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CERN COURIER

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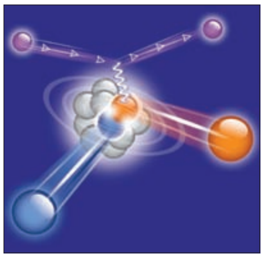
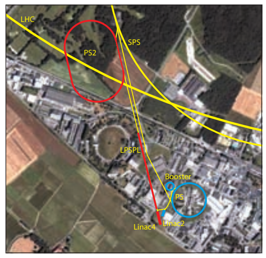
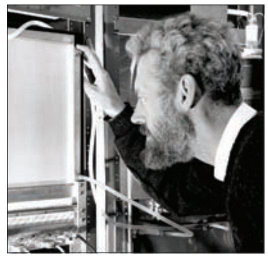






Cover: Construction and commissioning work on the silicon pixel detector for the ALICE experiment at the LHC (p28). (Courtesy Antonio Saba for CERN.).

Picture Courtesy of CERN

Advanced Light Detector

Hybrid Photo Detector (HPD), PLANACON, Image Intensifier Tubes, MCP/PMT

Photo Multiplier Tubes

XP 2020, large area PMT's, Ultra-Fast Timing PMT's, High Quantum PMT's

Extreme Detectors

High Neutron & Gamma Flux, Ultra-Fast Streak Tubes, Microchannel Plates for Extreme UV and X-ray optics, UV-detection and Imaging in Space.

NEWS

CERN

CERN Council looks forward to imminent start-up of the LHC

At its 147th meeting on 20 June, CERN Council heard news on progress towards start-up of the LHC later this summer. In addition, the latest in a series of audits covering all aspects of safety and environmental was presented to Council at the meeting. It addressed the question of whether there is any danger related to the production of new particles at the LHC.

Commissioning of the 27 km LHC started in 2007 with the first cool down of one of the machine's eight sectors (*CERN Courier* May 2007). Once successfully cooled, each sector has to pass through hardware commissioning, which involves intensive electrical tests, before being handed over to the operations team. By the time of the Council meeting, five of the eight sectors were at or close to the operating temperature of 1.9 K and the remaining three were at various stages of being cooled down. Moreover, sector 5-6 had passed through all steps of the hardware commissioning and was in the hands of the operations team.

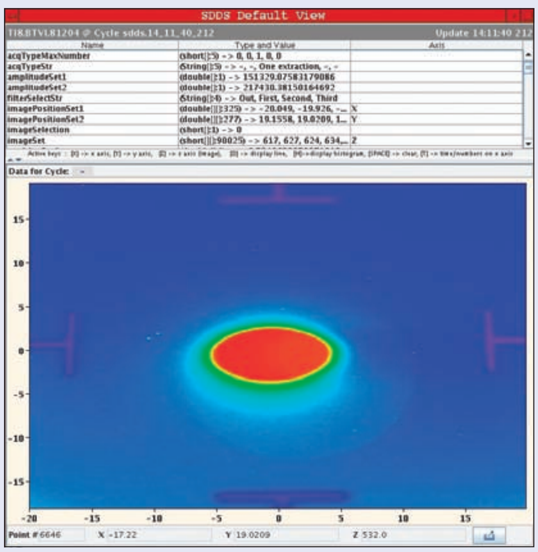
When the LHC starts up this summer, its proton beams will collide at higher energies than have ever been produced in a particle accelerator, although nature routinely produces higher energies in cosmic-ray collisions. Nevertheless, concerns about the safety of whatever might be created in such high-energy particle collisions have been addressed for many years.

The latest review of the safety of the LHC's collisions was prepared by the LHC Safety Assessment Group (LSAG), which comprises scientists at CERN, the University of California, Santa Barbara, and the Institute for Nuclear Research of the Russian Academy of Sciences. The LSAG report updates a 2003 paper by the LHC Safety Study Group and incorporates recent experimental and observational data. It confirms and strengthens the conclusion of the 2003 report that there is no cause for concern. Whatever the LHC will do, nature has already done many times over during the lifetime of the Earth and other astronomical bodies.

The new report has been reviewed by the Scientific Policy Committee (SPC), which advises Council on scientific matters. A panel of five independent scientists, including one Nobel Laureate, reviewed and endorsed the authors' approach of basing their arguments on irrefutable observational evidence to conclude that new particles produced at the LHC will pose no danger. The panel presented its conclusions to a meeting of the full 20 members of the SPC, who unanimously approved this conclusion, prior to the Council meeting.

● The LSAG report is accompanied by a summary in non-technical language. It is available together with other documents relating to the safety and environmental impact of the LHC at http://public.web.cern.ch/public/en/LHC/Safety-en.html.

Protons knock on the LHC's door



On 24 May, a proton beam arrived on the threshold of the LHC, passing down transfer line TI 8 to the LHC, which runs from the SPS towards the LHC, where it intersects just before point 8. The TI 8 line became operational in October 2004 (*CERN Courier* March 2005 p26). Now a beam has passed along it for only the second time, on this occasion in preparation for the full LHC start-up. The beam was extracted from the SPS, sent down the 2.8 km transfer line and stopped just 15 m or so from the LHC tunnel. A screen shot (left) shows beam in the TI 8 transfer line.

Sommaire

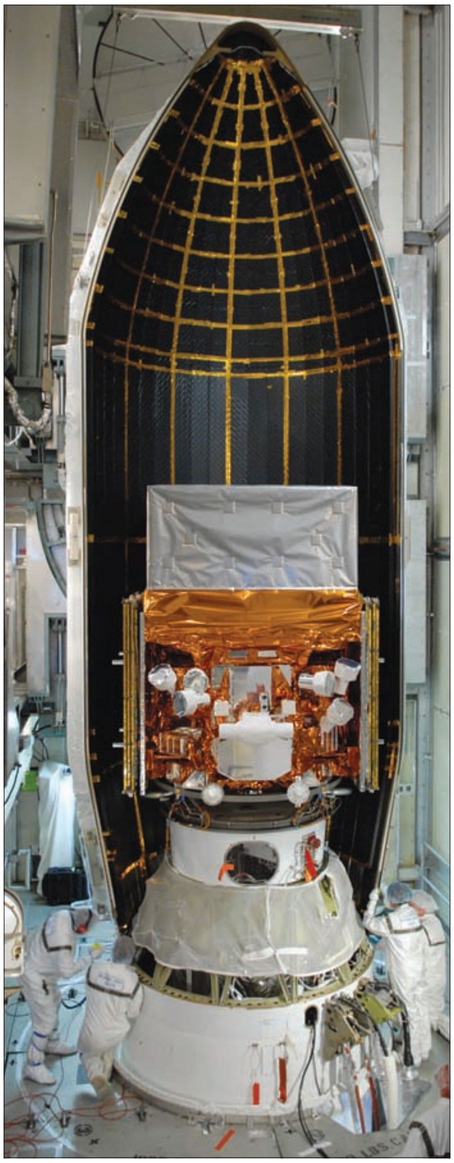
GAMMA RAYS

GLAST in orbit to explore extreme universe

The Gamma-Ray Large Area Space Telescope (GLAST) was launched by NASA on 11 June from the Cape Canaveral Air Force Station in Florida. GLAST is a next-generation, high-energy, gamma-ray observatory, designed to explore some of the most energetic phenomena in the universe and enhance knowledge of fundamental physics, astronomy and cosmology. It is an international, multi-agency mission with important contributions from research institutions in France, Germany, Italy, Japan, Sweden and the US.

GLAST will capture high-energy gamma rays (from 20 MeV to greater than 300 GeV) from a wealth of cosmic sources that are sites of very-high-energy particle acceleration. These include the supermassive black hole systems of active galactic nuclei, supernova remnants, neutron stars, galactic and solar system sources, and gamma-ray bursts (GRBs). The GLAST collaboration expects to discover thousands of new sources of different classes, which will shed light on many unresolved questions about the nature of dark matter, the origin of cosmic rays, the engines of GRBs, and acceleration mechanisms of high-energy cosmic particles. The discoveries may also provide tests of fundamental physical principles, such as Lorentz invariance.

The Large Area Telescope (LAT) is the main instrument on board (Michelson 2008). It is accompanied by the Gamma-Burst Monitor (GBM), an instrument primarily dedicated to the detection of GRBs between 8 keV and 30 MeV (von Kienlin *et al*. 2001). Together the GBM and LAT will cover a remarkable seven decades in energy.



GLAST within the spacecraft, on the launch pad at Cape Canaveral Air Force Station in Florida. (Courtesy NASA/Jim Grossmann)

The LAT is a pair-conversion telescope that measures the direction, energy and arrival time of incoming photons from the entire sky with unprecedented resolution and sensitivity. It will collect more than two orders of magnitude more gamma rays than its predecessor, EGRET (Thompson *et al*. 1993), and the current gamma-ray mission AGILE (Tavani *et al*. 2008). This leap in capabilities is made possible by combining information from three detector subsystems, all based on major developments in experimental particle physics. These are a silicon-strip tracker-converter, the largest of its class with its 70 m^2 of active surface and 900 000 digital channels; an 8.5 radiation-length CsI imaging calorimeter, capable of a very large dynamic range to ensure better than 15% energy resolution over the entire acceptance; and an outer, segmented plastic scintillator anticoincidence shield, which is used to reject charged particle background.

Teams in the participating institutes built and qualified the LAT subsystems for space before they were integrated at SLAC. The Max-Planck-Institute for Extraterrestrial Physics in Garching produced the GBM detectors, and these were integrated at the Marshall Space Flight Center in Huntsville. Both instruments were then integrated with the spacecraft at General Dynamics, in Phoenix, Arizona, to form the GLAST observatory. Environmental testing took place both at General Dynamics and at the Naval Research Laboratory in Washington DC. The calibration of the LAT relies on a combination of charge injection, ground and in-orbit cosmic-ray data, an advanced Monte Carlo simulation based on the Geant4 toolkit, and data from particle test beams collected from a calibration unit at CERN and GSI (Baldini *et al*. 2007).

Further reading

For more about GLAST see www.nasa.gov/glast.

P Michelson *et al*. (in preparation).
A von Kienlin *et al*. 2001 *ESA SP* **459** 529.
D J Thompson *et al*. 1993 *ApJS* **86** 629.
M Tavani *et al*. 2008 *NIM-A* **588** 52.
L Baldini *et al*. 2007 *AIP Conf. Proc.* **921**.

JEFFERSON LAB

Protons and neutrons certainly prefer each other's company

Researchers at the Jefferson Lab have found that neutron–proton pairs in the ground state carbon-12 nucleus are far more common than proton–proton pairs and neutron–neutron pairs. As many as 18% of the nucleons are involved in proton–neutron short-range correlations (SRCs), a result that could have implications for neutron stars.

In a typical nucleus, nucleons maintain an average distance of 1.7 fm. However, roughly one-fifth of nucleons are involved in short-range correlations, where two nucleons come to within a femtometre of each other. These pairs can create local densities five times that of average nuclear matter, thus providing a glimpse of dense nuclear matter as found in neutron stars.

Now a team working in Jefferson Lab's Hall A has made the first simultaneous measurement of SRCs and their constituents. The experiment used an incident electron beam of 4.627 GeV and a carbon-12 target. Proton-knockout events were defined by the two High-Resolution Spectrometers (HRS) in Hall A. The left HRS detected scattered electrons and the right HRS detected knock-out protons. A large acceptance spectrometer (BigBite) and a neutron array detected correlated high-momentum recoiling protons and neutrons, respectively.

The experiment selected (e,e'p) events with high missing momentum, greater than 300 MeV/*c*, and revealed that the missing momentum was balanced almost entirely by a single recoiling nucleon. This nucleon was initially back to back with the knock-out proton. The team found that 90% of these SRCs involved proton–neutron pairs. The remaining 10% were split between proton–proton and neutron–neutron pairs (Subedi *et al*. 2008). Calculations of this effect in recent theoretical work indicate that the large prevalence of neutron–proton pairs over proton–proton and neutron–neutron pairs is a result of the nucleon–nucleon tensor force (Sargsian *et al*. 2005 and Schiavilla *et al*. 2007).

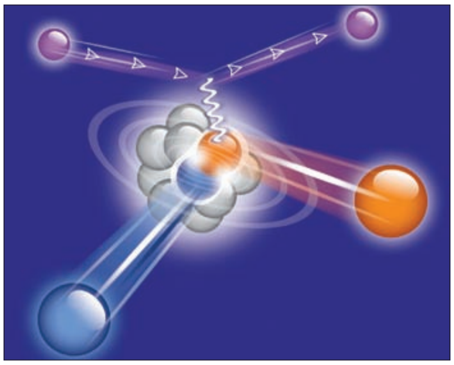
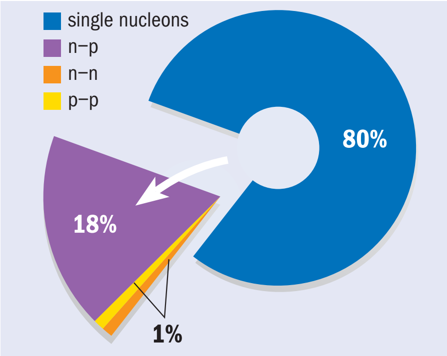


Illustration of the ^{12}C(e,e'pN) reaction. The incident electron beam couples to a nucleon–nucleon pair via a virtual photon. In the final state, the scattered electron is detected along with the two nucleons that are ejected from the nucleus.



