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CERN COURIER

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

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Cover: The Liz Lerman Dance Exchange fuses physics and dance in *The Matter of Origins* (p50). (Courtesy John Borstel.)

NEWS

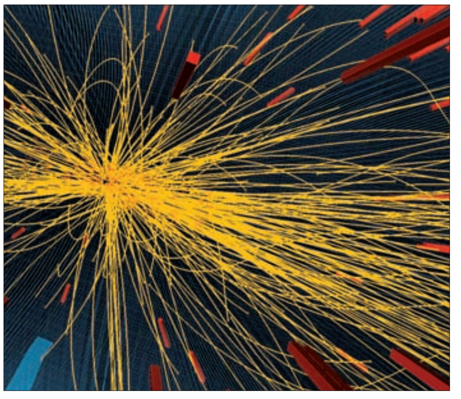
LHC EXPERIMENTS

The window opens on physics at 7 TeV

After almost six months of operation in a new energy region, the experiments at the LHC are yielding papers on physics at 7 TeV in the centre-of-mass. They include results aired at the International Conference on High-Energy Physics in Paris in July (p19).

At the end of September, the CMS collaboration announced the observation of intriguing correlations between particles produced in proton–proton collisions at 7 TeV. It measured two-particle angular correlations in collisions at 0.9, 2.36 and 7 TeV – the three centre-of-mass energies at which the LHC has run. At 7 TeV, a pronounced structure emerges in the two-dimensional correlation function for particle pairs in high-multiplicity events, with at least 100 charged particles and a transverse momentum of 1–3 GeV/*c*. The ridge-like structure occurs at $\Delta\phi$ (a measure of the difference in transverse angle) near zero and spans a rapidity range of $2.0 < |\Delta\eta| < 4.8$ (CMS collaboration 2010). This implies that some pairs of particles emerging with a wide longitudinal angle (which is related to $\Delta\eta$) are closely correlated in transverse angle. The effect bears some similarity to those already seen in heavy-ion collisions at the Relativistic Heavy Ion Collider at the Brookhaven National Laboratory, which have been linked to the formation of hot, dense matter in the collisions. However, as the CMS collaboration stresses, there are several potential explanations.

These developments will be of interest to the ALICE collaboration, whose detector is optimized for the study of heavy-ion collisions at the LHC, the first period of which is scheduled to begin in November. In the meantime, one of the interesting results from ALICE in proton–proton collisions concerns the ratio of the yields of antiprotons to protons at both 0.9 TeV and 7 TeV. The measurement relates to the question of whether baryon number can transfer from the incoming beams to particles emitted transversely (at mid-rapidity). Any excess of protons over antiprotons would indicate such a transfer, which would be related to the slowing down of the incident proton. The results show that the ratio rises from about 0.95 at 0.9 TeV to close to 1 at 7 TeV and is independent of both rapidity and transverse momentum (ALICE collaboration 2010). These findings are consistent with the conventional model of baryon-number transport, setting stringent limits on any additional contributions.



A 7 TeV proton–proton collision in CMS yielding more than 100 charged particles.

In the search for new physics, the ATLAS experiment recently set new limits on the mass of excited quarks by looking in the mass distributions of two-jet events, or dijets (*CERN Courier* October 2010 p6). Now, the collaboration has also produced the first measurements of cross-sections for the production of jets in proton–proton collisions at 7 TeV. It has measured inclusive single-jet differential cross-sections as functions of the jet's transverse momentum and rapidity and dijet cross-sections as functions of the dijet's mass and an angular variable χ. The results agree with expectations from next-to-leading-order QCD, so providing a validation of the theory in a new kinematic regime.

The LHCb collaboration is also measuring cross-sections in the LHC's new energy region. With its focus on the physics of b quarks, the experiment has looked, for example, at the decays of b hadrons into final states containing a D^0 meson and a muon to measure the $b\bar{b}$ production cross-section at 7 TeV (LHCb collaboration 2010). While some earlier results on the production of b-flavoured hadrons at 1.8 TeV at the Tevatron appeared to be higher than theoretical predictions, more recent measurements there at 1.96 TeV by the CDF experiment were consistent with theory. Now, LHCb's results have extended the measurements to a much higher centre-of-mass energy – and again show consistency with theory, this time at 7 TeV. Such measurements of particle yields are vital to LHCb in assessing the sensitivity for studying fundamental parameters, for example, in CP violation.

Further reading

ALICE collaboration http://arxiv.org/abs/1006.5432.
ATLAS collaboration http://arxiv.org/abs/1009.5908.
CMS collaboration http://arxiv.org/abs/1009.4122v1.
LHCb collaboration http://arxiv.org/abs/1009.2731/.

Sommaire

CERN

Council approves the Medium Term Plan

During an intense series of meetings, which concluded on 17 September, the CERN Council overwhelmingly approved the laboratory's revised Medium Term Plan for the period 2011 to 2015. The plan was originally presented to Council at its June session, at which Council asked CERN management to introduce cost-saving measures. In the revised plan, contributions from the member states will be reduced by a total SFr135 m over the five-year period; measures to consolidate CERN's social security systems will bring the total reduction to the programme to SFr343 m.

The plan protects the LHC programme, achieving cost savings by slowing down the pace of other programmes. CERN management considers this a good result for the laboratory given the current financial environment. "The plan we presented to Council is firmly science-driven," explained CERN's director-general, Rolf Heuer. "It reduces spending on research and consolidation through careful and responsible adjustment of the pace originally foreseen in a way that does not compromise the future research programme unduly. The reductions will be painful, but in the current financial environment, they are fair."

Among the programmes to be affected is the upgrade to the LHC's beam intensity. This will now proceed later than originally planned, with the new linear accelerator expected to be connected in 2016 instead of 2015. In addition, there will be no running of CERN's accelerators in 2012. The decision not to run the LHC in 2012 had already been taken in February for purely technical reasons; now the complete CERN accelerator complex will join the LHC in a year-long shutdown.

Looking further ahead, the plan allows for continuing R&D on the Compact Linear Collider (CLIC) study and on high-intensity proton sources, but at a slower pace than originally foreseen. Work on CLIC may provide technology for the development of a new machine to study in depth the discoveries made by the LHC, while high-intensity proton sources will allow CERN to play its part in global developments for neutrino physics.

"Council's decision is an important one for European science," said Council president Michel Spiro. "Although Council acknowledges that the cuts will be painful, we recognize the excellent performance of the LHC and its detectors, and consequently took decisions that minimize the disruption to CERN and its global user community. Council's decision underlines Europe's commitment to basic research, and is testimony to the robustness of the CERN model of international collaboration in science. Council is grateful for the pragmatism, and the realism of the CERN management in proposing real cost savings in time of crisis."

Georges Charpak 1924–2010

Georges Charpak, speaking at CERN when the Institute of Electrical and Electronics Engineers dedicated a "Milestone" plaque in recognition of the invention of electronic particle detectors at the laboratory. These include the multiwire proportional chamber, in 1968.

Many people around the world, not only particle physicists, were deeply saddened to learn that Georges Charpak passed away on 29 September.

A student of Frédéric Joliot-Curie at the Collège de France, Charpak joined CERN in 1959, just five years after the organization's foundation. From the start, he applied himself to the development of new particle-detector techniques. His outstanding and pioneering efforts – particularly the invention of the multiwire proportional chamber in 1968 – revolutionized particle physics, taking the field into the electronic age. The techniques he pioneered are reflected in many experiments today, not only in particle physics but in many other areas of research.

The significance of his work did not go unnoticed and was crowned with the award of the Nobel Prize in Physics in 1992. In making this award, the Swedish Academy recognized not only Charpak's contribution to science but also to society. Detectors evolved from his pioneering work have found applications in many walks of life ranging from medicine to security.

A full tribute and obituary will appear in the next issue of *CERN Courier*.

LHC NEWS

Bunch trains lead towards target luminosity

Three weeks of intense machine development on the LHC came to a satisfying conclusion on the night of 21 September with the final validation of the machine-protection systems for operation with "bunch trains". Less than three weeks later, the machine was running with 248 bunches per beam, giving a peak luminosity of 8.8×10^{31} cm^{-2} s^{-1}, close to this year's target of 10^{32} cm^{-2} s^{-1}.

Until the beginning of September, the LHC ran with bunches spaced by 1–2 μs, injected one bunch at a time from the Super Proton Synchrotron, the final stage in the injection chain. The change to injecting bunch trains – groups of bunches – not only reduces the time required to fill the machine but also allows for further increases in luminosity. It is therefore another important step on the route to full operation of the LHC. Eventually, the collider will run with 2808 bunches per beam, with 25 ns between bunches in a train. The target for 2010 was for a bunch spacing of 150 ns (equivalent to about 45 m) in the trains.

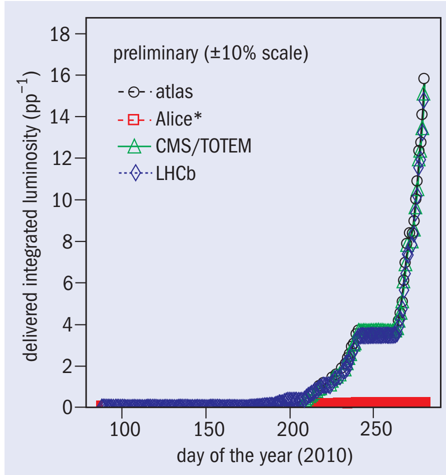
Running with bunch trains requires the careful setting-up of crossing angles between the beams at the interaction points in order to avoid unwanted collisions on either side of the experiments. Tests showed that the minimum angle needed to avoid parasitic collisions with the 150 ns trains is 100 μrad. They also revealed that there is more dynamic machine aperture at the interaction region than predicted at the nominal crossing angle, at injection, of 170 μrad. For the subsequent physics runs the crossing angle was reduced to 100 μrad during the ramp of the beam energy and the "squeeze".

Using crossing angles has the consequence that all the protection devices had to be set up to match the new trajectories round the machine, a process that alone took the best part of a week, but all was ready for the first physics fill with the new conditions on 22 September. For this, the operations team injected three trains of eight bunches to give 24 bunches per beam. The fill of 13.5 hours provided around 170 nb^{-1} of integrated luminosity. A day later, the number of bunches was increased to 56 per beam.

This initial work on bunch trains was with approximately the same total beam intensity as in August, but the first fill brought a bonus. Bunches of nominal intensity were injected into the LHC with a smaller-than-usual transverse size. While this might give a higher initial luminosity, it was expected to cause lifetime problems when the beams were brought into collision. However, the beam lifetime remained surprisingly high (around 25 hours) and the luminosity was significantly higher than expected.

The first step to higher intensity took place on 25 September, with an increase to 104 bunches per beam. The total intensity was now more than 10^{13} protons per beam and a single fill for physics could deliver more than 1 pb^{-1}. At 3.5 TeV the LHC had reached a stored energy per beam of 6 MJ, the highest for any collider and exceeding the record set at the Intersecting Storage Rings at CERN many years ago.

The next increase, to 152 bunches per beam, was made on 30 September by injecting 16 bunches at a time in two 8-bunch trains. This was followed on the night of 4–5 October with the first physics fill with 200 bunches, which provided 2 pb^{-1} in 12 hours. Then, on 7–8 October, the fill with 248 bunches was achieved, with bunch trains injected three at a time.



*The increase in luminosity delivered to the experiments after the work on bunch trains around day 250. (*ALICE low pile-up mode since 1 July.)*

The strategy for increasing the intensity is driven by the machine protection, as the stored beam energy increases with each step. The aim is to provide three successful fills for physics to deliver more than 20 hours of colliding beams before progressing to the next step. Running with protons is scheduled to stop towards the end of October, by which time the LHC should be running with 344 bunches per beam. There will then be a period to set up for the first runs with heavy ions, before a short shutdown at the end of the year.

AWARD

Graphene gathers Nobel Prize

The Nobel Prize in Physics for 2010 has been awarded to Andre Geim and Konstantin Novoselov, both of the University of Manchester, for their "groundbreaking experiments regarding the two-dimensional material graphene". Graphene – which consists of a layer of carbon just one atom thick – has exceptional properties that have made it a micro-laboratory for quantum physics (for example, see *CERN Courier* July/August 2009 p11). At a time when many researchers believed it was impossible for such thin crystalline materials to be stable, Geim and Novoselov extracted the graphene from a piece of graphite using only normal adhesive tape to obtain monatomic layers of carbon and transfer them to a silicon substrate. They used an optical method to identify the monolayers.

Not only is graphene the thinnest material ever made, it is also the strongest; it is also an excellent conductor and is almost completely transparent. These properties suggest applications that include very fast transistors (*CERN Courier* April 2010 p10) and transparent touch screens. When mixed into plastics, graphene can make new very strong materials, which are nevertheless thin, elastic and lightweight.

Novoselov, 36, first worked with Andre Geim, 51, as a PhD student in the Netherlands. He subsequently followed Geim to the UK. Both studied and began their careers in Russia and are now professors at Manchester.

DESY

European XFEL project passes milestones

On 3 September, the tunnel-boring machine TULA – for TUnnel for Laser – broke through the wall of its reception shaft to complete the first 480 m of the tunnel system for the European XFEL project, which will extend for 3.4 km from Schenefeld in northern Germany to the site of the DESY laboratory in Hamburg. The machine will excavate two of the photon tunnels plus the main tunnel for the superconducting linear accelerator that will drive the free-electron laser (*CERN Courier* September 2010 p32). It will be joined in late 2010 by a second, smaller machine that will excavate the other sections of the photon-tunnel system.

When TULA set out on its "maiden journey" at the beginning of July, it was not at all sure that it would reach its goal on schedule eight weeks later. How long the machine would take depended on the composition of the soil and on the presence of unknown potential obstacles underground. However, all apparently worked out perfectly and TULA has completed the first section of photon tunnel. The machine will now be dismantled and the various parts transported back to Schenefeld and reassembled again for its second assignment on a 594 m-long photon-tunnel section to begin in early November.

Another important milestone was reached on 7 September, this time towards the construction of the superconducting linac. Two workshops took place to co-ordinate the future collaboration of DESY with two firms elected for the industrial production of the superconducting accelerator structures. These structures are a joint contribution of DESY and INFN Milano, co-ordinated by DESY.

At the workshops, representatives of the firms and of DESY met to discuss their collaboration. DESY has commissioned each of the two firms – Research Instruments (Bergisch-Gladbach, Germany) and Zanon (Schio, Italy) – to produce 300 superconducting cavities, for a total of about €50 m. Each company will first deliver eight pre-production units to test the infrastructure newly installed at the firms. Another 280 cavities will follow together with 12 accelerator structures manufactured within the framework of the EU ILC HiGrade project. DESY is not only acting as a commissioner for the cavities but is also providing the superconducting niobium, its own machines and know-how for quality control.

The delivery of the pre-production cavities is to begin in the coming year, while that of the series production will start at the beginning of 2012 and should be finished within two years. After successful testing at DESY, the cavities will be transferred to Saclay, for the assembly of the XFEL accelerator modules.

The tunnel builders with Imke Gembalies from the European XFEL GmbH, centre left, and state minister Herlind Gundelach, centre right, in front of the cutterhead of TULA. (Courtesy European XFEL GmbH.)

ACCELERATORS

Fermilab constructs accelerator test facility

Fermilab has announced the start of phase II of the construction of a new facility to advance superconducting RF (SRF) technology. The facility, which will host a 140 m-long test accelerator, will be the first of its kind in the US.

Construction of the SRF Accelerator Test Facility is part of Fermilab's SRF R&D programme, which it is advancing with $52.7 m in funding from the American Recovery and Reinvestment Act (ARRA). Phase I of the construction began in March with the $2.8 m expansion of an existing building. For phase II, the laboratory has awarded a contract worth $4.2 m for the construction of two new buildings. Additional ARRA funds will go towards equipment and infrastructure that are needed for the building's operation.

The new facility will allow Fermilab to test SRF components and validate the manufacturing capability of vendors from US industry. The superconducting structures operate at low temperatures inside cryomodules and the plans are to test modules designed for two projects for future accelerators: Project X, a high-intensity proton accelerator complex that would be built at Fermilab, and the International Linear Collider, an electron–positron collider that could become the world's next high-energy machine, designed and built through an international effort. Researchers will also use the particle beams generated by the test accelerator to help them develop instruments and accelerator technology for application in other fields, including medicine and industry.

When complete, the prototype accelerator will comprise six cryomodules like this first example. Each weighs about 8 tonnes and contains eight SRF cavities. (Courtesy Fermilab Visual Media Services.)

Barton Malow Inc, a company based in Michigan, will do the civil construction for the new facility. This will consist of three interconnected structures: one will house the SRF test accelerator; the second will accommodate the area for testing cryomodules; and the third will house the equipment for a powerful new cryogenic plant to cool the cryomodules in the test accelerator and the test area. The company plans to finish the project by autumn 2011.

FELS

Jefferson Lab goes into the ultraviolet

The free-electron laser (FEL) at Jefferson Lab has produced its first beams at ultraviolet wavelengths. On 31 August, its first day of generating ultraviolet light, the FEL produced more than 50 W of laser light at a wavelength of 372 nm. It was then tuned from 363–438 nm, through many ultraviolet wavelengths and into the visible range.

Jefferson Lab's FEL, which is based on a superconducting energy-recovery linac, is well known as the most powerful tunable laser in the infrared and also as a powerful source of terahertz light. Its high-power beams of infrared laser light, deliver more than 10 kW in continuous wave operation (*CERN Courier* June 2005 p7). Now, a four-year effort has succeeded in extending the spectrum to the shorter wavelengths of the ultraviolet region.

By producing 372 nm at 50 watts in August, the Jefferson Lab team has also demonstrated that it can produce milliwatts of laser light at 124 nm, the third harmonic of the light at 372 nm. So far, the FEL, has produced UV laser light only in the vault, which contains the accelerator and the mirrors that produce the primary wavelength of laser light. Before experiments at the shorter wavelength can begin, the team will need to install a different mirror to extract the 124 nm light and characterize it. In the meantime, the FEL operators plan to test the machine's capabilities in the ultraviolet region. They expect the FEL to be capable of delivering more than a kilowatt of laser light at 372 nm. This should be ideal for studying many novel materials.

FACILITIES

Countries sign international treaty on construction of FAIR

The Facility for Antiproton and Ion Research (FAIR) was officially launched on 4 October in Wiesbaden. Nine countries signed the convention for the construction of the new facility: Germany, Finland, France, India, Poland, Romania, Russia, Slovenia and Sweden. This international agreement forms the framework for FAIR.

Representatives of the signatory countries in Schloss Biebrich, Wiesbaden. (Courtesy G Otto, GSI.)

Immediately after the signing, FAIR GmbH was established as a company. The first shareholders are Germany, Russia, India, Romania and the Swedish–Finnish consortium. In its first session, the council of the company appointed Boris Sharkov as scientific managing director and Simone Richter as administrative managing director. Beatrix Vierkorn-Rudolph was appointed as the first chair of the FAIR council.

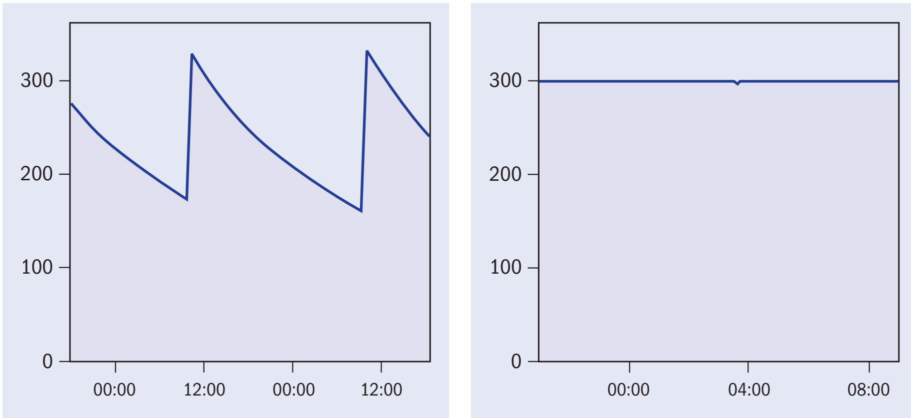
The countries that could not yet join because of their internal ratification procedures (France, Poland and Slovenia) are expected to do so within the next year. China, Saudi Arabia, Spain and the UK are also planning to contribute to FAIR.

