEP 2013 CONFERENCE

Highlights from Stockholm p37

Contents

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

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CERN COURIER

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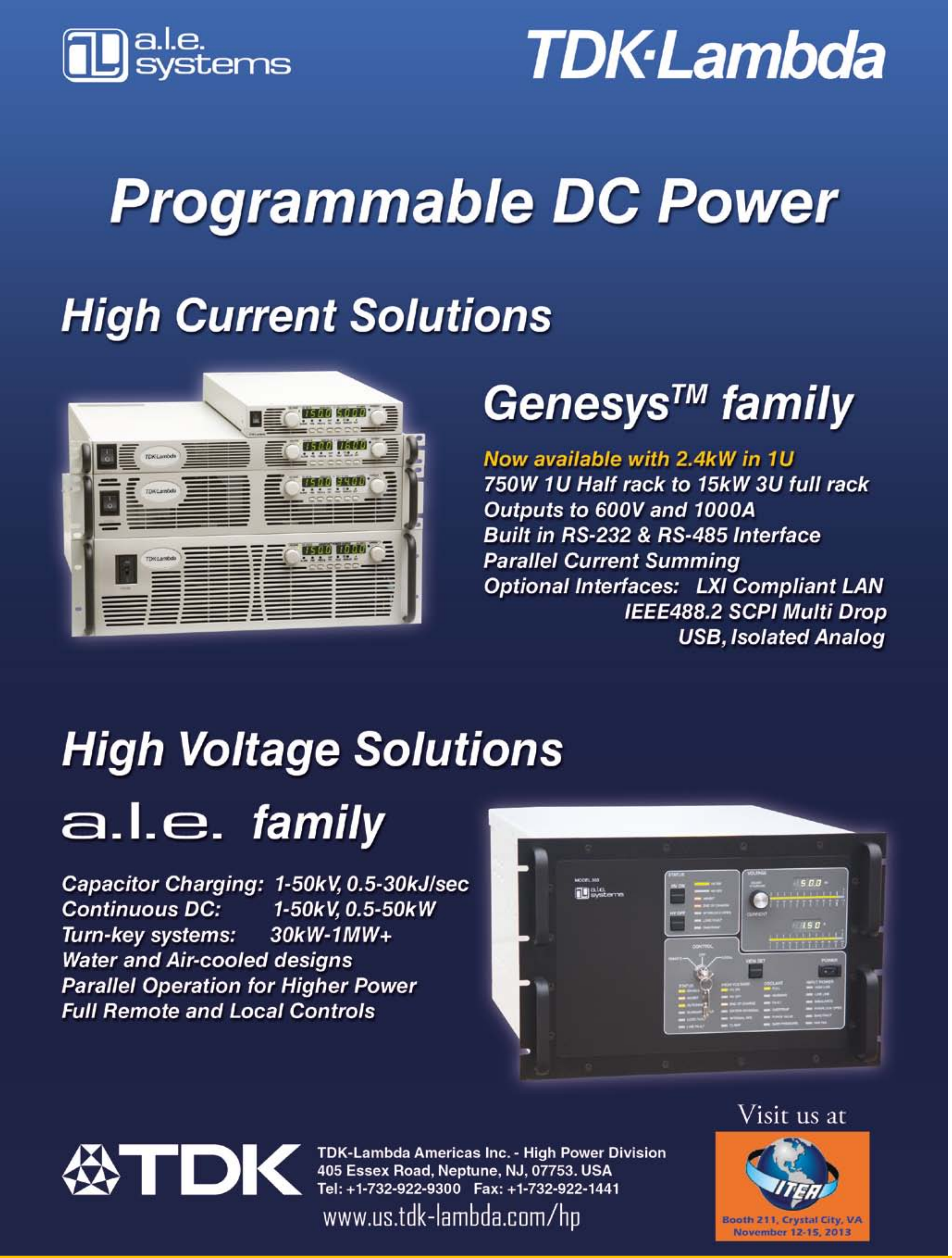
On the cover: Extracting the pixel detector from the heart of ATLAS, to allow the addition of a new, inner layer. This is just one of the many activities being undertaken by the ATLAS collaboration during the long shutdown (p28). (Image credit: Beniamino Di Girolamo.)



News

LHC NEWS

LS1: first missions accomplished

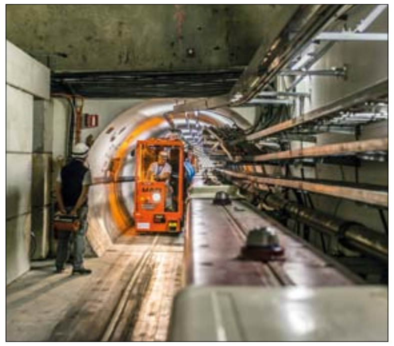
Work during the current long shutdown (LS1) of CERN's accelerator complex is making good progress since starting in February this year (*CERN Courier* March 2013 p26). Of the LHC's 1232 dipoles, 15 are being replaced together with three quadrupole-magnet assemblies. By the beginning of September, all of the replacement magnets had been installed in their correct positions and were awaiting reconnection.

Moving the heavy magnets requires specially adapted cranes and trailers. Moreover, there is only one access shaft – made for the purpose during the installation phase – that is wide enough to lower dipoles, each 15 m long and weighing 35 tonnes, to the tunnel. Underground, a specialized trailer carried the replacement magnets to where they were needed. Sensors fitted below the trailer enabled it to "read" and follow a white line along the tunnel floor.

Back in April, the first Superconducting Magnets and Circuits Consolidation (SMACC) teams began work in the tunnel. They are responsible for opening the interconnects between the magnets to lay the groundwork for the series of operations needed for the consolidation effort on the magnet circuits.

The cables of superconductor that form the LHC's superconducting dipoles and quadrupoles carry a current of up to 11,850 A. The SMACC project was launched in 2009 to avoid the serious consequences of electric arcs that could arise from discontinuities in the splices between the busbars of adjacent magnets (*CERN Courier* September 2010 p27). The main objective is to install a shunt – a small copper plate that is 50 mm long, 15 mm wide and 3 mm thick – on each splice, straddling the main electrical connection and the busbars of the neighbouring magnets. Should a quench occur in the superconducting cable, the current will pass through the copper part, which must therefore provide an unbroken path. In total, more than 27,000 shunts will have to be put in place – an average of one every three minutes for the teams of technicians, who work on a number of interconnects in parallel.

By the end of summer, three quarters of the interconnect bellows between magnets had been opened. Almost all of the SMACC consolidation activities had been completed in sector 5-6 and the first bellows were being closed again ready for testing. In sector 6-7, the installation of the shunts was being completed and the procedure was starting in sector 7-8. The aim is for completion of the task in July 2014.



(Top left) A replacement magnet is lowered slowly down the special access shaft to the transfer tunnel to the LHC. (Top right) The specialized trailer with one of the replacement magnets follows the white line en route to its final location in the LHC tunnel. (Above) A magnet is lifted off the trailer at its final location for installation in the LHC's 27 km ring.

Sommaire en français

FACILITIES

Fermilab's accelerators start up after long shutdown

One major change in the Recycler storage ring was the addition of two large RF cavities, which will be used to place adjacent proton bunches on top of one another, creating space for additional protons in the beam. (Image credit: Fermilab.)

After more than a year of upgrades, Fermilab's revamped accelerator complex is ready to send beam to its suite of fixed-target experiments, which now includes the new NOvA neutrino detector in northern Minnesota, 810 km north of the laboratory.

On 30 July, a beam of protons passed through the main injector for the first time since April 2012. With a circumference of 3.3 km, this synchrotron is the final stage of acceleration in the Fermilab accelerator complex, propelling protons from 8 to 120 GeV. Prior to the shutdown, the machine achieved a beam power of about 350 MW. The shutdown work paves the way to increase this to 700 MW.

The majority of this beam power from the main injector will be used to make neutrinos for the NOvA, MINOS and Minerva experiments. The first neutrinos were delivered on 4 September. A smaller fraction of the proton beam will go to the SeaQuest experiment and Fermilab's Test Beam Facility. In the future, the main injector will also provide beam for the planned Muon g-2 and Mu2e experiments and the Long-Baseline Neutrino Experiment.

Following the revamp, Fermilab's chain of accelerators begins with a new ion source and radio-frequency quadrupole (RFQ) to create a beam of negatively charged hydrogen ions, which are accelerated by the RFQ to an energy of 750 keV. The ions then enter the linac, which accelerates the particles to 400 MeV and sends them into the booster, where the particles pass through a foil that strips off the electrons and yields a proton beam. The upgraded booster, which accelerates protons to 8 GeV, now features solid-state RF stations and a few refurbished RF cavities. Once all of the RF cavities have been refurbished – in about two years from now – it will be able to operate at a repetition rate of up to 15 Hz. This work is part of the laboratory's Proton Improvement Plan.

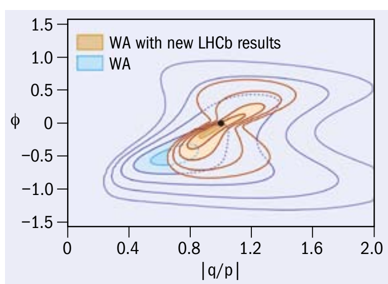
A major component of the upgraded accelerator complex is the revamped Recycler storage ring, which will play a major role in achieving higher beam power in the main injector. In the past, the Recycler stored 8 GeV antiprotons for the Tevatron collider. The Recycler is now being used for slip-stacking 8 GeV protons and as a result the main injector can deliver beam to Fermilab's neutrino experiments every 1.3 s. Previously, it could send beam every 2.2 s only.

LHC PHYSICS

New high-precision constraints on charm CP violation

There are four neutral mesons that allow particle–antiparticle transitions – mixing – and so make ideal laboratories for studies of matter–antimatter asymmetries (CP violation). Indeed, such an asymmetry has already been observed for three of these mesons: K^0, B^0 and B^0_s. So far, searches for CP violation in the fourth neutral meson – the charm meson D^0 – have not revealed a positive result. However, being the only one of the four systems to contain up quarks, the D^0 mesons provide unique access to effects from physics beyond the Standard Model.

The LHCb collaboration presented recently two new sets of measurements at the CHARM 2013 conference, held in Manchester on 31 August–4 September. Both measurements use several million decays of D^0 mesons into two charged mesons. The first is based on $D^0 \rightarrow K^+\pi^-$ decays and their charge conjugate, from data recorded in 2011 and 2012. Owing to the Cabibbo-Kobayashi-Maskawa mechanism, the direct decay is suppressed relative to its Cabibbo-favoured counterpart. However, the final state can also be reached through mixing of the D^0 meson into its antimeson, followed by the favoured decay $\overline{D}^0 \rightarrow K^+\pi^-$.



Stringent limits on CP violation: the combination of existing measurements to a world average of the CP-violation parameters |q/p| and ϕ without and with the two latest LHCb results included. The black dot marks the point corresponding to no CP violation.

These two components and their interference are distinguished through analysis of the decay-time structure of the decay – comparison of the structure for D^0 and $\overline{D}^0$ decays measures CP violation. The results give the best measurements to date of the mixing parameters in this system and are consistent with no CP violation at an unprecedented level of sensitivity (LHCb 2013a).

The second measurement is based on decays into a pair of kaons or a pair of pions and uses data that were recorded in 2011. The asymmetry between the mean lifetimes measured in D^0 and $\overline{D}^0$ decays is related to a parameter, A_Γ, which is the asymmetry between the inverse effective lifetimes of decays to the specific final state. It is a measurement of so-called indirect CP violation. The results for the two final states are $A_\Gamma(KK) = (-0.35 \pm 0.62 \pm 0.12) \times 10^{-3}$ and $A_\Gamma(\pi\pi) = (0.33 \pm 1.06 \pm 0.14) \times 10^{-3}$ (LHCb 2013b). This is the first time that a search for indirect CP violation in charm mesons has reached a sensitivity of better than 10^{-3}.

The combination of previous measurements performed by the Heavy Flavor Averaging Group hinted at potentially nonzero values for the parameters of CP-violation in D^0 mixing, |q/p| and ϕ. As the figure shows, the new results from LHCb do not support this indication. However, they provide extremely stringent limits on the underlying parameters of charm mixing, therefore constraining the room for physics beyond the Standard Model.

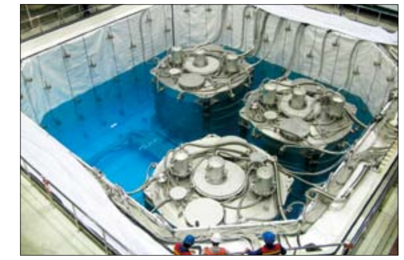
● Further reading

LHCb 2013a LHCb-PAPER-2013-053, submitted to *Phys. Rev. Lett.*

LHCb 2013b LHCb-PAPER-2013-054, submitted to *Phys. Rev. Lett.*

NEUTRINOS

Daya Bay releases new results



Antineutrino detectors in the far experimental hall of the Daya Bay experiment, located at distances of about 1.5/1.9 km from the two power plants. (Image credit Daya Bay group, University of Wisconsin.)

The international Daya Bay collaboration has announced new results, including their first data on how neutrino oscillations vary with neutrino energy, which allows them to measure mass splitting between different neutrino types. Mass splitting represents the frequency of neutrino oscillation while mixing angles represent the amplitude and both are crucial for understanding the nature of neutrinos.

The Daya Bay experiment, which is run by a collaboration of more than 200 scientists from six regions and countries, is located close to the Daya Bay and Ling Ao nuclear power plants, 55 km north-east of Hong Kong. It measures neutrino oscillation using electron antineutrinos created by six powerful nuclear reactors. Because the antineutrinos travel up to 2 km to underground detectors, some transform to another type and therefore apparently disappear. The rate at which they transform is the basis for measuring the mixing angle, while the mass splitting is determined by studying how the rate of transformation depends on the antineutrino energy.

Daya Bay's first results were announced in March 2012 and established an unexpectedly large value for the mixing angle θ_{13} – the last of three long-sought neutrino mixing angles (*CERN Courier* May 2012 p6). The new results, which were announced at the XVth International Workshop on Neutrino Factories, Super Beams and Beta Beams (NuFact2013) in Beijing, give a more precise value – $\sin^2 2\theta_{13} = 0.090 \pm 0.009$. The improvement in precision is a result both of having more data to analyse and of having the additional measurements on how the oscillation process varies with neutrino energy.

The KamLAND experiment in Japan and other solar neutrino experiments have previously measured the mass splitting Δm^2_{21} by observing the disappearance of electron antineutrinos from reactors some 160 km from the detector and the disappearance of electron neutrinos from the Sun. The long-baseline experiments MINOS in the US and Super-Kamiokande and T2K in Japan have determined the effective mass splitting $|\Delta m^2_{\mu\mu}|$ using muon neutrinos. The Daya Bay collaboration has now measured the magnitude of the mass splitting $|\Delta m^2_{ee}|$ to be $(2.54 \pm 0.20) \times 10^{-3}\ eV^2$.

The result establishes that the electron neutrino has all three mass states and is consistent with that from muon neutrinos measured by MINOS. Precision measurements of the energy dependence should further the goal of establishing a hierarchy of the three mass states for each neutrino flavour.

FUTURE COLLIDERS

ILC candidate site in Japan announced

The ILC site evaluation committee of Japan has announced the result of the assessment of the two candidate sites for an International Linear Collider (ILC). In a press conference held at the University of Tokyo on 23 August, the committee recommended the Kitakami mountains in the Iwate and Miyagi prefectures as the preferred location.

The search for an appropriate candidate site for the construction of an ILC in Japan has been ongoing since 1999, with more than 10 candidates announced in 2003. In 2010, the list was further reduced to two, consisting of Kitakami in the north-east of the main island of Japan and Sefuri in Kyushu, on Japan's south-west island. The process to assess these two remaining candidates to narrow them down from a scientific point of view began in January this year.

A site-evaluation committee of eight members was formed within Japan. In addition, two sub-committees of 16 technical experts and 12 socio-environmental experts were created separately to provide expertise on issues such as geological conditions, environmental impact, possible problems during construction and the social infrastructure of each candidate site.

After more than 300 hours of meetings, the site-evaluation committee made a tentative choice in early July. This choice was then submitted and reviewed by an international review committee. The committee recognized that the process to choose the site had been conducted with great care and that the selected site has excellent geological conditions for tunnelling and stability.

● For more information, see the Japanese ILC Strategy Council website http://ilc-str.jp/.

ASTROPARTICLE PHYSICS

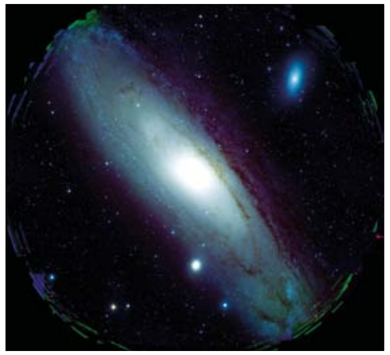
Hyper Suprime-Cam offers new view on universe

A stunning image of the nearby Andromeda galaxy (M31) captured by the Subaru Telescope's Hyper Suprime-Cam (HSC) has demonstrated the instrument's capability of fulfilling the goal to use the ground-based telescope to produce a large-scale survey of the universe. The combination of a large mirror, wide field of view and sharp imaging represents a major step into a new era of observational astronomy and will contribute to answering questions about the nature of dark energy and matter. The image marks a successful stage in the HSC's commissioning process, which involves checking all of its capabilities before it is ready for open use.

The Subaru Telescope, which saw first light in 1999, is an 8.2-m optical-infrared telescope at the summit of Mauna Kea, Hawaii, and is operated by the National Astronomical Observatory of Japan (NAOJ). The HSC – which was installed on the telescope in August last year – substantially increases the field of view beyond that which is available with the present instrument, the Subaru Prime Focus Camera, Suprime-Cam. The 3-tonnes, 3-m high HSC mounted at the prime focus contains 116 innovative, highly sensitive CCDs. Its field of view with a diameter of 1.5° is seven times that of the Suprime-Cam and with the 8.2-m primary mirror enables the high-resolution images that will underpin what will be the largest-ever galaxy survey.

First conceived of in 2002, the HSC Project was established in 2008. The major research partners are NAOJ, the Kavli Institute for the Physics and Mathematics of the Universe, the School of Science at the University of Tokyo, KEK, Academia Sinica Institute of Astronomy and Astrophysics and Princeton University, with collaborators from industry, Hamamatsu Photonics KK, Canon Inc. and Mitsubishi Electric Corporation.

Hyper Suprime-Cam. The instrument weighs 3 tonnes and is 3 m high. (Credit: NAOJ.)



M31, the Andromeda galaxy, captured by HSC. (Credit: HSC Project / NAOJ.)

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Wounded plants communicate electrically

Mammalian nervous systems send electrical signals at speeds of about 100 m/s and some plants such as the Venus flytrap are known to send electrical signals that propagate at slower speeds of 3 cm/s to trigger their leaf movements. Other plants move more slowly and none have nervous systems. Nevertheless they can send electrical signals, as Seyed Mousavi of the University of Lausanne and colleagues have recently discovered.

Using thale cress (*Arabidopsis thaliana*) plants with electrodes that are grounded in the soil or connected to the leaves, the researchers found that when Egyptian cotton leaf worm (*Spodoptera littoralis*) larvae walked on the leaves there were no changes in electrical potential. However, when the larvae started eating, electrical signals appeared at the attack site and propagated to other leaves at speeds of up to 9 cm/s. While this is slow compared with mammalian responses, it is similar to the speed of nerve-signal propagation in mussels.

Wounding in plants is known to send out a wave of reactive oxygen species. By inhibiting this, the team found that two glutamate-receptor-like proteins are involved in the production of the electrical wave. These are similar to glutamate receptors in animal nervous systems and the findings suggest an early origin for parts of mammalian nervous systems.

When one leaf of Arabidopsis thaliana *comes under attack, it sends electrical signals to trigger defence mechanisms in the others. (Image credit: Charles Andrès /CC-BY-SA_3.0.)*

● **Further reading**

S A R Mousavi *et al.* 2013 *Nature* **500** 422.

Soft actuator breakthrough

A long-standing problem is how to build soft actuators – things that could provide the sort of motion that is generated by muscles. Now, Christoph Keplinger of Harvard University and colleagues have developed a class of devices based on ionic conductors based on ionic hydrogels that stretch under an applied electric field. These muscle-mimics are fully transparent across the visible spectrum and can operate at frequencies above 10 kHz. The researchers demonstrated the technology by making a transparent actuator providing large area (up to 167%) strains and a transparent speaker that produces sound across the full audible range of frequencies.

● **Further reading**

C Keplinger *et al.* 2013 *Science* **341** 984.

Near-infrared metatronic nanocircuits

Lumped elements in electrical systems such as resistors, capacitors and inductors are hard to imagine at high frequencies but Humeyra Caglayan and colleagues at the University of Pennsylvania have shown that metamaterials using simple nanorod geometry and transparent plasmonic conducting oxides can do the job all of the way up to near-infrared wavelengths. Earlier approaches using silicon nitride could not reach the 1.55 μm wavelength that is used by most telecommunications optical fibres, a problem that is now overcome using indium tin oxide. Changing the shape and spacing of the nanorods, adding nickel chromium to the tops of the rods or filling the inter-rod gaps with lead sulphide can all be used to tune the circuits. Band-gap or band-pass filters at almost optical frequencies can now be conceived of and designed as electrical circuitry.