The average fraction of nucleons in the various initial-state configurations of carbon-12.

Together with previous work, including cross-section ratio measurements at Jefferson Lab (*CERN Courier* November 2005 p37) and proton-knockout experiments at Brookhaven National Laboratory, the new result yields a consistent picture of the short-distance structure of nuclear systems, from light nuclei to neutron stars. Most accepted models of neutron stars assume a make-up of 95% neutrons and 5% protons at the core. The presence of strong short-range, neutron–proton pairing could alter assumptions about the protons' momenta, thus affecting calculations of the density and/or lifetime of neutron stars.

Further reading

R Subedi *et al*. 2008 *Science* **320** 1476.
R Schiavilla *et al*. 2007 *Phys. Rev. Lett*. **98** 132501.
M M Sargsian *et al*. 2005 *Phys. Rev. C* **71** 044615.

SCIENTIFIC INFORMATION

High-energy physics labs become INSPIREd

CERN, DESY, Fermilab and SLAC have announced that they will join forces to build INSPIRE, the next-generation, high-energy physics (HEP) information system. The announcement came at the second annual Summit of Information Specialists in Particle Physics and Astrophysics, which was held at DESY on 20–21 May. Representatives from the four laboratories attended the event, together with leading publishers and information providers, including Cornell's arXiv.org and the SAO/NASA Astrophysics Data System.

The libraries of CERN, DESY, Fermilab and SLAC recently analysed the status of HEP information systems. A subsequent poll revealed that community-based services are overwhelmingly dominant in the research workflow of HEP scholars, whose needs are not met by existing commercial services. The poll found that HEP researchers attach paramount importance to three axes of excellence: access to full-text, depth of coverage and quality of content, possibly extended to connecting fields outside HEP.

Based on these results, the management of the laboratories seized the opportunity to build INSPIRE, a community-based and user-driven, next-generation information system, fully exploiting a new technological environment. It is being built by combining the successful SPIRES database, curated at DESY, Fermilab and SLAC, with the Invenio digital library technology developed at CERN. INSPIRE will offer the functionalities and quality of service that the HEP user community has grown to expect from SPIRES, an indispensable tool in their daily research workflow. It will develop long-awaited features, providing access to the entire body of HEP literature with full-text, Google-like search capabilities and enabling innovative text- and data-mining applications.

LHC EXPERIMENTS

CMS completes milestone installation of beam pipe…

On 10 June the CMS collaboration reached another major milestone when the heart of the detector, the beam pipe, was fully installed after 15 years of complex design and manufacture. This fragile, 44 m long component is one of the last elements of the CMS experiment to be installed.

The design of the beam pipe required compromising on numerous needs of the experiment, with the physicists calling for no material, no support and virtually nothing at the collision point, while the engineers wanted a thicker pipe for greater stability of the vacuum and better electrical conductivity. The compromise is a complex beam pipe made of changing thickness and materials. For 2 m on either side of the interaction point the pipe is of 0.8 mm thick beryllium, weighing less than 1.5 kg. Beyond that for 18 m on either side, and widening towards the ends, are sections of stainless steel, which is good for welding, assembly and precision alignment.

It is very important for both the LHC machine and the detector to have a good vacuum, and a recent "bake-out" should have cleaned out stray particles to ensure that this happens. During this process the beam pipe is heated to 200–250 °C for 48 hours. The length of the pipe is coated with non-evaporable getter material, made of titanium, zirconium and vanadium, which acts as a pump, constantly absorbing residual particles even at the interaction point where no pump would fit.

Technicians work to install the central section of the beam pipe, part of the CMS experiment.

…and time flies for the ALICE detector

During the last week of April, the ALICE experiment's time-of-flight (TOF) detector was completed and installed in the experimental cavern. The TOF lies inside the huge magnet of ALICE, 3.7 m from the beamline. It will operate together with the time projection chamber, which lies inside the cylinder formed by the TOF, in identifying charged particles, such as pions, kaons and protons produced in collisions in ALICE.

The TOF detector has a total surface area of 150 m^2 and is divided into 18 supermodules, each of which is further subdivided into five modules. It consists of 1638 strips of multigap resistive plate chambers, which were made at the INFN Laboratory in Bologna. Each module has been carefully checked for performance with cosmic rays before being assembled in the supermodules. Now that these modules are installed in the ALICE detector, all that remains for the team is to retest them to ensure that no damage occurred during installation and to connect and commission the electronics in the experimental cavern in preparation for start-up of the LHC.

One of the supermodules for the ALICE TOF under assembly at CERN. (Courtesy A Saba for CERN.)

SCIENCEWATCH

Compiled by Steve Reucroft and John Swain, Northeastern University

Nanoscale systems make 'memristor' a possibility

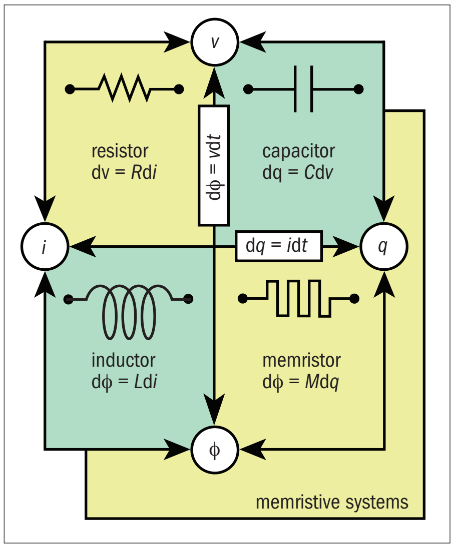
Textbooks on electronics discuss capacitors, inductors and resistors, but for a complete set of elements connecting current, voltage, charge and magnetic flux, there is actually one missing. In 1971, using symmetry arguments, Leon Chua proposed the idea of the "memristor", which would look electronically like a resistor with hysteresis and could be used as a memory element.

Now Dmitri Strukov and colleagues at HP Labs in Palo Alta have shown that "memristance" can be realized in nanoscale systems, with coupled ionic and electronic transports. Such devices could, in theory, be used as ultra-dense, non-volatile memories.

Further reading

L O Chua 1971 *IEEE Trans. Circuit Theory* **18** 507.

D B Strukov *et al.* 2008 *Nature* **453** 80.



How the memristor (a memory resistor) fits in with other more familiar electronic devices.

Multilayer films guide gamma rays

A new approach to gamma-ray optics provides flat and curved waveguides for 122 keV gamma rays and could be useful up to a few mega-electron-volts. Instead of using shallow angle reflection, which typically implies focal lengths of around 10 m, D M Tournear and colleagues at Los Alamos National Laboratory have used multilayer gold–palladium and polymer films to get focal lengths an order of magnitude smaller. This novel optics could find use in fields ranging from astrophysics to medical imaging.

Further reading

D M Tournear *et al.* 2008 *Appl. Phys. Lett.* **92** 153502.

Absinthe absolved

Absinthe has had a history as an intoxicant, being blamed for hallucinations, seizures and even for Vincent van Gogh's act of cutting off part of his left ear. The idea has long been that thujone, a convulsant present in the wormwood used to flavour the drink, was responsible for these side effects, so modern preparations are made with strict limits on how much of this substance can be present.

This may all have been unnecessary. D W Lachenmeier of the German government's Chemical and Veterinary Investigation Laboratory in Karlsruhe and colleagues have shown that even old samples of absinthe do not contain enough thujone to have triggered off major psychological effects.

Further reading

D W Lachenmeier *et al.* 2008 *J. Agric. Food Chem.* **56** 3073.

Chemistry has radical idea for avian migration

Animal migration associated with the Earth's magnetic field has long been thought to be based on tiny magnetic particles. However, now it appears that there could be suitable chemical reactions that would do the trick. Peter J Hore and colleagues at Oxford University and Arizona State University have investigated the proposal that magnetically–sensitive free-radical reactions could be involved, in particular in the migration of birds.

The team has discovered that a carotenoid-porphyrin-fullerene system can respond to magnetic fields as weak as that of the Earth – around 50 μT. This is the first such system to be found. The idea is that light produces radicals, which can have their spins changed, via chemical effects, by an external magnetic field. The system investigated is probably a poor model for what might really happen in biological systems. Moreover, it can detect the weak magnetic field only at –150 °C. However, the result is a proof of principle and could lead to a new understanding of the magnetic senses of animals.

Further reading

Kiminori Maeda *et al.* 2008 *Nature* **453** 387.

The Copernican principle could be put to the test

The Copernican principle – that the universe looks much the same from anywhere – is more of a hypothesis of desperation than one of logical necessity. It's difficult to see the universe from somewhere else, which makes the principle attractive but difficult to check. So it comes as a pleasant surprise from Jean-Philippe Uzan of the Université Pierre and Marie Curie – Paris VI and Chris Clarkson, and George Ellis at the University of Cape Town that there may be a way to test this idea.

They have combined the time drift of the cosmological red shift with distance data to reconstruct a spherically symmetric geometry that does not have to be of uniform density. One interesting possibility is that a non-uniform density of this kind could explain the apparent acceleration of the expansion of the universe without the need for dark energy.

Further reading

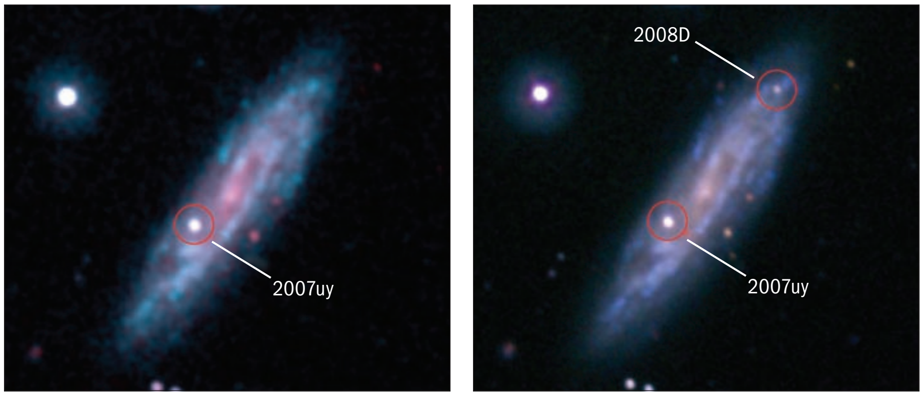
J-P Uzan, C Clarkson and G F Ellis 2008 *Phys. Rev. Lett.* **100** 191303.

Compiled by Marc Türler, ISDC and Observatory of Geneva University

A supernova is caught in the act of exploding

Astronomers have, for the first time, observed a star in the act of exploding. The event happened in January while NASA's Swift satellite was observing another supernova in the same galaxy. The supernova explosion was preceded by an X-ray outburst of about seven minutes. This new milestone in the study of supernova explosions was published just a week after the announcement of the discovery of the remains of the most recent supernova in our galaxy.

Supernova explosions occur about twice a century in spiral galaxies. This is also the case in our galaxy as derived from the rate of radioactive aluminium decay observed by ESA's INTEGRAL satellite (*CERN Courier* January/February 2006 p10). It is therefore surprising that since the supernova observed by Johannes Kepler in 1604 (*CERN Courier* December 2004 p15), no other exploding star has been seen in the Milky Way. It was long suspected that some supernovae could have been missed due to dust absorption along the line of sight. The first evidence of a recent, unnoticed explosion comes from the dating of the supernova remnant Cassiopeia A (*CERN Courier* October 2004 p19), which is only about 330 years old. A team led by Stephen Reynolds from the North Carolina State University has now identified another remnant, G1.9+0.3, precisely dated to be only 140 years old, located close to the galactic centre. The remnant was observed to be rapidly expanding between 1985 and 2008 in radio images obtained by the Very Large Array (VLA) in New Mexico.



Images recorded on 7 and 9 January 2008 (left and right respectively) show how Swift caught supernova SN 2008D in the act of exploding, while monitoring SN2007uy. (Courtesy NASA Swift Team.)

Because of the rate of only two supernovae per century, it is unlikely that two exploding stars can be seen simultaneously in the same galaxy, but it happened in the spiral galaxy NGC 2770. On 9 January 2008, while the Swift satellite performed on going observations of a first, one-month-old supernova, a second stellar explosion occurred. This time, Swift did not even have to use its rapid repointing ability – as it had for the supernova SN 2006aj following an X-ray flash (*CERN Courier* October 2006 p13). It was already pointing its optical, ultraviolet and X-ray telescopes towards the dying star.