FAIR is one of the largest projects for basic research in physics worldwide. Its accelerators will generate antiproton and ion beams of a previously unparalleled intensity and quality. When completed, the facility will comprise two linear accelerators and as many as eight circular accelerators – the two biggest being 1100 m in circumference. Altogether it will contain around 3.5 km of beam pipe. It is to be built in Darmstadt, where existing accelerators at the GSI will serve as injectors for the new facility.

Scientists from around the world will use FAIR to gain new insights into the structure of matter and the evolution of the universe since the Big Bang, complementing the research of CERN. Some 3000 scientists from more than 40 countries are already working on the planning of the experiment and accelerator facilities.

LIGHT SOURCE

Elettra operates in top-up mode



Decay mode on the left and top-up on the right (vertical scale current in mA and horizontal time in hours).

Elettra, the 2/2.4 GeV third generation Italian light source, has successfully joined the synchrotron facilities that operate fully in top-up mode. Located on the outskirts of Trieste, Elettra has operated for users since 1994, but during the past few years a large upgrade programme has taken place. This has included the construction and start-up operation of a full-energy injector. The new injector chain and the other machine and beam-line upgrades, together with the demands for intensity and thermal stability, naturally led to the change to top-up mode, in which frequent beam injections maintain a constant beam current in the storage ring during user operations. This is in contrast with the decay mode, where the stored beam is allowed to decay to some level before refilling occurs.

Elettra was not originally designed for this type of operation (and indeed even operated for many years without a full-energy injector). However, in May, only a year after establishing the stable operations of the new injector, the storage ring began to work successfully with top-up at the two user energies of 2 GeV and 2.4 GeV. Elettra has thus become another example showing how a third-generation synchrotron that previously operated in decay mode can advance to full top-up operation, in this case at multiple energies.

With top-up operation the photon intensity produced at Elettra is stable and the integrated intensity is 60% higher over a time period equal to the beam lifetime. Thus while keeping the optical components of the beam lines in thermal equilibrium, the integrated number of photons is also higher, so providing an additional gain in beam time for the experiments. At the same time the intensity-dependent electronics also remain stable, allowing submicron accuracy in the position of the electron beam and hence a higher stability of the photon beam.

Elettra's upgrade to top-up started in 2009 and included the addition of various diagnostic and radiation-safety instruments, modification of the control and interlock software, fine tuning of the timing of the kicker and septa, as well as a revised operation strategy. A great deal of effort in collaboration with the radiation-protection team resulted in a high-level application with a "top-up controller" handling and controlling all aspects of the procedure. Careful radiation measurements at each beam line under various conditions of the injected beam, together with the high injection efficiencies achieved at both energies, meant that no additional shielding was required for the beam lines. Radiation levels in all beam lines remain below 1 μSv/h for efficiencies higher than 90%.

The project for the full-energy injector started in 2005 and finished by providing beam in March 2008 on time and within budget. The new injection chain consists of a 100 MeV linear accelerator and a 2.5 GeV booster that sends the beam into the storage ring at a rate of up to 3 Hz. The storage ring beam current at 2 GeV is set by the users to 300 mA and top-up occurs every 6 minutes by injecting 1 mA in 4 s, thus keeping the current level constant to 3‰. At 2.4 GeV the stored beam current is set to 140 mA and top-up occurs every 20 minutes, injecting 1 mA in 4 s to maintain the current level constant to 7‰.

The users have chosen fixed current-interval top-up (1 mA) instead of a fixed time interval. The injection system is perfectly tuned and for the majority of the beam lines does not produce interference with data-acquisition processes. A gating signal is also provided, but up to now only a few, very sensitive beam lines see some interference and therefore are gated.

An aerial view of the Elettra laboratory, on the outskirts of Trieste. (Courtesy Elettra.)

The change to top-up mode required no transition period and once it began all went exceptionally smoothly, thanks to the very good preparation and the high level of expertise of the personnel involved. Although at the beginning, the operation in top-up was programmed for 20% of users' beam time, it became immediately clear that the users strongly preferred this mode and so Elettra has operated in top-up for 100% of the beam time dedicated to users right from the start in May.

Further reading

E Karantzoulis *et al.* Conference proceedings, IPAC 2010, Kyoto, Japan.

SCIENCEWATCH

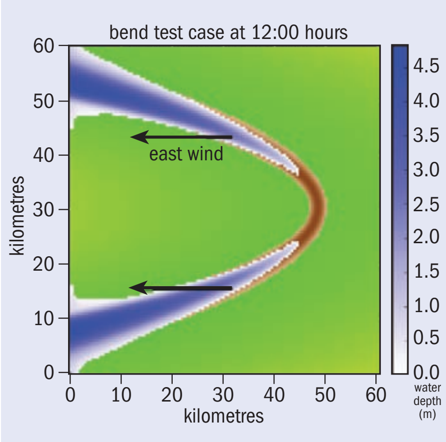
Compiled by John Swain, Northeastern University

Persistent strong winds could have parted Red Sea

Computer modelling has suggested a possible factual basis for the biblical story of the parting of the Red Sea. Carl Drews of the University of Colorado at Boulder and the National Center for Atmospheric Research (NCAR), and Weiqing Han, also of NCAR, have studied possible patterns of "wind setdown", which is the drop in water level that can occur when strong winds act on a surface of water for an extended period of time. In particular, they investigated a site in the eastern Nile delta, where an ancient branch of the Nile flowed into a coastal lagoon along the Mediterranean, known as the Lake of Tanis.

Drews and Han found that a strong, easterly wind of 28 m/s (near hurricane force) blowing overnight could have pushed the water back at the U-shaped bend where the ancient river merged with the coastal lagoon. A land bridge some 3–4 km long and 5 km wide could have appeared for as long as four hours. People could then have crossed the exposed mudflats before the water rushed back to cover them again after the wind stopped.

The work is part of a broader study of how winds can affect water depths, including the effects of typhoons. However, this study could also help archaeologists to identify places to look for evidence that the biblical story corresponds to an event that actually took place. Similar events have been recorded, including in the eastern Nile delta in 1882.



In this idealized case for the bend of water at Lake Tanis, green represents land surface, white and blue represent water, and brown represents exposed lake bottom. The wind blows from the right at 28 m/s for 12 hours and wind stress is uniform over the entire domain. The channel is originally 2 m deep and the banks are 1 m high, comparable to lakes and rivers in the Nile delta during spring.

- For videos, see www2.ucar.edu/news/parting-waters-computer-modeling-applies-physics-red-sea-escape-route.

Further reading

C Drews and W Han 2010 *PLoS ONE* **5**(8) e12481, doi:10.1371/journal.pone.0012481.

Predicting tipping points

The patterns in fluctuations of a population can indicate if it is about to go extinct, according to work by John Drake of the University of Georgia in Athens and Blaine Griffen of the University of South Carolina. The researchers have based their study on the fact that statistical mechanical systems respond more and more slowly to perturbations as they reach a critical point – a well known phenomenon called "critical slowing down". The basic idea is that fluctuations of a system can be used as perturbations, so that the essential information is in the frequency spectrum and variance of those fluctuations.

Drake and Griffen have verified this theory in a laboratory study of extinction in plankton populations. In addition to its obvious value in ecology, the method suggests a general approach for indicating when a system is about to undergo a catastrophic transition.

Further reading

John M Drake and B D Griffen 2010 *Nature* **467** 456.

Touch eases pain

Grabbing an injured part of your body can reduce a sharp pain but it works best if you grab it yourself rather than have someone else do it for you. The reason for this has now been studied by Marjolein Kammers of the University of London and colleagues.

The team used the "thermal grill illusion" in which putting a subject's middle finger in cool water and the fingers on either side into warm water creates a painful heat sensation in the middle one. They found that pushing the same three fingers of both hands together immediately afterwards reduced pain levels by 64% but the contact had to be complete and involve both hands.

Using a variety of different types of touch, the researchers discovered that the pain reduction appears to be linked to coherent information transfer across the whole body – it seems that we need to connect the affected part to a remote one. The work has obvious implications for the treatment of pain but it also shows why you do what you do when you hit your hand with a hammer.

Further reading

M P M Kammers *et al*. 2010 *Current Biology* **20** 10.1016/j.cub.2010.08.038.

Making light of opaque matter

Light passing through complex materials, such as biological tissues, can undergo such thorough multiple scattering that even though it gets through, any image is so degraded as to render the media effectively opaque. Now Sylvain Gigan and colleagues of the Institut Langevin in Paris and the Universities of Paris 6 and 7 have shown that measurements of the complex scattering matrix can invert the multiple scattering. This allows them to "see" an arbitrary object through such opaque media. The technique will work with any degree of complexity of scattering and could find applications in biology and medicine.

Further reading

S Popoff *et al*. 2010 *Nature Communications* **1** doi:10.1038/ncomms1078. arxiv.org/abs/1005.0532.

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

Exoplanet hunters find rich planetary systems

The time when isolated extrasolar planets were discovered is over, with the detection of two entire systems of six and possibly even seven planets orbiting nearby stars. These recent discoveries by two competing groups are opening a new era in exoplanet searches, in particular with the possible discovery of an Earth-sized planet within the habitable zone of one of the two systems.

More than 450 exoplanets have been detected since the discovery, 15 years ago, of 51 Peg b, the first extrasolar planet found around a normal star. The number of new detections per year is still rising and could surpass 100 new planets for 2010. Measurements of stellar radial-velocity remain the prime detection method, but detection via planetary transits is catching up rapidly since the launch of the French-European satellite for Convection, Rotation and planetary Transits (CoRoT) in 2006, and the NASA Kepler mission in 2009. As the occurrence of a planet transiting in front of the disc of its parent star is rare, these discoveries are made by looking at hundreds of thousands of relatively distant stars. Radial-velocity searches, by contrast, focus on hundreds of nearby stars and aim to detect the wobbling of the star that is induced by the gravity pull of the orbiting planet.

The exoplanets discovered first were gas giants akin to Jupiter and Saturn. A significant step forward was achieved in 2004 with the detection of Uranus- and Neptune-sized planets (*CERN Courier* October 2004 p19). A subsequent milestone was the detection of two planets, with sizes only slightly greater than that of Earth, orbiting Gliese 581 (*CERN Courier* June 2007 p12). The claim that at least one of them was in the habitable zone of this low-mass star made this stellar system a popular place to study, but subsequent investigations suggested that one of the planets is most likely too hot and the other too cool to keep water liquid on its surface.

Artist's impression of the planetary system around the Sun-like star HD 10180. (Courtesy ESO.)

Now, Gliese 581 is again in the headlines with the possible discovery of a new, even smaller planet that is located in between the two already found and thus at the appropriate distance from the star to sustain life. Together with another newly detected object at longer periods, the small planet – with a mass of 3 to 4 times the mass of the Earth – would bring to six the number of planets in this system, which is only 20 light-years away.

The presence of the two new planets has been derived from a study led by Steven Vogt of the Lick Observatory of the University of California. His team combined 122 radial-velocity measurements by the HIgh-Resolution Echelle Spectrometer (HIRES) of the Keck 10 m telescope on Mauna Kea, Hawaii, with 119 previously published measurements by the High Accuracy Radial-velocity Planet Searcher (HARPS) mounted on the 3.6 m telescope of the European Southern Observatory at La Silla, Chile. Although the HIRES measurements are less accurate than the HARPS ones, the combination of the two datasets improves the statistics.

The group using HARPS gained attention a month earlier with the detection of a rich stellar system of up to seven planets orbiting the solar-type star HD 10180, 130 light-years away. This study, led by Christophe Lovis of the Observatory of the University of Geneva, clearly detects five Neptune-like planets and there is good evidence for a heavier planet orbiting further out, as well as for an Earth-sized planet close to the star.

Although the existence of the new planets is still to be more firmly confirmed in both exoplanetary systems, these new studies show that they can be highly populated by low-mass planets and suggest that potentially habitable planets might be relatively common. According to Vogt, they could be present around a few tens of per cent of stars in the solar neighbourhood.

Further reading:

S S Vogt *et al.* 2010 *ApJ*, in press, arXiv:1009.5733.
C Lovis *et al.* 2010 *A&A*, in press.

Picture of the month

Tom Lowe from the US won the Royal Observatory's Astronomy Photographer of the Year competition with this artistic image of the Milky Way. Entitled "Blazing Bristlecone", the image beautifully juxtaposes the arch of the Milky Way from deep space with that of the dead tree on Earth. According to Marek Kukula, one of the judges, the jury was "blown away by the quality of all of the almost 500 entries this year". The public astronomer at the Royal Observatory Greenwich adds about the winning picture: "The bristlecone pines that you see in the foreground are some of the oldest living things on Earth, but yet they are dwarfed by the light shining behind them that has been travelling for almost 30 000 years. It is just a beautiful concept." (Courtesy Tom Lowe.)

CERN COURIER ARCHIVE: 1967

A look back to *CERN Courier* vol. 7, November 1967, compiled by Peggie Rimmer

CERN NEWS

Wide gaps at the PS

Two arrays of wide-gap spark chambers have been installed at the 28 GeV proton synchrotron PS in an unseparated pion beam (q5) in the South Hall. The experiment, by a mixed team from Bern, Geneva and CERN, uses a magnetic spectrometer to look at the mass spectrum of negative bosons.

The advantage of spark chambers *vis-à-vis* bubble chambers is that they can be triggered to record only interesting events. Until now, however, they have not been capable of giving complete event reconstruction as is possible in bubble chambers. "Conventional" spark chambers, developed in the late 1950s, consisted of a series of thin, parallel metal plates separated by gaps of a few millimetres filled with a gas. High-voltage pulses of a few kV are applied to alternate plates and ionization – along the track of a charged particle travelling through the chamber – creates sparks between the plates, which can be recorded. With a plate gap of several centimetres and a much higher applied voltage, a continuous spark can be detected giving much higher accuracy in determining the track position. Some events occurring within the gap can be detected and, most importantly, several sparks occurring at the same time can be identified.

The chambers used by the boson spectrometer team, developed at CERN by G E Chikovani [one of Russia's wide-gap pioneers], G Laverrière and P Schubelin, have four 5 cm gaps across which 50 kV is applied. Planes of wires are used and the co-ordinates of the particle tracks can, for the first time, be directly tapped off the wires using magnetostrictive read-out.

● Compiled from texts on pp 219–220.

Counting votes

The CERN CDC 3800 computer counted the votes registered in the Canton of Geneva for the Swiss elections to the "Conseil national" and the "Conseil des Etats" on 29 October. Voting papers were collected together at the Palais des Expositions and transferred to punched cards, two cards for each voting paper to allow for crosschecking. The cards were brought to CERN by police car and fed into the computer, where they were compared card by card. Differences were corrected by repunching the appropriate cards.

The computer recorded the total for each polling centre, the results for each commune and for the whole canton and various statistics concerning candidates and parties. It was not possible to produce all of the results by midnight as was hoped. Faulty card punching was the main cause of delay, with considerable time taken for repunching. Nevertheless, completely checked results were available early the following morning.

Shortly before counting the votes for the Swiss elections, a dress rehearsal was held at CERN in the presence of representatives of the Geneva Cantonal Administration and political parties.

This electronic counting of votes was the result of close collaboration between CERN, the University of Geneva (which did the programming) and the Geneva Cantonal Administration (which looked after the organization and co-ordination).

● Compiled from texts on pp 220–221.

COMPILER'S NOTE

Rafael Carreras was a trailblazer for outreach, long before that term became common currency. He joined CERN's Education Service in 1965 and spent more than 30 years explaining science "as it happened". His highly acclaimed weekly lectures, intended mainly for non-scientific staff, had an average audience of more than 400, including members of the general public. Once a month he gave an evening lecture, "Science today", that attracted people from all over the region, covering about 20 subjects, from astrophysics to the human sciences. For 19 years, until his retirement in 1997, Carreras compiled *Picked Up for You*, a popular fortnightly digest of the world's science press.

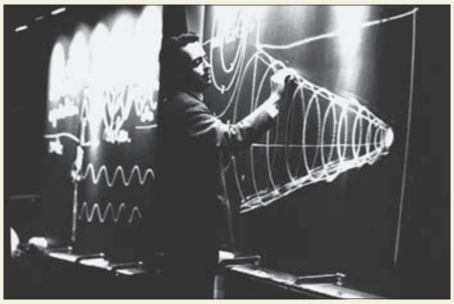
As for counting votes, it seems that hanging chads might have been troublesome for quite some time!

ISOLDE operation

On the evening of 16 October ISOLDE, the isotope separator on-line, received its first proton beam from the 600 MeV synchrocyclotron onto a target and made the first observation of separated isotopes. On 2–3 November, a seminar was held at CERN on "ISOLDE chemistry problems" attended by about 50 scientists from 10 countries, including Israel, the USA and the USSR.

At the opening talk, G Rudstam reported on the first test run. Isotopes of xenon, iodine and krypton, separated by chemical techniques, were measured during the run. The isotopes Xe^{116} and Xe^{117} were observed for the first time and their half-lives were measured as around 50 s. Traces of another previously unobserved isotope Kr^{73} were also seen but were insufficient for measurements. The achievements of this first run are very encouraging and make it possible to optimize various components ready for the start of more detailed experiments in December.

● Compiled from texts on pp 222–223.



The cover of the November 1967 issue featured Rafael Carreras during one of his weekly "Science for All" lectures organized by the Training and Education Services in the Personnel Division.

TRIUMF lays on a feast of nuclear physics

The INPC 2010 meeting in Vancouver revealed a healthy and dynamic research field, with many enthusiastic young researchers taking part. **Jens Dilling** reports on the conference.

The 25th International Nuclear Physics Conference (INPC) took place on 4–9 July at the University of British Columbia, hosted by TRIUMF, Canada's national laboratory for particle and nuclear physics in Vancouver. As the main conference in the field, this triennial meeting is endorsed and supported by the International Union for Pure and Applied Physics (IUPAP). This year it attracted more than 750 delegates – including 150 graduate students – from 43 countries and covered topics in nuclear structure, reactions and astrophysics; hadronic structure, hadrons in nuclei and hot and dense QCD; new accelerators and underground nuclear-physics facilities; neutrinos and nuclei; and applications and interdisciplinary research. Participants found many opportunities to connect with fellow nuclear physicists from across the globe. At conferences such as the INPC, which span an entire discipline, many unexpected links emerge, often leading to fruitful new discussions or collaborations.

Conference delegates enjoyed a fantastic banquet outside the famed UBC Museum of Anthropology, where they enjoyed spectacular views. (Courtesy Mike Clegg/Photo Blimp Photography.)

Impressive progress

INPC 2010 opened with an afternoon public lecture by Lawrence Krauss of Arizona State University. In his talk, "An atom from Vancouver", the renowned cosmologist and public speaker gave a broad perspective on why nuclear physics is key to a deeper understanding of how the universe was formed, as well as the birth, life and death of stars. The next morning, Peter Braun-Munzinger of GSI opened the scientific plenary programme with a talk that highlighted progress since the previous INPC in Tokyo in 2007, with theoretical and experimental examples from around the world. All topics at the conference were then well represented in both the plenary programme and the well attended afternoon parallel programme, where more than 250 invited and contributed talks were presented, as well as more than 380 posters. The poster presentations were among the most lively of the sessions, with many graduate students and postdoctoral fellows participating.

The scientific high points included the presentations in the field of hot and dense QCD, which reported on experimental and theoretical progress at Brookhaven's Relativistic Heavy Ion Collider. The session on nuclear reactions provided highlights from many new and exciting facilities, including the Radio Isotope Beam Factory at the RIKEN centre in Japan, as well as an outlook of what can be expected from the Facility for Antiproton and Ion Research in Germany and the Facility for Rare Isotope Beams in the US. The quest towards the "island of stability" in the superheavy-element community is still ongoing, and new progress was reported with the identification of element 114.

There is also impressive progress being made in the theoretical sector, in particular with new *ab initio* approaches to calculations. Applications of these methods and progress in nucleon–nucleon interactions, where three-body interactions are now considered state of the art, were presented in the sessions on nuclear structure. The predictions of such calculations can be tested by experiments, for example laser experiments and ion-trap measurements give access to the ground-state properties of exotic nuclei. In-beam or in-flight experiments pave the way to even more exotic isotopes, where new magic numbers for the nuclear-shell model are appearing. This will also prove relevant for nuclear astrophysics, where there has been significant experimental progress with new measurements of direct-capture reactions using rare-isotope beams and background-suppressed facilities located in underground laboratories. Presentations in this field also covered research on neutron stars and new results from the modelling of core-collapse supernovae, which clearly indicate the need for neutrino interactions to be included. ▷

Neutrinos played a large role in other sessions, for example on new facilities, where progress from the deep underground facilities was presented, together with other exciting new projects. The first results from long-baseline oscillation experiments show progress in this field, while double-beta-decay experiments are coming close to first results. These are keenly awaited not only by the community of nuclear physicists but by many others as well.