● **Further reading**

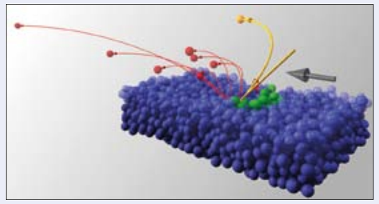
H Caglayan *et al.* 2013 *Phys. Rev. Lett.* **111** 073904.

Collisions in sandstorms

Computer simulations by Marcus Carneiro of the Swiss Federal Institute of Technology in Zurich and colleagues show that there is more to sandstorms than just "sand blowing around". In a sandstorm, the grains fly mostly close to the ground, but a few – "saltons" – are kicked upwards where they are accelerated by stronger winds. When they fall, they kick up new saltons. Surprisingly, when the simulations included mid-air collisions between grains, rather than diminishing, the amount of sand in the air could double through collisions between lower ejected grains or "leapers". It turns out that the optimal coefficient of restitution for the collision to maximize sand flux is about 0.7, similar to experimentally measured values.

● **Further reading**

M V Carneiro *et al.* 2013 *Phys. Rev. Lett.* **111** 058001.



In a simulated sandstorm, a "salton" (yellow) smashes into the dense particle bed near the ground and ejects "leapers" (red). The arrow indicates wind direction.

Nanoscale thermometry in living cells

Taking temperatures at nanoscales has become easier thanks to the work of G Kucsko of Harvard University and colleagues. They use tiny nanodiamonds with single-nitrogen atom impurities, creating a nitrogen-vacancy (NV) centre in which two neighbouring carbon atoms are replaced by a nitrogen atom and a vacancy. The ground state of the NV is split into two energy levels and the difference between them (in the microwave region) is a sensitive function of temperature because it depends on thermally induced lattice strains. Temperature differences of 1.8 mK can be measured on length scales of 200 nm. By putting gold nanoparticles that can be heated by a laser and nanodiamonds into a single human embryonic fibroblast they could also demonstrate temperature-gradient control and mapping at the subcellular level. This opens up new possibilities for research into what goes on inside cells.

● **Further reading**

G Kucsko 2013 *Nature* **500** 54.

Astrowatch

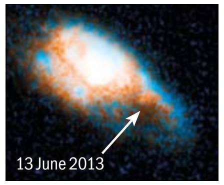
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

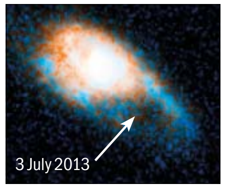
Kilonova solves the short GRB puzzle

Follow-up observations of a recent short-duration gamma-ray burst (GRB) provide the strongest evidence yet that these elusive bursts result from the merger of two neutron stars. The evidence is in the detection with the Hubble Space Telescope (HST) of a new kind of stellar blast – a kilonova.

During the 1990s, the detection of thousands of GRBs by the Burst and Transient Source Experiment (BATSE) revealed two bumps in the distribution of their duration. GRBs were therefore classified as being of either short or long duration, with a dividing line at 2 s. The origin of these brief flashes of gamma rays remained mysterious until the "rosetta stone" burst, GRB 030329 (*CERN Courier* September 2003 p15). A supernova explosion was found to be associated with this bright, relatively nearby burst of 29 March 2003 and therefore proved that long-duration GRBs result from core-collapse in massive stars. The collapse of the core forms a black hole, which powers a pair of relativistic jets that drill their way through the remains of the dying star and produce an energetic flash of gamma rays (*CERN Courier* June 2013 p12).

So what is the origin of the short-duration GRBs? Are they really of a different nature? The favoured hypothesis is that they are produced by the merger of two neutron stars, or a neutron star and a black hole (*CERN Courier* December 2005 p20). Theorists expect such mergers to produce neutron-rich radioactive isotopes, whose decay within days would lead to a transient infrared source. Such a hypothetical transient is called a kilonova because its brightness is about a thousand times that of a typical stellar nova, but is still 10 to 100 times less bright than a supernova explosion.





The host galaxy of GRB 130603B. On 13 June, Hubble's Wide Field Camera revealed a glow in near-infrared light at the source of the GRB (top). By 3 July, the source had faded (below). The fading glow provided key evidence that it was the decaying fireball of a new type of stellar blast – a kilonova. (Image credit: NASA/ESA/N Tanvir (University of Leicester)/A Fruchter (STScI)/A Levan (University of Warwick).)

A team of astronomers led by Nial Tanvir of the University of Leicester now claims to have detected the first kilonova associated with the short GRB 130603B. The burst was detected on 3 June by the Burst Alert Telescope on the Swift spacecraft. The subsequent detection of an optical afterglow allowed the team to pinpoint the location of this genuine short GRB, which lasted only about 0.2 s. The burst occurred in a known galaxy at a redshift of $z = 0.356$, an ideal target for the sharp vision of the Hubble Space Telescope (HST).

Two HST observations have been performed: one nine days after the burst and the second after 30 days. While no transient source is detected in visible light, the earlier near-infrared image has a point source at the position of the burst's afterglow, which is no longer present in the later observation. Furthermore, the brightness of this source is found to be significantly in excess of the extrapolation of the afterglow decay to nine days after the burst. This discrepancy reveals the presence of an additional component that Tanvir and his team suggest is the expected kilonova. The time delay, infrared brightness and the absence of emission in the visible light are characteristics that are all consistent with recent calculations for the emission of a kilonova.

If the infrared transient observed by the HST is correctly interpreted, this would be a new milestone in the understanding of GRBs. It would confirm that short GRBs are indeed produced by the merger of two compact stellar objects ejecting neutron-rich radioactive elements decaying in a kilonova blast. This would also be good news for searches for gravitational-wave signals from the merger of compact objects. Detecting the kilonova transient associated with a gravitational-wave signal would allow the location and distance of the source to be obtained, even in the absence of a detectable short GRB when the gamma-ray emission is pointing away from the Earth.

● **Further reading**
N R Tanvir *et al.* 2013 *Nature* **500** 547.

Picture of the month

This unprecedented image of a double jet from a young star combines radio observations acquired by the Atacama Large Millimeter/submillimeter Array (ALMA) with visible-light observations from ESO's New Technology Telescope (NTT). Young stars are violent objects that can eject material at speeds as high as 10^6 km/h. When this material crashes into the surrounding gas it glows, creating a Herbig-Haro object (Picture of the Month, *CERN Courier* September 2012 p14). Herbig-Haro 46/47 is a spectacular example that is situated about 1400 light-years away. Until now, the visible part of the jet (in pink and purple, upper left) had been seen. Now, the ALMA observations reveal for the first time the counter-jet (orange and green, lower right), which is hidden in the visible by an opaque cloud of gas and dust. (Image credit: ESO/ALMA (ESO/NAOJ/NRAO)/H Arce. Acknowledgements: Bo Reipurth.)

CERN Courier Archive: 1970

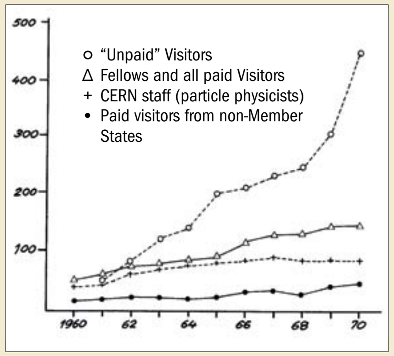
A LOOK BACK TO CERN COURIER VOL. 8, OCTOBER 1970, COMPILED BY PEGGIE RIMMER

CERN

Fellows and Visitors

It is not always realized that the major part of CERN's research programme is carried out by Fellows and Visitors. This summer their number was about 700 while staff members who are theoretical or experimental particle physicists numbered about 90. They come from 108 Universities and Research Institutes in CERN Member States and 72 in non-Member States. Most Visitors are "unpaid" (by CERN); financial support comes from their parent University.

In view of the importance of Fellows and Visitors for the research effort of the Laboratory and of Universities and Research Institutes in so many countries, a paper was prepared which reviewed the evolution of the programme since 1960 and made proposals for the years up to 1975; it was approved by Council in June. The proposals imply an increase of 30 to 50% in Fellows and Visitors from Member States. Expenditure on Visitors from non-Member States will remain at about 1% of the total personnel budget each year.



Evolution of (some) CERN personnel 1960–1970. Participation in electronic experiments at the Proton Synchrotron explains the recent marked increase in unpaid visitors.

Also, during the summer months, about a hundred University students (not included in the figure) come to CERN. They participate in the day-to-day work of research or technical groups and attend a special course of lectures.

● Compiled from texts on pp314–315.

COMPUTING

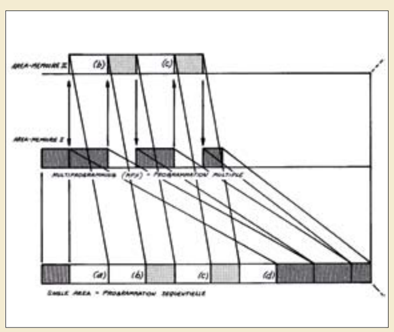
Multiprogramming on PS computer

The present capacity of the IBM 1800 computer controlling the PS would be greatly exceeded when the Booster is brought into operation, so a multiprogramming job-distribution system has been adopted to reduce "dead time" in the central processing unit, CPU.

A computer normally uses two kinds of memories. Internal memories (core or ferrite) are fairly expensive and generally installed in quantities that can store only small amounts of data. Their advantage is a very short access time, of the order of a microsecond. Cheaper auxiliary memories (disc or tape) are used to store large quantities of data; these cannot be transmitted as rapidly to the CPU.

Programs which the CPU needs often must be constantly available in "fixed core" ferrite memory. Others can be stored on discs and transferred, when needed, to reserved parts of "variable core" ferrite memory, taking from 50 ms to a few seconds.

Up to now time-sharing has been used, each program being processed in sequence according to its allocated priority. A higher priority program can interrupt one of lower priority, which returns to the disc until the higher priority one finishes. If a running program requires further data and there is a long waiting time (a frequent occurrence at the PS where data come from several machine cycles), it is possible to pass on to another program. However, this transfer can become complex and has not been used. The loss of time has been accepted and effective CPU time is a small fraction of the total time.



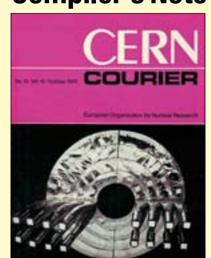
Operating time of the central processing unit in a computer. The bottom line shows time-sharing, where a program (dark blocks) is interrupted by a higher priority one (paler). Block (a) represents the time taken transferring to the disc store, (b) bringing in the higher priority program, (c) calling for more data and (d) returning the first program. In the top lines, multiprogramming illustrates time saving by shuffling between programs.

Multiprogramming uses several distinct variable cores. At the PS, there will be one for each of the three machine sections – linac, booster and synchrotron ring. Transition from one to another is very fast and it is possible to deal with a part of one program, then a second, then a third or a fourth, to use up dead time. Efficiency close to 50% should be possible, compared with the former rate of about 10%.

Multiprogramming requires increasing the number of "fixed cores" from 16 to 20 K words, and "variable cores" from 8 to 20 K words. This will quadruple the capacity for only 25% of the cost of the computer.

● Compiled from texts on pp275–276.

Compiler's Note



Anyone queuing for lunch at CERN these days cannot fail to notice the preponderance of young people. Research physicists on the CERN staff still number a modest 80 or so but there are now around 540 fellows, plus some 400 technical and administrative students and "stagiares" (trainees). CERN summer students swell the numbers for two or three months in the sunny season, 143 from member states and 133 from non-member states this year.

A most encouraging sign for the future, making it worth waiting in line!

Enlightening the dark

New results from XENON100 augur well for its larger successor, XENON1T, in the search for dark matter.

Numerous astronomical observations indicate that about one quarter of the energy content of the universe is made up of a mysterious substance known as dark matter. The Planck collaboration recently measured this to the precise percentage of 26.8%, which is slightly greater than the previous value from nine years of observations by the Wilkinson Microwave Anisotropy Probe (WMAP). Dark matter, which is five times more abundant than baryonic matter, provides compelling evidence for new physics and could be made of a new particle not present in the Standard Model. Theories beyond the Standard Model, such as supersymmetric models or theories with extra dimensions, suggest promising candidates and naturally predict so-called weakly interacting massive particles (WIMPs), which are stable or have lifetimes longer than the age of the universe.

There are several complementary strategies to detect dark matter. The ATLAS and CMS experiments at the LHC search for such particles produced in proton–proton collisions. Indirect searches, for example by the AMS-02 or IceCube detectors, aim at detecting the products of dark-matter annihilation in cosmic rays.

Because dark-matter particles are expected to be abundant in the Galaxy, with an energy density of about 0.3 GeV/c^2/cm^3 at the location of the Sun, the most direct strategy is to look for their interactions in laboratory-based detectors. In general, it is possible to study spin-independent WIMP–nucleon interactions – which scale with the square of the target's mass number, A – or spin-dependent couplings to unpaired nucleons in the target nucleus. Because of their nonrelativistic Maxwellian velocity distribution with a typical speed of around 220 km/s and because the WIMPs interact significantly only with nuclei (and not with the electrons), the expected signal is a featureless exponential nuclear-recoil spectrum. The recoil energies depend on the mass of the WIMP and on the target material and are typically of the order of a few tens of kilo-electron-volts.

Because the expected interaction rates are small, a sensitive WIMP detector needs to feature a large target mass, an ultralow background and a low energy threshold. In addition, it should allow the distinction of the nuclear-recoil signal (from WIMPs and also from background neutrons) from the overabundant electronic-recoil background from γ and β radiation.

The most sensitive dark-matter detector to date is XENON100, which is operated by the XENON collaboration and situated at the Italian Laboratori Nazionali del Gran Sasso (LNGS), under about 1.3 km of rock that provides a natural shield from cosmic rays. The experiment searches for WIMP interactions in a target of 62 kg of liquid xenon. The noble gas xenon is cooled to around –90°C to bring it to the liquid state with a density of around 3 g/cm^3. Its high mass number, A, of around 130 makes it one of the heaviest of all target materials for dark-matter detection.

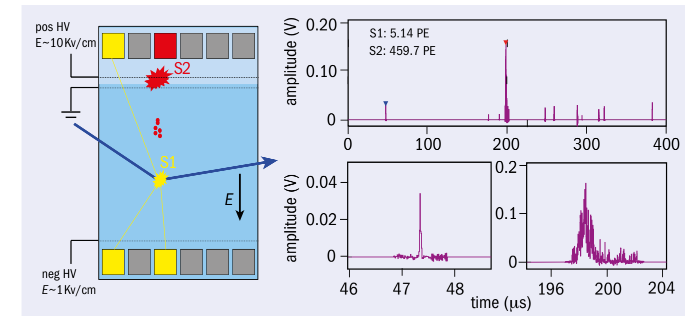


Fig. 1. The working principle of the dual-phase TPC. The waveform shows a low-energy event interacting in the XENON100 target (illustrated by the blue arrow), defined by the prompt (light, S1) and the secondary (charge, S2) scintillation signals.

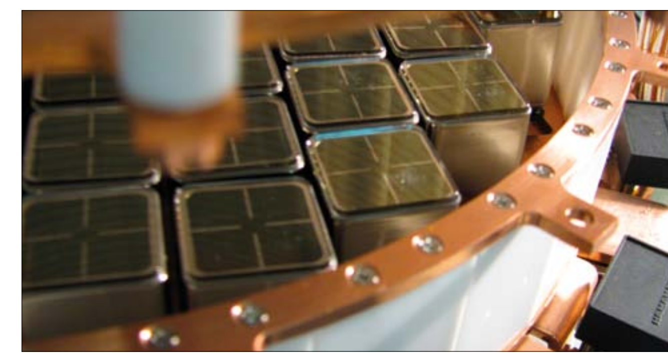


Fig. 2. A view inside the XENON100 detector shows the array of PMTs below the TPC. (Image credit: XENON collaboration.)

XENON100 is operated as a dual-phase time-projection chamber (TPC), as figure 1 illustrates. Particle interactions excite the liquid xenon, leading to prompt scintillation light, and also ionize the target atoms. A uniform electric field causes the ionization electrons to drift away from the interaction site to the top of the TPC. Here a strong electric field extracts them into the xenon-gas phase above the liquid. Subsequent scattering on the gas atoms leads to signal amplification and a secondary scintillation signal, which is directly proportional to the ionization extracted. Both the prompt and secondary scintillation light are detected by two arrays of low-radioactivity photomultipliers (PMTs), which are ▷

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VOLUME 53 NUMBER 8 OCTOBER 2013
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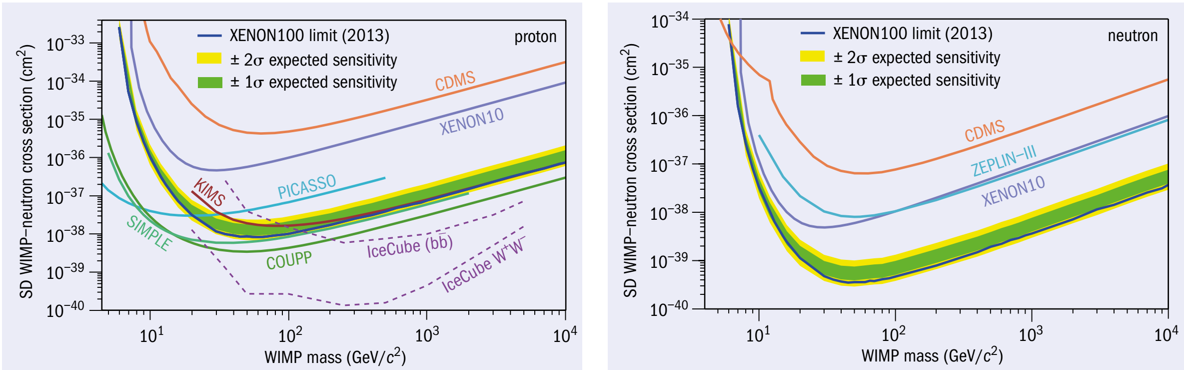


Fig. 3. XENON100 results on spin-dependent WIMP–nucleon interactions, assuming couplings only to protons (left) or neutrons (right).

installed above and below the cylindrical target of around 30 cm height and 30 cm diameter (figure 2, p13). The PMTs are immersed in the liquid and gaseous xenon to achieve the highest-possible light-detection efficiency and therefore the lowest threshold. The 3D position of the interaction vertex is obtained by combining the time difference between the prompt and the secondary scintillation signal with the hit pattern of the localized secondary signal on the array of 98 PMTs above the target. The number of secondary signals defines the event multiplicity.

The detector was built from materials selected for their low intrinsic radioactivity. Thanks to its novel detector design – placing most radioactive components outside of a massive passive shield – and the self-shielding provided by the liquid xenon, XENON100 features the lowest published background of all dark-matter experiments. The self-shielding is exploited by selecting only events that interact with the inner part of the detector ("fiducialization") and by rejecting all events that exhibit a coincident signal in the active veto, which is made of 99 kg of liquid xenon that surrounds the target. Because of their small cross-section, WIMPs will interact only once in the detector, so background can be reduced further by selecting single-scatter interactions with a charge-to-light ratio typical for the expected nuclear-recoil events.

In the summer of 2012, the XENON collaboration published results from a search for spin-independent WIMP–nucleon interactions based on 225 live days of data (XENON collaboration 2012). No indication for dark matter was found but the derived upper limits are the most stringent to date for WIMP masses above 7 GeV/c^2. The same data have now been interpreted in terms of spin-dependent interactions and the results published recently (XENON collaboration 2013). This latest analysis requires knowledge of the axial-vector coupling and the nuclear structure of the two xenon isotopes with unpaired nucleons, ^{129}Xe and ^{131}Xe. Improved calculations were employed here, which are based on chiral-effective field-theory currents. Compared with older calculations, these yield superior agreement between calculated and predicted nuclear energy-spectra (Menendez *et al*. 2012).

The specific nuclear structure of the relevant xenon isotopes leads to different sensitivities for the two extreme cases that are usually considered. For the case where WIMPs are assumed to couple to protons only, the new XENON100 limit is competitive with other results (figure 3, left). Indirect dark-matter searches looking for signals from the annihilation of WIMPs trapped in the Sun (which mainly consists of protons) are particularly sensitive to this channel. For the neutron-only coupling, XENON100 sets a new best limit for most masses, improving the previous constraints by more than an order of magnitude (figure 3, right).

While XENON100 continues to take science data at LNGS, the development of a larger liquid-xenon detector is well under way. XENON1T will be about 35 times larger than XENON100, with a TPC of around 100 cm in height and diameter. The aim is to reach a dark-matter sensitivity two orders of magnitude better than the current best value. This will probe a significant part of the theoretically favoured WIMP parameter space but will require the radioactive background of the new instrument to be 100 times lower than that of XENON100. The greatly increased liquid xenon target mass of more than two tonnes helps to achieve this goal.