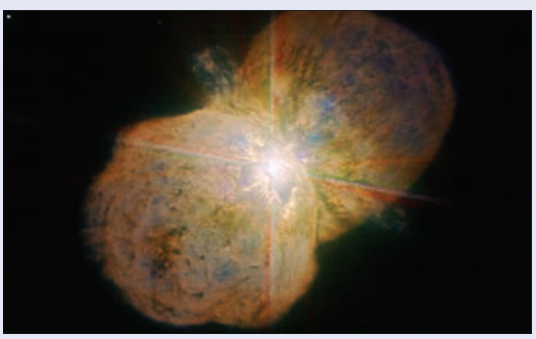
The surprise was to observe a strong X-ray outburst lasting about 400 s and preceding the supernova detection in visible light by 1.4 h. Although very luminous, the X-ray outburst was not detected in gamma-rays and is about thousand times less energetic than typical gamma-ray bursts.

The analysis of the multi-wavelength observations of SN 2008D has been published in *Nature* by an international group led by Alicia Soderberg from Princeton University. They show that the supernova is of type Ibc, the kind of stellar explosions associated with long gamma-ray bursts and X-ray flashes. However, they have no evidence of relativistic motion, and suggest that the X-ray outburst is not from a highly relativistic jet but is radiation associated with any normal supernova. The origin of the X-ray outburst would be the "shock break-out", when the ejected material, having bounced off the collapsed stellar core, crosses the surface of the dying star. But other astronomers interpret the outburst as a weak X-ray flash, the low-energy cousin of gamma-ray bursts.

Further reading

S P Reynolds *et al.* 2008 *ApJ* **608** L41.
A M Soderberg *et al.* 2008 *Nature* **453** 469.

Picture of the month



On the 10th anniversary of the Very Large Telescope, the European Southern Observatory (ESO) has released a stunning view of Eta Carinae, the most luminous star known in the Galaxy. Located about 7500 light-years away in a very active star-forming region (*CERN Courier* June 2007 p12), Eta Carinae is actually a very complex system of two massive stars with interacting winds producing energetic X-rays detected by the INTEGRAL satellite. It is surrounded by an expanding bipolar cloud of dust and gas known as the Homunculus ("little man" in Latin), which astronomers believe was expelled from the star during a great outburst seen in 1843. The fine structure of this near-infrared image, obtained thanks to adaptive optics correcting the blurring effect of the atmosphere, is just as detailed as the famous optical image of 1996 by the Hubble Space Telescope. (Courtesy ESO.)

CERN COURIER ARCHIVE: 1965

A look back to *CERN Courier* vol. 5, July and August 1965, compiled by Peggie Rimmer

THE ISR

30th session of CERN council

Delegates from the 13 Member States of CERN met at the laboratory on the 16 and 17 June for the 30th Session of the Council, held under its president, Mr J H Bannier, of the Netherlands. A brief survey of the current state of CERN was given by the director-general, Prof. V F Weisskopf, and various detailed points concerning the running of the organization were discussed. Most of the session, however, was devoted to the future of sub-nuclear physics research in Europe, and unanimous approval was given in principle to the construction of intersecting storage rings (ISR) for the proton synchrotron (PS), as a supplementary programme of the organization.

The ISR will provide a unique means for carrying out certain experiments in sub-nuclear physics at energies much higher than those currently available, or even planned. Indeed, to do these experiments in the conventional way, with accelerated protons striking, say, a liquid-hydrogen target, would require an accelerator some 60 times more powerful than the 28 GeV PS.

The equipment will consist essentially of a vacuum chamber formed by two concentric distorted rings, each about 300 metres in diameter, intersecting in eight places. Electromagnets round the rings will keep high-energy protons circulating in them, clockwise in one, anticlockwise in the other. Protons will be injected from the PS and successive bursts stored until a sufficiently high intensity is reached. The two beams will then be made to collide in one or more of the crossing regions where detection apparatus will enable the resulting interactions to be studied.

The actual start of construction of the ISR will be decided in December, when the budget will be voted by the member states who will take part in this supplementary programme. Almost all of the 13 member states have indicated that they are prepared to participate.

This decision, according to Mr Bannier, will assure the future of CERN-Meyrin for many years to come. He thanked all those at CERN who had worked on the design and also those in the Council and its Committees, the government authorities concerned, and others, who had made the decision possible. Prof. Weisskopf also thanked the Council for their demonstration of confidence, interpreting the decision not only as one of confidence in the ISR as such, but also in the future of high-energy physics in Europe.

● Compiled from July 1965 p99 and August 1965 pp117–118.

Physics with storage rings

At a meeting of the European Committee for Future Accelerators held at CERN on 19 October 1964, one of the speakers was Prof. G Cocconi of CERN's Nuclear Physics Division. After giving some indications on how proton-proton scattering and other experiments could be extended enormously in scope by the construction of the proposed ISR, he posed the more general question of why, in fact, we want to carry out such experiments at all.

I cannot finish without asking the general question that involves us all. Why do we want to know these things, and urgently? Could it be that we are a cast of maniacs, who try to solve problems created only by our machines, problems not at all important for the nature we live in? If that were the case, if our pure science were so pure as to be of no foreseeable utility, then I fear that we begin to be a burden to society when we go on asking for larger and costlier accelerators.

My answer to these disturbing questions is that, practical applications apart, we are not so queer and our problems are not Byzantine. My faith comes from the fact that there are places in the universe where matter consists uniquely of particles having an energy of 10^{12}–10^{13} eV each [10^{12} eV = 1 TeV = 1000 GeV], and these places are light years in dimensions and contain a number of particles equivalent to millions of suns. I have in mind, of course, the centre of the radio galaxies.

Mesonic matter [nuclear matter at energies above about 1 GeV] is thus not only produced in the odd situations present in our accelerators but it is the basic matter at the centre of not-so-rare galaxies. Thus the GeV, TeV world cannot be an abstraction, since it is deeply connected with the nature that surrounds us.

It is even imaginable that in time we will be able to exploit it to our advantage. I cannot help recalling that, what forty years ago looked like the impossible problem of understanding how the centre of the sun kept on burning, is nowadays reduced to the still difficult but not so impossible problem of making nuclear energy economically competitive with coal burning.

Can we afford to be ignorant about these problems? Can we afford to wait? According to the rules of the human game, we must go ahead, and as fast as we can.

● Compiled from July 1965, pp103 and 106.

COMPILER'S NOTE

In 1971, five years after approval for construction, the ISR delivered the world's first proton–proton collisions, at a centre-of-mass energy approaching 60 GeV. That event, and with it the possible creation of mesonic matter, probably did not excite too many members of society at the time.

Today the LHC is poised to exceed those collision energies by a factor of around 250, and the mood is quite different. Thanks to excellent outreach programmes and extensive media coverage the general public is now better informed than ever before. Lots of people know that the Large Hadron Collider might produce dark matter, tiny black holes, Higgs bosons, miniature Big Bangs and, better still, they are interested in the outcome – witness the success of CERN's recent open days. (*CERN Courier* June 2008, p35 and p58.)

So on we go.


Trouble in the production area: Blazing hot, intergalactic vibration and mind-numbing noise. Energy costs are ruining many organizations.
What's needed, Captain Vacuum, are ingenious solutions! May the Void be with you.
What?!?! Victims of that vacuum-quack Dr. NoVac are already turning up on Earth! Boss, how about a lightning-fast rescue with our latest drive system?
Beam me over with PentaLine. Thanks to its worldwide power supply, I'm ready for anything… Let's see what they need there.
WOOOOM
SWOOOM
Oh no – Not that innovation checker again!!!!!!
Haaaaa! This will take the hot air out of you, you nothingness nerd!
WOOOM
Grrrrrrr – he's always so fast. How does he manage to do that?
PentaLine installed. Organization equipped with quality vacuum and now on the success track. Production output and operating costs in the green.
TO BE CONTINUED …
PFEIFFER VACUUM

The stop-start approach to rare isotope beams

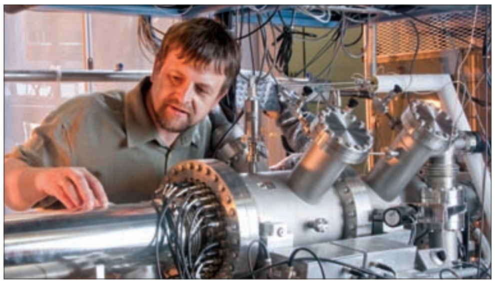
Don Monroe investigates plans to reaccelerate rare isotope beams at NSCL in Michigan.

The study of rare isotopes with proton and neutron compositions far outside the "valley of stability" provides critical tests of nuclear models. Several facilities around the world produce such isotopes by directing energetic beams of nuclei into solid targets. Now researchers are exploring ways to extend their investigations by collecting the rare isotopes and forming them into new reaccelerated beams.

There are two basic approaches to producing rare isotopes, which differ in the thickness of the target employed. Isotope separation on line (ISOL), developed some 40 years ago at CERN's ISOLDE facility, uses a target that is thick enough for the nuclei to come to a stop within it. The isotopes can then be extracted, but this is a slow process – a problem for short-lived isotopes. In addition, each new element requires dedicated development work and some elements, such as refractory metals, are difficult or impossible to obtain.

Nonetheless, facilities such as ISOLDE, the Isotope Separator and Accelerator (ISAC) at TRIUMF and the Holifield Radioactive Beam Facility at the Oak Ridge National Laboratory have made important scientific advances using ISOL sources. They have extended the ISOL method further by accelerating the isotopes produced. At ISOLDE, the Radioactive Beam Experiment (REX) post-accelerator has pioneered the technique of increasing the charge state of low-energy, singly charged ions in an electron-beam ion source (EBIS) before reaccelerating them (*CERN Courier* December 2004 p16). TRIUMF recently stepped up its own production of radioactive beams with a superconducting linear accelerator to push the energies of rare isotopes above the Coulomb barrier (*CERN Courier* June 2008 p23.)

The second approach to producing beams of rare isotopes is through projectile fragmentation, which separates the desired isotopes from the fragments that emerge when a fast heavy-ion beam impinges on a thin foil target. GANIL in France, RIKEN in Japan, GSI in Germany and the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) in the US all use this technique, which is less sensitive to the chemistry of the elements than ISOL. Projectile fragmentation makes it easier to produce and isolate rare isotopes, and it has made available thousands of different isotopes. The rate of generation tends to be smaller than for ISOL, however, and for experiments requiring slow beams the isotopes are not easy (or may even be impossible) to use because they emerge at a large fraction of the speed of light, with an energy in the region of 100 MeV per nucleon.



Georg Bollen inspects a cooler-buncher device that provides high-quality ion pulses for Penning trap mass measurements at NSCL. (Courtesy NSCL.)

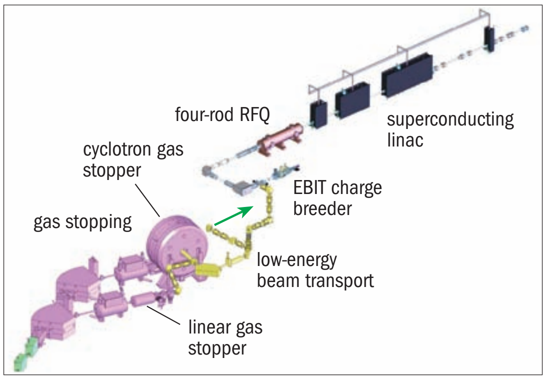
The obvious way to create low-energy beams is to slow down high-energy ones, but this severely degrades their quality. A better technical approach is to stop the beams, extract them and then reaccelerate them or use them at low energies. This is the path that MSU has opted for in upgrading its NSCL facility. To provide isotope beams with lower and more tightly distributed energies, it will combine new and established technology to stop the beams, increase the charge on the ions and then reaccelerate them. The resulting beams will enable users at NSCL to explore the excitations of rare isotopes – by either nucleon transfer or Coulomb excitation – to reveal their internal structure. In particular, their excited states provide stringent tests of nuclear models. "NSCL will be the first facility in the world to offer fast [about 50–150 MeV per nucleon], stopped and reaccelerated [up to 3 MeV per nucleon, for now] beams of rare isotopes, providing its users with an unusually broad arsenal of beams and experimental tools for their research," says Konrad Gelbke, the director of NSCL.

The particles in the beams will have energies similar to those encountered in astrophysical environments, such as stellar explosions. "With these reaccelerated beams you can measure reactions at the actual astrophysical energies," says MSU professor of nuclear astrophysics Hendrik Schatz. "That's the big step." Schatz and colleagues, including many among NSCL's community of 700 researchers, hope to use the reaccelerated beams to explore reactions of unstable nuclei with protons in fixed targets or helium nuclei. These are the same reactions that occur in the astrophysical rapid-proton (rp) process and are believed to be important in X-ray bursts – the most abundant thermonuclear explosions in the universe. Future advances in the technology may help to probe the rapid-neutron (r) process reactions of neutron-rich nuclei, which occur in supernovae and are thought to give rise to many heavier chemical elements. The upgrade will help to test, refine and improve technological approaches that could be used for exploring rare isotopes at future facilities.

The approach taken towards reacceleration at NSCL involves slowing a high-energy beam by passing it through a solid degrader and bringing the ions to a stop, decreasing their initial spread of energy. The best-established stopping technology is the linear ▷

gas stopper – a tube of helium gas at pressures up to 1 bar. One important challenge, however, is to separate the desired isotopes from the many helium ions created during the stopping process. NSCL has already pioneered the use of these techniques to slow down isotopes produced by projectile fragmentation, allowing them to capture the isotopes in Penning traps for precision measurements.