The sessions on fundamental symmetry are always one of the highlights of the INPC series, where tests of the Standard Model using atomic nuclei or nuclear physics methods can probe sectors complementary to those investigated by large particle-physics experiments, for example in experiments that measure atomic and neutron electric-dipole moments. Recent progress was reported in nuclear beta decay in the context of the testing of the unitarity of the Cabibbo-Kobayashi-Maskawa matrix, as well as measurements of the mass of the W-boson and the weak mixing-angle. Talks on the muon anomalous magnetic moment and its sensitivity for probing "new physics" showcased the burgeoning activity in this field.

One of the keenly anticipated presentations was given in a session on hadron structure, in which the collaboration that has measured the Lamb shift in muonic hydrogen at the Paul Scherrer Institute presented their results. Their measurement of the rms charge radius of the proton indicates a 5σ deviation from the established value, spawning a flurry of new experimental and theoretical activity.

The conference also featured discussions on the growing importance of nuclear physics in near-term societal and economic arenas. David Dean of the US Department of Energy shared an interesting perspective on the future of the field in relation to growing concerns about energy production and consumption. From India, Swaminathan Kailas of the Bhabha Atomic Research Centre talked about the utilization of nuclear technologies in the development of thorium-based nuclear reactors. Andrew Macfarlane of the University of British Columbia described the application of nuclear physics to probing magnetic behaviours at the nanoscale level in regimes relevant for condensed-matter physics.

The large programme of the oral and poster sessions was extended to include special presentations by the winners of the IUPAP Young Scientist prizes, which are awarded in the field of nuclear physics every three years during the INPC conference. This year's winners were: Kenji Fukushima of the Yukawa Institute for Theoretical Physics, Kyoto University; Peter Müller of Argonne National Laboratory; and Lijuan Ruan of Brookhaven National Laboratory. These three researchers represent the future excellence in nuclear physics, in the fields of theoretical QCD, precision experiments in low-energy nuclear-halo physics and experimental techniques related to quark-gluon plasma.

The organizers of INPC 2010 made a special effort to attract many graduate students and post-doctoral fellows to the conference. For example, TRIUMF combined its traditional summer school with the US National Science Foundation's summer school for nuclear physics, directly prior to the conference. This not only allowed the school to recruit some of the INPC delegates as lecturers, but also gave students a broad overview of the field of nuclear physics before the conference. In addition, INPC 2010 teamed up with *Nuclear Physics A* to provide awards for the best student oral presentation and the top three poster presentations at the conference. An international panel of judges together with members from the editorial board of *Nuclear Physics A* decided on the following award winners from a strong field of applicants: Paul Finlay (Guelph) for oral presentation; Young Jin Kim (Indiana), Evan Rand (Guelph) and Thomas Brunner (Munich) for posters.

The IUPAP Young Scientist Prize winners. Left to right: Jean-Michel Poutissou, secretary of IUPAP Commission C12; prize winners Kenji Fukushima, Lijuan Ruan and Peter Müller; Dan-Olof Riska, chair of C12, and Jens Dilling, chair of INPC 2010. (Courtesy Mindy Hapke/TRIUMF.)

A treat of a different kind awaited delegates at the conference banquet at Vancouver's famous Museum of Anthropology. Olivia Fermi, the grand-daughter of the famed nuclear physicist Enrico Fermi, was among the guests and in the after-dinner speech she shared anecdotes from her life growing up in the Fermi household. The first-nation artefacts and art pieces, together with the museum's setting overlooking the Pacific Ocean and the skyline of Vancouver, made this venue a perfect fit to a very special conference. The field clearly presented itself in a healthy and dynamic state, with many young people eagerly anticipating the advent of new experiments, theory and facilities. At the end of the conference, IUPAP announced the location of the next in the series, which will be held in Florence in 2013.

● For more about the full programme and presentations, see http://inpc2010.triumf.ca/.

Résumé

TRIUMF : la physique nucléaire à l'honneur

TRIUMF, le laboratoire national canadien de physique des particules et de physique nucléaire, situé à Vancouver, a accueilli la 25e Conférence internationale de physique nucléaire (INPC), qui a eu lieu du 4 au 9 juillet. Cette conférence, la principale dans ce domaine, a réuni cette année plus de 750 délégués, dont 150 étudiants de 3e cycle, venus de 43 pays. Au programme des sessions plénière et parallèles, des sujets très divers : structure nucléaire, réactions nucléaires, nouveaux accélérateurs, ou encore nouvelles installations souterraines de physique nucléaire. Il a aussi été question d'applications et d'exemples de recherche interdisciplinaire. Comme toujours, les participants ont trouvé de nombreuses occasions d'échanges avec d'autres physiciens de physique nucléaire venus du monde entier.

Jens Dilling, *TRIUMF.*

Physics buzz in Paris

ICHEP 2010 pushed towards new frontiers in particle physics, with the first results from the LHC, the latest searches for physics beyond the Standard Model and concepts for future accelerators among the highlights.

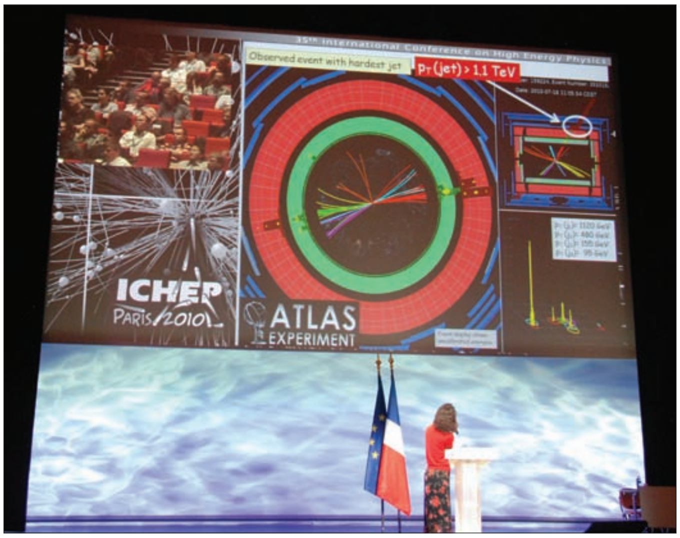
Sixty years ago, particle physics was in its infancy. In 1950 Cecil Powell received the Nobel Prize in Physics for the emulsion technique and the discovery of the charged pions, and an experiment at Berkeley revealed the first evidence for the neutral version. In New York, the first in a new series of conferences organized by Robert Marshak took place at the University of Rochester with 50 participants. The "Rochester conference" was to evolve into the International Conference on High-Energy Physics (ICHEP) and this year more than 1100 physicists gathered in Paris for the 35th meeting in the series.

ICHEP's first visit to the French capital was in 1982. CERN's Super Proton Synchrotron had just begun to operate as a proton–antiproton collider and the UA2 collaboration reported on the first observations of back-to-back jets with high transverse momentum. This year, as ICHEP retuned to Paris, jets in a new high-energy region were again a highlight. This time they were from the LHC, one undoubted "star of the show", together with the president of France, Nicolas Sarkozy (*CERN Courier* September 2010 p5).

Given the growth in the field since the first Rochester conference, this report can only touch on some of the highlights of ICHEP 2010, which took place on 22–28 July at the Palais des Congrès and followed the standard format of three days of parallel sessions, a rest day (Sunday) and then three days of plenary sessions. The evening of 27 July saw Parisians and tourists well outnumber physicists at the "Nuit des particules", a public event held at the Grand Rex theatre (see box, p21). On the rest day, in addition to various tours, there was the opportunity to watch the final stage of the 2010 Tour de France as it took over the heart of Paris.

A tour of LHC physics

The LHC project has had similarities to the famous cycle race – participants from around the world undertaking a long journey, with highs and lows *en route* to a thrilling climax. In the first of the plenary sessions, Steve Myers, director for accelerators and technology at CERN, looked back over more than a year of repair and consolidation work that led to the LHC's successful restart with first collisions in November 2009. With the collider running at 3.5 TeV per beam since March this year, the goal is to collect 1 fb^{-1} of integrated luminosity with proton collisions before further consolidation work takes place in 2012 to allow the machine to run at its full energy of 7 TeV per beam in 2013. The long-term goal is to reach 3000 fb^{-1} by 2030.



ATLAS spokesperson, Fabiola Gianotti, turns to the screen showing a two-jet event from ATLAS with the hardest jet so far. (Courtesy T Pritchard.)

This will require peak luminosities of $5\times10^{34}\ cm^{-2}s^{-1}$ in 2021–2030 for which studies are already underway, for example on the use of crab cavities.

The proposed long-term schedule envisages one-year shutdowns for consolidation in 2012, 2016 and 2020, with shorter periods of maintenance in December/January in the intervening years, and 6–8 month shutdowns every other year after 2020. Heavy-ion runs are planned for each November when the LHC is running, starting this year. Myers also provided glimpses of ideas for a 16.5 TeV version of the LHC that would require 20 T dipole magnets based on $NbSn_3$, NbAl and high-temperature superconductors.

What many at the conference were waiting for were the reports from the LHC experiments on the first collision data, presented both in dedicated parallel sessions and by the spokespersons on the first plenary day. Common features of these talks revealed just how well prepared the experiments were, despite the unprecedented scale and complexity of the detectors. The first data – much of it collected only days before the conference as the LHC ramped up in luminosity – demonstrated the excellent performance of the detectors, the high efficiency of the triggers and the swift distribution of data via the worldwide computing Grid. All of these factors combined to allow the four large experiments to rediscover the physics of the Standard Model and make the first measurements of cross-sections in the new energy regime of 7 TeV in the centre-of-mass.

The ATLAS and CMS collaborations revealed some of their first candidate events with top quarks – previously observed only at Fermilab's Tevatron. They also displayed examples of the more copiously produced W and Z bosons, seen for the first time in proton–proton collisions, and presented cross-sections that are in good ▷

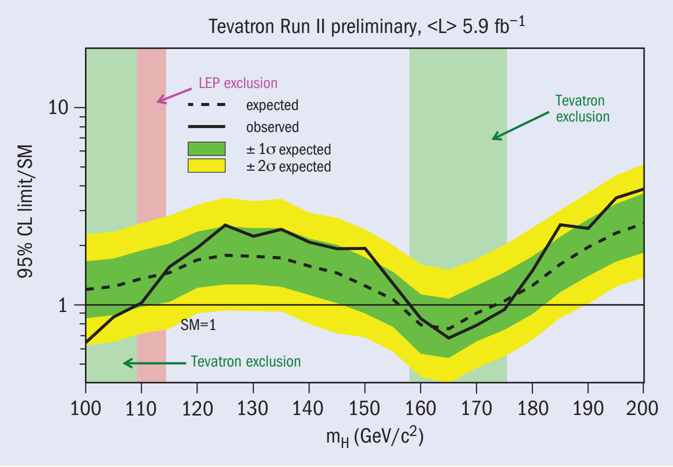
agreement with measurements at lower energies. Lighter particles provided the means to demonstrate the precision of the reconstruction of secondary vertices, shown off in remarkable maps of the material in the inner detectors.

Both ATLAS and CMS have observed dijet events, with masses higher than that of the Tevatron's centre-of-mass energy. The first measurements of inclusive jet cross-sections in both experiments show good agreement with next-to-leading-order QCD (p5). In searches for new physics, ATLAS has provided a new best limit on excited quarks, which are now excluded in the mass region $0.4 < M < 1.29$ TeV at 95% CL (*CERN Courier* October 2010 p6). For its part, by collecting data in the period between collisions at the LHC, CMS derived limits on the existence of the "stopped gluino", showing that it cannot exist with lifetimes of longer than 75 ns.

The LHCb collaboration reported clear measurements of several rare decays of B mesons and cross-sections for the production of open charm, the J/ψ and $b\bar{b}$ states (p5). With the first 100 pb^{-1} of data, the experiment should become competitive with Belle at KEK and DØ at Fermilab, with discoveries in prospect once 1 fb^{-1} is achieved.

The ALICE experiment, which is optimized for heavy-ion collisions, is collecting proton–proton collision data for comparison with later heavy-ion measurements and to evaluate the performance of the detectors. The collaboration has final results in charged multiplicity distributions at 7 TeV, as well as at 2.36 TeV and 0.9 TeV in the centre-of-mass. These show significant increases with respect to Monte Carlo predictions, as do similar measurements from CMS (*CERN Courier* September 2010 p36). ALICE also has interesting measurements of the antiproton to proton ratio (p5).

While the LHC heads towards its first 1 fb^{-1}, the Tevatron has already delivered some 9 fb^{-1}, with 6.7 fb^{-1} analysed by the time of the conference. One eagerly anticipated highlight was the announcement of a new limit on the Higgs mass from a combined analysis of the CDF and DØ experiments. This excludes a Higgs between 158–175 GeV/c^2, thus eliminating about 25% of the favoured region from analysis of data from the Large Electron–Positron collider and elsewhere. As time goes by, there is little hiding place for the long-sought particle. In other Higgs-related searches, the biggest effect is a 2σ discrepancy found in CDF for the decay to $b\bar{b}$ of the Higgs in the minimal supersymmetric extension to the Standard Model.



Nowhere to hide! The latest limits on the Higgs mass from the combined analysis by CDF and DØ, presented at ICHEP 2010.

Awards for young scientists

The International Union of Pure and Applied Physics (IUPAP) Commission on Particles and Fields (C11) awarded its Young Scientist Prizes in Particle Physics for 2010 during the ICHEP meeting. They went to Florencia Canelli, of the Enrico Fermi Institute, University of Chicago, and José Santiago, of the Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada. This is the second time these prizes have been awarded, following a proposal to initiate prizes for young scientists made at the IUPAP General Assembly in 2005.

This year Canelli received the award "for her pioneering contribution to the identification and precision measurements of rare phenomenon through the use of advanced analysis techniques to separate very small signals from large background processes at the Tevatron collider".

Santiago was rewarded "for his insight into a number of areas of particle physics, including QCD calculations, electroweak physics, gravity theories, extra dimensional models and composite Higgs models". The two recipients gave presentations during the first day of plenary sessions.

In addition, World Scientific and Imperial College Press awarded prizes for the best posters to Luke Corwin of Indiana University, Brendan Casey of Fermilab, Lars Sonnenschein of RWTH Aachen University and Daniel Kaplan of Illinois Institute of Technology.

Stressing the Standard Model

The strongest hint at the Tevatron for physics beyond the Standard Model comes from measurements of the decays of B mesons. The DØ experiment finds evidence for an anomalous asymmetry in the production of muons of the same sign in the semi-leptonic decays of B_s mesons, which is greater than the asymmetry predicted by CP violation in the B system in the Standard Model by about 3.2σ (*CERN Courier* July/August 2010 p6). While new results from DØ and CDF for the decay $B_s \rightarrow J/\psi + \phi$ show a better consistency with the Standard Model, they are not inconsistent with the measurement of A^b_{sl}.

Experiments at the HERA collider at DESY, and at the B factories at KEK and SLAC, have also searched extensively for indications of new physics, and although they have squeezed the Standard Model in every way possible it generally remains robust. Of course, the searches extend beyond the particle colliders and factories, to fixed-target experiments and detectors far from accelerator laboratories. The Super-Kaminokande experiment, now in its third incarnation, is known for its discovery of neutrino oscillations, which is the clearest indication yet of physics beyond the Standard Model, but it also searches for signs of proton decay. It has now accumulated data corresponding to 173 kilotonne-years and, with no evidence for the proton's demise, it sets the proton's lifetime at greater than 1×10^{34} years for the decay to $e^+\pi^0$ and greater than 2.3×10^{34} years for $\bar{\nu}K^+$.

The first clear evidence for neutrino oscillations came from studies of neutrinos from the Sun and those created by cosmic rays in the upper atmosphere, but now it is the turn of the long-baseline experiments based at accelerators and nuclear reactors to bring the

Particle Night Fever

How do you gather 2000 Parisians and tourists in the middle of summer to talk about particle physics for a whole night? Probably by following this recipe: find a magic venue, invite fascinating speakers and well known artists, explore the frontier between science and cinema and advertise, advertise, advertise. At least, this is how the "Nuit des particules" – Particle Night – organized on 27 July at the Grand Rex theatre in Paris came to be a success.

With this special science-and-cinema evening, the organizers of ICHEP 2010 wanted to provide an opportunity to discuss science in cinema and the mysteries of the infinitely small and the infinitely large with the public. The night started with a lecture for the general public by Michel Davier, professor at Paris-Sud University and member of the French Academy of Sciences, who explained the links between the cosmos and the particles. The debate that followed featured the actress Irène Jacob, winner of the Best Actress Award in 1991 at the Cannes Film Festival and the daughter of the late CERN theorist, Maurice Jacob. Inspired by the memories of her father she wrote, together with the Italian theatre actor-director Pippo Delbono, a short movie entitled *Alice*, which premiered at the Grand Rex. On stage also were Pierre Antilogus, a researcher in supernovae with the CNRS, Gautier Hamel de Monchenault, of the CEA and the CMS experiment, and Marie-Hélène Schune, of CNRS and the LHCb experiment. They all discussed fact and fiction in cinema, with excerpts from Ron Howard's *Angels & Demons* and Danny Boyle's science-fiction movie *Sunshine*. The night ended with a showing of *Sunshine* on the big screen of the Grand Rex.

The Grand Rex Cinema in Paris on "Nuit des particules", or "Night of the Particles". (Courtesy LAL/H Kerec.)

The "Nuit des particules" was organized with the support of the Centre National de la Recherche Scientifique (CNRS), the Cinemascience festival, the Commissariat à l'énergie atomique (CEA), the Mairie de Paris, Science sur Seine and *Le Monde*.

● From the article by Perrine Royole-Degieux in *ILC Newsline*, see www.linearcollider.org/newsline/readmore_20100805_ftr1.html.

field into sharper focus. At accelerators a new era is opening with the first events in the Tokai-to-Kamioka (T2K) experiment, as well as the observation of the first candidate υ_τ in the OPERA detector at the Gran Sasso National Laboratory, using beams of υ_μ from the Japan Proton Accelerator Research Complex and CERN respectively (*CERN Courier* April 2010 p8 and July/August 2010 p5).

While T2K aims towards production of the world's highest intensity neutrino beam, the honour currently lies with Fermilab's Neutrino beam at the Main Injector, which delivers ν_μ to the MINOS experiment, with a far-detector 735 km away in the Soudan Mine. MINOS now has analysed data for 7.2×10^{20} protons on target (POT) and observes 1986 events where 2451 would be expected without oscillation. The result is the world's best measurement for $|\Delta m^2|$ with a value of $2.35+0.11/-0.08\times10^{-3}$ eV^2, and $\sin^2 2\theta > 0.91$ (90% CL). MINOS also finds no evidence for oscillations to sterile neutrinos and puts limits on θ_{13}. Recently, the experiment has been running with an anti-neutrino beam, and this has proved to hint at differences in the oscillations of antineutrinos as compared with neutrinos. With antineutrinos, the collaboration measures $|\Delta m^2| = 3.36+0.45/-0.40\times10^{-3}$ eV^2 and $\sin^2 2\theta = 0.86\pm0.11$. As yet the statistics are low, with only 1.7×10^{20} POT for the antineutrinos, but the experiment can quickly improve this with more data.

The search for direct evidence of dark-matter particles, which by definition lie outside the Standard Model, continues to have tantalizing yet inconclusive results. Experiments on Earth search for the collisions of weakly interacting massive particles (WIMPs) in detectors where background suppression is even more challenging than in neutrino experiments. Recent results include those from the CDMS II and EDELWEISS II experiments, in the Soudan Mine and the Modane Underground Laboratory in the Fréjus Tunnel, respectively. CDMS II presented its final results in November 2009, following a blind analysis. After a timing cut, the analysis of 194 kg days of data yields two events, with an expected background of 0.8±01(stat.)±0.2 (syst.) events. The collaboration concludes that this "cannot be interpreted as significant evidence for WIMP interactions". EDELWEISS II has new, updated results, which now cover an effective 322 kg days. They have three events near threshold and one with a recoil energy of 175 keV, giving a limit on the cross-section of 5.0×10^{-8} pb for a WIMP mass of 80 GeV (at a 90% CL).