The largest background challenge comes from uniformly distributed traces of radioactive radon (mainly ^{222}Rn) and krypton (^{85}Kr, present in natural krypton at a fraction of about 10^{-11}) dissolved in the xenon, because the background from these isotopes cannot be reduced by target fiducialization. To achieve the background goals for XENON1T, the contamination of radon and krypton in the xenon filling will be reduced to below a level of parts per 10^{12} by careful material selection and surface treatment and by cryogenic distillation, respectively. Additionally, all of the construction materials for the detector are being carefully selected based on their intrinsic radioactivity using ultrasensitive germanium detectors. A few of the world's most sensitive detectors are owned and operated by institutions in the XENON collaboration.

The XENON1T detector will be placed inside a large water shield to protect it from environmental radioactivity (figure 4). The water will be equipped with PMTs to tag muons via emission of Cherenkov light, because muon-induced neutrons could mimic WIMP signals. The construction of the water tank is underway in Hall B of LNGS and will be finished by the end of 2013. Together with the XENON1T service building, it will be the first visible landmark of the experiment underground. The other XENON1T systems – from detector and cryogenics to massive facilities for the storage and purification of xenon – are currently being designed, built, commissioned and tested at the various collaborating institutions.

Fig. 4. Illustration of the XENON1T detector, installed underground inside a 9.6-m-diameter water shield, which is operated as a Cherenkov muon veto. The construction work commenced in summer this year, and commissioning is expected in 2014. (Image credit: The XENON collaboration.)

In particular, the challenges associated with building a TPC of 100 cm drift length, which will be the longest liquid xenon-based TPC ever, are being addressed with dedicated R&D set-ups.

Once the main underground facilities are erected, the XENON1T low-background cryostat – to contain the TPC and more than three tonnes of xenon – will be installed inside the water shield. The infrastructure for the storage, purification and liquefaction have been designed to handle more than double the amount of xenon initially used in XENON1T. Their commissioning underground is expected to be completed by the summer of 2014. The timeline foresees commissioning of the full XENON1T experiment by the end of 2014 and the first data by early 2015. After two years of data-taking, XENON1T will reach a sensitivity of 2×10^{-47} cm^2 for spin-independent WIMP-nucleon cross-sections at a WIMP mass of 100 GeV/c^2. This is a factor 100 better than the current best WIMP result from XENON100.

Further reading

XENON100 collaboration 2012 *Phys. Rev. Lett.* **109** 181301.
XENON100 collaboration 2013 *Phys. Rev. Lett.* **111** 021301.
J Menendez *et al.* 2012 *Phys. Rev.* **D86** 103511.

Résumé

Coup de projecteur sur l'univers noir

L'expérience XENON100 traque les interactions des particules massives interagissant faiblement (WIMP) dans une cible constituée de 62 kg de xénon liquide. Situé aux Nazionali del Gran Sasso (LNGS), ce détecteur de matière noire est le plus sensible à ce jour. Les résultats d'une étude réalisée d'après des données enregistrées durant 225 jours n'indiquent aucune présence de matière noire, mais les limites supérieures déduites sont à ce jour les plus restrictives pour une masse de WIMP supérieure à 7 GeV/c². Le détecteur XENON1T, qui sera environ 35 fois plus grand, est également en cours de développement. Le but est d'améliorer de deux ordres de grandeur la sensibilité de détection de la matière noire.

Marc Schumann, Albert Einstein Center for Fundamental Physics, Bern.

ALICE: on the trail of a new state of matter

A review of results on the hot, dense medium produced in heavy-ion collisions at the LHC.

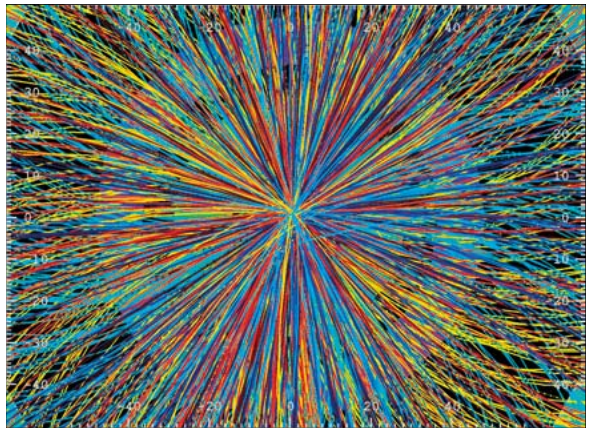


Fig. 1. The star-like burst of one of the events recorded by the ALICE experiment during the first lead–ion collisions at the LHC at a centre-of-mass energy of 2.76 TeV per nucleon pair.

The dump of the lead beam in the early morning of 10 February this year marked the end of a successful and exciting first LHC running phase with heavy-ion beams. It started in November 2010 with the first lead–lead (PbPb) collisions at $\sqrt{s_{NN}} = 2.76$ TeV per nucleon pair, when in one month of running the machine delivered an integrated luminosity of about 10 μb^{-1} for each experiment. In the second period a year later, the LHC's heavy-ion performance exceeded expectation because the instantaneous luminosity reached more than 10^{26} cm^{-2} s^{-1} and the experiments collected about 10 times more integrated luminosity. A pilot proton–lead (pPb) run at $\sqrt{s_{NN}} = 5.02$ TeV took place in September 2012, providing enough events for first surprises and publications. A full run followed in February, delivering 30 nb^{-1} of pPb collisions – precious reference data for the PbPb studies.

The ALICE experiment is optimized to cope with the large particle-densities produced in PbPb collisions and nothing was left unprepared for the first heavy-ion run in 2010. Nevertheless, immediately before the first collisions the tension was palpable until the first event displays appeared (figure 1). The image of the star-like burst with thousands of particles recorded by the time-projection chamber became an emblem for the accomplishment of a collaboration that had worked for 20 years on developing, building and operating the ALICE detector. With the arrival of a wealth of data, a new era for comprehension of the nature of matter at high temperature and density began, where QCD predicts that quark–gluon plasma (QGP) – a de-confined medium of quarks and gluons – exists.

Before the LHC started up, the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven was the most powerful machine of this kind, producing collisions between gold (Au) ions with a maximum energy of 200 GeV. After 10 years of analysis – just before the first PbPb data-taking at the LHC – the experimental collaborations at RHIC came to the surprising conclusion that central AuAu collisions create droplets of an almost perfect, dense fluid of partonic matter that is 250,000 times hotter than the core of the Sun. Their results indicate that because of the strength of the colour forces the plasma of partons (quarks and gluons) produced in these collisions has not yet reached its asymptotically gas-like state and, therefore, it has been dubbed strongly interacting QGP (sQGP). This finding raised several questions. What would the newly created medium look like at the LHC? How much denser and hotter would it be? Would it still be a perfect liquid or would it be closer to a weakly coupled gas-like state? How would the abundantly produced hard probes be modified by the medium?

Denser, hotter, bigger

In the most central PbPb collisions at the LHC, the charged-particle density at mid-rapidity amounts to $dN/d\eta \approx 1600$, which is about 2.1 times more per nucleon pair participating in the collision than at RHIC. Since the particles are also, on average, more energetic at the LHC, the transverse-energy density is about 2.5 times higher. This allows a rough estimate of the energy density of the medium that is produced. Assuming the same equilibration time of the plasma at RHIC and the LHC, the energy density has increased at the LHC by at least a factor of three, corresponding to an increase in temperature of more than 30% (*CERN Courier* June 2011 p17). ▷

Immediately before the first collisions the tension was palapable until the first event displays appeared.

A more accurate thermometer is provided by the spectrum of the thermal photons emitted by the plasma that reach the detector unscathed. Whereas counting inclusive charged particles is a relatively easy task, the thermal photons have to be arduously separated from a large background of photons from meson decays and photons produced by QCD processes in collisions with large momentum-transfer, p_T. The thermal photons appear in the low-energy region of the direct-photon spectrum ($p_T^{\gamma}<2$ GeV/*c*) as an excess above the yield expected from next-to-leading order QCD and have an exponential shape (figure 2). The inverse slope of this exponential measured by ALICE gives a value for the temperature, $T=304\pm51$ MeV, about 40% higher than at RHIC. In hydrodynamic models, this parameter corresponds to an effective temperature averaged over the time evolution of the reaction. The measured values suggest initial temperatures that are well above the critical temperature of 150–160 MeV.

In the same way that astronomers determine the space–time structure of extended sources using Hanbury-Brown–Twiss optical intensity interferometry, heavy-ion physicists use 3D momentum correlation-functions of identical bosons to determine the size of the medium produced (the freeze-out volume) and its lifetime. In line with predictions from hydrodynamics, the volume increases between RHIC and the LHC by a factor of two and the system lifetime increases by 30% (*CERN Courier* May 2011 p6).

Perfect quantum liquids are characterized by a low shear-viscosity to entropy ratio, η/s, for which a lower limit of $h/4\pi k_B$ is postulated. This property is directly related to the ability of the medium to transform spatial anisotropy of the initial energy density into momentum-space anisotropy. Experimentally, the momentum-space anisotropy is quantified by the Fourier decomposition of the distribution in azimuthal angle of the produced particles with respect to the reaction plane. The second Fourier coefficient, v_2, is commonly denoted as elliptic flow. With respect to RHIC, v_2 is found to increase in mid-central collisions by 30% (*CERN Courier* April 2011 p7). Calculations based on hydrodynamical models show that the v_2 measured at the LHC is consistent with a low η/s, close to or challenging the postulated limit.

Further knowledge on the collective behaviour of the medium has been obtained from the spectral analysis of pions, kaons and protons. The so-called blast-wave fit can be used to determine the common radial expansion velocity, $\langle\beta_r\rangle$. The velocity measured by ALICE comes to about 0.65 and has increased by 10% with respect to RHIC.

In di-hadron azimuthal correlations, elliptic flow manifests as cosine-shaped modulations that extend over large rapidity ranges. At the LHC, for central collisions, more complicated structures become prominent. These can be quantified by higher-order Fourier coefficients. Hydrodynamical models can then relate them to fluctuations of the initial density distribution of the interacting nucleons. Wavy structures that were formerly discussed at RHIC, such as Mach-cones and soft ridges, have now found a simpler explanation. By selecting events with larger than average higher-order Fourier coefficients, it is possible to select and study certain initial-state configurations. "Event shape engineering" has therefore been born.

As discussed above, using hydrodynamical models, the basic parameters of the medium can be extrapolated in a continuous manner between the energies of RHIC and the LHC and they turn out to show a moderate increase. Although this might not seem to be a spectacular discovery, its importance for the field should not be underestimated: it marks a transition from data-driven discoveries to precision measurements that constrain model parameters.

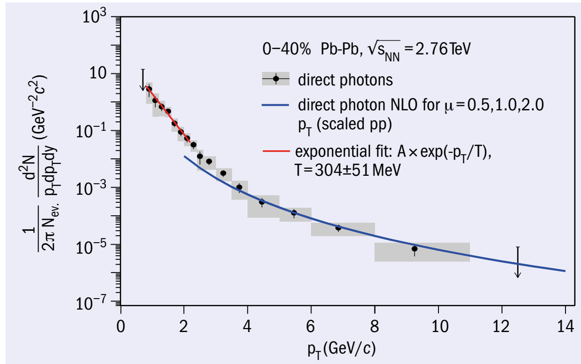


Fig. 2. The direct photon spectrum with exponential fit and next-to-leading order (NLO) prediction, as measured by ALICE in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV.

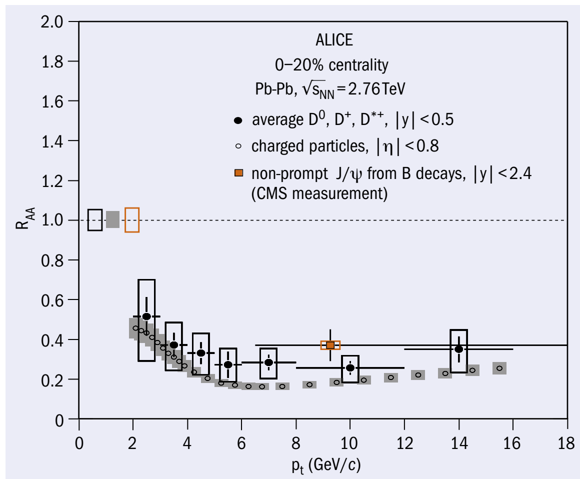


Fig. 3. Average nuclear-modification factor, R_{AA}, of D mesons in the 0–20% centrality class, compared with those for charged hadrons and non-prompt J/ψ from B decays in the same centrality class. The charged hadron R_{AA} is shown only for $2<p_T<16$ GeV/c.

Hard probes

What is new at the LHC is the large cross-section (several orders of magnitude higher with respect to RHIC) for so-called hard processes, e.g. the production of jets and heavy flavour. In these cases, the production is decoupled from the formation of the medium and, therefore, as quasi-external probes traversing the medium they can be used for tomography measurements – in effect, to see inside the medium. Furthermore, they are well calibrated probes because their production rates in the absence of the medium can be calculated using perturbative QCD. Hard probes open a new window for the study of the QGP through high-p_T parton and heavy-quark transport coefficients, as well as the possible thermalization and recombination of heavy quarks.

High-p_T partons are produced in hard interactions at the early stage of heavy-ion collisions. They are ideal probes because they traverse the medium and their yield and kinematics are influenced by its presence. The ability of a parton to transfer momentum to the medium is particularly interesting. Described by a transport parameter, it is related to the density of colour charges and the coupling of the medium: the stronger the coupling, the larger the transport coefficient and, therefore, the modification of the probe. Energy loss of partons in the medium is caused by multiple elastic-scattering and gluon radiation (jet quenching). This was first observed at RHIC in the suppression of high-p_T particles with respect to the appropriately scaled proton–proton (pp) and proton–nucleus (pA) references (the nuclear-modification factor R_{AA}) and from the disappearance of back-to-back particle correlations.

At the LHC, rates are high at transverse energies where jets can be reconstructed above the fluctuations of the background-energy contribution from the underlying event. In particular, for jet transverse energies $E_T>100$ GeV, the influence of the underlying event is relatively small, allowing robust jet-measurements. The ATLAS and CMS collaborations – whose detectors have almost complete calorimetric coverage – were the first to report direct observation of jet-quenching via the di-jet energy imbalance at the LHC (*CERN Courier* January/February 2011 p6 and March 2011 p6). However, the measurements of the suppression of inclusive single-particle production show that quenching effects are strongest for intermediate transverse momenta, $4<p_T<20$ GeV/*c*, corresponding to parton p_T values in the range around 6–30 GeV/*c* (*CERN Courier* June 2011 p17).

ALICE can approach this region – while introducing the smallest possible bias on the jet fragmentation – by measuring jet fragments down to low p_T ($p_T>150$ MeV/*c*). Although in jet reconstruction more of the original parton energy is recovered than with single particles, for the most central collisions the observed single inclusive jet suppression is similar to the one for single hadrons, with $R_{AA}^{jet}=0.2–0.4$ in the range $30<p_T^{jet}<100$ GeV/*c*. Furthermore, no indication of energy redistribution within experimental uncertainties is observed from the ratios of jet yields with different cone sizes (*CERN Courier* June 2013 p8).

The suppression patterns are qualitatively and – to some extent – quantitatively similar for single hadrons and jets. This can be best explained by partonic energy loss through radiation mainly outside the jet cone that is used by the jet reconstruction algorithm and in-vacuum (pp-like) fragmentation of the remnant parton. Before the LHC start-up, it was widely believed that jets are more robust objects, i.e. jet quenching would soften their fragmentation without changing the total energy inside the cone. The study of jet fragmentation would have allowed insight into the details of the energy-loss mechanism. The latter is still true, but the energy lost by the partons has to be searched for at large distances from the jet axis, where the background from the underlying event is large. Detailed studies of the momentum and angular distribution of the radiated energy – which require future higher-statistics jet samples – will provide more detailed information on the nature of the energy-loss mechanisms.

Heavy versus light

At the LHC, high-p_T hadron-production is dominated by gluon fragmentation. In QCD, quarks have a smaller colour-coupling factor with respect to gluons, so the energy loss for quarks is expected to be smaller than for gluons. In addition, for heavy quarks with $p_T<m_q$, small-angle gluon radiation is reduced by the so-called "dead-cone effect". This will reduce further the effect of the medium. ALICE has measured the nuclear-modification factor for the charm mesons D^0, D^+ and D^{*+} for $2<p_T<16$ GeV/*c* (figure 3). For central PbPb collisions, a strong in-medium energy loss of 0.2–0.34 is observed in the range $p_T>5$ GeV/*c*. For lower transverse momenta there is a tendency for the suppression of D^0 mesons to decrease (*CERN Courier* June 2012 p15, January/February 2013 p7).

The suppression is almost as large as that observed for charged particles that are dominated by pions from gluon fragmentation. This observation favours models that explain heavy-quark energy loss by additional mechanisms, such as in-medium hadron formation and dissociation or partial thermalization of heavy quarks through re-scatterings and in-medium resonant interactions. Such a scenario is further corroborated by measurement of the D-meson elliptic-flow coefficient, v_2. For semi-central PbPb collisions, a positive flow is observed in the range $2<p_T<6$ GeV/*c* indicating that the interactions with the medium transfer information on the azimuthal anisotropy of the system to charm quarks.

The suppression of the J/ψ and other charmonia states, as a result of short-range screening of the strong interaction, was one of the first signals predicted for QGP formation and has been observed both at CERN's Super Proton Synchrotron and at RHIC. At the LHC, heavy quarks are abundantly produced – about 100 $c\bar{c}$ pairs per event in central PbPb collisions. If these charm quarks roam freely in the medium and the charm density is high enough, they can recombine to form quarkonia states, competing with the suppression mechanism.

Indeed, in the most central collisions a lower J/ψ suppression than at RHIC is observed. Also, a smaller suppression is observed at low p_T compared with high p_T and it is lower at mid-rapidity than in the forward direction (*CERN Courier* March 2012 p14). In

LHC physics

line with regeneration models, suppression is reduced in regions where the charm-quark density is highest. In semi-central PbPb collisions, ALICE sees a hint of nonzero elliptic flow of the J/ψ. This also favours a scenario in which a significant fraction of J/ψ particles are produced by regeneration. The significance of these results will be improved with future heavy-ion data-taking.

Surprises from pPb reference data

The analysis of pPb collisions allows the ALICE collaboration to study initial and final state effects in cold nuclear matter, to establish a baseline for the interpretation of the heavy-ion results. However, the results from the data taken in the pilot run have already shown that pPb collisions are also good for surprises. First, the CMS collaboration observed from the analysis of two-particle angular correlations in high-multiplicity pPb collisions the presence of a ridge structure that is elongated in the pseudo-rapidity direction (*CERN Courier* January/February 2013 p9). Using low-multiplicity events as a reference, the ALICE and ATLAS collaborations found that this ridge-structure actually has a perfectly symmetrical counterpart, back-to-back in azimuth (*CERN Courier* March 2013 p7). The amplitude and shape of the observed double-ridge structure are similar to the modulations that are caused by the elliptic flow that is observed in PbPb collisions, therefore indicating collective behaviour in pPb. Other models attribute the effect to gluon saturation in the lead nucleus or to parton-induced final-state effects. These effects and their similarity to PbPb phenomena are intriguing. Their further investigation and theoretical interpretation will shed new light on the properties of matter at high temperatures and densities.