In parallel, Georg Bollen and colleagues at NSCL are developing a cyclotron stopper, which should be quite effective for lighter isotopes. Instead of travelling along a tube of helium several metres long, the ions tangentially enter a gas tube where a magnetic field diverts them into a circular orbit. As they travel multiple times around the circumference, they lose energy and spiral toward the axis, where they can be collected. The compact geometry allows this to be done effectively in the tens of milliseconds needed to use short-lived isotopes. The NSCL team plans to explore both an advanced version of linear gas stopping and cyclotron gas stopping in the reacceleration project to evaluate how these steps contribute to the overall system.



Schematic of the planned stopped and reaccelerated beam additions to the NSCL beamline. (Courtesy NSCL.)

Another enabling technology used for reacceleration is the breeding of high charges on the ions to get the maximum energy from limited acceleration voltage. The "classic" approach first accelerates singly charged ions, then passes them through foils to strip off electrons before further accelerating the multiply charged ions. This method – used, for example, in ISAC at TRIUMF – is robust and established, but creates a variety of charge states. Electron-cyclotron resonance plasmas, which are used in Japan and elsewhere for charge breeding, also create multiple charge states. Since only a single state can be selected, both of these techniques have an inherently limited efficiency in using precious rare isotopes.

NSCL will use a different breeder to increase the charges – namely the electron-beam ion trap, pioneered (as the EBIS) at REX-ISOLDE. Here, ions are electrostatically attracted to an intense electron beam as well as ionized by it. One advantage is that, by targeting stable electronic shells and selectively extracting charge states from the trap, the system can produce isotopes with a single high-charge state. "You can make use of noble-gas configuration – you get a nice enhancement in a single charge state," explains Bollen.

Once the isotopes have high charges, they are reaccelerated using a standard superconducting linear accelerator. The initial plans at NSCL call for relatively modest energies (around 3 MeV per nucleon) but more cavities can be added as needed to boost the energy. The system is designed for efficient processing of rare isotopes at each stage, as well as for the efficient transfer between successive stages.

The technologies developed for this upgrade will provide important technical experience for the Facility for Rare Isotope Beams (FRIB), for which the US Department of Energy (DOE) has invited proposals. This machine would use a linear accelerator for the primary beam and provide higher initial isotope fluxes than the current cyclotron source at NSCL, which could make more experiments (including on the neutron-rich side) possible. Researchers at NSCL, who will explore how well the various components of the reacceleration project can scale to higher beam currents, have already laid the groundwork for FRIB. In autumn 2007, the laboratory published a detailed white paper describing a next-generation facility based on a superconducting 200 MeV, 400 kW heavy-ion driver with the possibility of experiments using fast, stopped and reaccelerated beams (*CERN Courier* January/February 2007 p8). These are all elements required for FRIB.

Karsten Riisager of CERN acknowledges that the NSCL upgrade will complement existing capabilities, noting that no single technical approach is superior. Although ISOL-based facilities like CERN's REX-ISOLDE usually supply higher beam current, "for some of the exotic beams, such as short-lived isotopes, NSCL may have an advantage", he says. Some elements are not available at all using ISOL techniques. He notes, however, that NSCL provides only nuclei lighter than about the mass of tin. "We [ISOLDE] are the only place right now where you have the very heavy nuclei reaccelerated."

Bollen, who served as ISOLDE group leader in the late-1990s, and who plays a leading role at NSCL, is optimistic about the technology and science that the upgrade will enable. "We will produce reaccelerated beams which are not accessible at other facilities anywhere in the world now," he says. Adds Gelbke: "History has taught us that new and unique tools often go hand in hand with new discoveries – and lead to further refinements based on the unique experience gained."

Further reading

For more information about a possible next-generation facility at MSU, see www.nscl.msu.edu/isf.

For the 2007 long-range plan of the Nuclear Science Advisory Committee, jointly sponsored by the US National Science Foundation and DOE, including the recommendation to fund FRIB, see www.sc.doe.gov/np/nsac/docs/Nuclear-Science.Low-Res.pdf.

Résumé

Circulation en accordéon pour les faisceaux d'isotopes rares.

L'étude des isotopes rares situés en dehors de la « vallée de stabilité » permet de mettre à l'épreuve la validité des modèles du noyau. Plusieurs installations à travers le monde produisent de tels isotopes en précipitant des faisceaux de noyaux sur des cibles solides. Les physiciens explorent à présent des moyens d'élargir le champ de leurs recherches en récupérant les isotopes rares pour en faire de nouveaux faisceaux ré-accélérés. Une technique prometteuse qui consiste à stopper les faisceaux, les extraire puis les utiliser à de très basses énergies ou bien les accélérer de nouveau. C'est la voie qu'a choisie le Laboratoire national pour les cyclotrons supraconducteurs de l'Université d'État du Michigan.

Don Monroe, *New Jersey.*

The Super-LHC is on the starting blocks

While the eyes of the world are looking forward to witnessing the first beams and collisions in the LHC this year, preparation for its luminosity upgrade, the Super-LHC, is already under way.

Exploiting the full potential of physics at the LHC, which includes R&D that is focused on upgrading luminosity, is the highest priority of the European Strategy for Particle Physics, which was adopted unanimously by the CERN Council in July 2006 (*CERN Courier* September 2006 p29). The first LHC physics approaches ever nearer as the LHC hardware commissioning makes steady progress towards providing beams to the experiments later this year (p5). Meanwhile, accelerator and detector experts are already looking farther into the future. They have begun preparatory work for the luminosity upgrade, known as the Super-LHC (SLHC), which was announced in April with an event at CERN to "kick-off" R&D (see box, p18).

The current LHC configuration is set up to produce proton–proton collisions at a centre-of-mass energy of 14 TeV and a luminosity of up to 10^{34} $cm^{-2}s^{-1}$. It will also provide high-energy lead–lead ion collisions at a centre-of-mass energy as high as 1.15 PeV (1150 TeV). The SLHC project, however, aims for a tenfold increase in luminosity for 14 TeV proton–proton collisions, achieved through the successive implementation of several new elements and technical improvements that are scheduled for 2012–2017. These include the major replacement of several accelerators in the LHC proton-injector chain, upgrades of the LHC-interaction regions and enhancements to the general-purpose experiments ATLAS and CMS.

Understanding how to improve the luminosity yield of the LHC has required careful scrutiny of the whole proton-injection and accelerator chain to seek out bottlenecks, inherent weaknesses and reliability problems. The findings are that more luminosity gain can be obtained from improvements to the injector chain than from changes in the LHC machine itself. This is no surprise, considering that some elements of the injector chain date from as early as 1959, when no one would even have dreamed of a superconducting accelerator the size of the LHC. In the current chain, protons pass successively from the source through Linac2, the Booster, the PS and the SPS before final injection into the LHC. The SLHC plans propose a future sequence of Linac4, the Low-Power Superconducting Proton Linac (LPSPL), PS2 (a new machine) and the SPS. Figure 1 shows both present and future schemes, while the aerial view shows more directly how the injectors will be positioned on the site at CERN.

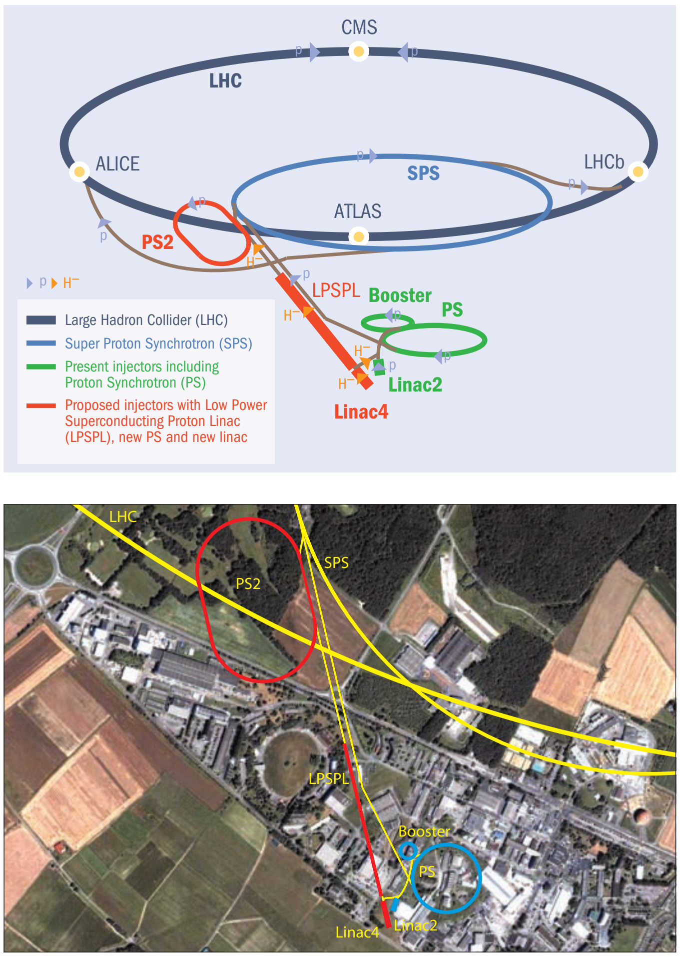


Fig. 1. Schematic layout of the accelerator complex at CERN (top) and aerial view of the Meyrin site (above), showing both the present and proposed future injection systems for the LHC. (Courtesy UNOSAT.)

The first bottleneck in the present layout occurs with the injection of proton bunches from Linac2 into the Booster. Protons are injected at 50 MeV by a multiturn injection process that inherently dilutes the beam brightness (the current within a ▷

given emittance). Much can be gained from using H^- particles in the linac followed by injection in the Booster using a charge-exchange technique that removes excess electrons. This method avoids a dilution of beam brightness and directly translates into a luminosity increase in the LHC. Capturing and accelerating the now more brilliant beam requires an energy increase in the linac, thus reducing the beam self-repulsion in the Booster. This justifies the present 50 MeV proton linac (Linac2) being replaced by a new 160 MeV linac (Linac4) operated with H^- ions. Plans for Linac4 are well advanced and its construction will begin soon, aiming for commissioning by 2012. This will result in a doubling of peak LHC luminosity.

Next in the present injector chain are the Booster and the PS, both of which suffer from inherent intensity limitations and reliability problems after many years of service. These both call for new injectors designed for the needs of the LHC, which also take into account potential future projects like a neutrino factory or a next-generation nuclear-isotope facility. Current plans concentrate on extending the energy of Linac4 to several giga-electron-volts (i.e. the LPSPL) and a new 50 GeV synchrotron called PS2, resulting in a higher performance – in particular, an increased SPS injection energy of 50 GeV and another doubling of the proton flux. Both machines are now entering the R&D and design-optimization stage, aiming for a decision on construction by 2011. The building of these new injectors can take place in parallel with operation of the LHC, with a changeover expected in 2017 after an extended shutdown.

The LHC and experiments

In the LHC itself, major elements of the interaction regions in the two high-luminosity insertions can be replaced to give yet another luminosity gain of a factor of two. In particular, new focusing triplets based on Nb-Ti superconducting technology are forseen. Compared to the present systems they will have a larger aperture and will allow the beam size at the interaction point to be reduced. The new triplets will require parallel improvements in the LHC collimation system and the separation elements near the interaction regions, to be implemented before the 2013 physics run.

The ATLAS and CMS experiments will also require upgrades to increase their sensitivity limits in the presence of the higher interaction rates and increased radiation levels. At the SLHC, "pile-up" will amount to as many as 400 events per bunch crossing. This requires adapting trigger and data-acquisition schemes, as well as the complete replacement of the central tracking detectors. The new trackers will have finer granularity and an increased radiation hardness, while particular emphasis will be placed on minimizing their material budget. The forward muon regions will need major modifications, complemented by new beam-pipe elements and reinforced shielding.

While all of these technical developments towards the SLHC take place, LHC operation will continue uninterrupted and the LHC experiments will pursue their quest for new discoveries in the head-on collisions of protons and ions of extraordinarily high energy. In particular, these are expected to increase our knowledge of the origin of mass, the formation of matter, matter–antimatter asymmetries and issues such as extra dimensions of space, microscopic black holes and dark matter in the universe. Profiting from the successive luminosity increases, the SLHC will undoubtedly allow for further probing of phenomena first detected at the LHC. It will also provide better access to the detection of low-rate phenomena that will be inaccessible to the LHC, and will push the sensitivity limits for new physics processes to higher mass-scales.

Many R&D activities for the SLHC are now starting, thanks to several national funding sources, additional funding made available to CERN from its member states, and funding from the European Commission. The corresponding collaboration frameworks with worldwide partners are being established for the accelerators and for the experiments.

April event kicks off for the SLHC

A public "kick-off" event, marking the start of SLHC developments, was held at CERN on 9 April. The aim was to inform a wide audience about the SLHC project. In a packed auditorium, the event began with a speech by CERN's chief scientific officer, Jos Engelen. He emphasized the importance of developments towards the SLHC within the European particle physics strategy and commended the position taken up by SLHC activities within CERN's overall programme. These will maintain the thrust of the numerous innovations accomplished for the design and implementation of the LHC, while working towards full exploitation of the LHC's new physics. Engelen also reported on the role taken up by the LHC Committee in peer reviewing the R&D for the upgrade, and he encouraged the audience to submit their proposals.