Higher energies, in nature and in the lab

Looking to the skies provides a window on nature's own laboratory of the cosmos. The annihilation of dark matter in the galaxy could lead to detectable effects, but the jury is still out on the positron excess observed by the PAMELA experiment in space (*CERN Courier* September 2009 p11). Back on Earth, the Pierre Auger Observatory and the High-Resolution Fly's Eye (HiRes) experiment in the southern and northern hemispheres, respectively, detect cosmic rays with energies up to 10^{20} eV (100 EeV) and more. Both have evidence for the suppression of the highest energies by the Greisen-Zatsepin-Kuzmin (GZK) cut-off. There is also evidence for a change in composition towards heavier nuclei at higher energies, although this may also be related to a change in cross-sections at the highest energies. The correlation of the direction of cosmic rays at energies of 55 EeV or more with active galactic nuclei, first reported by the Pierre Auger collaboration in 2007, has weakened with further data, from the earlier value of 69 + 11/−13% to stabilize around 38+ 7/−6%, now with more than 50 events.

Cosmic neutrinos provide another possibility for identifying sources of cosmic rays. The ANTARES water Cherenkov telescope in the Mediterranean Sea now has a sky map of its first 1000 neutrinos and puts upper limits on point sources and on the diffuse astrophysical neutrino flux. IceCube, with its Cherenkov telescope in ice at the South Pole, also continues to push down the upper limits on the diffuse flux with measurements that begin to constrain theoretical models.

In the laboratory, the desire to push further the exploration of the high-energy frontier continues to drive R&D into accelerator and detector techniques. The world community is already deeply involved in studies for a future linear e^+e^- collider. The effort behind the International Linear Collider to reach 500 GeV per beam is relatively mature, while work on the more novel two-beam concept for a Compact Linear Collider to reach 3 TeV is close to finishing a feasibility study (*CERN Courier* September 2008 p15). Other ideas for machines further into the future include the concept for a muon collider, which would require muon-cooling to create a tight beam, but could provide collisions at 4 TeV in the centre-of-mass. Reaching much higher energies will require new technologies to overcome the electrical breakdown limits in RF cavities. Dielectric structures offer one possibility, with studies showing breakdown limits that approach 1 GV/m. Beyond that, plasma-based accelerators still hold the promise of still greater gradients, as high as 50 GV/m.

Particle physics has certainly moved on since the first Rochester conference; maybe a future ICHEP will see results from a muon collider or the first plasma-wave accelerator. For now, ICHEP 2010 proved a memorable event, not least as the first international conference to present results from collisions at the LHC. Its success was thanks to the hard work of the French particle-physics community, and in particular the members of the local organizing committee, led by Guy Wormser of LAL/Orsay. Now, the international community can look forward to the next ICHEP, which will be in Melbourne in 2012.

● Proceedings of ICHEP 2010 are published online in the *Proceedings of Science*, see http://pos.sissa.it.

Résumé

La physique buzze à Paris

Plus de 1100 physiciens se sont rassemblés au Palais des Congrès, à Paris, du 22 au 28 juillet, pour assister à la 35e édition de l'ICHEP, où pour la première fois ont été annoncés des résultats du LHC. Cela a été l'occasion pour les physiciens, lors des sessions plénière et parallèles, de présenter et de discuter les résultats les plus récents et les plus stimulants d'expériences réalisées en physique des particules, en astrophysique des particules et en cosmologie, ainsi que de méthodes et prédictions théoriques innovantes et d'idées nouvelles pour les futurs accélérateurs et détecteurs de particules. Il a également été question des derniers résultats combinés des expériences CDF et DØ de Fermilab, qui ont permis de mieux délimiter encore le territoire où le boson de Higgs pourrait se cacher.

Christine Sutton, *CERN*.

The Palau de les Arts Reina Sofia opera house and cultural centre in Valencia, an excursion destination for PASCOS 2010. (Courtesy S King.)

Microcosm meets macrocosm in Valencia

Experts in particle physics, string theory and cosmology gathered in Spain to exchange ideas at the latest meeting in the PASCOS series.

The guiding spirit behind the series of annual symposia on Particles, Strings and Cosmology (PASCOS) is the unification of the microcosm with the macrocosm. It follows from the basic principles of uncertainty and mass-energy equivalence, which imply that when we probe deep inside subatomic space, we inevitably come across states of very high energy and mass that would have abounded in the early history of the universe. Recreating them in the laboratory is like recreating dinosaurs as in *Jurassic Park*, but is much more significant because it helps us to trace the very early history of the universe.

Making heavy particles such as the W and Z bosons and the top quark, as well as studying their interactions in the laboratory, helps us retrace the history of the universe to within a few picoseconds of its beginning. The discovery of the Higgs boson(s) and supersymmetric (SUSY) particles should, likewise, throw light on the nature of the phase transition that the universe experienced during those first few picoseconds – as well as on the nature of the cold dark matter (CDM) that permeates the universe today as a relic of its early history. But the story does not end there. We would like to follow the history of the universe right back to the instant of the Big Bang – and even beyond, where the standard tool of quantum field theory breaks down. The recent developments in string theory offer us the best hope of addressing these issues.

The interface of particle physics, string theory and cosmology is thus a highly active field of research at the frontiers of human knowledge. The PASCOS series of international symposia was started in the early 1990s in the US to recognize this interplay. The meetings strive to bring together researchers from these three areas to facilitate their mutual interaction and the cross-fertilization of ideas. After circulating round the US during its first decade, the series is now global, having visited India, South Korea, the UK, Canada and Germany.

PASCOS 2010, the 16th symposium in the series, took place on ▷

19–23 July in the Spanish city of Valencia and was organized by the Instituto de Fisica Corpuscular (IFIC), which is the largest particle-physics laboratory of the Spanish National Research Council (CSIC) and is jointly operated by the University of Valencia. This year's symposium, attended by more than 160 participants from around the world, was of particular significance because it came in the wake of the start-up of the LHC and the launch of the Planck satellite. In general, plenary sessions were held in the mornings, while the afternoons were devoted to parallel sessions focusing on the three areas of particles, strings and cosmology.

The microcosm

The first day's proceedings started with an overview of the status of the LHC by Richard Hawkings of CERN. This first run of the LHC should accumulate an integrated luminosity of $1\,fb^{-1}$ at a total energy of 7 TeV by the end of 2011. After a shutdown for a year to increase the total energy to 14 TeV, the next run is scheduled to start in early 2013. In talks on phenomenology, Manuel Drees of Bonn University and Werner Porod of the University of Würzburg and IFIC Valencia said that a meaningful SUSY search could already begin with the $1\,fb^{-1}$ data at 7 TeV. However, a meaningful search for Higgs bosons will require about $10\,fb^{-1}$ of data at 14 TeV, as Howard Haber of the University of California, Santa Cruz, discussed. If the Higgs does not show up then other physics may come into play, as Francesco Sannino of the University of Southern Denmark noted. In looking at alternative mechanisms he argued that a successful technicolour theory requires near-conformal dynamics.

Meanwhile experiments at the Tevatron have results based on $5\,fb^{-1}$ of data, which Vadim Rusu of Fermilab presented. These include the recent result from DØ on CP violation in $B–\overline{B}$ mixing in the like-sign di-muon channel, which disagrees with the Standard Model by $3.2\,\sigma$ (*CERN Courier* July/August 2010 p6). Searches for a Standard Model Higgs particle continue at the Tevatron with a very complex multichannel analysis that leads to a small window, only a few giga-electron-volts wide, of excluded masses around 165 GeV, with the window set to widen as the luminosity increases beyond $10\,fb^{-1}$ per experiment through 2011.

Assuming that SUSY does appear at the LHC, then quantitative predictions will be valuable. Kiwoon Choi, of the Korea Advanced Institute of Science and Technology, discussed SUSY-breaking from the perspective of string theory, including dilaton/moduli mediation, gauge mediation, anomaly mediation and D-term breaking. He argued that in string theory it is quite plausible that all mediation schemes could be present and give comparable contributions. Angel Uranga, of the Instituto de Física Teórica UAM/CSIC Madrid pointed out that, although string theory is unique (all versions being related by dualities), the way that the extra six dimensions are compactified is far from unique, leading to different low-energy physics. Current approaches include heterotic models, (intersecting) D-brane models and F-theory constructions, with concrete models leading to predictions for the spectrum for SUSY and exotic particles at the LHC.

An exciting possibility, discussed by Ignatios Antoniadis of CERN, is that the string scale is at energies of tera-electron-volts. This could in principle solve the gauge-hierarchy problem and provide an explanation of the weakness of gravity, provided that the extra dimensions perpendicular to the D-brane on which the Standard Model lives are large, which would lead to spectacular missing energy signals at the LHC. The extra tera-electron-volt-scale dimensions parallel to the brane also lead to Kaluza-Klein excitations of gauge bosons, and string/strong gravity effects, including the possible production of micro-black holes. "Are these ideas physical reality or imagination?" asked Antoniadis, replying that "the LHC will explore physics beyond the Standard Model".

The only solid new microscopic physics in the past dozen years has been the discovery of neutrino mass and mixing. Yoichiro Suzuki of the University of Tokyo tracked the progress of atmospheric and solar-neutrino experiments over this period, focusing on the results from SuperKamiokande. This talk was complemented by that of Mayly Sanchez of Iowa State University/Argonne National Laboratory, who reported on the latest results from accelerator and reactor experiments. These included the antineutrino results from the MINOS experiment that show a $2\,\sigma$ discrepancy with the neutrino results, and the OPERA detector's first observation of a τ event in the beam of muon neutrinos sent from CERN to the Gran Sasso National Laboratory (*CERN Courier* July/August 2010 p5).

Steve King of the University of Southampton considered the antineutrino results from MiniBooNE at Fermilab, which show an excess consistent with oscillations of the kind reported some years ago by the LSND collaboration at Los Alamos, while the neutrino results do not. He advocated a "wait and see" approach to these data and focused instead on the paradigm of three active neutrinos, as well as ideas such as SUSY R-parity violation and the several different types of see-saw mechanism that have been proposed and studied by José Valle's group at IFIC. King also discussed the exciting observation that accurate tribimaximal lepton mixing suggests a non-Abelian discrete family symmetry that might unlock the long-standing flavour puzzle, which began with the discovery of the muon in 1937. These ideas may be incorporated into a complete SUSY grand unified theory (GUT) of flavour, as Eduardo Peinado and Stefano Morisi of IFIC, and Reiner de Adelhart Toorop of Nikhef also discussed. This could include new SUSY GUT relations presented by Stefan Antusch of Max Planck Institut für Physik, Munich.

The macrocosm

Carlos Frenk of Durham University set the agenda for the challenges facing the macrocosm with an entertaining talk on "The Standard Model of cosmogony: what next?". After reviewing this "a *priori* implausible model but one which makes definite predictions and is therefore testable," he focused on the prospects for testing the three assumptions that underpin the ΛCDM model: dark energy density Λ with negative pressure; structure seeded by quantum fluctuations during inflation; and CDM particles.

Although the equation of state for dark energy can be constrained, with current combined limits giving the ratio of the pressure to the density, $w = -0.97 \pm 0.05$, Frenk regarded the prospects for understanding the nature of dark energy as questionable. However in a later talk on the self-tuning cosmological constant, Jihn Kim of Seoul National University reported on progress in the search for a non-anthropic solution to this big problem, including ideas such as inflation, the wave-function of the universe and "quintessential axions". By contrast, in talking of the holographic principle and the surface of last scatter, Paul Frampton of the University of North Carolina at Chapel Hill attempted to dispense with dark energy altogether,

From left to right: José Valle, Steve King, Howie Haber and Jihn Kim enjoy a drink before the conference dinner. (Courtesy Jihn Kim.)

starting from the observation that the observable universe is close to being a black hole. He argued that from our viewpoint, the apparent acceleration of the universe arises as a consequence of information storage on the surface of the visible universe because of the entropy of the black hole. The contrasting nature of these talks perhaps underscores Frenk's point that we are a long way from understanding dark energy.

Alessandro Melchiorri of Sapienza Università di Roma reviewed the latest results from seven years of observation by the Wilkinson Microwave Anisotropy Probe and presented the First Light Survey from the Planck satellite from September 2009. The polarization of the cosmic microwave background (CMB) will be measured accurately with Planck, including the curl-free E-mode and the divergenceless B-mode, which at large angular scales are produced only by gravitational waves and provide a key signature of inflation. Planck will measure the gravitational wave background at 3σ if the tensor-to-scalar ratio $r=0.05$, as could be the case in some of the inflation models discussed by Philipp Kostka and Jochen Bauman of the Max Planck Institut für Physik at Munich, as well as Lancaster University's Anupam Mazumdar and others. Qaisar Shafi of the University of Delaware also reviewed some recent ideas including gauge singlet Higgs inflation and Standard Model inflation, including a non-minimal coupling of the Higgs field to gravity, where the gravitational couplings can have desirable effects if their magnitude is tuned to be very large.

If CDM turns out to arise from weakly interacting massive particles (WIMPs), such as predicted for example in SUSY models with conserved R-parity, they could soon be discovered in direct detection experiments at underground laboratories. For example, the Cryogenic Dark Matter Search in the Soudan Mine has seen two candidate events, although, as both Jodi Cooley-Sekula of Southern Methodist University and Andrea Giammanco of the Catholic University of Louvain pointed out, neither of them are "golden events". Other direct detection experiments such as DAMA in Gran Sasso and CoGeNT, again in the Soudan Mine, also have candidate events, as Nicolao Fornengo of INFN/Torino described. He also talked about indirect WIMP detection signals that could be observed via annihilation radiation. Dark-matter effects in gamma rays could be seen by the Fermi Gamma-Ray Space Telescope, and leptonic anomalies in cosmic rays studied by the PAMELA satellite experiment, Fermi, the HESS Cherenkov telescope array and future experiments such as the Alpha Magnetic Spectrometer. Aldo Morselli of INFN Roma Tor Vergata showed that the positron excess observed by PAMELA is, however, well fitted by the assumption of nearby pulsar(s) and the electron discrepancies observed by Fermi are now being used to help constrain the pulsar models (*CERN Courier* September 2009 p7). A potentially clean signal of WIMPs could come as gamma-ray spectral lines from dwarf spheroidal galaxies, which are dark-matter dominated systems with low astrophysical background, but Fermi has not yet detected such signals.

The microcosm-macrocosm connection

Bhaskar Dutta of Texas A&M University illustrated the connection between particle colliders and dark matter in the framework of minimal supergravity (mSUGRA). The favoured CDM regions of mSUGRA, such as the co-annihilation region, imply distinctive signatures for gluinos produced at the LHC, including two jets, two τ leptons and missing energy. By suitable choices of kinematic variables, the SUSY particle masses can be reconstructed and the mSUGRA parameters determined to check for a consistent CDM region. John Gunion of University of California at Davis also discussed such connections in the next-to-minimal supersymmetric Standard Model (NMSSM), motivated by data from the Large Electron–Positron (LEP) collider, which prefers a Higgs mass at around 100 GeV. This is possible in the NMSSM if the dominant Higgs decays are to pairs of CP-odd Higgs bosons that are sufficiently light that they do not decay to b-quark pairs so as to escape LEP limits. Such a scenario with the lightest neutralinos at 5–10 GeV might also account for recent results from the CoGENT experiment. However these findings are already challenged by first data from the XENON 100 experiment in the Gran Sasso laboratory, with the next results from this powerful experiment eagerly expected soon.

In the quest to discover the particle responsible for dark matter, which experiment will be first, the LHC or XENON 100? Whatever happens, it is clear that these and other experiments will all be required in order to unveil the complete theory at the heart of both the microcosm and the macrocosm.

● Talks from PASCOS 2010 are available online at http://pascos2010.astroparticles.es/ and the proceedings will be published in *Journal of Physics: Conference Series*, see http://iopscience.iop.org/1742-6596.

Résumé

Microcosme et macrocosme réunis à Valence

L'interface entre physique des particules, théorie des cordes et cosmologie amène à considérer ensemble la physique de l'infiniment petit (microcosme) et la physique de l'infiniment grand (macrocosme). C'est ainsi que la série de colloques internationaux sur les particules, les cordes et la cosmologie (PASCOS) vise à rassembler les chercheurs de ces trois disciplines pour faciliter les échanges de vues et les interactions. Le colloque de cette année, tenu à Valence (Espagne), a rassemblé plus de 160 participants venus du monde entier. Ce colloque revêtait une importance toute particulière au moment des premières données du LHC et du satellite Planck.

Steve King, *Southampton University, and* **D P Roy**, *Tata Institute.*

Into Africa – a school i

An enthusiastic response to the first African School on Fundamental Physics and its Applications (ASP2010) gives a vital boost to the future development of the field across the African continent.

A discussion session dedicated to theoretical subatomic physics. John Ellis and Jean C

On 1 August, 65 students arrived at the National Institute for Theoretical Physics (NITheP) in Stellenbosch, South Africa. They were there to participate in the first African School on Fundamental Physics and its Applications (ASP2010). More than 50 participants had travelled from 17 African countries, fully supported financially to attend the intensive, three-week school. Others, from Canada, Germany, India, Switzerland and the US, helped to create a scientific melting pot of cultural diversity that fused harmoniously throughout the duration of the school.

ASP2010 was planned as the first in a series of schools to be held every two years in a different African country. It was sponsored by an unprecedentedly large number of international physics institutes and organizations, indicating the widespread interest that exists in making high-energy physics and its benefits the basis of a truly global partnership by reaching out to a continent where increased participation needs to be developed. The school covered a range of topics: particle physics, particle detectors, cosmology and accelerator technologies, as well as some of the applications, such as computing, medical physics, light sources and magnetic confinement fusion.

The courses were taught by physicists from around the globe, but included a significant number from South Africa, which has relatively well established research and training programmes in these areas of physics. The picture throughout the rest of Africa, in particular the sub-Saharan region, is rather different. As an example, consider the facts about African researchers at CERN. Currently, only 51 researchers of the 10 000 researchers registered at CERN have African nationalities, and only 18 of them currently work for African institutes. As CERN's director-general, Rolf Heuer, points out: "When I show people the map of where CERN's users come from, it's gratifying to see it spanning the world, and in particular to see southern-hemisphere countries starting to join the global particle-physics family. Africa, however, remains notable more for the number of countries that are not involved than for those that are." John Ellis, CERN's adviser for relations with non-member states and one of the school's founders, confirms that "sub-Saharan African countries are under-represented in CERN's collaborations".

"This new series of schools will strengthen existing collaborations and develop current and new networks involving African physicists," explains Fernando Quevedo, director of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, one of the sponsors of the school. He said: "This activity was a big success in all respects: lecturers of the highest scientific level, a perfect example of close collaboration among several international institutions towards a single goal and, most importantly, bringing the excitement and importance of the study of basic sciences to a community with great potential. The standard set for future activities is very high." ICTP, with its 46 years of experience in training, working and collaborating with scientists in developing nations, is committed to the ASP2010 wholeheartedly. The aims and mission of the school fit perfectly with ICTP's mission to foster science in Africa. The knowledge, relationships and collaborations that will result from it will enhance ICTP's existing programmes in Africa.

"An extraordinary opportunity"

A strikingly new aspect of the school was that a large number of national and international organizations and institutes collaborated to make it happen, thereby demonstrating a common belief in its importance and worth. These included Spain (Ministry of Foreign Affairs), France (Centre National de la Recherche Scientifique/IN2P3, Institut des Grilles, Commissariat à l'énergie atomique), Switzerland (École polytechnique fédérale de Lausanne, Paul Scherrer Institute), South Africa (NITheP, National Research Foundation), and the US (Fermilab, Department of Energy, Brookhaven, Jefferson Lab, National Science Foundation), as well as the international institutions CERN and ICTP. On top of this, the International Union of Pure

n fundamental physics

n Cleymans explain the mysteries of the subject on a two-sided whiteboard.

Khaleel Esra, an ASP2010 student from Sudan, is doing her MSc in nuclear physics at the University of Stellenbosch on the topic of spectroscopy of light neutron-rich nuclei. Like many other talented students, she is an enthusiastic young African opening the doors to "Ubuntu science", embracing the concept of togetherness.

Jan Govaerts, of the University of Louvain and a member of the organizing committee, gives the first lecture of ASP2010. (Photos courtesy C Darve.)

and Applied Physics offered travel grants to five female students. The number of involved organizations is set to increase in future editions of the school. Steve Muanza, a French experimental physicist of Congolese origin and also a founder of the school, says that in particular, "early support from IN2P3 was crucial for involving the other organizations in this new type of school in Africa".