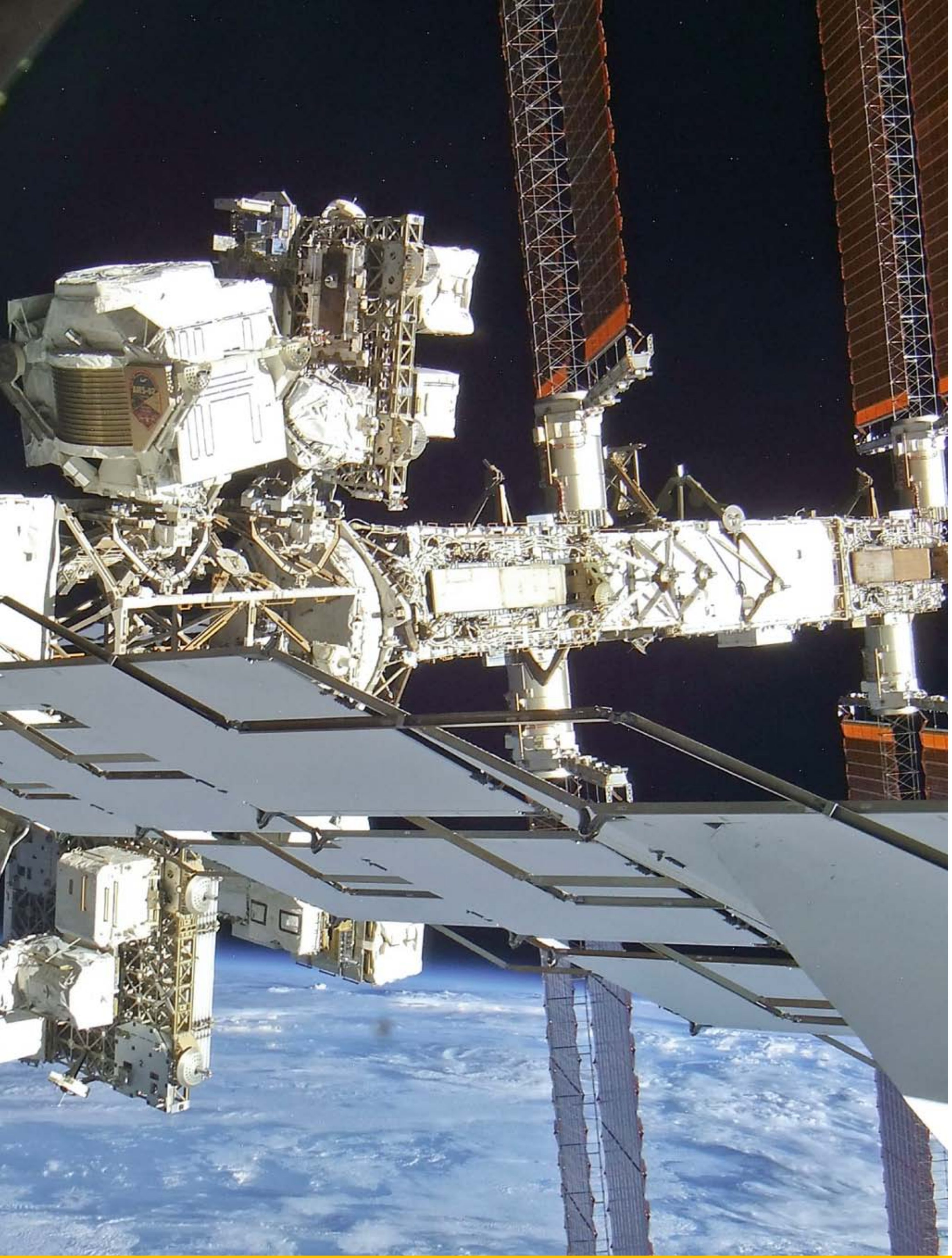
If pPb collisions do produce a QGP-like medium, its extension is expected to be much smaller than the one produced in PbPb collisions. However, the relevant quantity is not size but the ratio of the system size to the mean-free path of partons. If it is high enough, hydrodynamic models can explain the observed phenomena. If the observations can be explained by coherent effects between strings formed in different proton–nucleon scatterings, we must understand to what extent these effects contribute also to PbPb collisions. While the LHC takes a pause, the ALICE collaboration is looking forward to more exciting results from the existing data.

Résumé

ALICE : sur les traces d'un nouvel état de la matière

Après deux périodes de collisions plomb-plomb au LHC, complétées par des campagnes de collisions proton-plomb, de nouvelles perspectives s'ouvrent pour la compréhension de la matière à hautes température et densité, conditions dans lesquelles la chromodynamique quantique prédit l'existence d'un plasma de quarks et de gluons. Conçue pour supporter les fortes densités de particules générées par les collisions d'ions lourds, l'expérience ALICE a fourni de nombreuses mesures du milieu produit au LHC, qui sont ici résumées. Élément nouveau, la large section efficace pour les processus dits durs tels que la production de jets et de saveurs lourdes peut être utilisée pour « voir » à l'intérieur du milieu.

Andreas Morsch, CERN, on behalf of the ALICE collaboration.



AMS-02 provides a precise measure of cosmic rays

Results from the first two years of operation of the AMS experiment on the ISS were presented at ICRC 2013 in Rio de Janeiro.

More than 100 years have passed since the discovery of cosmic rays by Victor Hess in 1912 and there are still no signs of decreasing interest in the study of the properties of charged leptons, nuclei and photons from outer space. On the contrary, the search for a better understanding and clarification of the long-standing questions – the origin of ultrahigh energy cosmic rays, the composition as a function of energy, the existence of a maximum energy, the acceleration mechanisms, the propagation and confinement in the Galaxy, the extra-galactic origin, etc. – are more pertinent than ever. In addition, new ambitious experimental initiatives are starting to produce results that could cast light on more recent challenging questions, such as the nature of dark matter, the apparent absence of antimatter in the explored universe and the search for new forms of matter.

The 33rd International Conference on Cosmic Rays (ICRC 2013) – The Astroparticle Physics Conference – took place in Rio de Janeiro on 2–9 July and provided a high-profile platform for the presentation of a wealth of results from solar and heliospheric physics, through cosmic-ray physics and gamma-ray astronomy to neutrino astronomy and dark-matter physics. A full session was devoted to the presentation of new results from the Alpha Magnetic Spectrometer, AMS-02. Sponsored by the US Department of Energy and supported financially by the relevant funding and space agencies in Europe and Asia, this experiment was deployed on the International Space Station (ISS) on 19 May 2011 (figure 1). The results, which were presented for the first time at a large international conference, are based on the data collected by AMS-02 during its first two years of operation on the ISS.

AMS-02 is a large particle detector by space standards and built using the concepts and technologies developed for experiments at particle accelerators but adapted to the extremely hostile environment of space. Measuring 5 × 4 × 3 m^3, it weighs 7.5 tonnes. Reliability, performance and redundancy are the key features for the safe and successful operation of this instrument in space (*CERN Courier* July/August 2011 p18 and p23).

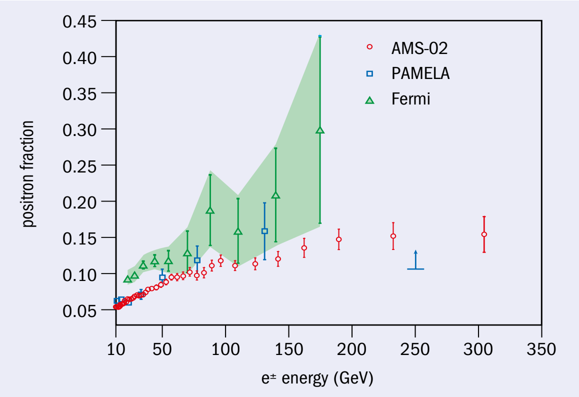


Fig. 2. The AMS experiment's measurement of the positron fraction compared with results from Fermi and PAMELA. With its sensitivity and precision, AMS now probes the excess of positrons, which has been observed for more than 20 years.

The main scientific goal is to perform a high-precision, large-statistics and long-duration study of cosmic nuclei (from hydrogen to iron and beyond), elementary charged particles (protons, antiprotons, electrons and positrons) and γ rays. In particular, AMS-02 is designed to measure the energy- and time-dependent fluxes of cosmic nuclei to an unprecedented degree of precision, to understand better the propagation models, the confinement mechanisms of cosmic rays in the Galaxy and the strength of the interactions with interstellar media. A second high-priority research topic is an indirect search for dark-matter signals based on looking at the fluxes of particles such as electrons, positrons, protons, antiprotons and photons.

Another important item on the list of priorities – which will be addressed in future – is the search for cosmic antimatter nuclei. This variety of matter is apparently absent in the region of the universe currently explored but – according to the Big Bang theory – it should have been highly abundant in the early phases of the universe. Last but not least, AMS-02 will explore the possible existence of new phenomena or new forms of matter, such as strangelets, which this state-of-the-art instrument will be in a unique position to unravel.

The AMS-02 detector was designed, built and is now operated ▷

Fig. 1. AMS, far left, was installed by NASA on the International Space Station on 19 May 2011, where it is the only major physical science experiment. It will operate there for the station's lifetime of approximately 20 years. (Image credit: NASA.)

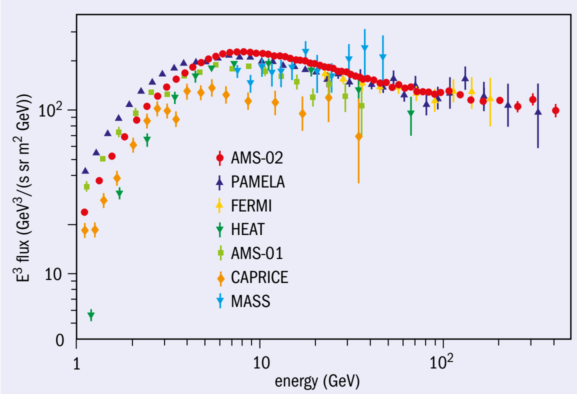


Fig. 3. The electron flux measured by AMS-02 in comparison with other measurements. The AMS results include statistical errors and uncorrelated systematic uncertainties. A normalization (scaling) uncertainty of around 4% is not included.

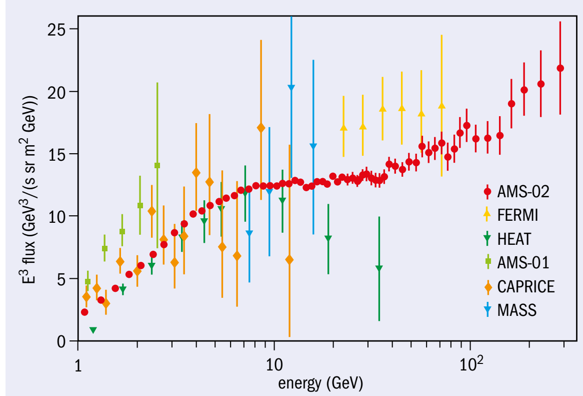


Fig. 4. The positron flux measured by AMS in comparison with other measurements. The data are presented on a linear scale to highlight the change of the spectral index in the AMS data at around 35 GeV. Note that the data from Fermi are off-scale above 100 GeV.

by a large international collaboration led by Nobel laureate Samuel C C Ting, involving researchers from institutions in America, Europe and Asia. The detector components were constructed and tested in research centres around the world, with large facilities being built or refurbished for this purpose in China, France, Germany, Italy, Spain, Switzerland and Taiwan. The final assembly took place at CERN, benefiting from the laboratory's significant expertise and experience in the technologies of detector construction. The instrument was then tested extensively with cosmic rays and particle beams at CERN, in the Maxwell electromagnetic compatibility chamber and the large-space thermal simulator at ESA-ESTEC in Noordwijk, as well as in the large facilities at the NASA Kennedy Space Center in the US.

The construction of AMS-02 has stimulated the development of important and novel technologies in advanced instrumentation. These include the first operation in space of a large two-phase CO_2 cooling system for the silicon tracker (*CERN Courier* June 2012 p29) and the two-gas (Xe-CO_2) system for the operation of the transition-radiation detector, as well as the overall thermal system. The latter must protect the experiment from the continual changes of temperature that the detector undergoes at every position on its orbit, which affect various parts of the detector subsystems in a manner that is not easy to reproduce. The use of radiation-tolerant fast electronics, a sophisticated trigger, redundant systems for data acquisition, associated protocols for communications with the NASA on-board hardware and a high-rate downlink system for the real-time transmission of data from AMS-02 to the NASA ground facilities, are a few examples that illustrate the complexity and the kind of challenges that the project has had to meet.

The operation of the Payload Operation and Control Center (POCC) at CERN, 24 hours a day and 365 days a year, in permanent connection with the ISS and the NASA Johnson Space Center, has also been a major endeavour (*CERN Courier* September 2011 p49). Fast processing of data on reception at the Science Operation Center at CERN has been a formidable tour de force, resulting in the timely reconstruction of 36.5×10^9 cosmic rays during the period 19 May 2011 – August 2013.

After almost 28 months of operation, AMS-02 – with its 300,000 electronics channels, 650 computers, 1100 thermal sensors and 400 thermostats – has worked flawlessly. To maintain performance and reliability, three space-flight simulators operate continuously at CERN, at the NASA Johnson Space Center and at the NASA Marshall Space Flight Center, where they test and certify the numerous upgrades of the software packages for the on-board computers and the communication interfaces and protocols.

First results

At ICRC 2013, the AMS collaboration presented data on two important areas of cosmic-ray physics. One addresses the fluxes, ratios and anisotropies of leptons, while the other concerns charged cosmic nuclei (protons, helium, boron, carbon). The following presents a brief summary of the results and of some of the most critical experimental challenges.

In the case of electrons and positrons, efficient instrumental handles for the suppression of the dominant backgrounds are: the minimal amount of material in the transition-radiation and time-of-flight detectors; the magnet location, separating the transition-radiation detector and the electromagnetic calorimeter; and the capability to match the value of the particle momentum reconstructed in the nine tracker layers of the silicon spectrometer with the value of the energy of the particle showering in the electromagnetic calorimeter.

The performance of the transition-radiation detector results in a high proton-rejection efficiency (larger than 10^3) at 90% positron efficiency in the rigidity range of interest. The performance of the calorimeter with its 17 radiation lengths provides a rejection factor better than 10^3 for protons with momenta up to 10^3 GeV/*c*. The combination of the two efficiencies leads to an overall proton-rejection factor of 10^6 for most of the energy range under study.

A precision measurement of the positron fraction in primary cosmic rays, based on the sample of 6.8 million positron and electron

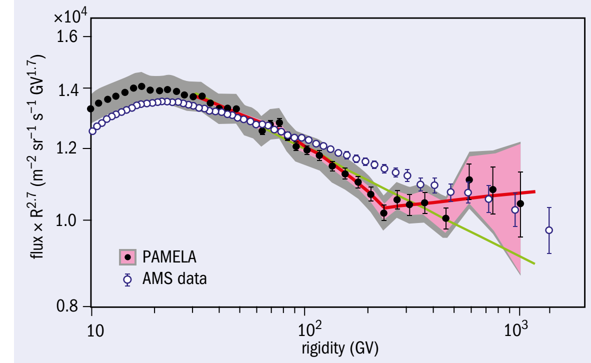


Fig. 5. The proton flux at high energies from the two years of AMS operations as a function of rigidity multiplied by $R^{2.7}$, together with recent data from PAMELA (Adriani et al. *2011* Science ***332*** *69). A 3.1% AMS normalization (scaling) uncertainty is not included. The AMS results show neither a break nor a fine structure in the spectrum.*

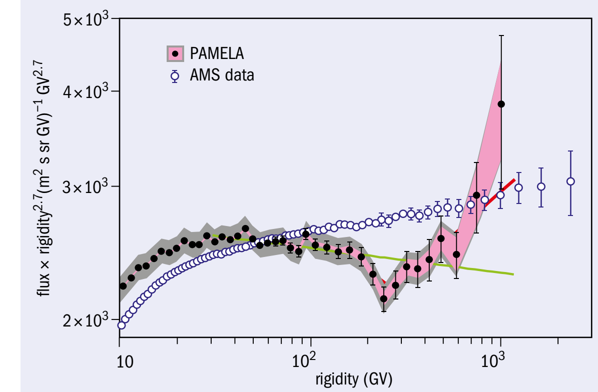


Fig. 6. The AMS helium spectrum at high rigidities multiplied by $R^{2.7}$ together with the recent PAMELA data (Adriani et al. *2011* Science ***332*** *69). A 3.5% AMS normalization (scaling) uncertainty is not included. AMS data show neither a break nor fine structure in the spectrum.*

events in the energy range of 0.5–350 GeV – collected during the initial 18 months of operation on the ISS – was recently published and presented at the conference (Aguilar *et al.* 2013 and Kounine ICRC 2013). The positron-fraction spectrum (figure 2, p23), does not exhibit fine structure and the highly precise determination shows that the positron fraction steadily increases from 10–250 GeV, while from 20–250 GeV, the slope decreases by an order of magnitude. The AMS-02 measurements have extended the energy ranges covered by recent experiments to higher values and reveal a different behaviour in the high-energy region of the spectrum.

AMS-02 has also extended the measurements of the positron spectrum to 350 GeV – that is, above the energy range of determinations by other experiments. The individual electron and positron spectra, with the E^3 multiplication factor and the combined spectrum, were presented at the conference (Schael, Bertucci ICRC 2013). Figure 3 shows the electron spectrum, which appears to follow a smooth, slowly falling curve up to 500 GeV. The positron spectrum, by contrast, rises to 10 GeV, flattens from 10–30 GeV, before rising again above 30 GeV (figure 4). For the time being, it is not obvious that the models or simple parametric estimations that are currently used to describe the rate spectrum can also describe the behaviour of the individual electron and positron spectra.

Using a larger data sample, comprising of the order of 9 million of electrons and positrons, the collaboration has performed a preliminary measurement of the combined fluxes of electrons and positrons in the energy range 0.5–700 GeV (Bertucci ICRC 2013). The data do not show significant structures, although a change in the spectral index with increasing lepton energies is clearly observed. However, the positron flux increases with energy and a promising approach to identifying the physics origin of this behaviour lies in the determination of the size of a possible anisotropy, arising in primary sources, in the arrival directions of positrons and electrons measured in galactic co-ordinates. AMS-02 has obtained a limit on the dipole anisotropy parameter $d < 0.030$ at the 95% confidence level for energies above 16 GeV (Casaus ICRC 2013).

Turning to cosmic nuclei, the first AMS-02 measurements of the proton and helium fluxes were presented at the conference (Haino, Choutko ICRC 2013). The rigidity ranges were 1 GV – 1.8 TV for protons and 2 GV – 3.2 TV for helium (figures 5 and 6). In both cases, the experiment observed gradual changes of the fluxes owing to solar modulation, as well as drastic changes after large solar flares. Otherwise, the spectra are fairly smooth and do not exhibit breaks or fine structures of the kind reported for other recent experiments.

The ratio of the boron to carbon fluxes is particularly interesting because it carries important information about the production and propagation of cosmic rays in the Galaxy. Boron nuclei are produced mainly by spallation of heavier primary elements present in the interstellar medium, whereas primary cosmic rays – such as carbon and oxygen – are predominantly produced at the source. Precision measurements of the boron-to-carbon ratio therefore provide important input for determining the characteristics of the cosmic-ray sources by deconvoluting the propagation effects from the measured data. The capability of AMS-02 to do multiple independent determinations of the electric charges of the cosmic rays allows a separation of carbon from boron with a contamination of less than 10^{-4}. Figure 7, p26, presents a preliminary measurement of the boron-to-carbon ratio in the kinetic-energy interval 0.5 – 670 GeV/n (Oliva ICRC 2013).

For the future

After nearly 28 months of successful operation, the results presented at ICRC 2013 already give a taste of the scientific potential of the AMS-02 experiment. In the near future, the measurements sketched in this article will extend the energy or rigidity coverage and the study of systematic uncertainties will be finalized. The experiment will measure the fluxes of more cosmic nuclei with unprecedented precision to constrain further the size and energy dependence of the underlying background processes.

High on the priority list for AMS-02 is the measurement of the antiproton flux and the antiproton/proton rate – a relevant ▷

Astroparticle physics

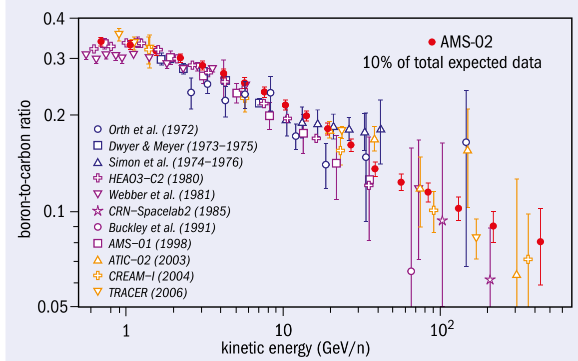


Fig. 7. The measured boron-to-carbon ratio. Previous boron-to-carbon measurements are shown for comparison.

and most sensitive quantity for disentangling, among the possible sources, those that induce the observed increase of the positron flux with energy. With the growing data sample and a deeper assessment of the systematic uncertainties, the searches for cosmic antinuclei will become extremely important, as will the search for unexpected new signatures.

By the end of the decade AMS-02 will have collected more than 150×10^9 cosmic-ray events. In view of what has been achieved so far, it is reasonable to be fairly confident that this massive amount of new and precise data will contribute significantly to a better understanding of the ever exciting and lively field of cosmic rays.

Further reading

For more about AMS-02, see www.ams02.org.

M Aguilar *et al.* 2013 *Phys. Rev. Lett. A* **110** 141102.
B Bertucci AMS collaboration ICRC 2013 (ID 1267).
J Casaus AMS collaboration ICRC 2013 (ID 1264).
V Choutko AMS collaboration ICRC 2013 (ID 1262).
S Haino AMS collaboration ICRC 2013 (ID 1265).
A Kounine AMS collaboration ICRC 2013 (ID 1264).
A Oliva AMS collaboration ICRC 2013 (ID 1266).
S Schael AMS collaboration ICRC 2013 (ID 1257).

Résumé

AMS-02 mesure les rayons cosmiques avec précision

Déployée le 19 mai 2011 sur la Station spatiale internationale (ISS), l'expérience AMS-02 a pour objet une étude de longue durée et de haute précision des noyaux cosmiques, des particules chargées et des rayons gamma. Le détecteur, qui jusqu'à présent a fonctionné parfaitement, a fourni des données sur 36,5 milliards de rayons cosmiques en 28 mois de service. Lors de la 33e Conférence internationale sur les rayons cosmiques (ICRC 2013), la collaboration AMS a présenté les premiers résultats relatifs à deux sujets importants : le premier concerne les flux, les taux et les anisotropies des leptons ; le second les noyaux cosmiques chargés (protons, hélium, bore, carbone).

Manuel Aguilar, CERN and CIEMAT, on behalf of the AMS collaboration.

CERN Courier October 2013
LHC experiments

ATLAS undergoes some delicate gymnastics

A year after the discovery of a Higgs boson, a huge programme of consolidation and improvements is under way at Point 1.