The event continued with three overview talks. Michelangelo Mangano of CERN's Theory Unit gave a talk on the present views on the physics potential of the SLHC – physics options that will become more refined as the LHC begins to reveal its secrets. Lyn Evans, LHC project leader, outlined the accelerator upgrade plans and associated timescales. Jordan Nash of Imperial College reported on the upgrade plans of both the ATLAS and CMS experiments. The event concluded with lively discussions on the impact of the announced gradual luminosity increases on the present physics, operation and upgrade plans of these experiments.

● For more about this event see http://indico.cern.ch/conferenceDisplay.py?confId=30583.

Résumé

Le Super LHC dans les starting-blocks.

Alors que la planète entière a les yeux rivés sur les faisceaux du LHC et les collisions à venir, les travaux préparatoires de l'étape suivante, le Super LHC (SLHC) ont déjà commencé. Le projet SLHC vise à multiplier par dix la luminosité du LHC pour arriver à des collisions proton-proton de 14 TeV. Cela se fera grâce à la mise en place de plusieurs nouveaux éléments dans la période 2012–2017, dont le remplacement de plusieurs accélérateurs de la chaîne d'injection et des améliorations des régions d'interactions du LHC et ainsi que des détecteurs ATLAS et CMS.

Lyn Evans *and* **Lucie Linssen**, *CERN.*

T2K: Tokai to Kamioka

Construction is well under way in Japan on the new facility to send neutrinos from J-PARC to the Super-Kamiokande detector nearly 300 km away. The facility is re-using the magnet that originally starred in the UA1 experiment at CERN, as **Koichiro Nishikawa** explains.

T2K is a second-generation, long-baseline, neutrino-oscillation experiment that will study the nature of neutrinos. A neutrino beam generated by the high-intensity proton accelerator of the Japan Proton Accelerator Complex (J-PARC) at Tokai will travel 295 km to the 50 kilotonne water Cherenkov detector, Super-Kamiokande, which is located about 1000 m underground in the Kamioka mine.

The J-PARC neutrino facility will follow the standard route for making a neutrino beam. This begins with an intense proton beam that strikes an appropriate target to create many secondary particles, including pions and kaons, which in turn decay to muons and the desired muon-neutrinos. The secondary particles pass through a decay volume followed by an absorber, or beam dump, which removes all but the muons and neutrinos from the beam. A further absorber – the rock in the Earth between the beam dump and the detector – removes the muons to leave only the neutrinos.

At J-PARC the primary beam line will consist of superconducting combined-function magnets for the arc section, with normal conducting magnets for fast extraction and the final focus. The target will form part of the secondary beam line, which will also contain the magnetic horn system to focus the pions and kaons into a beam, the decay volume, and the beam dump and muon monitors. The horn system being used consists of three horns, the first being combined with the target system. In addition, buildings for services such as power supplies and cooling water systems for the beam lines are under construction, as well as the building and underground pit for the near neutrino detector, ND280, which will monitor the neutrinos.

Work on the primary beam line is making good progress. The normal conducting magnets are all in place, and the installation of cabling and piping is under way. In the arc section, 12 of the 14 doublets of superconducting magnets have been installed, together with beam position monitors. The survey and alignment took place in April, with remaining work carried out after the commissioning of the main proton ring at 3 GeV. This saw the successful injection of 3 GeV protons from the rapid cycling proton synchrotron into the main ring on 22 May. Commissioning to 30 GeV will take place from December 2008 to February 2009, and the commissioning of the fast extraction for the neutrino beam should start in April 2009.

For the neutrino beam line, both the helium vessel for the decay volume and the target station (where the target and horn system will be installed) have been completed. Civil engineering around them continues on the target station building and the pit for the beam dump and muon monitors. The installation of the neutrino equipment into the target station should begin in July. The complete arrangement for the third horn was assembled at KEK in Tsukuba to debug the remote handling system that will be used for installation and maintenance. Tests on the operation of this horn began in April, while tests on assembling the target system and the first horn are scheduled for completion by July.

Superconducting combined function magnets in the arc of the primary beam line for the T2K facility. (All photos courtesy KEK.)

The first of three magnetic horns for T2K. This one will be combined with the target system at the start of the secondary beam line.

The beam dump consists of 14 core modules composed of graphite blocks and aluminium cooling plates. The modules were ▷

completed by the beginning of April, and by November they should be assembled together to form the beam dump, prior to installation in the beam-dump pit. Construction of the muon monitors is also under way and they are scheduled for testing with beam in July.

The pit for the neutrino monitor became available in April, so installation work could begin on the large magnet for the ND280 near detector, which is being assembled below ground before construction work begins on the surface building. The magnet has been donated by CERN, having been used in the UA1 experiment, for which it was built, and subsequently in the NOMAD neutrino experiment. It consists of 16 C-shaped yoke pieces, together with two carriages for the yokes, rails and other components. For the journey to Japan the yokes were disassembled into 32 short pieces and 16 long pieces, so as to fit into standard containers.

The various pieces travelled to Japan in three shipments, mainly by sea (*CERN Courier* April 2008 p7). The first and second shipments were for the yokes, carriages and jigs etc, while the third contained the delicate coils. The first shipment arrived at Japan's Hitachinaka port on 18 March, bringing 24 short yoke pieces in 12 containers each 20 ft long, together with the two carriages each in a 40 ft container, and a third 40 ft container with items such as jigs. The two carriages, jigs and other items were transported from the port to J-PARC on 28 March in readiness for installing the magnet in the neutrino monitor pit. The task of unloading the 24 short yoke pieces at the area began on 1 April and on 3–4 April they were moved to the neutrino monitor area.

The second shipment arrived at the port on 10 April, bringing the remaining eight short yoke pieces and the 16 long yoke pieces. The short yoke pieces were taken into the neutrino monitor area on 19 April, and by the end of the month, the mobile crane had unloaded the long yoke pieces and carried them to the area, ready for re-assembling the short and long pieces into the16 yokes prior to installation in the pit. The coils, in the third and last shipment, were due to be delivered to the neutrino monitor area in the middle of June, for subsequent installation in the magnet yoke.

The survey to put reference lines on the floor of the neutrino monitor pit was carried out soon after the site became available, and by 14 April the rails for the yoke carriages were in position. The carriages were then lowered into the pit and mounted on the rails. The system for aligning the yokes was also set up, ready for when the yokes are installed on the carriages.

The 16 full yokes are being assembled at a rate of one per day. After they are all assembled, they will be lowered into the pit and mounted on the carriages using the alignment system. The plan is to complete installation of the yokes by the beginning of June. By this time, the coils should have been delivered from the port to the neutrino monitor area, in time for installation into the magnet yokes. Complete installation of the magnet in the neutrino monitor pit is scheduled for the end of June. The complete J-PARC neutrino beam facility and the near detector ND280 should then be ready by March 2009 so that the T2K experiment can start in April 2009.

Installation of the sections of the magnet yoke familiar from UA1 and NOMAD gets under way in the neutrino monitor pit.

● The T2K collaboration thanks the CERN management and European colleagues for their generosity in donating the UA1 magnet and their hard work in its preparation at CERN and J-PARC.

Résumé

T2K : De Tokai à Kamioka

Le chantier est bien avancé pour la nouvelle installation japonaise qui enverra des neutrinos du complexe d'accélérateurs de protons J-PARC au détecteur Super-Kamiokande, à 300 km de distance. T2K est une expérience de deuxième génération d'étude de l'oscillation des neutrinos à longue distance. Un faisceau de neutrinos, généré par l'accélérateur de protons à haute intensité du J-PARC à Tokai, va parcourir 295 km jusqu'au détecteur Tchérenkov de 50 kilotonnes d'eau, le Super-Kamiokande, situé à environ 1000 m sous terre dans la mine de Kamioka. Cette installation réutilise l'aimant de l'expérience UA1 du CERN.

Koichiro Nishikawa, *T2K spokesperson, KEK.*


Cryogenic Valves
GLC Certified
Certified according ISO 9001:2000
Certified according PED 97/23/EC
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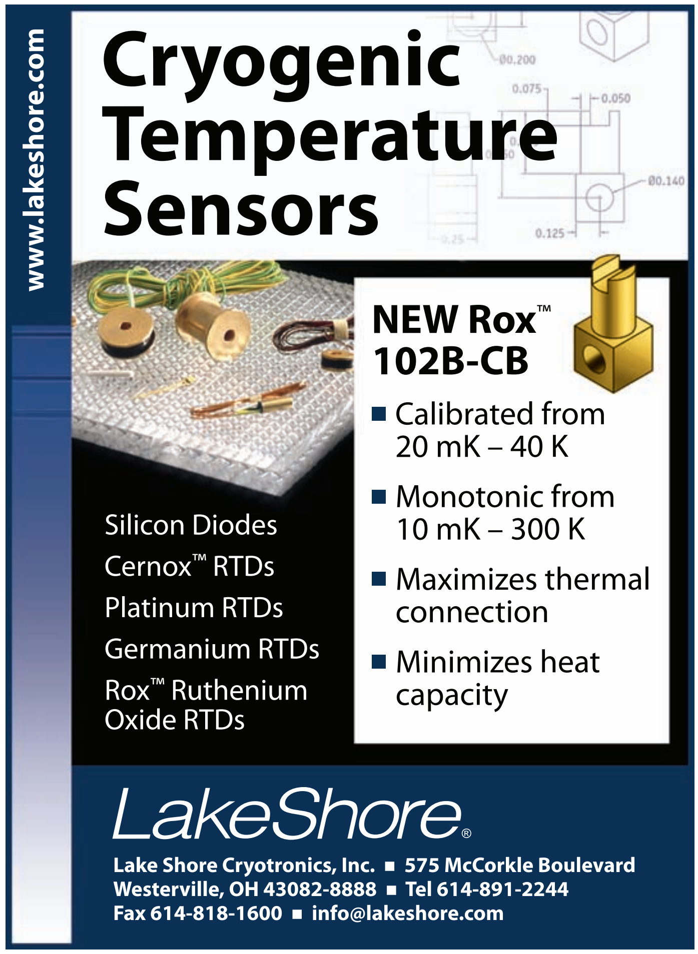
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DAΦNE provides a fine electron source

An electron test beam at the Frascati Φ-factory offers users a range of options in terms of both energy and intensity, and also includes the possibility of employing tagged photons.

The Beam Test Facility (BTF) is part of the DAΦNE Φ-factory complex, the most recent of the electron–positron colliders in the long history of the INFN Laboratori Nazionali di Frascati (LNF). The facility features a high-intensity linac that provides electrons and positrons up to 750 MeV and 550 MeV respectively, a damping ring to improve injection efficiency and two main rings designed for the abundant production of K mesons coming from the decay of the Φ resonance at 1.02 GeV (Mazzitelli *et al.* 2003). The main research goal is to study matter–antimatter asymmetry and the interactions of "s" quarks, but K mesons are also useful tools in nuclear and atomic physics.

Before the high-intensity electron or positron beam pulses produced by the 60 m long linac are injected into the double storage ring, they can be extracted to a transfer line that is dedicated to the calibration and ageing of particle detectors, the characterization and calibration of beam diagnostics, and the study of low-energy electromagnetic interactions (figure 1). Here, the number of particles can be reduced to a single electron or positron per pulse by means of a variable thickness copper target. The particle momentum is then selected, with an accuracy better than 1%, using a dipole magnet and a set of tungsten collimators. The energy range is typically 25–500 MeV, and up to 49 pulses per second can be extracted (20 ms repetition time), with a bunch length of 10 or 1 ns. When not operating in conjunction with the collider, the linac's maximum beam energy can be raised to 750 MeV (for electrons) and the intensity increased to a maximum of 10^{10} particles per second, limited by radiation safety.

When operating in low-intensity mode, particles are selected from the secondary showers emerging from the target, so either electron or positron beams can be chosen. The final intensity can easily be tuned (by adjusting the tungsten collimators) over a range of several orders of magnitude – from 10^4–10^5 particles per pulse, down to a single particle (Poisson distributed). An optical system of four quadrupoles along the BTF transfer line allows the transverse distribution of the beam to be tuned. A typical beam spot of 2×2 mm^2 transverse section (1σ profile), with an angular divergence of about 2 mrad, is produced at 500 MeV in single-particle mode (figure 2). Two different beamlines are available, depending on the configuration of the final dipole magnet in the experimental hall (figure 3).