The 65 students were selected from more than 150 applicants. Among them were some of the brightest aspiring physicists in the continent, who represent the future of fundamental physics and its applications in Africa. Chilufya Mwewa, a participant from Zambia, summarizes what the school meant for her: "Attending ASP2010 was such an extraordinary opportunity that it had a huge positive impact on my life. The school indeed enhanced my future career in physics. Thanks to you and other organizers for opening us up to other physics platforms that we never had a chance to know about in our own countries." Ermias Abebe Kassaye, a student from Ethiopia, underlines these aspects: "I have got a lot of knowledge and experience from the school. The school guides me to my future career. I obtained the necessary input to disseminate the field to my country and encourage others to do research in this field. I am working strongly to achieve my desire and to shine like a star, and your co-operation and help is essential to our success."

Apart from highlighting established research in fundamental physics in South African universities and research institutes, ASP2010 also emphasized the role of high-energy physics in the innovation of medicine, computing and other areas of technology through the "applications" aspect of the programme. The iThemba Laboratory for Accelerator Based Sciences (iThemba LABS), situated between Cape Town and Stellenbosch, is a significant player in this area. "As well as being an important producer of radioisotopes, it is the only laboratory in the southern hemisphere where hadron therapy is performed with neutron and proton beams, which have to date treated more than 1400 and 500 patients, respectively," explains Zeblon Vilakazi, director of the iThemba LABS. ▷

Students, organizers and lecturers at ASP2010 during the week dedicated to experimental subatomic physics.

Students at iThemba LABS get acquainted in the use of scintillation detectors during the last week of the school, which was dedicated to accelerators and the applications of fundamental physics.

Participating students had the opportunity to perform two practical courses in which they became acquainted with the use of scintillation detectors and performed measurements of environmental radioactivity. Laser practicals and a computing tutorial for simulations using the GEANT4 toolkit were also available at the University of Stellenbosch. The breaks between lectures provided the opportunity for many informal discussions to continue. "In these discussions, practical information was given to the students about opportunities for fellowships for further education, research positions and other schemes, such as Fermilab International fellowships, the CERN summer student programme and the ICTP Diploma Programme," explains Ketevi Assamagan, a Brookhaven physicist of Togolese origin and a member of the ASP2010 organizing committee.

A number of additional demonstrations and talks were also incorporated into the programme. A video conference with Young-Kee Kim, Fermilab's deputy-director, provided a vision of science on a planetary scale; a webcast that connected the students to the CERN Control Centre enabled them to experience a live demonstration of proton acceleration; and special talks by John Ellis, Albert De Roeck and Philippe Lebrun of CERN, and Jim Gates, of the University of Maryland (and a scientific adviser to President Obama), also made big impressions on the students. In parallel, several of the school's lecturers gave public lectures in Cape Town. Anne Dabrowski, a former South African physics student, provided a role model to support the dream of African participation in high-energy physics. Now an applied physicist in the Beams Department at CERN, she was a member of the local organizing committee.

South Africa has recently formed a programme for collaboration with CERN and has become the second African country to join the ATLAS collaboration (*CERN Courier* September 2010 p32). "We are ready to do our best to assist any deserving student or postdoc to become involved via one of our member universities or national facilities that are participating in activities at CERN," says Jean Cleymans, the director of the SA-CERN Programme. "Students are welcome to visit our SA-CERN website or the ASP2010 website for further information and to get in contact with us." From discussions with the students, it was clear that several were keen to take advantage of these opportunities.

Several high-profile South African scientists and government officials participated in the last day of the school. This outreach and forum day reviewed the practical aspects of fundamental physics, which could be used as a gateway to innovation and to enhance future collaborations. The inspirational enthusiasm of the students at ASP2010 indicates that overall the future of fundamental science and technology on the African continent is in very good hands.

● For more about ASP2010, see http://AfricanSchoolofPhysics.web.cern.ch/.

Résumé

Afrique : première École de physique fondamentale

La première École africaine sur la physique fondamentale et ses applications (ASP2010) a eu lieu en août à l'Institut national de physique théorique de Stellenbosch (Afrique du Sud). Plus de 50 des 65 étudiants venaient de pays africains – 17 en tout. Grâce à des bourses, ils ont pu assister à ce cours intensif de trois semaines, appuyé par un très grand nombre d'instituts et d'organisations de physique internationale. Le cours couvrait des sujets très variés – physique des particules, cosmologie, technologies des accélérateurs et certaines applications, notamment de physique médicale. L'enthousiasme manifesté par les étudiants donne bon espoir pour l'avenir de la discipline sur le continent africain.

Bobby Acharya, *ICTP and member of the ASP2010 organizing committee, and* **Christine Darve**, *Fermilab and main organizer.*

Second Banff Workshop debates discovery claims

With the era of LHC discoveries about to begin, particle physicists, astrophysicists and statisticians met in Banff to discuss search methods and clarify what claiming discovery – or failing to do so – entails. **Luc Demortier** reports from the recent workshop.

On 11–16 July, the Banff International Research Station in the Canadian Rockies hosted a workshop for high-energy physicists, astrophysicists and statisticians to debate statistical issues related to the significance of discovery claims. This was the second such meeting at Banff (*CERN Courier* November 2006 p34) and the ninth in a series of so-called "PHYSTAT" workshops and conferences that started at CERN in January 2000 (*CERN Courier* May 2000 p17). The latest meeting was organized by Richard Lockhart, a statistician from Simon Fraser University, together with two physicists, Louis Lyons of Imperial College and Oxford, and James Linnemann of Michigan State University.

Smiles all round at the second Banff Worskhop – which is what a correct discovery claim might bring to the faces of astrophysicists, particle physicists and statisticians everywhere. (Courtesy Banff International Research Station.)

The 39 participants, of whom 12 were statisticians, prepared for the workshop by studying a reading list compiled by the organizers and by trying their hand at three simulated search problems inspired by real data analyses in particle physics. These problems are collectively referred to as the "second Banff Challenge" and were put together by Wade Fisher of Michigan State University and Tom Junk of Fermilab.

Significant issues

Although the topic of discovery claims may seem rather specific, it intersects many difficult issues that physicists and statisticians have been struggling with over the years. Particularly prominent at the workshop were the topics of model selection, with the attendant difficulties caused by systematic uncertainties and the "look-elsewhere" effect; measurement sensitivity; and parton density function uncertainties. To bring everyone up to date on the terminology and problematics of searches, three introductory speakers surveyed the relevant aspects of their respective fields: Lyons for particle physics, Tom Loredo of Cornell University for astrophysics and Lockhart for statistics.

Bob Cousins of the University of California, Los Angeles, threw the question of significance into sharp relief by discussing a famous paradox in the statistics literature, originally noted by Harold Jeffreys and later developed by Dennis Lindley, both statisticians. The paradox demonstrates with a simple measurement example that it is possible for a frequentist significance test to reject a hypothesis, whereas a Bayesian analysis indicates evidence in favour of that hypothesis. Perhaps even more disturbing is that the frequentist and Bayesian answers scale differently with sample size (*CERN Courier* September 2007 p39). Although there is no clean solution to this paradox, it yields several important lessons about the pitfalls of testing hypotheses.

One of these is that the current emphasis in high-energy physics on a universal "5σ" threshold for claiming discovery is without much foundation. Indeed, the evidence provided by a measurement against a hypothesis depends on the size of the data sample. In addition, the decision to reject a hypothesis is typically affected by one's prior belief in it. Thus one could argue, for example, that to claim observation of a phenomenon predicted by the Standard Model of elementary particles, it is not necessary to require the same level of evidence as for the discovery of new physics. Furthermore, as Roberto Trotta of Imperial College pointed out in his summary talk, the emphasis on 5σ is not practiced in other fields, in particular ▷

cosmology. For example, Einstein's theory of gravity passed the test of Eddington's measurement of the deflection of light by the Sun with rather weak evidence when judged by today's standards.

Statistician David van Dyk, of the University of California, Irvine, came back to the 5σ issue in his summary talk, wondering if we are really worried about one false discovery claim in 3.5 million tries. His answer, based on discussions during the workshop, was that physicists are more concerned about systematic errors and the "look-elsewhere" effect (i.e. the effect by which the significance of an observation decreases because one has been looking in more than one place). According to van Dyk, the 5σ criterion is a way to sweep the real problem under the rug. His recommendation: "Honest frequentist error rates, or a calibrated Bayesian procedure."

Many workshop participants commented on the look-elsewhere effect. Taking this effect properly into account usually requires long and difficult numerical simulations, so that techniques to simplify or speed up the latter are eagerly sought. Eilam Gross, of the Weizmann Institute of Science, presented the work that he did on this subject with his student Ofer Vitells. Using computer studies and clever guesswork, they obtained a simple formula to correct significances for the look-elsewhere effect. In his summary talk, Luc Demortier of Rockefeller University showed how this formula could be derived rigorously from results published by statistician R B Davies in 1987. Statistician Jim Berger of Duke University explained that in the Bayesian paradigm the look-elsewhere effect is handled by a multiplicity adjustment: one assigns prior probabilities to the various hypotheses or models under consideration, and then averages over these.

Likelihoods and measurement sensitivity

Systematic uncertainties, the second "worry" mentioned by van Dyk, also came under discussion several times. From a statistical point of view, these uncertainties typically appear in the form of "nuisance parameters" in the physics model, for example a detector energy scale. Glen Cowan, of Royal Holloway, University of London, described a set of procedures for searching for new physics, in which nuisance parameters are eliminated by maximizing them out of the likelihood function, thus yielding the so-called "profile likelihood". An alternative treatment of these parameters is to elicit a prior density for them and integrate the likelihood weighted by this density; the resulting marginal likelihood was shown by Loredo to take better account of parameter uncertainties in some unusual situations.

While the marginal likelihood is essentially a Bayesian construct, some statisticians have advocated combining a Bayesian handling of nuisance parameters with a frequentist handling of parameters of interest. Kyle Cranmer of New York University showed how this hybrid approach could be implemented in general within the framework of the RooFit/RooStats extension of CERN's ROOT package. Unfortunately, systematic effects are not always identified at the beginning of an analysis. Henrique Araújo of Imperial College illustrated this with a search for weakly interacting massive particles that was conducted blindly until the discovery of an unforeseen systematic bias. The analysis had to be redone after taking this bias into account – and was no longer completely blind.

In searches for new physics, the opposite of claiming discovery of a new object is excluding that it was produced at a rate high enough to be detected. This can be quantified with the help of a confidence limit statement. For example, if we fail to observe a Higgs boson of given mass, we can state with a pre-specified level of confidence that its rate of production must be lower than some upper limit. Such a statement is useful to constrain theoretical models and to set the design parameters of the next search and/or the next detector. Therefore, in calculating upper limits, it is of crucial importance to take into account the finite resolution of the measuring apparatus.

How exactly to do this is far from trivial. Bill Murray of Rutherford Appleton Laboratory reviewed how the collaborations at the Large Electron–Positron collider solved this problem with a method known as CL_S. He concluded that although this method works for the simplest counting experiment, it does not behave as desired in other cases. Murray recommended taking a closer look at an approach suggested by ATLAS collaborators Gross, Cowan and Cranmer, in which the calculated upper limit is replaced by a sensitivity bound whenever the latter is larger. Interestingly, van Dyk and collaborators had recently (and independently) recommended a somewhat similar approach in astrophysics.

Parton density uncertainties

As Lyons pointed out in his introductory talk, parton distribution functions (PDFs) are crucial for predicting particle-production rates, and their uncertainties affect the background estimates used in significance calculations in searches for new physics. It is therefore important to understand how these uncertainties are obtained and how reliable they are. John Pumplin of Michigan State University and Robert Thorne of University College London reviewed the state of the art in PDF fits. These fits use about 35 experimental datasets, with a total of approximately 3000 data points. A typical parametrization of the PDFs involves 25 floating parameters, and the fit quality is determined by a sum of squared residuals. Although individual datasets exhibit good fit quality, they tend to be inconsistent with the rest of the datasets. As a result, the usual rule for determining parameter uncertainties ($\Delta\chi^2 = 1$) is inappropriate, as Thorne illustrated with measurements of the production rate of W bosons.

The solution proposed by PDF fitters is to determine parameter uncertainties using a looser rule, such as $\Delta\chi^2 = 50$. Unfortunately, there is no statistical justification for such a rule. It clearly indicates that the assumption of Gaussian statistics badly underestimates the uncertainties, but it is not yet understood whether this is the result of unreported systematic errors in the data, systematic errors in the theory or the choice of PDF parametrization.

Statistician Steffen Lauritzen of the University of Oxford proposed a random-effects model to separate the experimental variability of the individual datasets from the variance arising from systematic differences. The idea is to assume that the theory parameter is slightly different for each dataset and that all of these individual parameters are constrained to the formal parameter of the theory via some distributional assumptions (a multivariate t prior, for example). Another suggestion was to perform a "closure test", i.e. to check to what extent one could reproduce the PDF uncertainties by repeatedly fluctuating the individual data points by their uncertainties before fitting them.

In addition to raising issues that require further thought, the workshop provided an opportunity to discuss the potential usefulness of statistical techniques that are not well known in the physics community. Chad Schafer of Carnegie Mellon University presented an approach to constructing confidence regions and testing hypotheses that is optimal with respect to a user-defined performance criterion. This approach is based on statistical decision theory and is therefore general: it can be applied to complex models without relying on the usual asymptotic approximations. Schafer described how such an approach could help solve the Banff Challenge problems and quantify the uncertainty in estimates of the parton densities.

Harrison Prosper of Florida State University criticized the all-too frequent use of flat priors in Bayesian analyses in high-energy physics, and proposed that these priors be replaced by the so-called "reference priors" developed by statisticians José Bernardo, Jim Berger and Dongchu Sun over the past 30 years. Reference priors have several properties that should make them attractive to physicists; in particular their definition is very general, they are covariant under parameter transformations and they have good frequentist sampling behaviour. Jeff Scargle, of NASA's Ames Research Center, dispatched some old myths about data binning and described an optimal data-segmentation algorithm known as "Bayesian blocks", which he applied to the Banff Challenge problems. Finally, statistician Michael Woodroofe of the University of Michigan presented an importance-sampling algorithm to calculate significances under nonasymptotic conditions. This algorithm can be generalized to cases involving a look-elsewhere effect.

After the meeting, many participants expressed their enthusiasm for the workshop, which raised issues that need further research and pointed to new tools for analysing and interpreting observations. The discussions between sessions provided a welcome opportunity to deepen understanding of some topics and exchange ideas. That the meeting took place in the magical surroundings of the Banff National Park could only help its positive effect.

Further reading

The most recent PHYSTAT conference was at CERN in 2007, see http://phystat-lhc.web.cern.ch/phystat-lhc/. (Links to the earlier meetings can be found at www.physics.ox.ac.uk/phystat05/reading.htm.) Details about the 2010 Banff meeting are available at www.birs.ca/events/2010/5-day-workshops/10w5068.

Résumé

Deuxième atelier de Banff – découvertes et statistiques

À l'heure où l'on s'attend aux premières découvertes au LHC, des physiciens des particules, des astrophysiciens et des statisticiens se sont retrouvés en juillet à Banff à l'occasion d'un séminaire consacré au lien entre la revendication, ou la non-revendication, de la découverte d'un objet, et différents effets statistiques. Il s'agit de la deuxième réunion de ce type à Banff, et la neuvième d'une série d'ateliers et de conférences « PhyStat » lancée au CERN en janvier 2000. Les sujets abordés étaient notamment la sélection de modèles, avec les difficultés créées par les incertitudes systématiques, la sensibilité des mesures, et des incertitudes dans les fonctions de densité de parton. Dans l'ensemble, l'atelier a été l'occasion de soulever des questions appelant de nouvelles recherches et de mettre en évidence de nouveaux outils pour l'analyse et l'interprétation des observations.

Luc Demortier, *Rockefeller University.*

AWARDS

Tim Berners-Lee receives the UNESCO Niels Bohr Gold Medal

In a ceremony on 14 September at the Royal Danish Academy of Science and Letters, in Copenhagen, three leading researchers received the UNESCO Niels Bohr Gold Medal for their outstanding contributions to research in physics, which have or could have a significant influence on the world. The medal, which UNESCO created in 1985 to commemorate the centenary of Niels Bohr's birth, was previously awarded in 1998 and 2005. The 2010 laureates are Sir Tim Berners-Lee of the Massachusetts Institute of Technology, Sir John Pendry of Imperial College London and Kip Thorne of the California Institute of Technology. Getachew Engida, deputy director-general of UNESCO, presented the medals on behalf of UNESCO.

Berners-Lee is honoured "for the development of hypertext, the World Wide Web and the far-reaching consequences for global communication and exchange of information"; Pendry "for pioneering contributions to the development of metamaterials (i.e. materials with remarkable and new optical properties)" and Thorne "for groundbreaking contributions to the study of black holes and gravitational waves".

Left to right: Jens Jørgen Gaardhøje, chair of the medal-selection committee and president of the science committee of the Danish national commission for UNESCO, Sir Tim Berners-Lee, Sir John Pendry, Getachew Engida, deputy director-general of UNESCO, and Kip Thorne. (Courtesy H Ferrold.)

ACS rewards research with radioactive ion beams

David Morrissey, distinguished professor of chemistry at Michigan State University and a faculty member of the National Superconducting Cyclotron Laboratory, is to receive the 2011 Glenn T Seaborg Award for Nuclear Chemistry. Presented annually by the Division of Nuclear Chemistry and Technology of the American Chemical Society (ACS), the award honours outstanding contributions to nuclear or radiochemistry or to their applications.

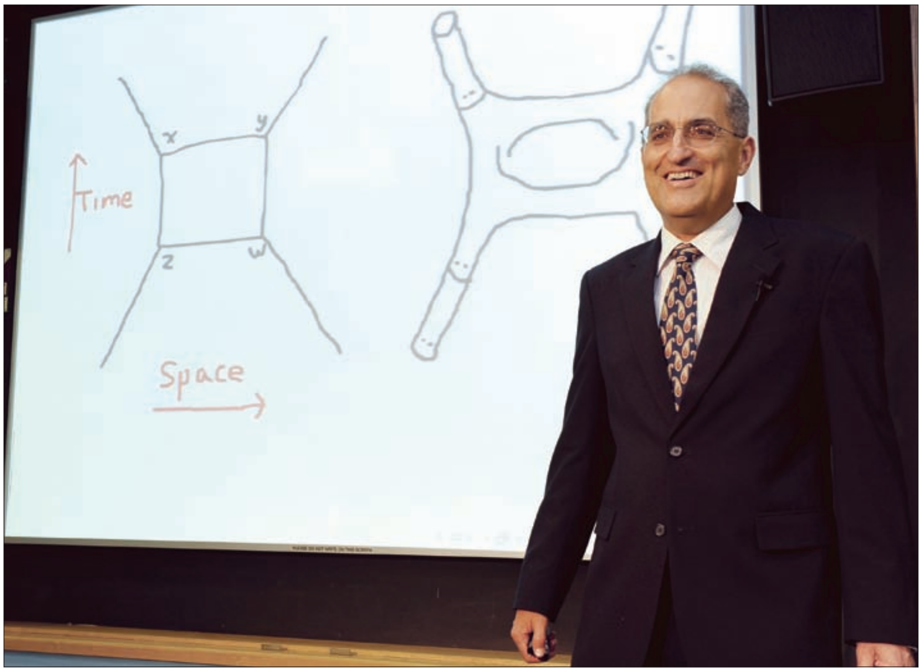
Morrissey's research centres on the experimental investigation of heavy-ion-induced nuclear reactions and nuclear mechanisms, such as the production of radioactive ion beams, measurements of the beta-decay of nuclei at the limits of stability (*CERN Courier* December 2007 p37). Recent work includes the thermalization of fast radioactive ions in a buffer gas for further manipulation and study.

David Morrissey. (Courtesy G L Kohuth, Michigan State University.)

Witten heads list of IOP's 2010 prize-winners

The UK's Institute of Physics (IOP) has awarded its Isaac Newton Medal and Prize for 2010 to theoretical physicist Edward Witten of the Institute for Advanced Studies in Princeton. The Newton Medal, which is the only international IOP award, is in its third year – previous awards being given to Anton Zeilinger of the University of Vienna in 2008 and Alan Guth of Massachusetts Institute of Technology in 2009.

Witten is honoured for "his many profound contributions that have transformed areas of particle theory, quantum field theory and general relativity ... His combination of tremendous physical insight and mathematical power have had impact in areas ranging from the phenomenology of particle physics and cosmology to theoretical areas of string theory and quantum gravity." As winner of the medal, Witten gave the associated Newton Lecture at the IOP, London, in July, on "string theory and the universe".



Witten talked on string theory and the universe when he gave the Newton Lecture. (Courtesy IOP.)