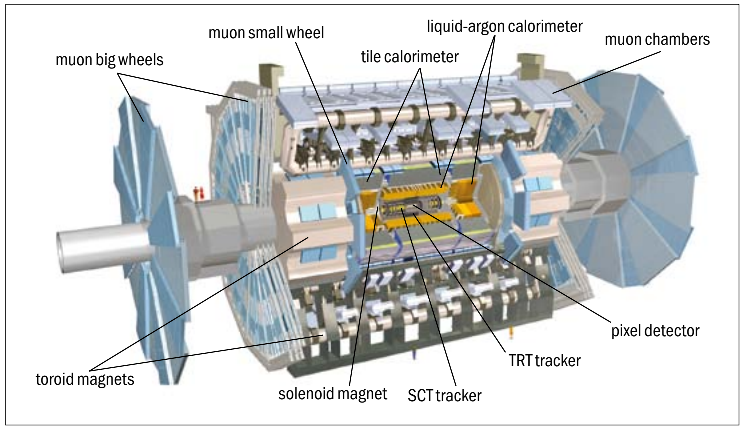
The LHC's Long Shutdown 1 (LS1) is an opportunity that the ATLAS collaboration could not miss to improve the performance of its huge and complex detector. Planning began almost three years ago to be ready for the break and to produce a precise schedule for the multitude of activities that are needed at Point 1 – where ATLAS is located on the LHC. Now, a year after the famous announcement of the discovery of a "Higgs-like boson" on 4 July 2012 and only six months after the start of the shutdown, more than 800 different tasks have been already accomplished in more than 250 work packages. But what is ATLAS doing and why this hectic schedule? The list of activities is long, so only a few examples will be highlighted here.

The inner detector

One of the biggest interventions concerns the insertion of a fourth and innermost layer of the pixel detector – the IBL. The ATLAS pixel detector is the largest pixel-based system at the LHC. With about 80 million pixels, until now it has covered a radius from 12 cm down to 5 cm from the interaction point. At its conception, the collaboration already thought that it could be updated after a few years of operation. An additional layer at a radius of about 3 cm would allow for performance consolidation, in view of the effects of radiation damage to the original innermost layer at 5 cm (the b-layer). The decision to turn this idea into reality was taken in 2008, with the aim of installation around 2016. However, fast progress in preparing the detector and moving the long shutdown to the end of 2012 boosted the idea and the installation goal was moved forward by two years.

To make life more challenging, the collaboration decided to build the IBL using not only well established planar sensor technology but also novel 3D sensors. The resulting highly innovative detector is a tiny cylinder that is about 3 cm in radius and about 70 cm long but it will provide the ATLAS experiment with another 12 million detection channels. Despite its small dimensions, the entire assembly – including the necessary services – will need an installation tool that is nearly 10 m long. This has led to the so-called "big opening" of the ATLAS detector and the need to lift one of the small muon wheels to the surface.

The "big opening" of ATLAS is a special configuration where at one end of the detector one of the big muon wheels is moved as far as possible towards the wall of the cavern, the 400-tonne endcap toroid is moved laterally towards the surrounding path structure, the small muon wheel is moved as far as the already opened big



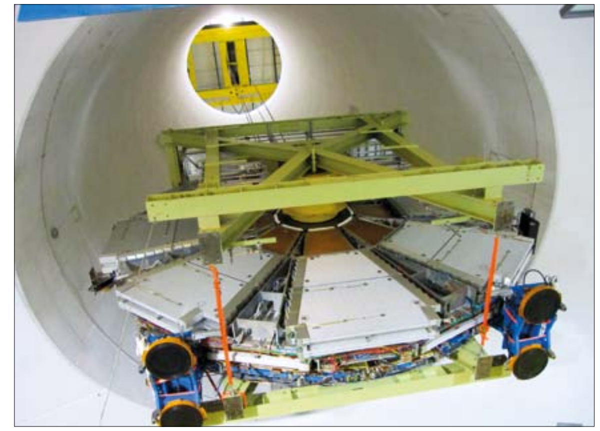
The layout of the ATLAS detector, showing some of the key components. Overall, the detector is 25 m tall and spans some 40 m from end to end.

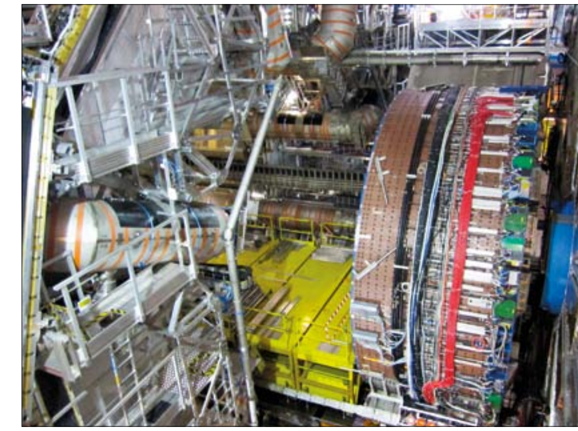
wheel and then the endcap calorimeter is moved out by about 3 m. But that is not the end of the story. To make more space, the small muon wheel must be lifted to the surface to allow the endcap calorimeter to be moved further out against the big wheels.

This opening up – already foreseen for the installation of the IBL – became more worthwhile when the collaboration decided to use LS1 to repair the pixel detector. During the past three years of operation, the number of pixel modules that have stopped being operational has risen continuously from the original 10–15 up to 88 modules, at a worryingly increasing rate. Back in 2010, the first concerns triggered a closer look at the module failures and it was clear that in most of the cases the modules were in a good state but that something in the services had failed. This first glance was then augmented by substantial statistics after up to 88 modules had failed by mid-2012.

In 2011, the ATLAS pixel community decided to prepare new services for the detector – code-named nSQP for "new service quarter panels". In January 2013, the collaboration decided to deploy the nSQP not only to fix the failures of the pixel modules and to enhance the future read-out capabilities for two of the three layers but also to ease the task of inserting the IBL into the pixel detector. This decision implied having to extract the pixel detector and take it to the clean-room building on the surface at Point 1 to execute the necessary work. The "big opening" therefore became mandatory.

The extraction of the pixel detector was an extremely delicate operation but it was performed perfectly and a week in advance of the schedule. Work on both the original pixels and the IBL is now in full swing and preparations are under way to insert the enriched four-layer pixel detector back into ATLAS. The pixel detector will then contain 92 million channels – some 90% of the total number





Left: Making enough space to remove the pixel detector required lifting a small muon wheel to the surface. Right: The "big opening" of ATLAS, showing the endcap calorimeter (right) and toroid magnet coils (left). (Image credits: B Di Girolamo.)

of channels in ATLAS.

But that is not the end of the story for the ATLAS inner detector. Gas leaks appeared last year during operation of the transition radiation tracker (TRT) detector. Profiting from the opening of the inner detector plates to access the pixel detector, a dedicated intervention was performed to cure as many leaks as possible using techniques that are usually deployed in surgery.

Further improvements

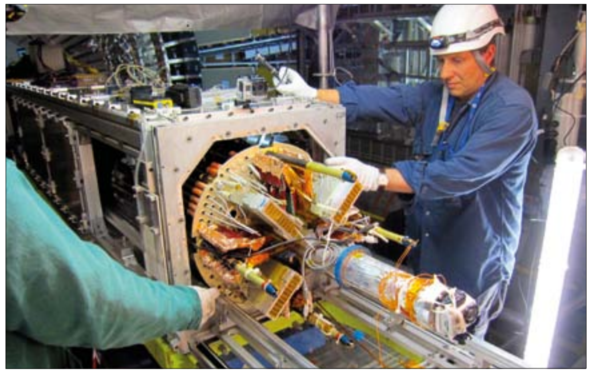
Another important improvement for the silicon detectors concerns the cooling. The evaporative cooling system that was based on a complex compressor plant has been satisfactory, even if it has created a variety of problems and interventions. The system allowed operating temperatures to be set to –20 °C with the possibility of going down to –30 °C, although the lower value has not been used so far as radiation damage to the detector is still in its infancy. However, the compressor plant needed continual attention and maintenance. The decision was therefore taken to build a second plant that was based on the thermosyphon concept, where the pressure that is required is obtained without a compressor, using instead the gravity advantage offered by the 90-m-deep ATLAS cavern. The new plant has been built and is now being commissioned, while the original plant has been refurbished and will serve as a redundant (back-up) system. In addition, the IBL cooling is based on CO_2 cooling technology and a new redundant plant is being built to be ready for the IBL operations.

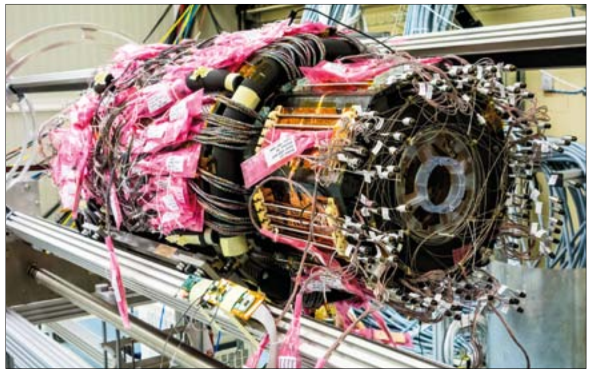
Both the semiconductor tracker and the pixel detector are also being consolidated. Improvements are being made to the back-end read-out electronics to cope with the higher luminosities that will go beyond twice the LHC design luminosity.

Lifting the small muon wheel to the surface – an operation that had never been done before – was a success. The operation was not without difficulties because of the limited amount of space for manoeuvering the 140-tonne object to avoid collisions with other detectors, crates and the walls of the cavern and access shaft. Nevertheless, it was executed perfectly thanks to highly efficient preparation and the skill of the crane drivers and ATLAS engineers, with several dry runs done on the surface. Not to miss the opportunity, the few problematic cathode-strip chambers on the small wheel that was lifted to the surface will be repaired. A specialized tool is being designed and fabricated to perform this operation in the small space that is available between the lifting frame and the detector.

Many other tasks are foreseen for the muon spectrometer. The installation of a final layer of chambers – the endcap extensions – which was staged in 2003 for financial reasons has already been completed. These chambers were installed on one side of the detector during previous mid-winter shutdowns. The installation on the other side has now been completed during the first three months of LS1. In parallel, a big campaign to check for and repair leaks has started on the monitored drift tubes and resistive-plate chambers, with good results so far. As soon as access allows, a few problematic thin-gap chambers on the big wheels will be exchanged. Construction of some 30 new chambers has been under way for a few months and their installation will take place during the coming winter.

At the same time, the ATLAS collaboration is improving the calorimeters. New low-voltage power supplies are being installed for both the liquid-argon and tile calorimeters to give a better performance at higher luminosities and to correct issues that have been encountered during the past three years. In addition, a broad campaign of consolidation of the read-out electronics for the tile calorimeter is ongoing because it is many years since it was ▷





Left, extracting the pixel detector from the heart of ATLAS, complete with the beam pipe, which is to be replaced. Right, the detector on the surface with its service panels removed. (Image credits: Left, B Di Girolamo; right, H Pernegger.)

constructed. Designing, prototyping, constructing and testing new devices like these has kept the ATLAS calorimeter community busy during the past four years. The results that have been achieved are impressive and life for the calorimeter teams during operation will become much better with these new devices.

Improvements are also under way for the ATLAS forward detectors. The LUCID luminosity monitor is being rebuilt in a simplified way to make it more robust for operations at higher luminosity. All of the four Roman-pot stations for the absolute luminosity monitor, ALFA, located at 240 m from the centre of ATLAS in the LHC tunnel, will soon be in laboratories on the surface. There they will undergo modifications to implement wake-field suppression measures that will fight against the beam-induced increase in temperature that was suffered during operations in 2012. There are other plans for the beam-conditions monitor, the diamond-beam monitor and the zero-degree calorimeters. The activities are non-stop everywhere.

The infrastructure

All of the above might seem to be an enormous programme but it does not touch on the majority of the effort. The consolidation work spans the improvements to the evaporative cooling plants that have already been mentioned to all aspects of the electrical infrastructure and more. Here are a few examples from a long list.

Installation of a new uninterruptible power supply is ongoing at Point 1, together with replacement of the existing one. This is to avoid power glitches, which have affected the operation of the ATLAS detector on some occasions. Indeed, the whole electrical installation is being refreshed.

The cryogenic infrastructure is being consolidated and improved to allow completely separate operation of the ATLAS solenoid and toroid magnets. Redundancy is implemented everywhere in the magnet systems to limit downtime. Such downtime has, so far, been small enough to be unnoticeable in ATLAS data-taking but it could create problems in future.

All of the beam pipes will be replaced with new ones. In the inner detector, a new beryllium pipe with a smaller diameter to allow space for the IBL has been constructed and installed already in the IBL support structure. All of the other stainless-steel pipes will be replaced with aluminium ones to improve the level of background everywhere in ATLAS and minimize the adverse effects of activation.

A back-up for the ATLAS cooling towers is being created via a connection to existing cooling towers for the Super Proton Synchrotron. This will allow ATLAS to operate at reduced power, even during maintenance of the main cooling towers. The cooling infrastructure for the counting rooms is also undergoing complete improvement with redundancy measures inserted everywhere. All of these tasks are the result of a robust collaboration between ATLAS and all CERN departments.

LS1 is not, then, a period of rest for the ATLAS collaboration. Many resources are being deployed to consolidate and improve all possible aspects of the detector, with the aim of minimizing downtime and its impact on data-taking efficiency. Additional detectors are being installed to improve ATLAS's capabilities. Only a few of these have been mentioned here. Others include, for example, even more muon chambers, which are being installed to fill any possible instrumental cracks in the detector.

All of this effort requires the co-ordination and careful planning of a complicated gymnastics of heavy elements in the cavern. ATLAS will be a better detector at the restart of LHC operations, ready to work at higher energies and luminosities for the long period until LS2 – and then the gymnastics will begin again.

Résumé

ATLAS se refait une santé

L'arrêt de longue durée du LHC a donné l'occasion de mettre en œuvre un important programme de consolidation et d'amélioration pour le détecteur ATLAS. L'une des interventions majeures est l'installation d'une quatrième couche au détecteur à pixels, au plus près du centre. Cette opération a nécessité un démontage de grande envergure d'ATLAS, au cours duquel une petite roue à muons a été remontée à la surface. De même, le détecteur à pixels a été remonté pour subir des réparations. D'autres opérations visent à améliorer les chambres à muons et les calorimètres et à consolider l'infrastructure du détecteur.

Beniamino Di Girolamo and **Marzio Nessi**, CERN.

Quarks, gluons and sea in Marseilles

Results from the LHC were a key element of the latest DIS workshop.

The regular "DIS" workshops on Deep-Inelastic Scattering and related subjects usually bring together a unique mix of international communities and cover a spectrum of topics ranging across proton structure, strong interactions and physics at the energy frontier. DIS2013 – the 21st workshop – which took place in the Palais des Congrès in Marseilles earlier this year was no exception. Appropriately, this large scientific event formed part of a rich cultural programme in the city that was associated with its status as European Capital of Culture Marseilles-Provence 2013.

A significant part of the programme was devoted to recent and exciting experimental results, which together with theoretical advances and the outlook for the future created a vibrant scientific atmosphere. The workshop began with a full day of plenary reports on hot topics, followed by two and a half days of parallel sessions that were organized around seven themes: structure functions and parton densities; small-x, diffraction and vector mesons; electroweak physics and beyond the Standard Model; QCD and hadronic final states; heavy flavours; spin physics; future experiments.

Participants outside the Palais des Congrès in Marseilles. (Image credit: Dirk Hoffmann, CPPM.)

Higgs and more

The meeting provided the opportunity to discuss in depth the various connections between strong interactions, proton structure and recent experimental results at the LHC. In particular, the discovery of a Higgs boson and the subsequent studies of its properties attracted a great deal of interest, including from the perspective of the connections with proton structure. A tremendous effort was made in the past year to provide an improved theory, study the constraints from the wealth of new experimental data and adopt a more robust methodology in analyses that determine the proton's parton distribution functions (PDFs). The PDFs are an essential ingredient for most LHC analyses, from characterization of the Higgs boson to self-consistency tests of the Standard Model. The first "safari" into the new territory at the LHC and the impressive final results with the full data set from Fermilab's Tevatron have revealed no new phenomena so far. However, it might well be that the search for new physics – which will be re-launched at higher energies during the next LHC run – will be affected by the precision with which the structure of the proton is known.

The most recent experimental results from continuing analysis from HERA – the electron–proton collider that ran at DESY during 1992–2007 – were presented. In particular, both the H1 and ZEUS collaborations have now published measurements at high photon virtualities (Q^2). While the refined data from HERA form its immensely valuable legacy, the transfer of the baton to the LHC has already begun. A large number of recent results – in particular from the LHC – provide further constraints on the PDFs, such as in the case of final states with weak bosons or top quarks, which are already in the regime of precision measurements with about 1% accuracy. Stimulated by an active Standard Model community that has many groups that are working on the determination of PDFs (such as ABM, MSTW and CTEQ) and by the release of common analysis tools such as HERAFitter, the new measurements from the LHC are rapidly interpreted in terms of valuable PDF constraints, as figure 1 shows (p34). More exclusive final states have the ▷

The proton's PDFs are an essential ingredient for most LHC analyses.

potential to complement inclusive measurements: for instance, measurements on the W in association with the charm quark could shed new light on the strangeness content of the proton. A huge step in the precision of PDF determination – which might be essential to study new physics – complemented by a standalone programme at the energy frontier would be possible at the proposed Large Hadron Electron Collider (LHeC), which could provide a new opportunity to study Higgs-boson couplings.

The understanding of proton structure would not be complete without understanding its spin. Polarized experiments – including fixed-target DIS experiments at Jefferson Lab and CERN, as well as the polarized proton–proton programme at Brookhaven's Relativistic Heavy-Ion Collider (RHIC) – continue to provide new data and to open new fields. The goal is to understand the parton contributions to the proton's spin, long considered a "puzzle" because of the unexpected way that it is shared between the quarks – with only a quarter – the gluons and the relative angular momentum. Recent, more precise measurements of W-boson production in polarized proton–proton collisions at RHIC have the potential to constrain further the valence quark contributions, while semi-inclusive DIS scattering at fixed-target experiments (for instance, using final states with charm mesons) continue to reduce the uncertainty on the gluon contribution. The goal of the spin community – manifest in the project for a polarized Electron-Ion Collider (EIC) – is to produce a 3D picture of the proton with high precision using a large number of observables across an extended phase space.

Impressive precision

The current scientific landscape includes many experiments that are based on hadronic interactions, with the LHC taking these studies to the highest energies. These are reaching impressive, increasing precision across a large phase space, not only in final states with jets but also in more exclusive configurations including photons, weak bosons or tagged heavy flavours. The measurements performed in diffraction – by now a classical laboratory for QCD tests – are also available from the LHC in inclusive and semi-inclusive final states and enforce the global understanding of the strong interactions. An interesting case concerns double-parton interactions where the final state originates from not one but two parton–parton collisions – a contribution that in some cases can pollute final-state configurations (including bosons or Higgs production). Although the measurements are not yet precise enough to identify kinematical dependencies or parton–parton correlations, they are beginning to unveil this contribution, which may prove in future to be related to profound aspects of the proton structure, such as the generalized parton distributions and the proton spin.

A global picture and complete understanding of the strong force can only emerge by using all of the available configurations and energies. In particular, the measurements of the hadronic final states performed in electron–proton collisions at HERA and the refined measurements at the Tevatron provide an essential testing ground for the increasingly precise calculations. Figure 2 illustrates this statement, presenting measurements of the strong coupling from collider experiments – including the most recent measurements from the LHC.

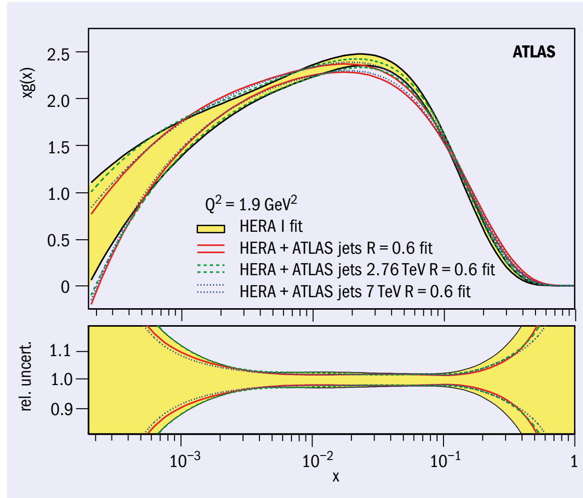


Fig. 1. Gluon density in the proton extracted from a common fit of HERA and ATLAS data.

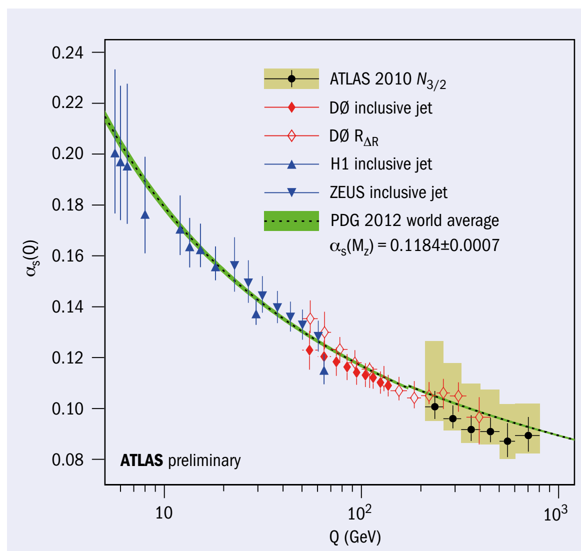


Fig. 2. Measurements of the strong coupling constant, α_s, from various collider data.