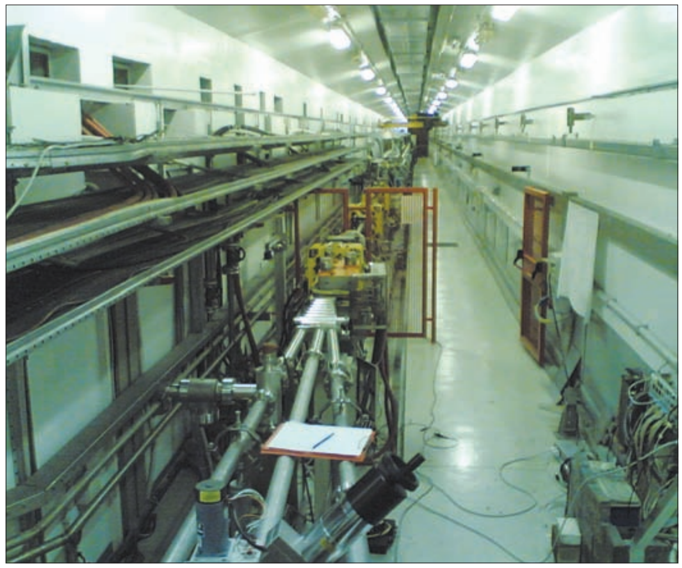


Fig. 1. The DAΦNE linac and the transfer line (the middle line in the photograph) for the Beam Test Facility (BTF). (Courtesy LNF-INFN.)

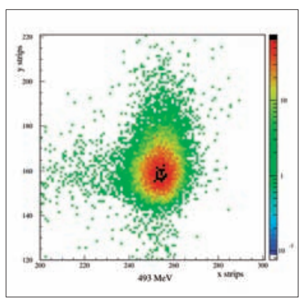


Fig. 2 (left). A BTF beam spot (on silicon microstrip detectors, 0.240 mm pitch). (Courtesy AGILE.) Fig. 3 (right). The BTF hall, showing the last dipole with the double beam exit. (Courtesy G Federici/LNF-INFN.)

When needed, the full-intensity beam can be extracted to the BTF area by removing the copper target from the beamline.

The commissioning of the transfer line, the two BTF exit lines and all the diagnostic devices needed for a reliable operation of a test-beam facility was completed in autumn 2002. The facility has since ▷

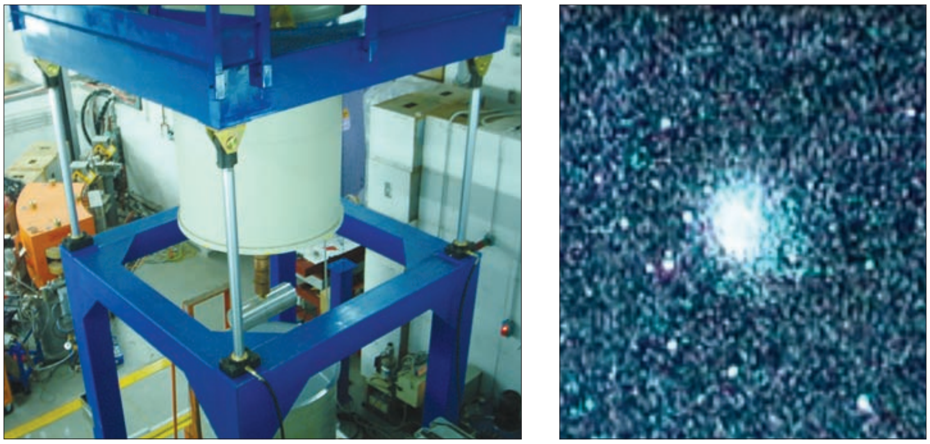


Fig. 4. The arrangement to test the thermoacoustic detection of particles on an ultracryogenic resonant antenna (left), which is sensitive enough to detect the impact of cosmic rays. The detector vibrates when it is hit by the full intensity of the Beam Test Facility beam (right). (Courtesy LNF-INFN.)

Fig. 5. The Italian Space Agency's AGILE *payload during calibration runs with the BTF tagged photon beam. (Courtesy AGILE.)*

hosted tens of groups from all over Europe, who have run a variety of experiments and tests with electron and positron beams.

The applications of the BTF beam – with its intensity and energy range, good spatial and excellent timing properties – are extremely wide ranging. Typical uses of the facility in its single-electron mode of operation include testing the ring-imaging Cherenkov system for the LHCb experiment at CERN's LHC and using electrons at 500 MeV to make highly accurate measurements of the efficiency of OPAL lead glass used in the NA62 experiment at the SPS. A more unusual investigation concerned the thermoacoustic detection of particles by the type of ultracryogenic resonant antenna used for gravitational-wave detection. Such antennae are sensitive enough to detect the impact of cosmic rays, and indeed the tests could observe the vibration occurring when the full force of the high-intensity BTF beam struck the antenna (figure 4).

An important upgrade of the BTF line was completed in 2005, with the installation of dedicated devices for the production of a beam of tagged photons. To intercept the BTF beam with a small, but not negligible, probability of emitting a bremsstrahlung photon, an active target made of four layers of single-sided silicon microstrip detector planes can now be inserted just before the last dipole magnet that selects one of the two exit lines. In this case the electron is not transported through the dipole but instead hits the inner wall of the vacuum pipe inside the magnet. Its energy is then detected by a series of silicon microstrip detector modules installed outside the beam-pipe, thus allowing the reconstruction of its bending radius. Combined with the measurement of position and angle in the active target, this yields the energy of the radiated photon with a resolution of 7% in the 200–500 MeV range, at a typical production rate of 0.5 Hz. This photon-tagging system has been used successfully for the calibration of the scientific payload (in particular the tungsten/silicon detector mini-calorimeter) of the gamma-ray astronomy satellite *AGILE*, launched by the Italian Space Agency in summer 2007 (figure 5).

Since March 2007 the duty factor of the facility has been improved from 40% up to 90% of the operation time of DAΦNE, thanks to the installation of a new dedicated pulsed-dipole magnet, designed, in collaboration with Maurizio Incurvati and Claudio Sanelli at INFN-LNF, by CERN (Maccaferri and Chiusano 2006). This is capable of driving any of the 50 linac pulses per second to either the accumulator ring or the BTF transfer line. The BTF, operated by the Frascati Accelerator Division staff, typically provides beam for an average period of 250 days a year.

The BTF facility is already equipped with instrumentation and diagnostics capable of covering the entire energy and intensity range. It is also continuously being improved to satisfy the growing interest of the broad scientific community that it serves. The support and collaboration of the users is crucial for better operation and development of the facility. Many improvements of the BTF diagnostic tools have been introduced in collaboration with hosted groups. The requests and proposals made by the user community are important in pushing exploration towards new operating schemes and new possibilities, including projects for the production of a low-intensity neutron beam and R&D studies for high-precision diagnostics at high intensities, all of which are under way.

Further reading

R Maccaferri and F Chiusano 2006 CERN/AT-2006-014.
G Mazzitelli *et al.* 2003 *Nucl. Instrum. Meth. A* **515** 516. See also www.lnf.infn.it/acceleratori/btf/docs/NIM515_3.pdf.

Résumé

DAΦNE : un large choix de faisceaux

L'installation de faisceaux d'essai BTF (Beam Test Facility) fait partie du complexe d'accélérateurs pour « DAΦNE », le plus récent des collisionneurs électron-positon du laboratoire INFN de Frascati. Elle produit une large gamme de faisceaux d'électrons ou de positons de différentes intensités et énergies, et permet d'utiliser des photons « étiquetés ». L'intensité peut être réduite à une seule particule par impulsion ou bien être portée à 10^{10} *particules par seconde lorsque le collisionneur n'est pas en marche. Les énergies sont généralement comprises entre 25 et 500 MeV. Les applications du BTF sont extrêmement diverses, de l'étalonnage des détecteurs de particules à l'étude des interactions électromagnétiques à basse énergie.*

Giovanni Mazzitelli, *INFN Laboratori Nazionali di Frascati, and* **Paolo Valente**, *INFN Roma.*

Frank Krienen: a talent for ingenious invention

Colleagues and friends of Frank Krienen recall some of his major contributions to experimental particle physics, from the 600 MeV Synchrocyclotron, CERN's first accelerator, to wire spark chambers and measurements of g-2 for the muon.

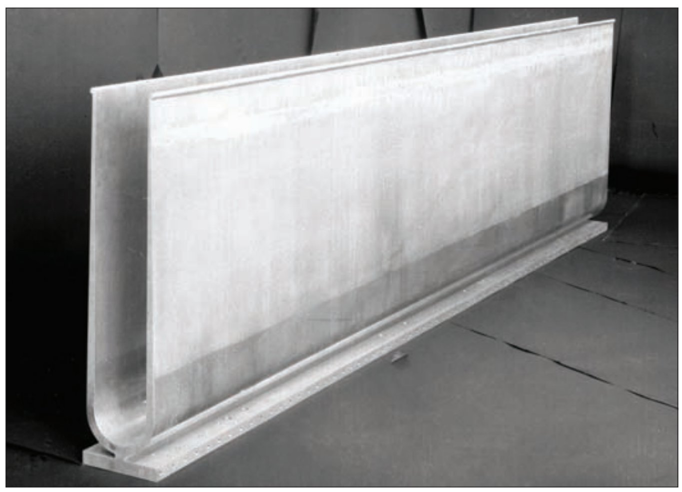
Krienen, who died on 20 March (p43), began his long association with particle physics in 1952, before the European Organization for Nuclear Research officially came into being, in the days of the provisional council that gave CERN its name. He had spent the first few years of his professional life in the research laboratories of Philips at Hilversum. Combined with his academic background as an engineer-physicist at the University of Delft, this gave him the thorough training in the basics of materials and electromagnetism (radar) that was to manifest itself so clearly when he joined CERN.

Already an assistant to Cornelis Bakker at the Zeeman Laboratory at Amsterdam University, Krienen was perfectly suited to be one of the first recruits to the accelerator programme for the new European laboratory. The first project was the 600 MeV proton Synchrocyclotron (SC), with Bakker in charge. This was to be one of the highest-energy accelerators in the world, with the aim of providing a source of particles to initiate an experimental programme in pion and muon physics. The speed of construction was an important element, because CERN needed to become a focus for attracting many of the physicists who had migrated away from Europe. In the meantime, the planning and construction of the much more ambitious proton synchrotron (which became the 25 GeV PS) had also begun, although this was a longer enterprise by necessity.

A small team of young, enthusiastic people was established for the SC, led and advised by experts with more experience. Initially (1952 to 1954) they were scattered in small groups at European universities and laboratories that already had activities in particle physics research (Liverpool, Paris, Uppsala, Stockholm). They all moved to Geneva when the final choice of the CERN site was made.

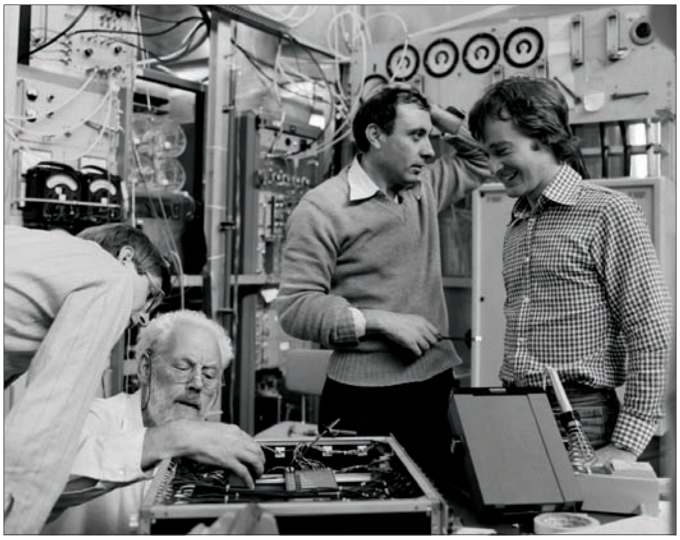
Krienen had essentially two responsibilities: a specific one for the accelerating RF component of the machine and a more general one for keeping overall control and ensuring the necessary connections between the various groups. His competence made him the undisputed guide and mentor: critical at times, but always enthusiastic and forward-looking. His leadership in dealing at the highest level with industrial firms – some of them the largest in Europe – was an important contribution. Very soon the younger members of the SC team, some only 25 years old, learned enough to feel confident and carry on alone.

Krienen with one of his wire spark chambers in 1963.



A 2 m wide aluminium alloy tuning fork. Krienen designed this as the vibrating variable capacitor that was used to modulate the frequency of the RF system for the SC, which was CERN's first accelerator.

For the RF, most other high-energy synchrocyclotrons had adopted mechanical, rotating capacitors (reminiscent of the tuning capacitors of old-fashioned radio receivers). This allowed for the frequency modulation needed to accompany the relativistic energy increase that occurs in all circular accelerators with energies ▷



Krienen working at the Initial Cooling Experiment in 1978, with Fernando Cataneo (second from right) and John Chaney (far right).

higher than a few tens of millions of electron-volts. To avoid the recurrent difficulties encountered with rotating capacitors (arising from operation in high vacuum, overheating, bearings, sparking, etc), Krienen adopted a bold, elegant solution: a vibrating, light alloy capacitor in the form of a tuning fork. The self-oscillating operation (at 50 Hz) was driven from the base of the fork, via an electromagnet. Special feedback circuits assured the control of the amplitude. Krienen studied the possible problems, such as parasitic vibration modes, metallurgy and fatigue, and came up with brilliant solutions. A spare, twin tuning fork was provided for the SC, but in many years of operation it was never needed.