Among other IOP awards, the Hoyle Medal and Prize for 2010, for distinguished research in astrophysics, gravitational physics or cosmology, goes to Carlos Frenk of the University of Durham, for "his major contributions to the development of the now widely accepted cold dark-matter model by using cosmological simulations, novel methods for calculating the physics of galaxy formation and analysis of galaxy surveys".

James Binney of the University of Oxford receives the 2010 Dirac Medal and Prize, awarded for outstanding contributions to theoretical physics, for "his contribution to our understanding of how galaxies are constituted, how they work and how they were formed". Brian Cox, of the University of Manchester, receives the 2010 Kelvin Medal and Prize, for outstanding contributions to the public understanding of physics, in reward for "communicating the appeal and excitement of physics to the general public through the broadcast media".

● For the video of Witten's Newton Lecture, see www.iop.org/resources/videos/lectures/page_44292.html.

Victor Hess Prize 2010 for work at Belle

The Nuclear and Particle Physics section of the Austrian Physics Society has awarded the 2010 Victor Hess Prize for the best thesis in the field of nuclear and particle physics to Wolfgang Dungel for research with the Belle experiment at KEK. He receives the prize for his PhD thesis on "Precision measurements of the CKM-matrix element $|V_{cb}|$ and the form factors of semileptonic decays of B mesons".

Dungel wrote his PhD thesis at the Institute of High Energy Physics of the Austrian Academy of Sciences (HEPHY) as a member of the Belle collaboration. One of Belle's goals is the detailed investigation of parameters of the theory developed of the Cabibbo–Kobayashi–Maskawa (CKM) matrix (p39).


Wolfgang Dungel receives the Victor Hess Prize.

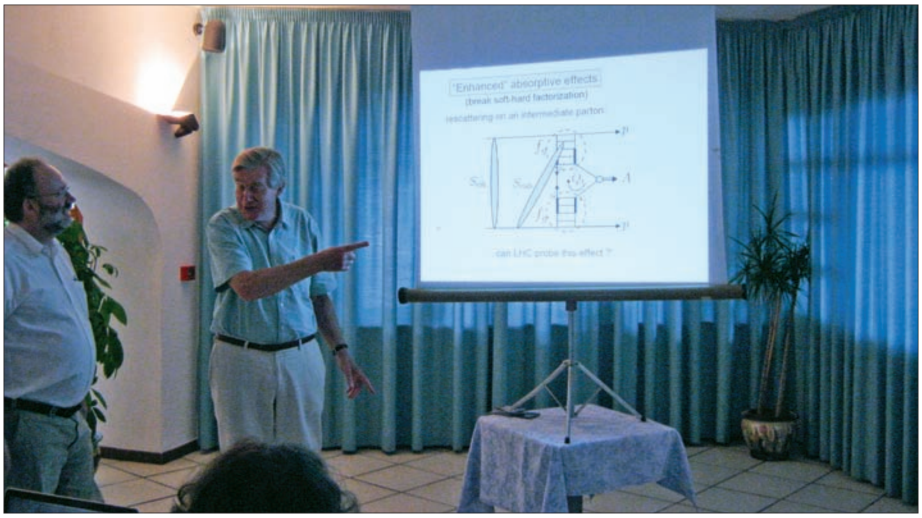
NEW PRODUCTS

ZTEC Instruments has announced the ZT8101 RF Test Set comprised of three PXI instruments for RF testing: the ZT8441 RF/IF Digitizer, the ZT8711 LO Synthesizer and the ZT8611 RF Downconverter. These test sets have as standard an ultrawide 150 MHz modulation bandwidth to meet current and future communication protocols, vector-signal analysis capability for digital-modulation analysis and image-free down conversion for high-performance spectral analysis, spur search, and false-measurement avoidance. The ZT8101 can also be paired with third-party instruments. For more information, tel +1 505 924 0611, fax +1 505 342 0222, or visit their website at www.ztecinstruments.com.

SUMMER SCHOOL

Learning how gluons team up for diffractive processes

The summer school "Diffractive and Electromagnetic Processes at High Energies" took place on 6–10 September in Acquafredda, Italy. The school was a timely opportunity to review the understanding of diffraction at the HERA and the Tevatron colliders to prepare the programme of diffractive physics at the LHC. With the analysis of the first proton–proton collisions at the LHC, several issues in diffractive physics have already attracted the attention both of theorists and of experimentalists. However, many aspects of diffraction remain mysterious and they are the topic of intense debates among experts. Some of these mysteries were discussed during the first LHC physics day organized by the LHC Physics Centre (LPCC) at CERN on 7 May.



Alan Martin discusses possible diffractive measurements at the LHC with Albert De Roeck.

At LHC energies, approximately 30% of the proton–proton collisions are from diffractive reactions, hence an improved knowledge of diffractive mechanisms is necessary for a comprehensive understanding of proton–proton interactions at high energies. Diffractive phenomena are understood to arise from the strong interaction. In QCD, the theory of the strong interaction, gluons transmit the strong force by carrying a colour charge that they constantly exchange between the quarks. The nature of the interaction is such that stable particles with net colour cannot exist and no free quark has ever been detected in an experiment, despite numerous efforts. Gluons can, however, team up so that their individual colour charges add up to being colour neutral. These teams of gluons then act very differently than they do as single gluons with colour charge.

It is the exchange of this colourless multigluon team, rather than the exchange of single-coloured gluons, that gives rise to the strong interaction in diffractive processes, and it leads to many of the features of diffraction in hadron–hadron collisions. For example, the team of gluons passing between the protons can exchange only a little energy and momentum, otherwise it would break up and would no longer be a team. The colliding protons are therefore deflected only a little and mainly continue "forward", near to their original direction, where they can be measured in detectors positioned very close to the beam. Another feature of diffractive events is the presence of "rapidity gaps" corresponding to large parts of the experiment where the proton–proton collision does not deposit any energy. Such rapidity gaps can be used to identify diffractive events.

The dynamics of such colourless gluon teams is at present poorly understood within the framework of QCD. The expectation is that new insight will be gained at the new-energy frontier of the LHC, so the diffractive-physics community is eagerly waiting for the analysis of diffractive events at the new collider.

The lectures at the Acquafredda school covered many of the topics necessary for understanding diffraction at the LHC. Alan Martin, from the Institute for Particle Physics Phenomenology at Durham University gave a series of talks in which he reviewed the current theoretical understanding of diffraction, thereby introducing the students to the necessary formalism. These theoretical lectures were complemented by the presentations of Martin Poghosyan of the University Torino, who discussed particle production in soft hadronic interactions. Paul Newman from the University of Birmingham covered the lessons learned from the diffractive-physics programme at the HERA collider at DESY, whereas Christina Mesropian of Rockefeller University, reported on results on diffraction from Fermilab's Tevatron. The LHC and the diffractive-physics programmes of the LHC experiments were the topics for CERN's Albert De Roeck.

The participants of the Acquafredda school taking a break from the physics discussions. (Photos courtesy Rainer Schicker.)

Many of the participants at the school presented their research results in seminars. De Roeck complemented the scientific programme with an evening lecture on many exciting physics questions that are waiting to be answered by data from the LHC experiments, concerning for example, mini black holes, extra dimensions and diffractive fireballs.

● For more information about the school, see http://school-diff2010.physi.uni-heidelberg.de/ and for the physics day on diffraction at the LHC at the LPCC, see http://indico.cern.ch/conferenceDisplay.py?confId=9125.

SCIENCE SLAM

Missing antimatter wins the applause in Munich

Scientists of the Max Planck Institute for Physics participated at the first Munich Science Slam and Scientific Dialogue on 25 August. At the "Scientific presentation tournament" scientists gave short popular talks explaining their research focus for the public. The idea is related to the poetry slam, founded in Chicago during the 1980s, in which people present their own poems or prose. During the contest in Munich, which was the first science slam totally dedicated to particle physics, the six participating scientists took on the challenge of presenting their research area in experimental or theoretical particle physics in the hope of winning the contest.

What would the institute's former director Werner Heisenberg have said about the idea of explaining, within 12 minutes, complex topics in fundamental physics, such as the ATLAS detector, supersymmetry or the building blocks of the universe? In particular, if the audience were to be the jury, voting with their applause for the most understandable and enjoyable talk? While no one knows what Heisenberg would have thought, an auditorium packed with an audience of all kinds, including journalists, spoke for itself.

Philipp Weigell, representing the biggest experiment in which the institute is involved, took the 200 people present to ATLAS at CERN in his "journey of discovery". Given the laughs and excitement of the audience they definitely seemed to enjoy particle physics. Even though topics such as string theory or supersymmetry appeared to be "tough to explain" during the weeks of preparing for the event, it turned out that Jan Germer, for instance, a PhD student in the phenomenology group, came across very well in using Dirac's "Scissor experiment" as a simple demonstration of quantum mechanical effects. Additional animations on slides supported his explanation. Peter Graf, the last participant in this verbal contest, presented himself as "the hope", in reference to the Jedi Knights, since astroparticle physicists may reveal the secrets of dark matter and dark energy in the universe. However, it was Andreas Moll, from the institute's research group working on the Belle experiment at KEK, who cast a spell over the auditorium with just the simple act of the "left-hand-rule". He finally had the audience on his side as they tracked matter and antimatter using interactive games in his talk "The hunt for the missing antimatter".

Andreas Moll casts his spell with the left-hand rule. (Courtesy A Griesch/Max-Planck-Institut für Physik.)

The rating by the audience led to the final decision, with the help of the "applausometer" – a sound-level meter that quantified the intensity of the applause – to measure which talk gained the most applause. They were all very close, but in the end, Moll proved to have convinced the public with his explanations about the annihilation of matter and antimatter.

Many questions arose during the slam and the relaxed atmosphere of the scientific dialogue that followed, complete with drinks and food, provided the opportunity for the audience to address all of their questions to the scientists.

VISITS

Issei Tajima (right), Japanese senior vice-minister of the environment, and **Hiroshi Kamiyama** (left), first secretary for the permanent mission of Japan, were welcomed to CERN on 2 September. On the agenda were visits to the ATLAS control centre with ATLAS collaboration member, **Taka Kondo**, and to the *Universe of Particles* exhibition.

Ene Ergma (right), the president of the Riigikogu, the Estonian parliament, visited CERN on 19 July. She toured the LHC superconducting magnet test hall with **Andrzej Siemko**, leader of the machine protection and electrical integrity group in the technology department, and also saw the CERN Control Centre, the CMS experiment and the LHC tunnel.

During his visit on 29 July, **Jung Hyun Kim** (left), vice-minister for education, science and technology of the Republic of Korea, learnt about CERN's LHC computing grid project from **Frédéric Hemmer**, head of the information technology department. In addition, the vice-minister toured the ATLAS visitor centre, the CMS control centre, the ALICE experiment's exhibition and control room, and he met Korean scientists at CERN.

On 20 July, **Tsetska Tsacheva** (centre right), president of the national assembly of the Republic of Bulgaria, met with members of the Bulgarian community at CERN. In addition, she toured the CMS control room, the LHC tunnel, the CMS underground experimental area and the LHC superconducting magnet test hall.

Federal councillor for the Swiss federal department of the interior, **Didier Burkhalter** (centre), visited the ATLAS control centre at CERN on 23 August, together with **Fabiola Gianotti**, the ATLAS spokesperson. The federal councillor also toured the LHC superconducting magnet test hall and the *Universe of Particles* exhibition.

Chair of the national people's congress standing committee for the People's Republic of China, **Wu Bangguo** (far right) came to CERN on 20 July. He visited the Alpha Magnetic Spectrometer experiment (AMS) with (from left to right) **Samuel Ting**, the AMS collaboration spokesperson, **Zhang Ruizhen**, wife of Wu Bangguo, and **Susan Ting**, wife of Samuel Ting.

It was the turn of the Austrian federal minister for science and research, **Beatrix Karl** (centre), to visit CERN on 29 July. She toured the CMS experiment with CERN's director-general, **Rolf Heuer** (left) and the head of international relations, **Felicitas Pauss** (right). The minister also saw the *Universe of Particles* exhibition in the Globe of Science and Innovation, and met with Austrian scientists working at CERN.

OBITUARIES

Bruno Ferretti 1913–2010

Bruno Ferretti, a leading figure in Italian and European physics and in the early days of CERN, passed away on 11 August aged 97. His research encompassed a vast spectrum of scientific interests, from experimental physics to fundamental theory.

Born and educated in Bologna, in 1937 Ferretti was invited by Enrico Fermi to join his group in Rome. When Fermi left for the US in 1938, Ferretti joined forces with the people in Rome who were pursuing research in fundamental physics, despite the hardships of the times. For a while he was the only senior theoretician, a responsibility that he took very seriously. He followed in detail all developments in the field, working out many of the answers for himself, and had an exceptional influence on the education of young theorists in Italy. (On leaving, Fermi had suggested that Ferretti should take charge of lecturing in his place.) He was also a beacon for experimental physicists, listening to them and then discussing their problems in depth, often suggesting the experimental touches that would make a measurement a success and ensure its significance.

Bruno Ferretti (centre) at the Solvay conference in 1948 with Felix Bloch (left), Homi J Bhabha (right) and Wolfgang Pauli (behind). (Courtesy Pauli Archive/CERN.)

Ferretti became a full professor at Milan University in 1947 and then at Rome in 1948. It was at the Physics Institute in Rome that he worked with Edoardo Amaldi on ideas for what was to become CERN. In December 1950, at a meeting called by Pierre Auger in the headquarters of the Centre européen de la culture promoted by Denis de Rougemont, Ferretti submitted to the group for scientific studies and research a concise proposal, including costs, for “a European nuclear physics laboratory based on a large accelerator of elementary particles” (in the words of the group’s resolution). This laid the foundations of the future CERN laboratory, fixing its direction in “basic science”.

CERN’s theory group was originally based in Copenhagen, but in 1957, Ferretti became the first director of the Theoretical Studies Division in Geneva. During his time at CERN, the experimental programme for the 600 MeV Synchrocyclotron and the up-coming 25 GeV Proton Synchrotron was outlined, following wide consultation in the Member States and in many seminars at CERN. Then in April 1959 Markus Fierz took over as head of theory, and Ferretti returned to Bologna, where he held the chair of theoretical physics until his retirement in 1988.

Ferretti’s original interests were in cosmic rays, on which he worked with Gilberto Bernardini, Oreste Piccioni and Gian Carlo Wick, among others, and in classical electromagnetism. However his main interest, throughout his research work, was in field theory and its more fundamental problems. He made profound contributions concerning the problem of macroscopic causality and its relation to Lorentz invariance, and he also made important remarks on the problem of renormalization. In his aim for clarity and precision he considered particularly the problem of the definition of the state and its relation to measurement in quantum electrodynamics. In a more pragmatic vein, he worked on the Dyson–Feynman approach and on indefinite metrics.

More recently, Ferretti focused on the question of indefiniteness in position, for which he was searching for the existence of minorants. In his last years, he was interested in measurements of gravitation, proposing an experiment with gravitational radiators and detectors.

In addition to his work on questions

in fundamental physics, Ferretti developed some more speculative ideas, such as a neutrino theory of light, and energy-dependent symmetries. He was also interested in areas other than field theory, for example in the physics of bremsstrahlung in crystals, and in some problems of statistical mechanics, particularly density fluctuations near criticality. In the field of high-energy phenomenology he worked on nuclear forces and on pion–nucleon scattering.

A taste for experimental and applied physics being one of Ferretti's special characteristics, he studied the problems posed by nuclear energy and conceived of a new type of nuclear reactor. A prototype was built near Bologna, where Ferretti also laid the foundations for the School and Laboratories for Nuclear Engineering. Nor did he stop posing and answering questions related to the teaching of physics at any level and instigated original research in science education. He remained active and enthusiastic in research until his very last years, always deeply convinced that theory should keep in touch with feasible measurements.

Ferretti was remarkable for his vast knowledge and discernment in many fields of physics, sometimes very different and widely separated. Discussions with him could last entire afternoons, and he was always well informed and rich in ideas. This was all part of a life that was totally and unconditionally devoted to physics and to the search for new insights.

His friends and colleagues.

Nicola Cabibbo 1935–2010

Nicola Cabibbo, one of the most important theoretical physicists of our time, died in Rome on 16 August.

The son of a Sicilian lawyer, Nicola was born in Rome on 10 April 1935. He graduated in theoretical physics at the Universita' di Roma "La Sapienza" in 1958 under the supervision of Bruno Touschek, whom he always considered as his mentor.

At the beginning of the 1960s, Touschek and his collaborators were building the first e^+e^- collider at Frascati Laboratory, near Rome. Raoul Gatto was also at the laboratory at the time and played an important role in guiding the young Cabibbo towards frontier theoretical physics. Together, they wrote a number of important papers, including a pioneer study on the physics reach of e^+e^- colliders, which remained a standard reference on the subject for years to come.

Nicola Cabibbo. (Courtesy INFN.)

Nicola then left Rome for the US and CERN. While at CERN, in 1963 he formulated what came to be known as the "Cabibbo universality" of weak currents. He showed that strangeness changing and non-changing β-decays had to be described by a single hadronic weak current, determined in terms of an unknown parameter — the Cabibbo angle, θ_C. With a value for $\sin\theta_C$ of around 0.22 and the use of unitary symmetry, Nicola was able to describe the β-decays of strange mesons and baryons, and to explain the small discrepancy between the neutron and muon Fermi-constants, the former being about 2.5% smaller than the latter.

Later, he reformulated the same concept in the context of the quark model, by stating that the weak charged current couples the u quark to an orthogonal combination of the d and s quarks that is determined by the angle θ_C. His formulation was extended to include charm (the c quark), and explain the absence of flavour-changing neutral currents, by Sheldon Glashow, John Iliopoulos and Luciano Maiani. It was later expanded to encompass three families of fermions by Makoto Kobayashi and Toshihide Maskawa, and more recently applied also to neutrino mixing. Today the Cabibbo–Kobayashi–Maskawa (CKM) matrix plays an essential role in the description of fundamental interactions.

In 1967 Nicola settled back in Rome where he taught theoretical physics and created a large school with younger colleagues and brilliant students. Like all great minds, he could find simple arguments to explain the most difficult concepts. His students were fascinated by his simplicity, gentle manners and sense of humour. Inspired by Nicola's physical intuition, mathematical skill and personal charisma, the Rome school contributed significantly to establishing what is today referred to as the Standard Theory of particle physics.

We were extremely lucky to work with him at the time, and remember the long hours spent in his large office in discussions with him. Often he left us there, struggling with some problem or calculation, while he went back home for a long lunch break, which was devoted to his family and to the cultivation of numerous other interests and hobbies. When he returned in the afternoon he could often solve our problems and indicate the next step. He was known for his phlegmatic way of working. He would approach a physics problem very much as a cat approaches its prey, with great caution up to the point when he decided that the solution was within his reach. Then he suddenly became very active and enthusiastic until the work on the problem was completed.

Over the years Nicola applied his extremely lucid, deep and flexible intellect to a wide range of problems. These also included experiments, such as the measurement in 1963 of the electron helicity in muon decay, and the conception and design of the parallel computers in the APE project, which he developed with Giorgio Parisi and younger collaborators in the early 1980s, for the simulation of QCD on a discretized space–time (or lattice). In a pioneering paper he first applied lattice techniques to extract the CKM parameters from hadronic observables.

Highly respected for his range of competence, international recognition, political and managerial skills, Nicola was appointed to important positions in Italy. He was president of the INFN from 1983 to 1992, during which time the Gran Sasso Laboratory was inaugurated. He was also president of the Italian energy agency, ENEA, from 1993 to 1998, and was president of the Pontifical Academy of Sciences from 1993. He held these important positions with vision, managerial ability and universally appreciated integrity.

In 2004, Nicola spent a year at CERN as guest professor. Free from non-scientific burdens, and with youthful enthusiasm, he plunged back into current research, joined the NA48 collaboration and, among other contributions, quantitatively explained an intriguing feature of the data in $K \rightarrow 3\pi$ decay in terms of the final state π–π interaction computable from chiral symmetry theory.

Nicola Cabibbo will be sorely missed by all of those who had the chance to work with him and to appreciate directly his outstanding qualities as a person and as a physicist.

Guido Altarelli, Luciano Maiani and Roberto Petronzio.

Jean-Daniel Berst 1942–2010

Jean-Daniel Berst, an outstanding electronics engineer from the Institut Pluridisciplinaire Hubert Curien (IPHC) in Strasbourg, passed away on 13 September.