The high-energy heavy-ion collisions at both RHIC and the LHC have been a constant source of new results and paradigms during the past few years and this proved equally true for the DIS2013 conference. Probes such as mesons or jets "disappear" when high densities of the collision fireball are reached. The set of such probes has been consolidated at the LHC, where the experimental capabilities and large phase space allow further measurements involving strangeness, charm or inclusive particle production. In addition, the recently achieved proton–lead collisions provide new testing grounds for the collective behaviour of the quarks and gluons at high densities.

A total of 300 talks were given covering the seven themes of the workshop, distributed across two and a half days of parallel sessions, a few of which combined different themes. As tradition requires at DIS workshops, the presentations were followed by intense debates on classic and new issues, including a satellite workshop on the HERAFitter project. On the last day, the working group convenors summarized the highlights of the rich scientific programme of the parallel sessions.

The conference ended with a session on future experiments, where together with upgrades of the LHC experiments and other interesting projects related to new capabilities for QCD-related studies (AFTER, CHIC, COMPASS, NA62, nuSTORM, etc.), the two projects for new colliders EIC and LHeC were discussed. Rolf Heuer, CERN's director-general, presented the recently updated European Strategy for Particle Physics. The programme at the energy frontier with the LHC will be followed for at least 20 years and studies for further projects are ongoing. The conference ended with an inspiring outlook talk by Chris Quigg of Fermilab, with hints of a possible QCD-like walk on the new physics frontier. In the evening, Heuer gave a talk for the general public to an audience of more than 200 people on recent discoveries at the LHC.

In addition to the workshop sessions, participants enjoyed a dinner in the Pharo castle – with a splendid view of the old and new harbours of Marseilles – where they found out why the French national anthem is called *La Marseillaise*. There was also half a day of free time for most of the participants – except maybe for convenors who had to prepare their summary reports – with two excursions organized at Cassis and in the historic centre of Marseilles.

In summary, the DIS2013 workshop once again allowed an insightful journey around the fundamental links between QCD, proton structure and physics at the energy frontier – an interface that will continue to grow and create new research ideas and projects in the near future. The next – 22nd – DIS workshop will be held in Warsaw in April 2014.

Further reading

DIS2013 conference website http://dis2013.in2p3.fr.

Résumé

Des quarks et des gluons s'invitent à Marseille

Les ateliers DIS (diffusion profondément inélastique et sujets connexes) rassemblent des chercheurs de divers horizons et couvrent de nombreux sujets, allant de la structure du proton aux interactions fortes en passant par la physique aux frontières des hautes énergies. DIS2013, la 21e édition, qui s'est tenue à Marseille cette année, n'a pas dérogé à la règle. Cette rencontre a permis aux participants de discuter en détail des rapports entre les interactions fortes, la structure du proton et les derniers résultats des expériences du LHC. Cet événement scientifique majeur s'est parfaitement inséré dans le riche programme culturel de Marseille-Provence 2013, Capitale européenne de la culture.

Cristinel Diaconu, Centre de Physique des Particules de Marseilles, CNRS/IN2P3 and Aix-Marseilles Université.

Conference time in Stockholm

The city of Stockholm provided a beautiful setting for the 2013 edition of EPS-HEP, one of the major international summer conferences in particle physics. (Image credit: Marina Lukashova/Dreamstime.com.)

The Higgs boson, dark matter and rare processes were among the highlights of the 2013 International Europhysics Conference on High-Energy Physics.

When the Swedish warship *Vasa* capsized in Stockholm harbour on her maiden voyage in 1628, many hearts must have also sunk metaphorically, as they did at CERN in September 2008 when the LHC's start-up came to an abrupt end. Now, the raised and preserved *Vasa* is the pride of Stockholm and the LHC – following a successful restart in 2009 – is leading research in particle physics at the high-energy frontier. This year the two icons crossed paths when the International Europhysics Conference on High-Energy Physics, EPS-HEP 2013, took place in Stockholm on 18–24 July, hosted by the KTH (Royal Institute of Technology) and Stockholm University. Latest results from the LHC experiments featured in many of the parallel, plenary and poster sessions – and the 750 or so participants had the opportunity to see the *Vasa* for themselves at the conference dinner. There was, of course, much more and this report can only touch on some of the highlights.

Coming a year after the first announcement of the discovery of a "Higgs-like" boson on 4 July 2012, the conference was the perfect occasion for a birthday celebration for the new particle. Not only has its identity been more firmly established in the intervening time – it almost certainly is a Higgs boson – but many of its attributes have been measured by the ATLAS and CMS experiments at the LHC, as well as by the CDF and DØ collaborations using data collected at Fermilab's Tevatron. At 125.5 GeV/c^2, its mass is known to within 0.5% precision – better than for any quark – and several tests by ATLAS and CMS show that its spin-parity, J^P, is compatible with the 0^+ expected for a Standard Model Higgs boson. These results exclude other models to greater than 95% confidence level (CL), while a new result from DØ rejects a graviton-like 2^+ at >99.2% CL.

The new boson's couplings provide a crucial test of whether it is the particle responsible for electroweak-symmetry breaking in the Standard Model. A useful parameterization for this test is the ratio of the observed signal strength to the Standard Model prediction, $\mu = (\sigma \times BR)/(\sigma \times BR)_{SM}$, where σ is the cross-section and BR the branching fraction. The results for the five major decay channels measured so far ($\gamma\gamma$, WW*, ZZ*, bb and $\tau\tau$) are consistent with the expectations for a Standard Model Higgs boson, i.e. $\mu = 1$, to 15% accuracy. Although it is too light to decay to the heaviest quark – top, t – and its antiquark, the new boson can in principle be produced together with a $t\bar{t}$ pair, so yielding a sixth coupling. While this is a challenging channel, new results from CMS and ATLAS are starting to approach the level of sensitivity for the Standard Model Higgs boson, which bodes well for its future use.

The mass of the top quark is in fact so large – 173 GeV/c^2 – that it decays before forming particles, making it possible to study the "bare" quark. At the conference, the CMS collaboration announced the first observation, at 6.0σ, of the associated production of a top quark and a W boson, in line with the Standard Model's prediction. Both ATLAS and CMS had previously found evidence for this process but not to this significance. The DØ collaboration presented latest results on the lepton-based forward–backward ▷

lepton asymmetry in $t\bar{t}$ production, which had previously indicated some deviation from theory. The new measurement, based on the full data set of 9.7 fb^{-1} of proton–antiproton collisions at the Tevatron, gives an asymmetry of (4.7±2.3 stat.$^{+1.1}_{-1.4}$ syst.)%, which is consistent with predictions from the Standard Model to next-to-leading order.

The study of B hadrons, which contain the next heaviest quark, b, is one of the aspects of flavour physics that could yield hints of new physics. One of the highlights of the conference was the announcement of the observation of the rare decay mode $B_s^0 \to \mu\mu$ by both the LHCb and CMS collaborations, at 4.0 and 4.3σ, respectively (*CERN Courier* September 2013 p19). While there had been hopes that this decay channel might open a window on new physics, the long-awaited results align with the predictions of the Standard Model. The BaBar and Belle collaborations also reported on their precise measurements of the decay $B \to D^{(*)}\tau\nu_\tau$ at SLAC and KEK, respectively, which together disagree with the Standard Model at the 4.3σ level. The results rule out one model that adds a second Higgs doublet to the Standard Model (2HDM type II) but are consistent with a different variant, 2HDM type III – a reminder that the highest energies are not the only place where new physics could emerge.

Precision, precision

Precise measurements require precise predictions for comparison and here theoretical physics has seen a revolution in calculating next-to-leading order (NLO) effects, involving a single loop in the related Feynman diagrams. Rapid progress during the past few years has meant that the experimentalists' wish-list for QCD calculations at NLO relevant to the LHC is now fulfilled, including such high-multiplicity final states as W + 4 jets and even W + 5 jets. Techniques for calculating loops automatically should in future provide a "do-it-yourself" approach for experimentalists. The new frontier for the theorists, meanwhile, is at next-to-NLO (NNLO), where some measurements – such as $pp \to t\bar{t}$ – are already at an accuracy of a few per cent and some processes – such as $pp \to \gamma\gamma$ – could have large corrections, up to 40–50%. So a new wish-list is forming, which will keep theorists busy while the automatic code takes over at NLO.

With a measurement of the mass for the Higgs boson, small corrections to the theoretical predictions for many measurable quantities – such as the ratio between the masses of the W and the top quark – can now be calculated more precisely. The goal is to see if the Standard Model gives a consistent and coherent picture when everything is put together. The GFitter collaboration of theorists and experimentalists presented its latest global Standard Model fit to electroweak measurements, which includes the legacy both from the experiments at CERN's Large Electron–Positron Collider and from the SLAC Large Detector, together with the most recent theoretical calculations. The results for 21 parameters show little tension between experiment and the Standard Model, with no discrepancy exceeding 2.5σ, the largest being in the forward–backward asymmetry for bottom quarks.

There is more to research at the LHC than the deep and persistent probing of the Standard Model. The ALICE, LHCb, CMS and ATLAS collaborations presented new results from high-energy lead–lead and proton–lead collisions at the LHC. The most intriguing

The museum that now houses the 17th century Swedish warship Vasa *provided a fascinating venue for the conference dinner. (Image credit: Bluesunphoto/Dreamstime.com.)*

results come from the analysis of proton–lead collisions and reveal features that previously were seen only in lead–lead collisions, where the hot dense matter that was created appears to behave like a perfect liquid. The new results could indicate that similar effects occur in proton–lead collisions, even though far fewer protons and neutrons are involved. Other results from ALICE included the observation of higher yields of J/ψ particles in heavy-ion collisions at the LHC than at Brookhaven's Relativistic Heavy-Ion Collider, although the densities are much higher at the LHC (*CERN Courier* September 2013 p6). The measurements in proton–lead collisions should cast light on this finding by allowing initial-state effects to be disentangled from those for cold nuclear matter.

Supersymmetry and dark matter

The energy frontier of the LHC has long promised the prospect of physics beyond the Standard Model, in particular through evidence for a new symmetry – supersymmetry. The ATLAS and CMS collaborations presented their extensive searches for supersymmetric particles in which they have explored a vast range of masses and other parameters but found nothing. However, assumptions involved in the work so far mean that there are regions of parameter space that remain unexplored. So while supersymmetry may be "under siege", its survival is certainly still possible. At the same time, creative searches for evidence of extra dimensions and many kinds of "exotics" – such as excited quarks and leptons – have likewise produced no signs of anything new.

The number of papers with dark matter in the title is growing faster than those on the Higgs boson.

However, evidence that there must almost certainly be some kind of new particle comes from the existence of dark, non-hadronic matter in the universe. Latest results from the Planck mission show that this should make up some 26.8% of the universe – about 4% more than previously thought. This drives the search for weakly interacting particles (WIMPs) that could constitute dark matter, which is becoming a worldwide effort. Indeed, although the Higgs boson may have been top of the bill for hadron-collider physics, more generally, the number of papers with dark matter in the title is growing faster than those on the Higgs boson.

While experiments at the LHC look for the production of new kinds of particles with the correct properties to make dark matter, "direct" searches seek evidence of interactions of dark-matter particles in the local galaxy as they pass through highly sensitive detectors on Earth. Such experiments are showing an impressive evolution with time, increasing in sensitivity by about a factor of 10 every two years and now reaching cross-sections down to 10^{-8} pb. Among the many results presented, an analysis of 140.2-kg days of data in the silicon detectors of the CDMS II experiment revealed three WIMP-candidate events with an expected background of 0.7. A likelihood analysis gives a 0.19% probability for the known background-only hypothesis.

"Indirect" searches, by contrast, involve in particular the search from signals from dark-matter annihilation in the cosmos. In 2012, an analysis of publically available data from 43 months of the Fermi Large Area Telescope (LAT) indicated a puzzling signal at 130 GeV, with the interesting possibility that these γ rays could originate from the annihilation of dark-matter particles. A new analysis by the Fermi LAT team of four years' worth of data gives preliminary indications of an effect with a local significance of 3.35σ but the global significance is less than 2σ. The HESS II experiment is currently accumulating data and might soon be able to cross-check these results.

With their small but nonzero mass and consequent oscillations from one flavour to another, neutrinos are the one type of known particle that provide a view outside the Standard Model. At the conference, the T2K collaboration announced the first definitive observation at 7.5σ of the transition $\nu_\mu \to \nu_e$ in the high-energy ν_μ beam that travels 295 km from the Japan Proton Accelerator Complex to the Super-Kamiokande detector (*CERN Courier* September 2013 p8). Meanwhile, the Double CHOOZ experiment, which studies $\bar{\nu}_e$ produced in a nuclear reactor, has refined its measurement of θ_{13}, one of the parameters characterizing neutrino oscillations, by using two independent methods that allow much better control of the backgrounds. The GERDA collaboration uses yet another means to investigate if neutrinos are their own antiparticles, by searching for the neutrinoless double-beta decay of the isotope ^{76}Ge in a detector in the INFN Gran Sasso National Laboratory. The experiment has completed its first phase and finds no sign of this process but now provides the world's best lower limit for the half-life at 2.1 × 10^{23} years (*CERN Courier* September 2013 p8).

On the other side of the world, deep in the ice beneath the South Pole, the IceCube collaboration has recently observed oscillations of neutrinos produced in the atmosphere. More exciting, arguably, is the detection of 28 extremely energetic neutrinos – including two with energies above 1 PeV – but the evidence is not yet sufficient to claim observation of neutrinos of extra-terrestrial origin (*CERN Courier* July/August 2013 p5).

Plenary sessions took place in the magnificent Aula Magna lecture theatre on the Stockholm University campus. (Image credit: T Pritchard.)

Towards the future

In addition to the sessions on the latest results, others looked to the continuing health of the field with presentations of studies on novel ideas for future particle accelerators and detection techniques. These topics also featured in the special session for the European Committee for Future Accelerators, which looked at future developments in the context of the update of the European Strategy for Particle Physics. A range of experiments at particle accelerators currently takes place on two frontiers – high energy and high intensity. Progress in probing physics that lies at the limit of these experiments will come both from upgrades of existing machines and at future facilities. These will rely on new ideas being investigated in current accelerator R&D and will also require novel particle detectors that can exploit the higher energies and intensities.

For example, two proposals for new neutrino facilities would allow deeper studies of neutrinos – including the possibility of CP violation, which could cast light on the dominance of matter over antimatter in the universe. The Long-Baseline Neutrino Experiment (LBNE) would create a beam of high-energy ν_μ at Fermilab and detect the appearance of ν_e with a massive detector that is located 1300 km away at the Sanford Underground Research Facility. A test set-up, LBNE10, has received funding approval. A complementary approach providing low-energy neutrinos is proposed for the European Spallation Source, which is currently under construction in Lund. This will be a powerful source of neutrons that could also be used to generate the world's most intense neutrino beam.

Paris Sphicas (left), chair of the international organzing committee, with Peter Higgs. (Image credit: T Pritchard.)

The LHC was first discussed in the 1980s, more than 25 years before the machine produced its first collisions. Looking to the long-term future, other accelerators are now on the drawing board. One possible option is the International Linear Collider, currently being evaluated for construction in Japan (see p7). Another option is ▷

EPS-HEP 2013

to create a large circular electron–positron collider, 80–100 km in circumference, to produce Higgs bosons for precision studies (*CERN Courier* July/August 2013 p26).

The main physics highlights of the conference were reflected in the 2013 EPS-HEP prizes, awarded in the traditional manner at the start of the plenary sessions. The EPS-HEP prize honoured both ATLAS and CMS – for the discovery of the new boson – and three of their pioneering leaders (Michel Della Negra, Peter Jenni and Tejinder Virdee). François Englert and Peter Higgs were there to present this major prize and took part later in a press conference together with the prize winners. Following the ceremony, Higgs gave a talk, "Ancestry of a New Boson", in which he recounted what led to his paper of 1963 and also cast light on why his name became attached to the now-famous particle. Other prizes acknowledged the measurement of the all-flavour neutrino flux from the Sun, as well as the observation of the rare decay $B_s^0 \to \mu\mu$, work in 4D field theories (*CERN Courier* July/August 2013 p39)) and outstanding contributions to outreach. In a later session, a prize sponsored by Elsevier was awarded for the best four posters out of the 130 that were presented by young researchers in the dedicated poster sessions.

To close the conference, Nobel Laureate Gerard 't Hooft presented his outlook for the field. This followed the conference summary by Sergio Bertolucci, CERN's director for research and computing, in which he also thanked the organizers for the "beautiful venue, the fantastic weather and the perfect organization" and acknowledged the excellent presentations from the younger members of the community. The baton now passes to the organizing committees of the next EPS-HEP conference, which will take place in Vienna on 22–29 July 2015.

● This article has touched on only some of the physics highlights of the conference. For all of the talks, see http://eps-hep2013.eu/.

Résumé

Conférence-anniversaire à Stockholm

Un an après l'annonce de la découverte au CERN d'un boson type Higgs, l'édition 2013 de la Conférence EPS-HEP à Stockholm a été l'occasion de célébrer l'anniversaire de la jeune particule. De nombreux résultats présentés indiquent à quel point cette particule « colle » au Modèle standard. D'autres thèmes ont été à l'ordre du jour, notamment les recherches toujours plus poussées sur la matière noire, sur la supersymétrie et sur d'autres indices de la physique au-delà du Modèle standard. Malgré des mesures de plus en plus précises, rares sont les éléments susceptibles de manifester des effets nouveaux. Voilà un véritable défi pour les théoriciens et pour les futures expériences.

Christine Sutton, CERN, with thanks to the communication team of Sten Hellman, Stockholm University, Pauline Gagnon, Indiana University, and Abha Phoboo and Ashley WennersHerron, CERN.

Faces & Places

AWARDS

Enrico Fermi Prize honours LHC physicists

The Italian Physical Society has honoured five Italian physicists with the Enrico Fermi Prize for their work on LHC experiments, in their roles as current or former spokespersons.

Former ATLAS and CMS spokespersons, Fabiola Gianotti and Guido Tonelli, respectively, were awarded the prize for the discovery with their experiments "of a new fundamental particle with mass around 125 GeV and properties consistent with a Higgs boson, theoretically predicted almost 50 years ago, the existence of which ensures a huge insight in the understanding of the Standard Model of particle physics".

Spokesperson for LHCb, Pierluigi Campana, received the prize for "the first observation, with the LHCb experiment, of CP violation in B_s meson decays and for a large number of high-precision measurements in heavy flavour physics". TOTEM's spokesperson, Simone Giani, was honoured for "the first direct confirmation… that the total proton–proton cross-section increases with energy and for further in-depth studies on the proton structure". Paolo Giubellino, spokesperson for ALICE, received the award for "the unveiling, with the ALICE experiment, of the new features of the hottest and densest state of matter ever produced in high-energy nucleus–nucleus collisions".

The award was established 12 years ago in honour of Enrico Fermi's 100th birthday to recognize outstanding work done by members of the Italian Physical Society. The recipients received their awards at the society's annual meeting in September.





Recipients of the 2013 Enrico Fermi prize. Left to right top, Pierluigi Campana, Simone Giani, Fabiola Gianotti; below, Paolo Giubellino and Guido Tonelli.

Dirac Medals highlight evolution of the universe

The Abdus Salam International Centre for Theoretical Physics (ICTP) has awarded its 2013 Dirac Medal to three physicists whose work has deepened the understanding of the early universe, galaxy formation and black holes. Thomas Kibble, James Peebles and Martin Rees share the award for "independent, ground-breaking work throughout their careers elucidating many aspects of fundamental physics, cosmology and astrophysics".

Kibble, of Imperial College London, has made important contributions to the physics of spontaneous symmetry breaking and to its cosmological consequences. In the 1960s, he was among the first to study the example of spontaneous symmetry breaking by which subatomic particles first gain their mass (*CERN Courier* January/February 2008 p17). He also investigated what happens when a symmetry apparently disappears as the universe evolves from the Big Bang and understood the importance of topological defects as relics of the past symmetrical phase.

Tom Kibble. (Image credit: Thomas Angus, Imperial College London.)

Peebles, of Princeton University, was one of the first physicists to predict the existence of the cosmic microwave background (CMB) and to study its implications for the development and evolution of the universe. He also made major contributions on nucleosynthesis, dark matter, dark energy and structure formation. Rees, of Cambridge University, is well known for his important contributions on the origin of quasars and active galactic nuclei and the prediction of supermassive black holes at the centres of galaxies. His work also includes the physics of gamma-ray bursts, the polarization of the CMB and the study of dark matter.

The ICTP Dirac Medal is awarded annually on Paul Dirac's birthday – 8 August – to scientists who have made significant contributions to theoretical physics.