For the firm in charge of the construction of the SC, Philips, this was both a new adventure and a successful collaboration with the world of particle-physics research. Thanks to the dedication and efforts of all, and of Krienen in particular, the machine was built in less than three years and first operated in August 1957. It subsequently proved to be a reliable workhorse and after many additions and improvements, it completed its career in 1990, following 33 years of very successful experiments in particle and nuclear physics.

Spark chambers and g-2

Krienen also turned his talents to the benefit of particle-tracking detectors. In the early 1960s many experiments used spark chambers for this purpose. The sparks formed between metal planes in a gas when a high voltage was applied after the passage of a particle. The tracks that the chambers revealed in this way were recorded optically, initially on photographic films that were scanned offline to digitize the track co-ordinates. Later, TV cameras were used, allowing digital information about the co-ordinates of the tracks to be written onto magnetic tape. Acoustical methods, where transducers measured the arrival time of the sound wave of a spark, were also used successfully to measure the co-ordinates online.

In 1961, participants at a symposium on spark chambers at Argonne National Laboratory heard of some ideas for improving spark chambers by replacing the metal plates with wire planes. However, it was at the 1962 Conference on Instrumentation for High Energy Physics at CERN that Krienen presented the first extensive work on chambers with wire planes. He proposed the digital wire spark chamber, employing a novel method to read out wire planes with ferrite-ring core memories, as used in computers in those days. Each wire in a detector plane passed through a ferrite-ring core to ground or even to high voltage. The current through the wires touched by a spark, which was controlled and relatively low, set the magnetic cores, thus directly storing the track co-ordinate. This could be read out conveniently at high speed using the same procedures as used in computers.

The device marked a real breakthrough in the field of detectors. In the subsequent years, a large number were constructed and used in experiments at CERN, DESY, Brookhaven National Laboratory (BNL), Saclay and many other laboratories worldwide. However, a drawback of magnetic core read-out was that it could not be used in magnetic fields. This is one reason why spark chambers gradually became less popular. They were replaced by further developments of the wire chamber, such as multiwire proportional chambers, drift chambers, time-projection chambers, microstrip gas chambers, and finally by silicon trackers.

Krienen in the meantime continued to apply his inventiveness in the field of accelerators at CERN. In 1972 he made a major contribution to the 14 m diameter muon storage ring designed to measure the anomalous moment of the muon, g-2, to a few parts per million. This required a uniform magnetic field of 1.5 T with the vertical focusing provided by electric quadrupoles almost all of the way round the ring, operating at about 25 kV. Krienen, assisted by Wilfried Flegel, designed the quadrupole system and soon discovered that high-voltage quadrupoles in a magnetic field regularly spark over, even in the best vacuum. Studying the phenomenon, he realized that electrons were trapped in the combined fields (which resemble a Penning gauge) and that the breakdown occurred when the trapped charge had built up to a threshold value, which took a few milliseconds. However, the muon lifetime in the ring (lengthened by relativistic time dilation) was to be only 64 μs, and all would be gone in 800 μs, after which the quadrupoles could be switched off. So Krienen provided pulsed modulators to drive the electric plates and there was no significant breakdown.

The muons were injected by pion decay in flight inside the ring and filled all of the available phase space. Some passed close to the limiting apertures, so inevitably a small fraction (<1%) were lost per muon lifetime. This had a small effect on the g-2 measurement and limited the measurement of the time-dilated muon lifetime. Krienen then invented "electric scraping" to remove the muons at the edge of the population, which were the ones most likely to be lost. This was accomplished in a simple way by pulsing the quadrupoles asymmetrically at the beginning of the fill and then slowly bringing them up to the fiducial value. The loss was reduced to 0.1% per lifetime, and could be measured and a correction applied. Finally time dilation in a circular orbit was verified to 1 part in 1000 at a γ of 29.6. This remains one of the most precise tests of Einstein's special theory of relativity.

In 1977 Krienen took charge of the design and development of the electron-cooling apparatus for CERN's Initial Cooling Experiment (ICE) ring. Electron cooling, suggested by Gersh Itskovich Budker in 1966 and experimentally demonstrated in his laboratory in Novosibirsk in 1974 to 1976, consists of reducing the phase spread of ion beams circulating in a storage ring through Coulomb interactions with cooler electrons. Ions and electrons are mixed together along a straight section of the ring where they travel at the same average speed, the electrons being constantly renewed. At the limit, neglecting noises and instability, the temperature of the ions should be equal to that of the electrons, that is: $T_i \simeq T_e \rightarrow \theta_i \simeq \theta_e \sqrt{(M_e/M_i)}$, where θ_i and θ_e are the angular divergences of the ion and electron beams respectively. The very small mass ratio M_e/M_i makes this method extraordinarily favourable.

ICE was an alternating gradient storage ring and was constructed at CERN in less than a year, metamorphosing the existing g-2 zero-gradient ring, which had just finished its task. The idea was to demonstrate the feasibility of intense antiproton beams with the aim of using them in the Super Proton Synchrotron (SPS), operating as a proton–antiproton collider. Carlo Rubbia was the initiator and strenuous supporter of the whole project, which was to produce and thereby discover the intermediate bosons $W^{\pm}$ and Z^0 predicted by the Standard Model.

The decision was taken that the ICE ring should also incorporate the appropriate equipment for the stochastic cooling system that Simon van der Meer had invented at CERN in 1974, which had already been successfully partially tested at the Intersecting Storage Rings. Between late 1977 and spring 1978, the potential of stochastic cooling became so evident that this system was adopted alone in the proton–antiproton complex, ultimately with great success.

Krienen, however, was pursuing the hard work of completing the electron-cooling system. He could not go fast because he had to design every part of the apparatus from scratch, and then construct and adjust it, as well as develop the detailed theory. In 1979, about two years after the start of ICE, his apparatus worked properly, achieving a factor of 10^7 in the six-dimensional phase space density of the circulating protons. It was too late for the proton–antiproton project at the SPS, but new aims appeared. Krienen's device was moved, with minor modifications, to the Low Energy Antiproton Ring. After a few years and more substantial improvements, it was moved again to the Antiproton Decelerator.

After his retirement from CERN, Krienen moved to the US, where he often returned to this cooling method, suggesting improvements and new applications in several papers. In 1986 he joined Boston University as professor of engineering and applied physics, and set to work on the new muon g-2 experiment at BNL. This was broadly similar to the CERN machine but had many improvements: the magnet aperture and yoke were wider, and particles were to be injected many times for each cycle of the Alternating Gradient Synchrotron. Krienen realized that a pulsed inflector, as had been used at CERN, would need to be longer, therefore requiring more energy, and that it would be impossible to recharge the capacitors in time for them to be triggered many times per second. So he devised instead a superconducting inflector that would cancel the main field along the desired track, but have no leakage field outside, using no iron or ferrite, which would have perturbed the main field.

To achieve this with a steady current was a tour de force. Krienen used two $\cos\theta$ windings of different diameters, one inside the other, carrying equal and opposite currents. Outside the device the magnetic field was strictly zero, but inside the inner winding the field was uniform and the return flux was confined to the space between the windings. Working with his PhD student Wuhzeng Meng, Krienen

First steps towards the g-2 collaboration at BNL in 1984. Back row, left to right: Gordon Danby, John Field, Francis Farley, Emilio Picasso and Frank Krienen. Front row: John Bailey, Vernon Hughes and Fred Combley. (Courtesy Brookhaven National Laboratory.)

proved the concept with model windings and the final superconducting version was made by Akira Yamamoto at KEK in Japan. This invention was crucial to the success of the g-2 experiment at BNL.

Krienen was an inventive and original thinker with the ability to make his ideas work in detail. His work ranged from accelerator and beam optics through superconducting injection devices and slow extraction methods, to ion sources, RF and klystron technology, and many kinds of particle detector. His motivation was always the advancement of physics. He impressed his colleagues and friends with his vast knowledge of theory and practice, and with his enthusiasm and creativity, which he maintained until the end of his long life. He was a good team player with strong loyalty to colleagues. We will remember him with warm affection.

Résumé

Frank Krienen : le remarquable talent d'un inventeur

Frank Krienen, qui nous a quittés le 20 mars, était une des premières recrues du CERN. Dans cet article, ses collègues se souviennent des contributions majeures qu'il a apportées à la physique des particules expérimentale, à commencer par le modulateur de fréquence à diapason pour le premier accélérateur du CERN, le synchrocyclotron. Dans les années 1960, Frank Krienen s'était consacré à la trajectographie des particules, avec l'invention de la chambre à étincelles. Il avait ensuite développé l'anneau de stockage utilisé au CERN pour mesurer le moment magnétique anormal du muon (g-2), ainsi que des appareils de refroidissement par électrons. Aux États-Unis, il a contribué de manière inestimable à l'expérience g-2 du Laboratoire américain de Brookhaven.

Franco Bonaudi, **Francis Farley**, **Guido Petrucci**, **Emilio Picasso** *and* **Henk Verweij**, *Krienen's former colleagues and friends.*

Pixels make for perfect pa

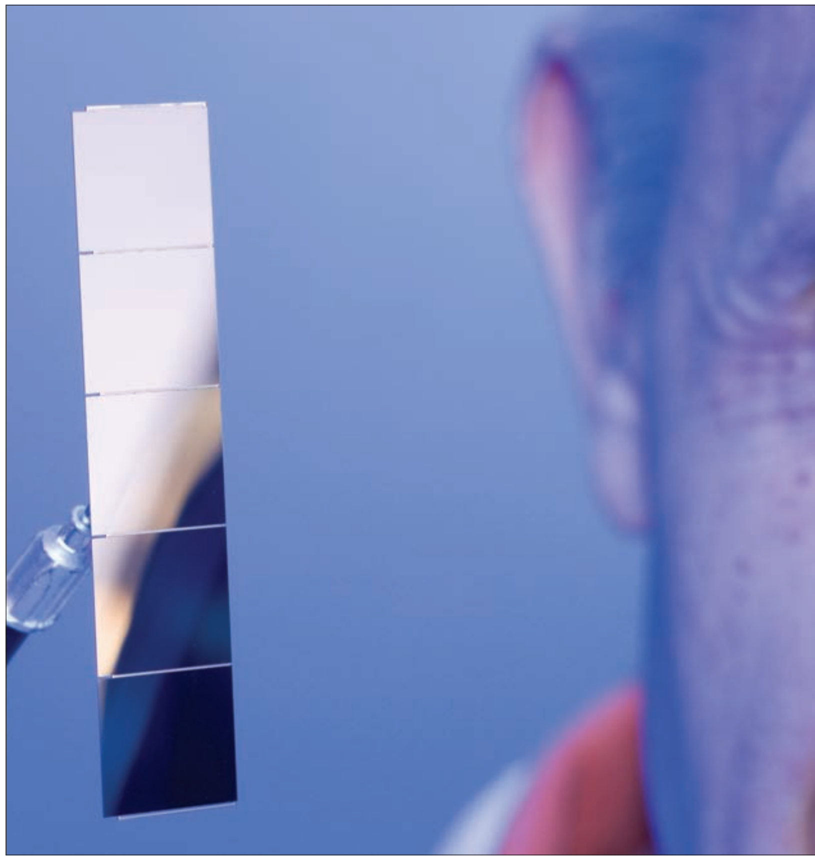
The silicon pixel detector in ALICE has an important role to play in demanding conditions at the

The ALICE experiment at the LHC is optimized for the study of heavy-ion collisions to investigate the behaviour of strongly interacting matter under extreme conditions of compression and heat. The interpretation of the data will rely on a systematic comparison of measurements with the same observables in proton–proton (pp) and proton–nucleus (pA) collisions, as well as in collisions of lighter ions under the same experimental conditions. The tracking and particle-identification capabilities of ALICE are designed to allow a precise study of these benchmarking processes and to perform efficiently in the particularly demanding conditions of the heavy-ion programme.

A key characteristic of heavy-ion collisions at the LHC energy is the high number of particles produced per event, more than two orders of magnitude higher than in a typical proton–proton collision in the central region. The design of ALICE is optimized for a charged particle multiplicity of around 4000 and has been tested with simulations up to double this number. The use of mainly 3D hit information with many points (up to 150) in a moderate magnetic field of 0.5 T makes the tracking capability particularly safe and robust.

Tracking in the central barrel of ALICE is divided into a six-layer silicon-vertex detector, which forms the inner tracking system (ITS) surrounding the beam pipe, and the time-projection chamber (TPC). The main functions of the ITS are the localization of the primary vertex (with a resolution better than 100 μm), the reconstruction of the secondary vertices from the decays of D and B mesons and hyperons, the tracking and identification of particles with momentum below 200 MeV/c, and improving the momentum and angle resolution for particles reconstructed by the TPC. The silicon pixel detector (SPD) forms the innermost two layers of the ITS, which is surrounded by two layers of drift detectors and two layers of double-sided microstrips. The drift and microstrip layers are equipped with analogue readout for independent particle identification via energy loss, dE/dx, in the non-relativistic region, thus providing the ITS with stand-alone capability as a spectrometer for particles with low transverse momentum, p_t.