Born in Alsace in April 1942, Jean-Daniel received his PhD from the University of Strasbourg in 1969 and became an engineer at the CNRS in August 1970 at the High Energy Division of the Centre de Recherches Nucleaires in Strasbourg. He started there with the group working on the hyperon experiment at CERN (WA2), for which he developed a CAMAC programmable processor. He then joined the NA10 experiment, making an invaluable contribution by developing the GESPRO, one of the first bit-slice microprocessors to perform a complete read-out chain, with online data reduction and data reprocessing. The GESPRO processor was later adapted for the data-acquisition system for the L3 experiment at the Large Electron–Positron (LEP) collider.

Moving on to the DELPHI collaboration at LEP, Jean-Daniel was in charge of the development and commissioning of the TDC system in the barrel ring-imaging Cherenkov detector. He then transferred to the Laboratoire d'Electronique et de Physique des Systèmes Instrumentaux (LEPSI) in Strasbourg, where he was Technical Director for 15 years, successfully coordinating all of the R&D programmes in which LEPSI was involved. While at LEPSI, he also instigated the creation of the Microelectronics Department at IPHC-Strasbourg.

Jean-Daniel Berst. (Courtesy IPHC.)

Jean-Daniel joined the LHC programme in 1994, and led the design of the front-end circuit for the microstrip gas chambers, based on DMILL technology. During the same period, he coordinated the teams who developed and commissioned the ASICs, HAL25 and ALICE128C, for the ALICE experiment at the LHC and STAR at Brookhaven.

When the CMS Collaboration decided to choose an all-silicon tracker using 0.25 μm technology, Jean-Daniel and his group of engineers were in charge of the hybrid circuit to read out the complete tracker. Faced with many contradictory requirements, he found an elegant and workable solution for each of the problems, which arose from factors varying from the geometry to the choice of materials. He coordinated prototyping, tests, choice of manufacturers for the production, and the assembly of more than 20 000 hybrids. He designed all of the quality-control strategies, devoting himself to this task until the last hybrid was delivered, even after his illness was diagnosed. It is not an exaggeration to say that Jean-Daniel is one of the few people to whom CMS owes its successful tracker.

In 1999 he received the "Cristal du CNRS", the highest possible award for an engineer at CNRS, and in March, was presented with an Achievement Award for CMS construction for his "Outstanding Contribution to the CMS Tracker Front End Hybrids".

Jean-Daniel was an exceptional person in all aspects of his life. He sought the most elegant technical solutions for all electronic problems and would never accept easy short-cuts. As the leader of teams of engineers and technicians, he always motivated his colleagues by setting the example of working hard on the floor right up until his retirement in 2007. It is difficult to imagine how to continue experiments without him.

He is survived by his wife, Nadine, two children and two grandchildren.

His friends and colleagues.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

MONTE CARLO.

DESY, Zeuthen location, is seeking:

Scientist (m/f)

DESY

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

The position

For the DESY Zeuthen site we are looking for a physicist to take a leading role in the Analysis Centre of the Helmholtz Alliance "Physics at the Terascale" with focus on Monte Carlo developments for detector simulations. This includes the support of the Alliance members and contributions to schools and other educational projects. The successful candidate is supposed to work for about 50% of his or her time on related subjects in one of the DESY LHC groups.

Requirements

- PhD in physics
- At least two years of postdoctoral experience
- Experience in development of Monte Carlo tools for physics and detectors
- Experience in a particle physics experiment is welcome

For further information please contact Klaus.Moenig@desy.de or Sabine.Riemann@desy.de. Interested candidates are encouraged to send their complete application package (including CV, three letters of reference and a statement of research interests).

The position is limited initially to 3 years and can become permanent in case of positive evaluation. Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Please send your application quoting the reference code, also by e-mail, to:
Deutsches Elektronen-Synchrotron DESY
Human Resources Department | Code: 106/2010
Notkestraße 85 | 22607 Hamburg | Germany
Phone: +49 40 8998-3392 | E-mail: personal.abteilung@desy.de
Deadline for applications: 21 November 2010
www.desy.de

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

HELMHOLTZ | GEMEINSCHAFT

Georg-August-Universität Göttingen

Fakultät für Physik

The Department of Physics at the Georg-August-Universität Göttingen invites applications for

a W1-Helmholtz-Juniorprofessorship (salaray scale W1 BbesO, initially temporary appointment) with Tenure Track-Option (salary scale W2 BbesO)

in the specific area of

Theoretical Physics, in particular High Energy-Collider-Particle Physics and Phenomenology

at the earliest possibility of availability.

The appointment into civil service will be initially for a period of three years with a possible extension by another three years, provided positive evaluation. After a positive evaluation of the entire phase of junior professor (tenure track), an indefinite appointment as university professor (salary scale W2 BbesO) is foreseen.

The successful applicant is expected to do research in the fields of
– Phenomenology of elementary particles and
– Physics at the Terascale.

The objectives of research are to supplement the current and future range of research topics of the Experimental Particle Physics group in the Department of Physics in the field of elementary particle physics at the Terascale (physics of the top quark, heavy gauge bosons, search for Higgs bosons, and b-physics at LHC and ILC) and be closely integrated into the Helmholtz Alliance on "Physics at the Terascale". The successful candidate is expected to take part in teaching the subject of theoretical physics (Bachelors' and Masters' courses) as well as the specialization subject of particle physics. Active participation in committees of academic self administration is expected.

Preconditions for appointments are laid down in § 30 of the Law on Higher Education of Lower Saxony. The Public Law Foundation Göttingen University holds the right of appointments. In case the completion of the doctorate was preceeded or followed by employment as an academic assistant or collaborator, the period of doctorate and the period of employment together should not exceed six years. The Tenure-Track option can only be considered for applicants with scientific activities of at least two years after their PhD outside the University of Göttingen. Further information on the junior professorship and the application process can be found at **http://physik.uni-goettingen.de**.

We explicitly welcome applications from abroad. Disabled persons with corresponding aptitude for the position will be favoured. The University strives to increase its proportion of female staff and expressly encourages qualified women to apply.

Under certain circumstances part-time employment is possible.

Applications, including CV, a description of your teaching and research track record, a list of publications and, in particular, a research proposal are requested by 08.November 2010 electronically via the link **http://physik2.uni-goettingen.de/juniorprofessur/Helmholtz_JP_Ausschreibung_goettingen_englisch.html**

UNIVERSITY OF Cincinnati

Postdoctoral Fellow — Belle and Belle II

The experimental particle physics group invites applications for a Postdoctoral Fellow position with the Belle and Belle II experiments. We seek a recent Ph.D. physicist to join us in development and construction of the "Imaging Time-of-Propagation" (iTOP) hadron ID device for Belle II as well as exploitation of Belle's tremendous data sample in the Upsilon energy region, especially in B_s studies at the $\Upsilon(5S)$.

Details on applying may be found at
http://homepages.uc.edu/physics/facultyStaff/jobs.html.
We will begin reviewing applications immediately and continue until the position is filled.

The University of Cincinnati is an equal opportunity/affirmative action employer. Women, people of color, people with disabilities and veterans are encouraged to apply.

LEON M. LEDERMAN Postdoctoral FELLOWSHIP

The Fermi National Accelerator Laboratory (Fermilab) invites applications for the Lederman Postdoctoral Fellowship in experimental particle physics. The Lederman Fellow will work within the broad program of experimental research at Fermilab which includes research at the Tevatron and the LHC, neutrino physics, particle astrophysics, and experiments at the Intensity Frontier. In recognition of Leon Lederman's outstanding career in research and his commitment to the teaching of physics, we are looking for candidates who have demonstrated exceptional ability in research and who also wish to participate in physics outreach for a fraction of their time.

The Lederman Fellowship is a three-year appointment with a possible extension. Candidates should have obtained a Ph.D. in experimental particle physics, astrophysics, or a closely related field, after November 1, 2009, or should expect to obtain a Ph.D. in the same fields by June 2011.

Applications including a curriculum vitae, a description of prior research, a statement of research interests, and details of experience and interest in outreach, should be sent to LMLFAPP@fnal.gov. Applicants should also arrange for three or four references to be sent to the same address. Applications and their references should be received by December 20, 2010.

Fermilab

Fermilab is an Equal Opportunity Employer M/F/D/V

RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

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

Doctoral Fellowships

in its core areas of modern fundamental physics: (a) Fundamental Interactions and Cosmology, (b) Astronomy and Cosmic Physics and (c) Quantum Dynamics and Complex Quantum Systems. 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. 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. Membership in the IMPRS for Quantum Dynamics in Physics, Chemistry and Biology **(http://www.mpi-hd.mpg.de/imprs-qd)** as well as the IMPRS for Precision Tests of Fundamental Symmetries in Particle Physics, Nuclear Physics, Atomic Physics and Astroparticle Physics at the University of Heidelberg **(www.mpi-hd.mpg.de/imprs-ptfs)** is envisaged if appropriate.

Highly qualified and motivated national and international students are invited to apply. Applicants should hold a Master of Science or equivalent degree in physics. 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 5, 2010.

THE UNIVERSITY *of* WISCONSIN
MADISON

The Department of Physics at the University of Wisconsin – Madison seeks to fill a faculty position beginning August 2011.

We are targeting candidates in experimental neutrino physics at the Assistant Professor level. Ph.D and post-doctoral experience required prior to start of appointment.

Applications must be submitted by December 31, 2010 through the web site: **http://www.physics.wisc.edu/apply/fac-search-2010/**. The material submitted should provide evidence of teaching skills and the ability to carry out an independent research program.

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

RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

The Department of Physics and Astronomy of the **Ruprecht-Karls-University Heidelberg**, Germany, invites applications for a

W3-Professorship in Theoretical Physics

We are looking for an outstanding theoretical physicist active in the field of fundamental particle physics beyond the Standard Model, complementary to our activities in LHC physics and cosmology. Possible research areas include dark matter, new ideas to understand physics at the TeV scale or future precision experiments.

The new professor is expected to demonstrate a commitment to teaching excellence in Theoretical Physics at both the undergraduate and graduate levels. He/she is also expected to be an active member of the Graduate School of Fundamental Physics.

Prerequisites for application are a university degree, a Ph.D. in physics and (in accordance with Article 47, paragraph 2 of the Higher Education Law of the State of Baden-Württemberg), a Habilitation, a successfully evaluated junior professorship or equivalent qualification.

The University of Heidelberg seeks to achieve a higher proportion of women in areas where they have not been adequately represented so far. Women with the required qualifications are particularly encouraged to apply. Preference will be given to disabled applicants with equal qualifications for the position.

Qualified candidates are invited to submit their application including CV, list of publications and a research plan until **January 6, 2011**, to **Prof. M. Salmhofer, Dekan der Fakultät für Physik und Astronomie der Universität Heidelberg, Albert-Ueberle-Str. 3-5, D-69120 Heidelberg**

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 astronomy. The LIGO Laboratory is managed by Caltech and MIT, and is sponsored by the National Science Foundation. It operates observatory sites equipped with laser interferometric detectors at Hanford, Washington and Livingston, Louisiana. The initial detectors have achieved design sensitivity and a data set spanning more than a year of coincidence operation has been collected. Analysis is ongoing, with extensive participation by the LIGO Scientific Collaboration (LSC). Further observation is now underway, with incrementally improved instruments. A major upgrade (Advanced LIGO) is underway in parallel. In addition, a vigorous R&D program supports the development of enhancements to the detectors as well as future capabilities.

The LIGO Laboratory may have several postdoctoral research positions at Caltech, MIT and at the two LIGO observatory sites. 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. Expertise related to astrophysics, modeling, data analysis, electronics, laser 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 referred 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, 2010 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

UNIVERSITY of ROCHESTER

Tenure Track Faculty Position in Experimental Particle Physics in the Department of Physics and Astronomy

The Department of Physics and Astronomy at the University of Rochester invites applications for a tenure-track faculty position in Experimental Particle Physics. With this position, we seek to broaden the research portfolio of our existing program, which includes research in hadron collider physics at CMS (LHC), CDF and D0, neutrino physics at MINERvA and T2K and quark flavor physics at CLEO and BES. We are particularly interested in considering candidates with a research interest in non-accelerator based particle physics or particle astrophysics, but will consider candidates across the spectrum of Experimental Particle Physics.

Applicants should have a Ph.D., an outstanding record of research, and a commitment to excellence in teaching at both the undergraduate and the graduate level. We seek applications from junior-level candidates; an appointment at a more senior level can be considered for exceptionally well qualified applicants. Each candidate should submit a letter of application, a curriculum vitae including a list of publications, and a description of research and teaching plans. The candidate should arrange for at least four letters of recommendation to be sent to:

HEP Faculty Search Committee, c/o Ms. Shirley Brignall
Department of Physics and Astronomy, University of Rochester
Rochester, NY 14627

Applications may also be submitted by email sent to **shirl@pas.rochester.edu**. Applications will be considered on an ongoing basis beginning in November 2010.

The University of Rochester has a strong commitment to diversity and actively encourages applications from candidates from groups underrepresented in higher education. The University of Rochester is an Equal Opportunity employer and encourages applicants from members of minority groups and women. All applications are considered without regard to race, sex, age, religion or national origin. Salary will be competitive.

Postdoctoral Position in Astroparticle Physics
at the
Institute of Physics, Academia Sinica, Taiwan

Applications are invited for a postdoctoral position in astroparticle physics with the AMS (Alpha Magnetic Spectrometer) Experiment at Institute of Physics, Academia Sinica, Taiwan, to work at CERN, Geneva.

AMS is a TeV magnetic spectrometer to search for antimatter, dark matter, strangelets and other unexpected phenomena, as well as to measure precisely cosmic ion spectra aboard the International Space Station from 2011 to 2020 and beyond.

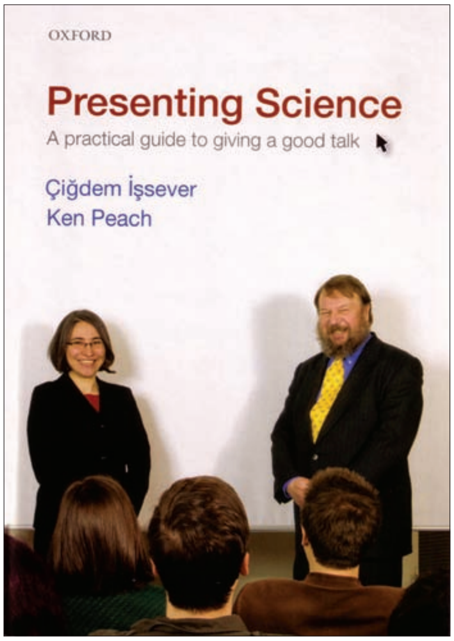
Academia Sinica is the leading research institute in Taiwan. Its research in particle physics includes the ATLAS experiment at CERN and the reactor neutrino experiment TEXONO at Taiwan.

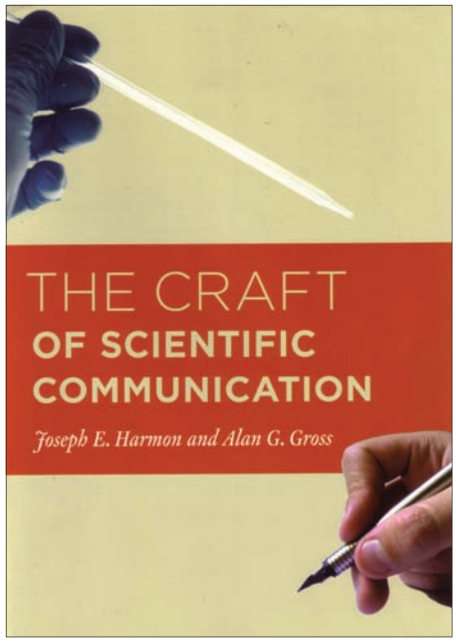
Candidates should have a Ph.D in astroparticle physics at the date of the appointment. Applicants should send a curriculum vitae, a list of publications, a brief statement of research interests, and arrange for at least three letters of recommendation to be sent via email to
Prof. Shih-Chang Lee (phsclee@phys.sinica.edu.tw).

The position will remain open until filled.

BOOKSHELF

Presenting Science: A Practical Guide to Giving a Good Talk by Çiğdem Işsever and Ken Peach, OUP. Hardback ISBN 9780199549085, £39.95 ($75). Paperback ISBN 9780199549092, £19.95 ($35).
The Craft of Scientific Communication by Joseph E Harmon and Alan G Gross, Chicago University Press. Hardback ISBN 9780226316611, $55. Paperback ISBN 9780226316628, $20. E-book ISBN 9780226316635, $7–$20.





Communication takes many forms, each with its own "how to" manual. Peer-to-peer, communication with the media, reaching exhibition visitors and the public in general: all now have their guides. Each audience deserves particular attention, but the ground rules are always the same: define your objectives, work out a strategy for achieving those objectives and then plan your tactics. This approach comes across loud and clear in these two very different books.

Physicists Çiğdem Işsever and Ken Peach give a practical guide to preparing a talk, while science communicators Joseph Harmon and Alan Gross take a rather more academic look, focusing on the craft of writing a scientific paper.

Işsever and Peach deserve high praise not only for producing this book, but also for recognizing that communication skills are important enough to be taught to science students: their book is based on a course they deliver at the University of Oxford. Their key message is to be prepared: know who your audience is, why you are talking to them and what messages you want them to carry away. "The aim," they write, in bold text, "is to get your message across to your audience clearly and effectively."

The book walks its readers through the steps towards achieving that goal, urging would-be speakers to research the event that they'll be talking at and the audience they'll be talking to, before giving advice on how to prepare the ubiquitous PowerPoint presentation. "The purpose of the slides," reads chapter two, "is to help the audience understand the subject. Once you start to relax on this and make the slides serve some other purpose (like being intelligible to those who were not there) you risk confusing the audience." In other words, choose your message, package it for your audience and stick to it. It's good advice.

Later chapters develop key themes. Chapter three talks about structure: tell people what you're going to say, say it and then remind them of what you've said. Chapter four develops the theme of understanding the audience's needs, while chapter five addresses style: if you're talking to an audience of particle physicists, for example, you'll adopt a different style from what you would choose for school pupils.

Işsever and Peach are somewhat disparaging about the use of corporate image, arguing that it takes up too much space and leaves little for content. In corporate communication, this is often the case, but it doesn't have to be that way. Whether we like it or not, the word "branding" has entered the lexicon of communication in particle physics: we're all jostling for a place in the public's consciousness, and brand identity helps. Establishing the brand has been a key ingredient of CERN's communication, for example, throughout the start-up phase of the LHC. Partly as a result, CERN and the LHC are fast becoming household names, providing a strong platform on which to build scientific and societal messages.

The book winds up where it began: reminding readers that the key to success is thorough preparation. Like much of the book's advice, this applies equally well to any form of communication, be it with lab visitors, journalists or even your neighbours.

Harmon and Gross take an altogether more academic approach, analysing and dissecting the scientific paper through the ages to identify and codify what works and what doesn't. It is the classic textbook to Işsever and Peach's field guide, each chapter ending with exercises for the student.

It's a bold thing to attempt to improve on some of the most successful papers of the 20th century, but on page 22 Harmon and Gross do just that, while being careful to point out that their book was not subject to the same length constraints that a journal imposes. The point they make is that each part of a paper has a specific role to play, and by respecting that rule you'll craft a better paper. A typical abstract, they argue, tells the reader what was done, how it was done and what was discovered. On page 22, they add a fourth element: why it matters. In doing so, the abstract becomes not only informative but also persuasive.

Harmon and Gross go on to apply the same rigorous approach to communications, ranging from grant proposals to writing for the general public, inevitably arriving at the subject of PowerPoint. In a chapter that resonates strongly with Işsever and Peach, they point out a common failing of PowerPoint presentations: their creators often forget that audiences have only a minute or two to view each slide. Their key message? A PowerPoint slide is not a page from a scientific paper.

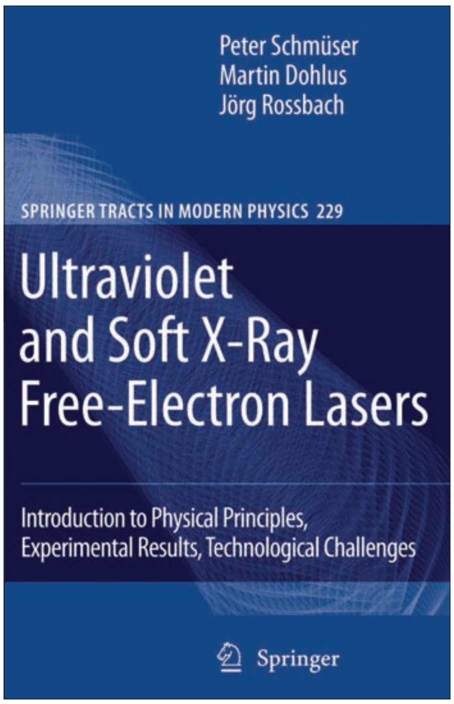
The book concludes with a final thought that, while most of us will never scale the intellectual heights of the great names of

science, we can all aspire to approach them in terms of the clarity of our communication. These are two very different books on science communication, but their authors share a common belief that good science communication is a craft that can be learnt. Either one is a good place to start.
James Gillies, CERN.