CERN receives three National Instruments awards

At the NIWeek conference in Texas on 5–8 August, computer-engineering company National Instruments presented three awards to CERN: the National Instruments Graphical System Design Achievement Award, the National Instruments Humanitarian Award and the Intel Intelligent Systems Award.

The Graphical System Design Achievement Awards recognize companies and universities that use graphical-system design to develop applications that meet complex challenges in science and engineering. CERN was selected for the particle accelerator and control systems for the *Med*Austron ion-therapy facility, which was designed and constructed under the guidance of CERN in Austria (*CERN Courier* October 2011 p33).

Johannes Gutleber received the awards on behalf of CERN and gave a keynote presentation on CERN's synchrotron accelerator for medical applications and the underlying control-system technologies at NIWeek. Control systems can contribute significantly to the performance of ion-therapy facilities. The system must control the magnetic fields of several hundred magnets accurately, reconfigure the accelerator for large numbers of beam characteristics in a timely and reliable way and must be easy for medical teams to use.

Johannes Gutleber, centre, receives the National Instruments humanitarian award on behalf of CERN from NI cofounders – president James Truchard, left, and Jeff Kodosky, right. (Image credit. National Instruments.)

Three young ISOLDE scientists win awards

Three young Portuguese researchers participating in an experiment on emission-channelling lattice location with short-lived isotopes (EC-SLI) at CERN's ISOLDE facility have won awards at major conferences in materials science.

Lino Pereira, a postdoc at the Instituut voor Kern- en Stralingsfysica (IKS) of KU Leuven in Belgium, was runner-up in the Young Researcher for Best Manuscript Competition (sponsored by Elsevier) at the 21st International Conference on Ion Beam Analysis, which was held in Seattle on 23–28 June. Lígia Amorim, a PhD student who is also at IKS/KU Leuven with a masters degree from Lisbon University, won the Award for Best Student Oral Presentation at the 17th International Conference on Radiation Effects in Insulators, which took place in Helsinki on 3 June–5 July. Last but not least, Daniel Silva, a PhD student from Porto University in Portugal, won the prestigious J W Corbett prize at the 27th International Conference on Defects in Semiconductors, which was held in Bologna on 21–26 July.

All three awards resulted from studies by the ISOLDE experiment IS453, which includes researchers from IST/ITN Lisbon, the Centre for Nuclear Physics of the University of Lisbon (CFNUL), the University of Aveiro, the University of Porto and IKS/KU Leuven. The work made use of the Portuguese and Belgian experimental infrastructure that was commissioned and is maintained at ISOLDE by researchers from IST/ITN, CFNUL and KU Leuven. It was partially funded by the Portuguese Science Foundation Fundação para a Ciência e a Tecnologia within its CERN Projects funding scheme and by the Flemish Science Foundation FWO.

ACCELERATORS

First TTC Topical Meeting highlights continuous-wave SRF

The first topical meeting of the TESLA Technology Collaboration (TTC) took place this year at Cornell University on 12–14 June on the topic of continuous-wave (CW) superconducting-radiofrequency (SRF) technology. As more CW accelerators are planned and designed, CW SRF technology has increased in importance and more laboratories are pursing R&D in this area. The topics that were covered during the meeting included cavity design for CW, SRF guns, CW cavity operation, high-Q performance and treatment procedures, couplers, high-order mode absorbers and CW cryomodules. More than 60 participants listened to 50 presentations, which focused on open issues and technical aspects. The programme allowed for discussion time that was used efficiently for knowledge exchange on research topics in CW SRF.

Participants at the three-day workshop at Cornell. (Image credit: J Butler/Cornell University.)

The TTC evolved from the TeV-Energy Superconducting Linear Accelerator (TESLA) collaboration in 2004, when the International Committee for Future Accelerators decided that work towards a future international linear collider should be based on SRF technology. The TESLA collaboration renamed itself the TTC, with the redefined aim of advancing SRF-technology R&D and related accelerator studies across a range of scientific applications. The TTC has grown to encompass the whole SRF community, so the collaboration board decided recently to reduce the frequency of full TTC meetings and alternate them with smaller TTC topical meetings that are narrower in scope and do not include a meeting of the collaboration or technical boards.

● For the full programme, see http://lepp.cornell.edu/Events/TTCWorkshop/.

APPOINTMENT

Gianotti becomes honorary professor at Edinburgh

CERN's Fabiola Gianotti – former spokesperson of the ATLAS collaboration – has been appointed an honorary professor in the School of Physics and Astronomy at the University of Edinburgh. She will be associated with the experimental particle-physics group, which carries out research with the ATLAS and LHCb experiments at the LHC. She will work with staff and PhD students from Edinburgh who are based at CERN and visit the university for specialist lectures.

Gianotti is a member of the International Advisory Committee of the Higgs Centre for Theoretical Physics at the University of Edinburgh. Last year, she co-announced, with Joe Incandela of CMS, the discovery at CERN of a new particle – later confirmed as a Higgs boson. Peter Higgs has been associated with the university since 1960.

Fabiola Gianotti, second from right, during a visit of senior members of Edinburgh University including, left to right, Peter Higgs, Victoria Martin and Tim O'Shea, the principal.

About 150 physicists met in Orsay and Paris at the 4th Higgs Hunting Workshop held on 24–27 July. Taking place just after the 2013 EPS-HEP Conference in Stockholm (p37), it provided an ideal occasion for in-depth discussions on the latest results from on-going analyses and detailed studies of the new boson that was discovered last year at CERN. Among those attending were, left to right, Ludwig Faddeev, Karl Jakobs, Guido Altarelli and Monica Pepe-Altarelli. (Image credit: L Fayard.)

SCHOOLS

INSS2013: nurturing young neutrino physicists in Beijing

Students, lecturers and organizers of INSS2013. (Image credit: Li Chen/INSS2013.)

Co-hosted by the Institute of High Energy Physics (IHEP) and Fermilab, the International Neutrino Summer School (INSS) 2013 took place in Beijing on 6–16 August. The school aims to provide a comprehensive programme to prepare young neutrino physicists who are either postgraduate students or in the early stage of their postdoctoral career. This is the first time that INSS and the annual NuFact workshop – before which it usually occurs – have been held in China.

Organized by a committee led by Deborah Harris of Fermilab and Zhi-zhong Xing of IHEP, the two-week immersion school attracted 89 students and young researchers from nine countries. The curriculum covered the breadth of neutrino physics and related fields such as astrophysics and cosmology. Topics included an introduction to the Standard Model; neutrino-oscillation phenomenology; neutrino-mass models; neutrino cosmology and astrophysics; Majorana/Dirac neutrinos and absolute-mass measurements; fundamentals of neutrino cross-sections; physics of neutrino detection; accelerator-based neutrino programmes and non-accelerator-based neutrino programmes.

A concluding lecture offered a snapshot of the field and future directions.

The school also included research projects on involved and realistic theoretical and experimental problems. Students worked in international collaborations of three to five members on problems that they had chosen together from a collection that was suggested by lecturers and members of the organizing committee. At the end of the school, each collaboration gave a 10-minute presentation on their solutions and/or designs. Three groups received prizes awarded for "Outstanding pedagogy", "Most unexpected answer" and "Most prolific answer". Owing to the high quality of work by all of the groups and to reward the hard-working students, the school added three honorable mentions for "The most engaging and energetic presentation and the biggest dreamers", "The bravest collaboration" and "The most efficient large collaboration". IHEP generously provided a gift to each individual or collaboration and Yifang Wang, IHEP's director, kindly signed certificates for the students. In addition to the lectures and projects, the students and lecturers enjoyed social events organized by the school, including an excursion to the Great Wall and two banquets.

Based on anonymous feedback, the students had a great time learning neutrino physics and interacting with their future international collaborators. In the words of one student: "INSS 2013 was just what I was hoping. It delivered answers to all of the neutrino-related questions I have had since entering the field."

● For further information about INSS2013, including more details on the topics and lecturers, see http://inss2013.ihep.ac.cn. In 2014, INSS and NuFact will be hosted by the University of Glasgow and INSS2014 will be held in St Andrews, Scotland.

HASCO 2013 gives credits for hadron-collider physics

Participants at HASCO 2013, at Göttingen University. (Image credit: Arnulf Quadt.)

The second Hadron Collider Physics Summer School (HASCO 2013) took place on 7–19 July in Göttingen, where 65 undergraduate students from 20 institutes in eight countries and 20 lecturers spent two weeks learning about hadron-collider physics. The students learnt about the foundations of quantum field theory and physics.

Numerous research topics that are relevant for hadron-collider physics were discussed, including QCD, jet physics, statistical methods in data analysis, accelerator physics, detector physics, physics of the top quark and searches for supersymmetry or exotic models and particles. This year's focus, however, was the physics of the Higgs boson – a suitable emphasis after the discovery of a Higgs-like boson by the ATLAS and CMS experiments, which was announced just a week before HASCO 2012 took place last year.

This type of fundamental research can be carried out only in large international collaborations, so the school aims for the students not only to learn about the relevant physics but also to experience the creative and productive atmosphere of working in an international team at an early stage in their career. Forming pairs from different institutes and countries, they summarized recent published papers from the LHC, the Tevatron or from theory. Excursions to the Phaeno Science Centre in Wolfsburg or to Wernigerode and the Brocken mountain in the Harz region rounded off the programme.

All participating students passed the written examination at the end and received six European Credit Transfer System (ECTS) points each, which they can invest in study programmes at their home institutions. Many of the students became more interested in studying particle physics.

The HASCO school is funded as an ERASMUS Intensive Programme by the German Academic Exchange Service and the EU. The 20 partner institutes are the universities of Amsterdam, Barcelona, Bern, Bologna, Bratislava, Clermont-Ferrand, Geneva, Glasgow, Göttingen, Grenoble, Krakow, Madrid, Manchester, Milano, Orsay, Oxford, Roma Sapienza, Saclay, Stockholm and Uppsala, as well as CERN. In addition, five guest students from Cambridge (UK), Ferara, Ljubljana, Sherbrooke in Canada and Tokyo Tech also took part.

● For further information, see http://hasco.uni-goettingen.de.

MEETINGS

The **27th ISODARCO Winter Course, Nuclear Governance: Prospects for a Strengthened Nonproliferation Regime**, will take place at Andalo on 8–15 January 2014. Topics will include: technical aspects of protecting the nuclear fuel cycle; assessing new efforts to secure, cut off and reduce fissile material stockpiles; issues posed by recent nuclear proliferation; the roles of international law and domestic measures in supporting a strengthened non-proliferation regime. Founded in 1966 by Edoardo Amaldi and Carlo Schaerf, ISODARCO (the International School on Disarmament and Research on Conflicts) emphasizes the importance of inviting young people to attend meetings. For further information, see http://isodarco.it/courses/andalo14/andalo14.html.

ICTR-PHE 2014, the **2014 International Conference on Translational Research in Radio-Oncology and Physics for Health in Europe**, will be held on 10–14 February in Geneva. ICTR-PHE aims at developing new strategies for improved diagnosis and treatment of cancer by uniting biology and physics with clinics. The five-day conference will review the most recent advances in translational research in physics, biology and clinical oncology. Through the various sessions and symposia, the scientific programme will offer the delegates the opportunity to discuss the latest progress in physics breakthroughs for health applications. For further details, including information on registration, see http://ictr-phe12.web.cern.ch/ICTR-PHE14.

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

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

Visits

Robert Madelin, right, director-general of the European Commission Directorate General for Communications Networks, Content and Technology (DG Connect), visited CERN on 4 July. After signing the guestbook he visited the CMS experimental area with collaboration deputy spokesperson Joao Varela, left.

On 16 July, the visit of **Dalit Stauber**, left, director-general of the Israeli Ministry of Education, included a descent to the LHC tunnel with **Laurent Tavian**, right, from CERN's technology department and **Giora Mikenberg**, centre, from the Weizmann Institute of Science and ATLAS collaboration.

Italian health ministers **Giuseppe Ruocco**, director-general for prevention, left, and **Daniela Roderigo**, director-general for European and international relations, right, visited CERN on 23 July to see the ATLAS experiment cavern and presentations of CERN's medical and health collaborations.

Aneliya Klisarova, left, Bulgarian minister of education and sciences, visited CERN on 16 August. As well as a tour of the CMS cavern, she saw the LHC tunnel accompanied by **Zornitsa Zaharieva**, right, of the beams department.

Letters

How to build an accelerator

Having read *The Particle at the End of the Universe* (reviewed in *CERN Courier* July/August 2013 p52), and especially the section on accelerators (pp55–73), I feel that more is needed to do justice to the work of accelerator physicists and engineers (while agreeing with the reviewer's praise for the particle-physics chapters).

Sean Carroll writes on p56: "The technological challenge is clear: Accelerate particles to as high an energy as we can, smash them together, and look to see what new particles are created". This may pinpoint a necessary condition for colliders (but not for all classical accelerators) but it does not provide all of the sufficient ones. In fact, the particle beams notably have to be as intense as possible (particles per unit time) and as "dense" as possible (take up the smallest possible volume in transverse and in longitudinal phase space) – and this is usually more difficult to achieve than the quoted necessary condition (see for example, *CERN Courier* September 2013 pp25–47).

A full description of what that means would first describe the basic aspects to be dealt with by the builders. How to obtain the wanted type, intensity and "density" of particles from an appropriate source; which transfer system(s) to build to get the particles from the source to the first preaccelerator, to the next ones in the accelerator chain and to the main ring; how to achieve the very low pressure in the beam pipes; how to design the bending and focusing magnets that keep the beams individually together and guide them along the theoretical path, plus the accelerating units that increase the beam energy and the instrumentation that enables continuous detailed beam observation. All of this often requires the development of advanced technologies such as outgassing of vacuum chambers and superconducting magnet coils and accelerating cavities.

Second, the hardware components have to perform in a way that achieves the theoretical beam behaviour. This requires close collaboration between accelerator theoreticians and hardware designers. It concerns, for instance, the time-shape of the magnet cycle as a function of the energy increase, the change in accelerating frequency as a function of the energy reached, as well as the minimization of perturbing influences. As an example, the mechanical stability requirements for the CERN Proton Synchrotron led to its installation on a concrete ring beam hung from a series of reinforced pillars. The positioning of each finely adjustable magnet unit on that beam was done with the help of a specially designed sophisticated geodetic system.

Last, the bibliography on accelerators could be more plentiful. Interested readers can search the web for books on particle accelerators.

● *Helmut Reich, formerly working at CERN.*

The web goes public

On p43 of the September 2013 issue, under the title "CERN launches project to restore info.cern.ch", there is the sentence "On 30 April 1993, CERN published a statement making World Wide Web technology available on a royalty-free basis."

In fact, the official document, of which I am one of the authors, put the software in the public domain and relinquished all intellectual property rights in it. This is quite different from "royalty free". The declaration on p2 of the document – which is available on http://cds.cern.ch/record/1164399 – leaves no ambiguity in reference to either "public domain" or the "intellectual property rights".

However, the declaration concerns only the software of that moment. There never was a statement about the technology, whatever indeed that might mean.

● *Robert Cailliau, Prévessin.*

3D trench electrode detectors

I read with interest the article published in *CERN Courier* (April 2013 p35) that accurately copied parts of an erroneous press release from Brookhaven National Laboratory on Zheng Li. Li won an award from the IEEE Long Island section for his "groundbreaking work in the development of novel silicon detectors," including the development of the "3D trench electrode detector" – one in which at least one type of electrode is made by depositing doped polycrystalline silicon in etched trenches.

However, I would like to make it clear that Zheng Li was not the first to discuss the "3D trench electrode detector," which was in fact already proposed in our group by Chris Kenney. Sensors were fabricated in 1998 at the Stanford Nanofabrication Facility with internal and peripheral trenches as part of our first 3D sensor batch. Our group also made and tested all-trench electrode sensors and showed photographs of them at the 2003 IEEE Nuclear Science Symposium.

Li also wrote an article, "New BNL 3D-Trench electrode Si detectors for radiation hard detectors for sLHC and for X-ray applications" (Li 2011), where on p91 references to our 2001 paper on wall or trench electrodes (Kenney *et al.* 2001) are made: "There was a trench-wall-electrode proposed by Kenney et al. [11], where the detector boundary was etched and doped as trench-wall for the fabrication of edgeless or active-edge detectors, while the electrodes in the bulk are column ones." On the third page of our 2001 paper, taking almost a quarter of the page, is figure 5, a photomicrograph of "part of a sensor with alternating n-type wall and p-type cylinder electrodes" clearly fitting Li's definition of a 3D trench electrode detector.

It is difficult to see how Li could make the sweeping comment "while the electrodes in the bulk are column ones" without looking at our first wall or trench electrode paper (his reference 11). It is equally difficult to see how he could look at the paper and miss the obvious figure 5.

Still, I would like to express my happiness to see Zheng Li working on 3D technology. He must just avoid incorrect claims of originality and should feel free to ask members of our 3D group for help on that subject.

● *Sherwood Parker, member, ATLAS collaboration.*

● Further reading

Z Li 2011 *Nucl. Inst. Meth.* A **658** 90.

C Kenney *et al.* 2001 *IEEE TNS Trans. Nucl. Sci.* **NS-48** 2405.

Correction

The article on IceCube's detection of neutrinos with energies >1 PeV (*CERN Courier* July/August 2013 p5) should have stated that "the probability that the two observed events are background is 2.9×10^{-3}". Unfortunately, the word "not" entered this sentence by mistake.

OBITUARY

Lorenzo Resegotti 1928–2013

Lorenzo (Renzo) Resegotti, renowned accelerator physicist and engineer at CERN from 1954 to 1988, passed away on 23 May 2013.

A native of Piemonte, Italy, Renzo earned his laurea in industrial and electrical engineering at the prestigious Politecnico di Torino, later gaining a diploma in radio engineering from the National Electro-Technical Institute. He became interested in accelerators during a further year spent as a fellow at the Institute of Physics, Rome University. This training provided the perfect background for working at CERN and he was recruited to work in the newly formed organization in April 1954.

Renzo quickly acquired a reputation for being technically competent, rigorous and hard-working – attributes that led him to being given ever-increasing responsibilities in the young organization. His first assignments included the design, purchase and commissioning of the power supply for the Proton Synchrotron, as well as the design and construction of the 120-cm heavy-liquid bubble chamber and its magnet where, with Colin Ramm as his chief and mentor, he honed practical skills of equipment design and project leadership that complemented the thorough understanding of electromagnetism and mechanics that was acquired through his formal studies.

From 1961, he was deputy head of the Nuclear Physics Apparatus division. He was therefore a natural choice to lead the Magnet Group under Kjell Johnsen in the newly created Intersecting Storage Rings (ISR) department in 1966. In common with the other ISR group leaders, Renzo was determined to design, measure and install top-quality equipment, purchased at the lowest price. The success of the ISR bore witness to this dedication. In addition, he regarded it as his duty to imbue the engineers and scientists in his group with training of the sort that he had received (e.g. to get best value for taxpayers' money by applying the "Would you buy at that price with your own money?" rule). When the magnet equipment was installed and working, the group continued to work on the machine and evolved into the Beam Optics and Magnets group (BOM) – an ideal creation for improving the accelerator by optimal use of the magnet system. Therefore coupling-control systems using sets of skew quadrupoles were designed, plus low-β insertions to enhance luminosity.

Lorenzo Resegotti. (Image credit: Ruth Haas.)

Aware of the recent advances in superconductivity and of the importance that this could have for CERN, Renzo established a strategic project to build a set of eight reliable superconducting quadrupoles (four magnets per ring) to equip a crossing point at the ISR with a powerful low-β insertion. This was to be the first major use of superconducting magnets in an accelerator and the magnets were to be developed at CERN and built in industry. Through this project CERN not only acquired an extremely useful piece of apparatus – the ISR achieved the record luminosity of $1.4 \times 10^{32}\,cm^{-2}\,s^{-1}$ – but in parallel it trained engineers and scientists in the practical application of superconductivity and associated cryogenics. This enabled the organization to continue and progress – and eventually led to the LHC.

Renzo was a tough master, truly devoted to doing his utmost for the good of the organization and expecting the same of others. It is generally agreed that he could be "difficult", but he was always straight and just and would be caring with regard to the families of group members. In the words of one scientist on hearing the sad news of Renzo's death, "He was hard – but definitely the best boss I ever had!" The BOM group went on to develop the magnets for the Large Electron-Positron collider, a machine for which Renzo accumulated the responsibility of being a member of the Management Board. However, plagued by ill-health, he found it increasingly difficult to live up to his own standards and took early retirement in 1988. He subsequently devoted himself to voluntary work with his wife Katy through their church in Meyrin and performed duties within the pensioners' association for several years where his insight and common-sense were highly esteemed. The sense of camaraderie instilled into the members of the ISR/BOM group is such that to this day there is a biannual reunion.

● *His friends and colleagues.*

NEW PRODUCTS

Agilent Technologies has introduced the IDP-15 Dry Scroll Pump and the TwisTorr 304 FS Turbomolecular pumps. The IDP-15 Dry Scroll vacuum pump offers a peak pumping speed of 15.4 m³/h (60 Hz) and 12.8 m³/h (50 Hz). The TwisTorr 304 FS turbomolecular high-vacuum pump combines TwisTorr drag stage technology and Agilent Floating Suspension. In the TwisTorr 304 FS, the bearing and dry lubrication eliminate oil and maintenance, and permit operation of the pump in any orientation. For more details, visit www.chem.agilent.com.

ID Quantique has added two new detectors to its id120 series of compact single-photon detector modules based on a silicon avalanche-photodiode that is sensitive in the visible spectral range. The new detectors have high efficiency (up to 80%) in the red region of the visible spectrum and a 500 µm large active area. The modules – which are equipped with a dual universal output signal port – are versatile with a LabView interface that allows the user to control quantum efficiency, dark count rate, etc. For more information, see www.idquantique.com/instrumentation.html.

XP Power has announced the SDL400 series of 400 W single- and dual-output AC-DC power supplies. Suitable for 1U applications, they are available in four mechanical formats, most less than 39.9 mm high. Single-output models are available with nominal outputs between +12 and +48 VDC, as well as +54 and +60 VDC variants. Dual-output models have a +5 VDC output in combination with a +12, +24 or +48 VDC, or +12/+24 VDC. For further details, contact Steve Head, tel +44 118 984 5515, e-mail shead@xppower.com or visit www.xppower.com.

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
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Please contact us for information about rates, colour options, publication dates and deadlines.

Postdoctoral Research Positions
LIGO Laboratory

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

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

The LIGO Laboratory anticipates having one or possibly more postdoctoral research positions at one or more of the LIGO sites -- Caltech, MIT and at the two LIGO observatories beginning in fall 2014, pending availability of funds. Hires will be made based on the availability of funding. Successful applicants will be involved in the operation of LIGO itself, analysis of data, both for diagnostic purposes and astrophysics searches, as well as the R&D program for future detector improvements. We seek candidates across a broad range of disciplines. Expertise related to astrophysics, modeling, data analysis, electronics, laser and quantum optics, vibration isolation and control systems is desirable. Most importantly, candidates should be broadly trained physicists, willing to learn new experimental and analytical techniques, and ready to share in the excitement of building, operating and observing with a gravitational-wave observatory. Appointments at the post-doctoral level will initially be for one-year with the possibility of renewal for up to two subsequent years.

Applications for post-doctoral research positions with LIGO Laboratory should indicate which LIGO site (Caltech, MIT, Hanford, or Livingston) is preferred by the applicant. Applications should be sent to HR@ligo.caltech.edu (Electronic Portable Document Format (PDF) submittals are preferred).

Applications should include curriculum vitae, list of publications (with refereed articles noted), and the names, addresses, email addresses and telephone numbers of three or more references. Applicants should request that three or more letters of recommendations be sent directly to HR@ligo.caltech.edu (Electronic Portable Document Format (PDF) submittals are preferred. Consideration of applications will begin December 1, 2013 and will continue until all positions have been filled.

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

LBNL PHYSICS DIVISIONAL FELLOW

The Physics Division at Lawrence Berkeley National Laboratory (LBNL) invites applications for a Divisional Fellow position from scientists with a record of substantial accomplishment and creative ability. A Divisional Fellow is a five-year appointment with the expectation of promotion to a career position as Senior Staff Scientist and is comparable to a tenure track junior faculty position at a university. Applicants should have several years of experience in experimental physics beyond the PhD or overall equivalent experience, and have demonstrated leadership and original achievements in research.We welcome all applicants with exceptional promise to advance the art of experimentation in particle physics, and particularly encourage applications in the areas of neutrino physics, direct detection of dark matter, and cosmology.

The Divisional Fellow is expected to play a leadership role in her/his scientific field and will be encouraged to originate research in detection and/or related experimental techniques that may enable transformational advances or new opportunities in scientific research. LBNL has a long tradition of pioneering work developing new detectors, devices, and methods for fundamental physics. Beginning with the invention of the cyclotron itself, this history includes the development of the bubble chamber, the time projection chamber, red-sensitive CCDs, a variety of precision semiconductor tracking systems, and innovative microelectronics and systems.

Within the LBNL Physics Division, there is a broad range of research related to collider, flavor, and neutrino physics, rare decays, cosmology, and direct searches for dark matter. We support a diverse program for state of the art instrumentation development, with significant technical capabilities available through partnerships with the LBNL Engineering, Nuclear, Materials, Computing Sciences Divisions, and the Accelerator and Fusion Research Division. We also form collaborations with the Electronic Engineering, Nuclear Engineering, and Physics departments at the adjacent campus of the University of California at Berkeley.

How to Apply: Please go to **https://academicjobsonline.org/ajo/jobs/1653** to create a profile and submit the requested application materials. Note that applications can only be made via this Academic Jobs Online URL. For inquiries please contact Dominga Estrada via email (EstradaDR@lbl.gov). For full consideration all application materials must be submitted by November 15, 2013.

Requested application materials: Curriculum vitae (CV), Publication list, Statement describing research interests, Arrange for at least five letters of reference to be submitted via the Academic Jobs Online URL above.

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universitätbonn

JÜLICH FORSCHUNGSZENTRUM

The University of Bonn is a research university that operates internationally, actively seeks cooperation and sets clear subject priorities. Its academic profile is shaped by internationally recognized strengths. The University of Bonn will be consolidating and sharpening this profile over the coming years. In developing its chosen specializations, the University of Bonn works very closely in selected fields with research partners such as Forschungszentrum Jülich from the ABC science region (Aachen, Bonn, Cologne).

With 5,000 employees, Forschungszentrum Jülich – a member of the Helmholtz Association – is one of the large interdisciplinary research centres in Europe and stands for the next generation of key technologies. Work with us on the grand challenges in the fields of health, energy & environment, and information technology, as well as on the many and varied tasks of research management.

In a joint procedure with the University of Bonn, Forschungszentrum Jülich is seeking an internationally respected scientist for the position of a

DIRECTOR (f/m) (W3)

at the Nuclear Physics Institute – Large-Scale Nuclear Physics Equipment (IKP-4)

In accordance with the Jülich Model, the successful applicant will also be appointed professor of experimental physics at the University of Bonn.

The Nuclear Physics Institute (IKP), which consists of four divisions, conducts basic research in the fields of hadron physics, particle physics, and nuclear physics. The institute focuses on hadron physics with polarized hadronic probes. IKP-4 currently operates the cooler synchrotron COSY, with a priority on further developments in beam cooling, polarization, and spin manipulation. With the construction of the high-energy storage ring HESR, IKP-4 has taken on an important role in the FAIR project. Strategic cooperation is maintained with RWTH Aachen University within the framework of JARA-FAME.

Applications are welcome from internationally respected scientists in the field of accelerator physics who will both further develop the acceleration, storage, cooling, and spin manipulation of charged hadrons to the highest level, and can also realize the construction of HESR within the approved time schedule and budget. The successful candidate will be expected to play a leading role in the scientific development and implementation of pioneering accelerator-based projects. The ability to head an institute as a member of the board and a willingness to cooperate are essential. The successful candidate will be expected to contribute adequately to the teaching of experimental physics at the University of Bonn, for example by holding lectures for the master's course in physics, and is also encouraged to carry out joint research projects with the University of Bonn.

Prerequisites for the position are a PhD, a Habilitation, or equivalent scientific achievements, as well as experience in leading a scientific working group and in teaching.

Forschungszentrum Jülich and the University of Bonn aim to increase the proportion of women in executive positions, and therefore particularly welcome applications from women.

We also welcome applications from disabled persons.

Forschungszentrum Jülich has a dual career service and is a member of the Dual Career Network Rhineland. More information at www.fz-juelich.de/dualcareer

Please send your application in English with the usual documents **preferably by email** by 12 November 2013 to:

Board of Directors of Forschungszentrum Jülich GmbH
52425 Jülich
Germany
berufungen@fz-juelich.de

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

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

DOCTORAL FELLOWSHIPS

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

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

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

Applicants have to initiate their application registering via a web form available at **http://www.fundamental-physics.uni-hd.de/fellowships**. Applications should reach us by December 1, 2013.

NATIONAL TAIWAN UNIVERSITY
Leung Center for Cosmology and Particle Astrophysics

Distinguished Junior Fellowship

The Leung Center for Cosmology and Particle Astrophysics (LeCosPA) of National Taiwan University is pleased to announce the availability of several Post-Doctoral Fellow or Assistant Fellow positions in theoretical and experimental cosmology and particle astrophysics, depending on the seniority and qualification of the candidate. Candidates with exceeding qualification will be further offered as LeCosPA Distinguished Junior Fellows with competitive salary.

LeCosPA was founded in 2007 with the aspiration of contributing to cosmology and particle astrophysics in Asia and the world. Its theoretical studies include dark energy, dark matter, large-scale structure, neutrino cosmology, and quantum gravity. The experimental investigations include the balloon-borne ANITA project in Antarctica and the ground-based ARA Observatory at South Pole in search of GZK neutrinos, and a satellite GRB telescope UFFO that is capable of slewing to the burst event within 1sec.

These positions are available on September 1, 2014. Interested applicant should email his/her application with curriculum vitae, research statement, publication list and three letters of recommendation before December 15, 2013 to
Ms. Yen-Ling Lee ntulecospa@ntu.edu.tw

For more information about LeCosPA, please visit its website at
http://lecospa.ntu.edu.tw/

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

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN FACULTY OF PHYSICS

As one of Europe's leading research universities, Ludwig-Maximilians-Universität (LMU) in Munich is committed to the highest international standards of excellence in research and teaching. Building on its more than 500-year-long tradition, it offers a broad spectrum that covers all areas of knowledge within its 18 Faculties, ranging from the humanities, law, economics and social sciences, to medicine and the natural sciences.

The **Faculty of Physics** invites applications for a

Professorship (W2)(6 years/tenure track) of Experimental Physics – Elementary Particle Physics

commencing on 1.4.2014.

The appointment is within the scope of the Cluster of Excellence Origin and Structure of the Universe. The cluster is operated jointly by the physics departments of the two Munich Universities, several Max-Planck Institutes, and the European Southern Observatory (ESO). It aims at a deeper understanding of the fundamental forces and the dynamics which drive the expansion of our universe, the creation of the elements, and the growth of large-scale structures.

Within this framework we are seeking candidates for the position of a research group leader who will focus on Experimental Particle Physics and the study of matter-antimatter asymmetry. We are looking for an outstanding personality playing a leading role in experiments devoted to the study of the matter-antimatter asymmetry with B-mesons at electron-positron or hadron colliders, and/or with a special engagement in tagging-techniques of B-mesons for the search of new physics.

LMU Munich seeks to appoint a highly qualified junior academic to this professorship and, therefore, especially encourages early-career scholars to apply. Prerequisites for this position are a university and a doctoral degree. With an excellent record in research and teaching to date, prospective candidates will have demonstrated the potential for an outstanding academic career.

The initial appointment will be for six years. After a minimum of three years, it can be converted into a permanent position pending a positive evaluation of the candidate's performance in research and teaching as well as his or her personal aptitude and if all legal conditions are met.

Under the terms of the "LMU Academic Career Program", in exceptional cases and subject to outstanding performance in research and teaching, the position may be converted from a W2 into a W3 Full Professorship at a later date.

LMU Munich makes a point of providing newly appointed professors with various types of support, such as welcoming services and assistance for dual career couples.

LMU Munich is an equal opportunity employer. The University continues to be very successful in increasing the number of female faculty members and strongly encourages applications from female candidates. LMU Munich intends to enhance the diversity of its faculty members. Furthermore, disabled candidates with essentially equal qualifications will be given preference.

Please submit your application comprising a curriculum vitae, documentation of academic degrees and certificates as well as a list of publications to the **Dean of the Faculty of Physics, Schellingstr. 4, D-80799 Munich, Germany,** no later than **15 November 2013.**

Europäisches Patentamt
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In 2014 the European Patent Office plans to recruit more than 200

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to work as patent examiners

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We offer a competitive net salary (EUR 4 200-8 000 per month, depending on experience) as well as various benefits and allowances.

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ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

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KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

Scientific Staff

Postdoctoral Fellows
Assistant Professors
Associate and Full Professors

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

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

We intend to make appointments in all three categories of the 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 faculty, and encourage full-time members to be away from the Institute for between 1 and 3 months every year.

The focus of Kavli IPMU includes but is not limited to: all areas of mathematics (e.g. algebra, geometry, analysis, and statistics); string theory and mathematical physics; particle theory, collider phenomenology, beyond the standard model physics phenomenology; cosmology and astrophysics theory; astronomy and observational cosmology; and particle and underground experiments. We are leading efforts on the XMASS dark matter experiment, the KamLAND-Zen neutrino experiment, the Hyper Suprime-Cam (HSC) project for weak lensing surveys and Prime Focus Spectrograph (PFS) for the dark energy at the Subaru Telescope, GADZOOKS! at Super-Kamiokande,the Belle II experiment, T2K long baseline neutrino experiment, SDSS-IV/MaNGA for a survey of galaxies, POLARBEAR CMB B-mode polarization measurement and R&D for future large neutrino detectors. Kavli 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, 2013.

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

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

The Excellence Cluster for Fundamental Physics
'Origin and Structure of the Universe'

TUM LMU

RESEARCH FELLOW

in Astrophysics, Cosmology, Nuclear and Particle Physics

The Cluster of Excellence 'Origin and Structure of the Universe' is a joint research institution at the Technische Universität München (TUM) funded by the Excellence Initiative of the Federal Government of Germany. In 2012, the Universe Cluster's funding has been prolonged until 2017 allowing to intensify the research program.

The Universe Cluster is a co-operation by the physics departments of the TUM and the Ludwig-Maximilians University, four Max-Planck Institutes (MPA, MPE, MPP, IPP), ESO and the computer centre LRZ. The main goal of the Universe Cluster is to solve fundamental questions of particle physics, astrophysics and cosmology. It fosters interdisciplinary work between these disciplines.

For our **FELLOWSHIP PROGRAM** we are looking for excellent young scientists on the postdoc level who will pursue their individual research activities and are interested in a strong collaboration with existing Cluster research groups. Fellows will benefit from an ideal scientific infrastructure at the Garching Campus. **The duration of the contract is 3 years.** Fellows will receive their **own budget** for travel and other costs.

The advancement of women in the science is an integral part of the Cluster's and the university's policy. Women are therefore especially encouraged to apply. Persons with disabilities will be given preference to other applicants with equal qualifications.

Application: Candidates should prepare a covering letter and the following documents as PDF files: a CV, a publication list, certificates (diploma, PhD), past research activities and a research plan. These files can be uploaded in the job section on the Cluster website **www.universe-cluster.de**. Further, applicants are asked to arrange for three letters of recommendation to be sent to **job@universe-cluster.de**. The application deadline is on **15 November 2013.**

Contact: Technische Universität München – Excellence Cluster Universe – Dr. Andreas Müller – Boltzmannstraße 2 – 85748 Garching - Germany

A POSTDOCTORAL OPPORTUNITY

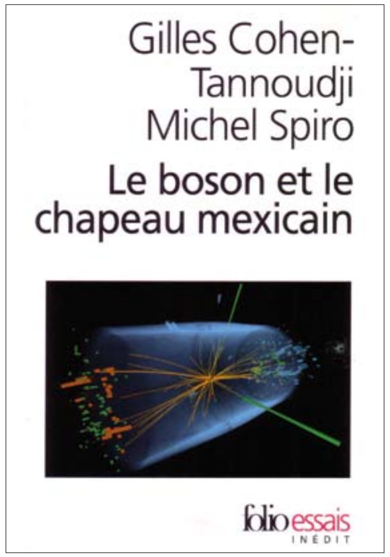
for a computational condensed matter scientist in the area of multiferroics (especially, solid solutions) and ferroelectrics in their bulk and nanostructure forms is available at the **University of Arkansas**.

For more information, see

http://www.uark.edu/misc/aaron5/index.html

Bookshelf

Le boson et le chapeau mexicain – Un nouveau grand récit de l'Univers
Par Gilles Cohen-Tannoudji et Michel Spiro. Postface de Michel Serres.
Gallimard
Broché: €9.90
Format numérique: €9.40



Gilles Cohen-Tannoudji et Michel Spiro revisitent plusieurs siècles de physique, en s'attardant bien sûr sur le XX^{e}, qui a vu les révolutions de la théorie de la relativité et de la mécanique quantique. Si la partie consacrée au passage de la mécanique quantique à la théorie quantique des champs n'est pas de lecture vraiment aisée pour le non-spécialiste, celui-ci peut vite retrouver le rythme grâce à l'introduction des diagrammes et amplitudes de Feynman, qui sont une mise en musique de la théorie dynamique des interactions fondamentales. Le Modèle standard est évoqué rapidement, ainsi que les théories de jauge. La nécessité de mécanisme de BEH (pour Brout, Englert et Higgs) est alors introduite avec l'émergence des masses. Il faut noter que jamais les auteurs ne se laissent aller au raccourci facile de l'expression « boson de Higgs » ni ne parlent de « particule de Dieu » : tout au long de l'ouvrage, le boson est nommé, à juste titre, « BEH ».

Le non-physicien devra s'armer de courage pour parcourir le chapitre sur la chromodynamique quantique mais en sera récompensé en découvrant l'explication de l'énigmatique titre du livre, qui associe le boson et le chapeau mexicain.

L'histoire du CERN, de sa compétition avec les laboratoires à accélérateurs d'outre-Atlantique et de ses succès, tient une grande place dans ce livre. Les auteurs n'hésitent pas à développer les aspects techniques de l'aventure. Le plaisir que j'ai eu à lire ce livre a été d'autant plus grand que j'ai eu le privilège d'interagir avec Michel Spiro durant son mandat de président du Conseil du CERN. Il m'appelait souvent tôt le matin afin d'avoir des nouvelles de la santé du LHC et voulait savoir pourquoi on ne poussait pas plus rapidement les performances de cette fantastique machine à découvertes. C'est dire l'importance qu'il attache à la découverte du boson BEH, annoncée le 4 juillet 2012 au CERN : consécration d'une longue traque mondiale qui n'a pu être obtenue que grâce à la conception, à la construction et à la mise en service de l'accélérateur LHC.

Les aspects politiques du CERN ne sont pas oubliés : ils sont décrits comme des ingrédients essentiels du succès de l'organisation, et cette description est magistralement développée dans la postface de Michel Serres, ode au CERN et à son mode de gouvernance, où le philosophe défend l'idée que le modèle fonctionne si bien qu'il devrait être reproduit dans d'autres domaines des sciences. Cette postface remarquable de clarté et de richesse aurait pu être mieux valorisée – si le texte avait servi de préface, il aurait permis au lecteur de mesurer encore mieux le rôle du CERN dans la découverte du boson.

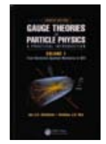
Ce livre, que les auteurs ont voulu à moins de 10 €, est écrit dans la langue de Louis de Broglie et François de Rose, pères fondateurs du CERN. Il décrit avec précision et passion la quête du boson BEH qui ouvre les portes la physique au-delà du Modèle standard. Ne boudons pas cette chance de pouvoir lire un tel ouvrage en français !

Il précise que l'aventure n'est pas terminée. Le boson BEH n'est qu'une étape et de nombreuses questions demeurent : le Modèle standard ne décrit que 4% de la matière de l'Univers. Comme le mentionnent les auteurs, il faut dès maintenant semer les graines des prochaines technologies des accélérateurs et des détecteurs afin d'être en mesure de construire les machines post-LHC. En fonction des résultats du LHC quand il fonctionnera à une énergie de 13–14 TeV après le long arrêt technique de 2013–2014, il faudra financer et construire un accélérateur capable d'atteindre des énergies proches de 100 TeV.

● *Frédérick Bordry, CERN.*

Books received

Gauge Theories in Particle Physics: A Practical Introduction, Fourth Edition – 2 Volume Set
By Ian J R Aitchison and Anthony J G Hey
CRC Press
Hardback: £82



The fourth edition of this well-established, highly regarded two-volume set continues to provide a fundamental introduction to advanced particle physics while incorporating new experimental results, especially in the areas of CP violation and neutrino oscillations. It offers an accessible and practical introduction to the three gauge theories included in the Standard Model of particle physics: QED, QCD and the Glashow-Salam-Weinberg (GSW) electroweak theory.

In the first volume, a new chapter on Lorentz transformations and discrete symmetries presents a simple treatment of Lorentz transformations of Dirac spinors. Along with updating experimental results, this edition also introduces Majorana fermions at an early stage, making the material suitable for a first course in relativistic quantum mechanics.

Covering much of the experimental progress made in the past 10 years, the second volume remains focused on QCD and the GSW electroweak theory – the two non-Abelian quantum gauge field theories of the Standard Model – and includes a new chapter on CP violation and oscillation phenomena. This new edition also discusses the exciting discovery of a boson with properties consistent with those of the Standard Model Higgs boson. It also updates many other topics, including jet algorithms, lattice QCD, effective Lagrangians, and three-generation quark mixing and the Cabibbo-Kobayashi-Maskawa matrix.

Higgs. Le boson manquant
Par Sean Carroll
Belin
Broché: €22

Translated by Bertrand Nicquevert, a research engineer at CERN, this French edition also contains a preface by Lyn Evans, former LHC project leader, and a postface written by the translator together with ATLAS physicist Pauline Gagnon, Indiana University. For a review of the English edition see *CERN Courier* July/August 2013 p 52.

CERNCOURIER

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Contents