Ultraviolet and Soft X-ray Free-Electron Lasers: Introduction to Physical Principles, Experimental Results, Technological Challenges by Peter Schmüser, Martin Dohlus and Jörg Rossbach, Springer. Hardback ISBN 9783540795711, £126 (€139.95, $189).

Even at first glance my impression of this book was positive. Many coloured illustrations with detailed comments attracted my attention, so initially I began to read around them. A further study did not alter this first impression.

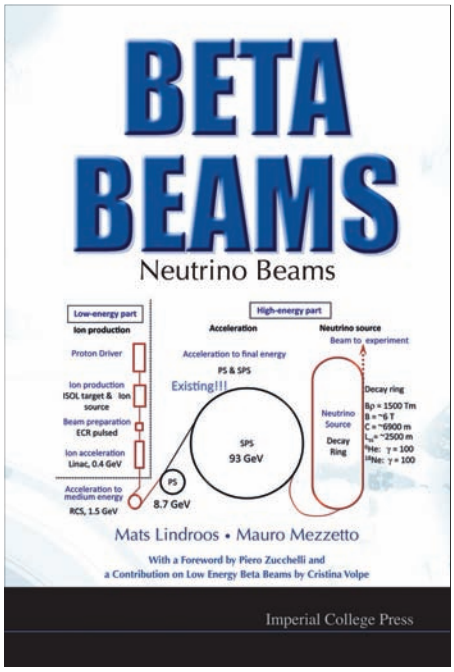
The field of free-electron laser (FEL) technology has reached a high state of the art in recent years, with operation demonstrated at high power (14 kW at Jefferson Lab), for soft X-rays (FLASH at DESY) and hard X-rays (the Linac Coherent Light Source at SLAC). The authors are well known experts in the field. Jörg Rossbach, for example, led the successful development of FELs at DESY for many years. Therefore, their book is interesting not only as a primer on FEL physics for students, but also as a reflection of the "view from inside", expressing the personal opinions of people who made a real FEL with unique radiation parameters.



"We must study a lot to learn something." This three-century-old aphorism of the Baron de Montesquieu is fully true for modern technology, and in particular for FEL technology. One really needs to know much to understand how an FEL works, and much more to design and build an FEL facility. The book therefore covers both the theoretical description of FEL physics and the experimental methods used to build an FEL and to control the radiation parameters.

The first half provides an introduction to the theory of the FEL. It gives the reader a clear picture of electron motion in an FEL, with the 1-D FEL equations used to demonstrate principles of FEL operation. Analytical and numerical solutions of these equations, combined with a discussion of limitations of the 1-D theory, give the full and explicit picture of FEL physics. Despite the use of simplified mathematical models, the authors succeed in presenting a physically transparent description of issues as advanced as self-amplified spontaneous emission (SASE), the FEL radiation spectrum, radiation-energy fluctuations etc. Parametrizations of numerical results allow the reader to make fast but reasonable estimates of the influence of the electron-beam parameters on the length and output power of a SASE FEL. Some theoretical issues, which are frequently not included in courses on general physics, but are useful for deeper understanding, are briefly described with references to more detailed textbooks and are given in several appendices.

The second part of the book contains a description of experimental results and the FEL installation at the FLASH facility, which provides an excellent example for the explanation of technical details. It is recent enough to use relatively new techniques and approaches, but has operated long enough as a user facility for the experimental techniques to be well developed and tested, as well as for the real parameters of the electron and radiation beams and the corresponding limitations to be explored. The authors compare measurements with theoretical predictions for the dependence of the radiation power and the degree of bunching on the co-ordinate along the undulator, for



example. This confirms that the numerous formulae of the first part are really useful.

The main part of the description of FLASH is devoted to the accelerator and electron-beam parameters. This is natural, because the cost of the accelerator and the efforts for its operation are the dominant parts of the cost and effort of the whole FEL installation. The undulator line, which is another important part of the FEL, is described only briefly, probably indicating that the FLASH undulator is so good and reliable that people almost forget about it. A brief discussion of the challenges and prospects for X-ray FELs concludes the book.

Because the book focuses on X-ray FELs, it cannot touch all aspects of FEL physics and technology, so some important FEL-related issues must be studied through other books and papers. For undulators the authors refer to the corresponding book by J A Clarke, *The Science and Technology of Undulators and Wigglers* (OUP 2004). A better understanding of high-gain FEL physics can be achieved by reading old books on microwave travelling-wave tubes, which contain almost all the equations and results of 1-D FEL theory. Indeed, the first high-gain FEL – the travelling-wave tube with undulator called the "ubitron" (150 kW peak power at 5 mm wavelength) – was built by Robert M Phillips in 1957. Further study may be continued through the annual FEL conference proceedings and references to papers they contain.

Thus, this book is very useful for students who are beginning to study FEL physics. It is also valuable for experts, who may look at their research from a different point of view and compare the authors' way of presenting material with their own way of explaining FEL physics.

Nikolay Vinokurov, Budker Institute of Nuclear Physics.

Beta Beams: Neutrino Beams by Mats Lindroos and Mauro Mezzetto, with a foreword by Piero Zucchelli and contribution by Cristina Volpe, Imperial College Press. Hardback ISBN 9781848163775, £61 ($88). E-book ISBN 9781848163782, $114.

The use of accelerated beams of light, ionized radioactive isotopes as sources of electron neutrino and antineutrino beams – "beta beams" – was first proposed in 2002 by Piero Zucchelli, at that time a research physicist at CERN. To my knowledge this is the first book to give a complete description of the concept of beta beams as neutrino sources, of their potential to study neutrino oscillations and of the technical problems that must be solved in order to build this new type of facility.

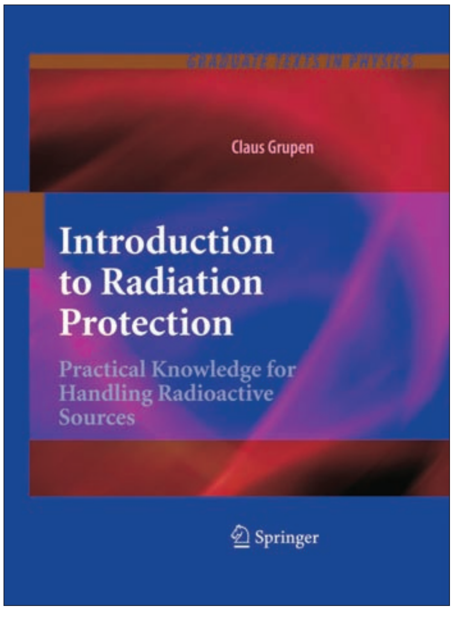
The book is divided into five chapters. The first of these reviews the existing evidence for neutrino mixing and measurements of the oscillation parameters performed so far using both natural neutrino sources (the Sun and cosmic rays) and neutrino beams from nuclear reactors and accelerators. This introduction leads to a discussion of the next generation of neutrino experiments aimed at the precise measurement of the three mixing angles, in particular θ_{13}, which is currently consistent with zero, and the CP-violating phase δ, which is accessible only if θ_{13} is different from zero.

Chapter 2 discusses the machine aspects of a beta-beam facility: radioactive ion sources, ionization, bunching, transfer to an accelerating structure, and finally stacking and storage in a magnetic ring with long straight-sections pointing to neutrino detectors. Specific examples are provided by calculating the expected neutrino fluxes for two ion beams, ^{6}He (producing antineutrinos) and ^{18}Ne (producing neutrinos), as a function of the Lorentz factor, γ, after acceleration. This chapter contains enough basic information on the physics of particle accelerators to be accessible to any physics student with a good knowledge of classical electromagnetism.

In the third chapter, the authors consider the physics potential of a hypothetical beta-beam facility installed at CERN, using as much as possible the existing CERN infrastructure, and coupled to a water Cherenkov detector with a mass of about 1 megatonne installed in the Modane underground laboratory at a distance of 130 km. Acceleration of ^{18}Ne and ^{6}He in the Super Proton Synchrotron would limit the Lorentz factor, γ, to 250 and 150 respectively, producing neutrino beams with energies up to around 600 MeV. This would nevertheless provide a sensitivity to θ_{13} and δ much higher than that of experiments currently running or in preparation at existing facilities.

Chapter 4 moves on to the physics potential of other possible beta-beam facilities with higher-energy beams, such as those that could be obtained by accelerating ^{8}B and ^{8}Li in Fermilab's Tevatron, to produce ν_e and anti-ν_e beams respectively, with energies around 1 GeV. The authors also discuss the possibility of generating mono-energetic neutrinos (but not antineutrinos) using sources of radioactive isotopes decaying by electron capture.

Finally, a fifth chapter by Cristina Volpe, reviews other measurements in neutrino physics that would benefit from a low-energy beta-beam facility coupled with a near detector.



This book summarizes a large amount of conceptual work carried out in the framework of several workshops on neutrino physics over the past eight years. One gets the impression that beta beams indeed represent a promising tool for next-generation experiments on neutrino oscillations. An obvious conclusion is that it is now time to start serious R&D work on the main components of a beta-beam facility in order to demonstrate its feasibility.

Luigi DiLella, Pisa.

An Introduction to Radiation Protection: Practical Knowledge for Handling Radioactive Sources by Claus Grupen, Springer. Hardback ISBN 9783642025853, £72 (€84.35, $99).

An Introduction to Radiation Protection aims to provide the reader with a useful reference tool for all areas of radiation protection, from introductory concepts including standard units and basic nuclear physics to the more specific techniques for selecting instrumentation and practical safety measures. The text is based on a series of lectures delivered by the author throughout his career, and it is worth noting that this edition is a translation from the original German publication.

The book is broken down into 18 chapters, each of which covers a particular topic of radiation protection, or background scientific information. These include comprehensive chapters on detectors for radiation protection, international safety standards for radiation protection and practical safety measures. Chapters 2 to 15, the main body of the text, each conclude with a series of problems aimed at re-enforcing knowledge gathered during the reading of the particular chapter, with the solutions provided as a separate chapter at the end of the text. The book also features useful diagrams, which are used well to explain particular concepts; light-hearted cartoon sketches drawn by the author also feature throughout the text.

On the whole, the book provides a comprehensive reference for many areas of radiation protection, but it lacks the specific detail and covers too wide a range of areas and nations to provide more than an overview for the majority of the topics. The book is also quite mathematical, and while it should be well suited to those with a mathematics or physics background, the mathematics is presented in a way that other readers may find challenging. I personally found the way that the chapters moved between different topics somewhat confusing, and felt that there were some slight inaccuracies, although this is inevitable given the rate of change in technologies of concern to those in radiation safety.

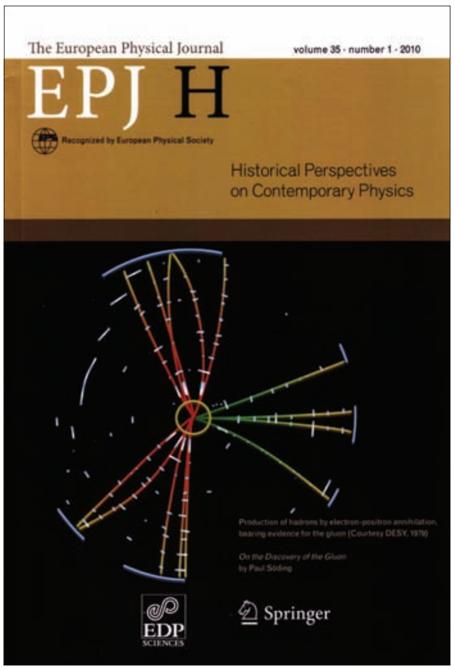
Overall the book would prove a useful addition to a radiation-safety professional's bookshelf, albeit it more likely as a reference tool for the reader in selecting topics of interest as and when required rather than as a cover-to-cover read.

Steve Pritchard, Health Protection Agency, Chilton.

The European Physical Journal H, Wolf Beiglböck *et al.* (ed.), Springer. Print ISSN 21026459; electronic ISSN 21026467.

When physicists talk shop, the conversation usually turns sooner or later to their subject's history, if only fleetingly. One might therefore expect that physicists often get together with professional historians, yet discussions between them are relatively infrequent and rarely constructive. This new journal aims to put that right.

It is the historical strand of the *The European Physical Journal*, which itself was a merger and continuation of seven discontinued publications, including *Il Nuovo Cimento*, *Journal de Physique* and *Zeitschrift für Physik*. Known as *EPJ H*, it is the first journal concerned with the history of basic concepts in physics, and seeks to be a common forum for physicists, historians and philosophers of science. In my view, these communities have much to learn from each other. Although not often acknowledged in polite company, physicists can be sentimental and prone to hero-worship when they talk about their subject's history, while historians can be naive and doctrinaire about how physics is actually done.



The first edition of *EPJ H* is extremely promising. It begins with a long and well referenced article, "On the discovery of the gluon" by Paul Söding, who impressively presents the story from the point of view of a practicing particle physicist. You won't find any credence given here to the view – voiced by some deluded social commentators – that the gluon is a social construct; rather, he rightly treats it as a particle no less real than the photon. This article will prove to be a valuable resource, not just for physicists but for others who want to focus more on the epistemology and on the socioeconomics of fundamental research.

The other three articles in this issue are strong, too, notably Virginia Trimble's virtuoso review of the cosmological origins of the chemical elements before 1957. Any cosmologist would benefit from a perusal of this extremely well informed study.

In aiming to bring together two distinct communities, sometimes at loggerheads, *EPJ H* has set itself a considerable challenge, which is not without dangers. It might evolve mainly into a forum for veteran physicists to reflect on their careers and historians might come to see it as a dumping ground for second-rate papers. I am confident that the distinguished editorial board will avoid these possibilities and that, one day, it will succeed in persuading physicists and historians to collaborate as authors.

My only quibble with the first edition is that its binding is so weak that it fell apart in my hands within minutes of opening it. With the rapid shift of journals to the web, this will no doubt soon be irrelevant. But let me not end on a gripe: this is an important publishing innovation and I very much hope that it flourishes. If it is successful, the entire culture of physics will be enriched.

Graham Farmelo, author of The Strangest Man*, a biography of theoretical physicist Paul Dirac.*

Books received

History of Science, Philosophy and Culture in Indian Civilization, Volume XIII Part 1: India in the World of Physics: Then and Now

by Asoke N Mitra (ed.), Pearson Education. Hardback ISBN 9788131715796, Rs. 2200.

This volume is part of the prestigious 96-volume *Project of History of Indian Science, Philosophy and Culture in Indian Civilization* (PHISPC), being published under the aegis of D P Chattopadhyaya. In the pre-independence period, Indian pioneers such as C V Raman, S N Bose and S Chandrasekhar set the scale for physical research not only in India, but the world. However, not enough work exists on the contributions by Indian physicists in the post-independent era. This book highlights the creation of state-of-the-art techniques for experimental infrastructure in independent India, including atomic energy, space technology and defence research. Divided into 11 parts, each highlighting particular areas of physics research, it begins by charting the path from quantum field theory to string theory. Other essays capture perspectives in the domains of physics from the small (nuclear and hadronic) to the large (cosmology and general relativity), including geophysics – especially cosmogenic geophysics.

Causality, Measurement Theory and the Differentiable Structure of Space–Time

by R N Sen, Cambridge University Press. Hardback ISBN 9780521880541, £75 ($130). Online ISBN 9780511669422, $104.

Introducing graduate students and researchers to mathematical physics, this book discusses two recent developments: the demonstration that causality can be defined on discrete space–times; and Sewell's measurement theory, in which the wave packet is reduced without recourse to the observer's conscious ego, nonlinearities or interaction with the rest of the universe. The definition of causality on a discrete space–time assumes that space–time is made up of geometrical points. Using Sewell's measurement theory, the author concludes that the notion of geometrical points is as meaningful in quantum mechanics as it is in classical mechanics, and that it is impossible to tell whether the differential calculus is a discovery or an invention.


"I need precise, detailed data with every measurement"
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The Matter of Origins

Ariane Koek discovers that physics and dance make for a great partnership.

A dance piece, conversation, floor show, game show and a chance to meet big minds – that's how Liz Lerman, an award-winning American choreographer, bills her latest multimedia piece, *The Matter of Origins*. As the title playfully suggests, physics is the main partner for this new work, with dancers making equations with their bodies and pushing gravity to the limits.

But that's not all. Physics also provides the intellectual framework on which the whole piece hangs. For one hour, dancers young and old, spin, leap, fall, balance and re-balance through critical moments of atomic and subatomic history: Marie Curie and the discovery of radium, the Manhattan Project, the LHC at CERN and the Hubble telescope.

These historical moments also provide the stunning visuals for the scenery, too, with the vast swathes of the New Mexico desert surrounding Los Alamos and a video tour of the LHC at CERN projected onto the dance space. *The Matter of Origins* is a fusion between the ideas of physics with the physical possibilities – and impossibilities – of dance. The normally reticent *Washington Post* this September critically acclaimed the world premiere at the University of Maryland as "a work of expansive range, emotional depth and singular beauty".

The story of how this partnership between dance and physics happened was a total surprise, even to the choreographer. It began with a chance encounter between Lerman, who has run her own dance company, Dance Exchange, since 1976, and Gordy Kane, a physicist at the University of Michigan and director of the Michigan Center for Theoretical Physics. He knew that she was interested in science and the affect that it has on the way people think about themselves, having seen her previous work, *Ferocious Beauty: Genome*, which examined the nature of discovery and the implications of research into genetics.

Kane captivated her interest in physics by telling her about the search for the origins of the universe at CERN and the mysteries of dark matter. So she came with her company of dancers to CERN for a few weeks in 2007/2008 to explore the possibility of making a piece, speaking to the scientists about their ideas and even dancing in the LHC tunnels and in several work spaces. And so, the project on *The Matter of Origins* was born, and in the process Lerman began to discover many unusual and quirky facts about the history of physics that might appear insignificant but nevertheless find their way into her piece.

The Liz Lerman Dance Exchange fuse physics and dance in their critically acclaimed dance piece, The Matter of Origins. *(Courtesy John Borstel.)*

Take, for example, the extraordinary story of Edith Warner, whom Robert Oppenheimer hired to feed the physicists working on the Manhattan Project at Los Alamos. She ran the Los Alamos tea house, serving her special chocolate cake to, among others, a scientist she knew as Dr Baker, but who was in fact Niels Bohr. The audience at *The Matter of Origins* is invited literally to chew over this fact – and many others, including Warner's secret chocolate-cake recipe – because when the dance finishes at the end of Act One, they are unexpectedly swept into a room full of tea, tables and chocolate cake and asked to sit down for Act Two. At each table, a host – or provocateur, in Lerman's words – who is usually a physicist, invites the audience to discuss what they experienced watching the dance, as well as big science and its relation to society.

It is an extraordinary and exceptional bravura move, which Lerman readily explains: "Act One is, in European terms, a multimedia piece, with a video artist and animator, as well as the dancers and the science. It is a lot for an audience to take in. In my last science-dance piece, I noticed that the audience lingered and stayed to discuss the piece far more than normal. They didn't want a post-performance discussion: they wanted to be the discussion. So my idea was to make this happen, giving individuals the chance to re-experience what they had just witnessed and to deepen their experience even further."

Thus, between tea and talk, dancers also weave between the tables, adding yet more dimensions, including discussions about the uncertainty principle, which Lerman says is, in many ways, where every artist stands. "For an artist it is always a question of finding momentum and of poise while in uncertainty."

Lerman is also adamant about another aspect that shows how dance and physics share common ground – it isn't just in the intellectual footwork. "The arts can help people find the place where they intersect with science. Awe, imagination and the grit to be relentless to make something work – that's what scientists and artists both do. What is fascinating in both cases, is the relationships scientists and artists have towards making mistakes – how we puzzle over them, and the obsession and passion, which ensures that we get it right in the end."

But as Lerman's piece shows, we may be merely at the beginning. Act Two ends with the beginning of Act One. The end has become a new beginning. Or, perhaps, it is just that the beginning is never ending.

● For more about the Liz Lerman Dance Exchange, see http://danceexchange.org/.

Ariane Koek, CERN.