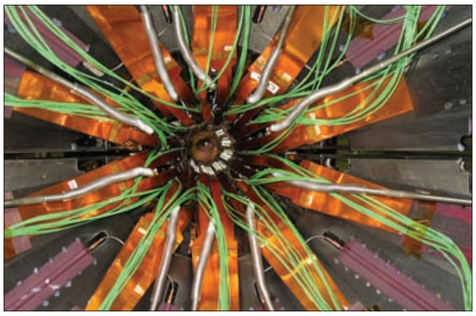
The SPD will operate in a region where the track density could be as high as 50 tracks/cm^2. It has a key role in the determination of the position of the primary vertex and in the measurement of the impact parameter of secondary tracks originating from the weak decays of strange, charm and beauty particles. The active length of the two SPD layers is about 28 cm, with an acceptance coverage in pseudorapidity of $\eta = \pm 2.0$ for the inner layer and $\eta = \pm 1.4$ for the outer one, located around the beam pipe at average distances of 39 mm and 76 mm from the beam axis, respectively. The smallest clearance between the inner layer and the wall of the beam pipe – an 800 μm thick beryllium cylinder with an outer diameter of 59.6 mm – is less than 5 mm.

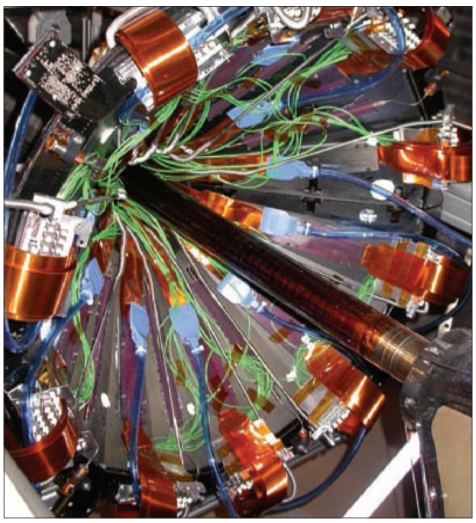


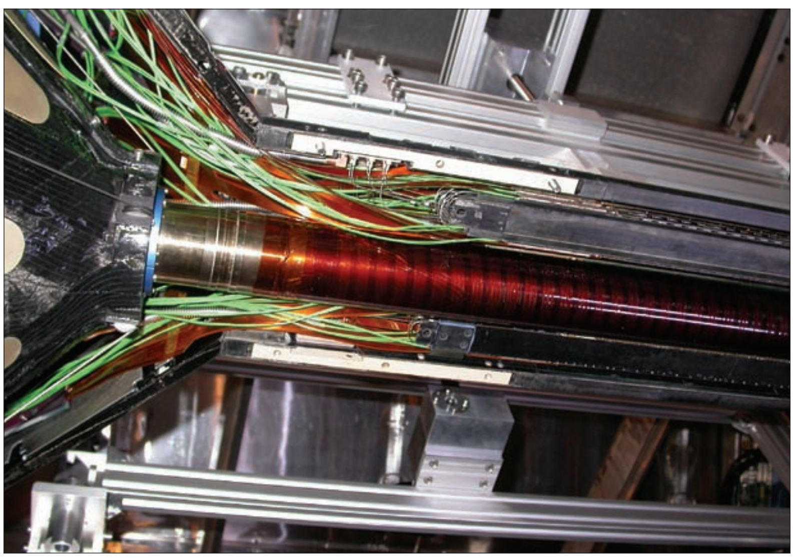
Top left: the detector element, a ladder, consists of a silicon-sensor matrix bump bonde
barrel during assembly test. Above left, middle right and above right: three views of the S

particle tracking in ALICE

the LHC. **Vito Manzari** and **Giorgio Stefanini** describe the construction and commissioning.







nded to five readout pixel chips. (Courtesy Antonio Saba for CERN.) Top right: the SPD the SPD installation show clearly the beryllium beam pipe.

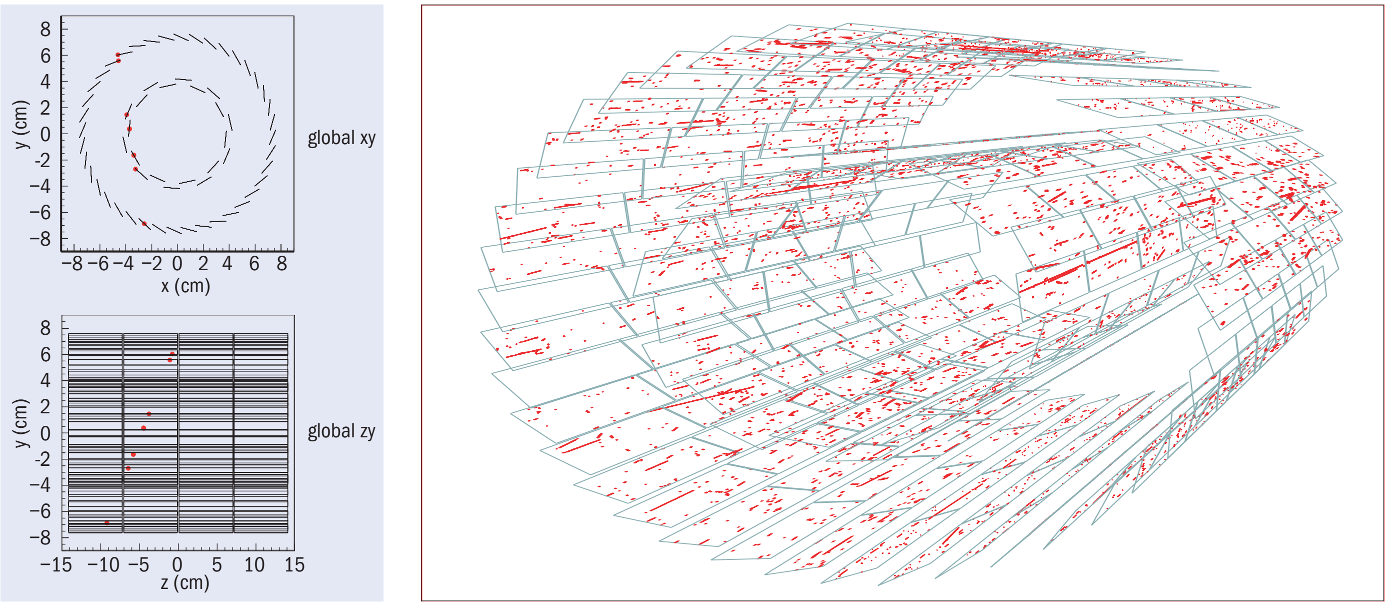
A distinctive feature of the SPD is the reduced amount of material seen by traversing particles. The resolutions in momentum and impact parameter for low-momentum particles are dominated by multiple scattering in the material of the detector. To keep the p_t cutoff as low as possible, the SPD design uses several specific solutions to minimize the amount of material in the active volume. The result is that a straight track perpendicular to the detector surface traverses on average an amount of material per layer corresponding to about only 1% of a radiation length.

Another important consideration is the amount of radiation to which the SPD will be exposed during LHC operation. For 10 years of a standard running scenario, the integrated radiation levels of total dose and fluence on the inner layer are estimated to be 2.7 kGy and 3×10^{12} n/cm^2 (1 MeV neutron equivalent), respectively. While this is lower than for other LHC detectors, the on-detector ASICs for the SPD have nevertheless been implemented in radiation-hard, deep-submicron technology, like the other more demanding cases at the LHC. The relatively modest radiation levels allow the detector to operate at ambient temperature without the risk of significant long-term degradation of the sensor characteristics. The total power dissipation in the on-detector electronics is around 1.35 kW. This is not high; however, because the mass of the detector is low, if the cooling system were to fail, the temperature would rise at a rate of about 1 °C/s. For this reason, the SPD has fast-acting, redundant temperature safety systems.

The basic components of the SPD are hybrid silicon pixels in the form of a two-dimensional matrix of reverse-biased silicon detector diodes. Each diode is connected through a conductive solder bump to a contact on a readout chip that corresponds to the input of a readout cell. The readout is binary: for each cell, a threshold applied to the pre-amplified and shaped signal produces a change in the digital output level when the signal is above a set threshold.

The SPD contains 1200 readout pixel chips and a total of 10^7 cells. The detector element is called a ladder, which consists of a silicon-sensor matrix bump-bonded to five readout pixel chips. The ladder sensor matrix contains 256×160 cells measuring 50 μm (rφ) by 425 μm (z), with longer sensor cells in the boundary region to assure coverage between readout chips. The ladders are attached in pairs to an interconnect (the pixel bus) that carries data/control bus lines and power/ground planes; a multi-chip module (MCM), located at one end of the pixel bus, controls the front-end electronics and is connected to the off-detector readout system via optical-fibre links.

Two ladders, the pixel bus and the MCM together form the basic detector module, known as a "half stave". Two half staves, attached head-to-head along the z direction to a carbon-fibre support sector, with the MCMs at the two ends, form a stave. Each sector of ▷



Left: Cosmic tracks in the SPD. Right: Longitudinal tracks along one or even two ladders from muons produced during the beam injection test.

the SPD supports six staves; two on the inner layer and four on the outer layer, and ten sectors mounted together in enclosed geometry around the beam pipe form the full two-layer barrel. Each half stave generates an 800 Mb/s output serial-data stream. The 120 half staves that form the SPD are all read in parallel, with full detector readout taking around 256 μs.

Although small in physical size, the SPD is packed with advanced and novel technical solutions, including the following few examples. To obtain the lowest material budget, the pixel ASIC wafers were thinned down to 150 μm after deposition of the solder bumps, which are about 20 μm in diameter. They were then diced and the die flip-chip bonded to 200 μm thick silicon sensors to form a ladder. This whole process was challenging and required specific developments by the industrial partners (VTT in Finland, Canberra in Belgium and ITC-irst, now FBK, in Italy).

Material budget considerations also led to the development of the pixel bus, a high-density aluminium/polyimide multi-layer flex. This technology, in which aluminium is used in place of copper, is not an industry standard and was made possible by the expertise available in the TS-DEM workshop at CERN. The optical transceiver module (one on each MCM), housed in a silicon package barely 2 mm thick, is a custom development by the same company that produced the optical links for the two larger LHC detectors.

The cooling system is of the evaporative type based on C_4F_{10} and has required a specific system development. The sectors are equipped with cooling tubes and capillaries embedded in the carbon-fibre support sector, running underneath the staves (one per stave). The cooling tubes are made from a corrosion-free metal alloy (Phynox) with walls only 40 μm thick.

A unique feature of the SPD is its capability to generate a prompt trigger based on an internal Fast-OR. Each pixel chip provides a Fast-OR digital pulse when one or more of the pixels in the matrix are hit. This was originally included for self-test purposes, but it became clear that it could be adapted to generate a multiplicity trigger with a considerable interest for physics.

The Fast-OR signals of the 10 chips on each of the 120 half staves are transmitted every 100 ns on the 120 optical links that are also used for the data readout. They are processed in a separate processor unit according to a variety of predefined trigger algorithms to generate a signal that can contribute to the Level 0 (L0) trigger decision in the ALICE central trigger processor (CTP). Simulations have shown that using the Fast-OR information in the L0-trigger decision significantly improves background rejection in proton–proton interactions and event selection in heavy-ions runs.

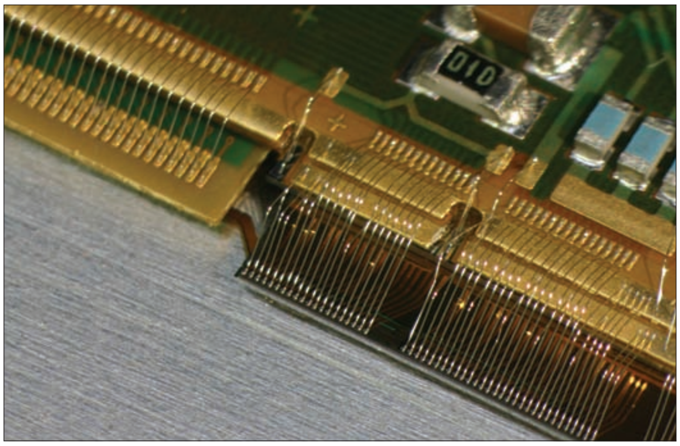
The pixel-trigger signal generated by the Fast-OR processor must reach the CTP within about 800 ns of the interaction to meet the latency requirements of the L0-trigger electronics. The design has brilliantly met this challenging requirement for the trigger processor in tests and the full system is now being commissioned in ALICE with cosmic rays.

A major challenge for the LHC collaborations has been to bring together components and subsystems developed at institutes and production laboratories in different countries and locations. The SPD is no exception. The laboratories that took part in the design, development and construction of the SPD are: CERN, INFN and the University and Politecnico of Bari, INFN and the University of Catania, INFN/Laboratori Nazionali di Legnaro, INFN and the University of Padova, INFN and the University of Salerno, INFN and the University of Udine, and the Slovak Academy of Sciences of Košice.

The final integration of the SPD took place at CERN's Departmental Silicon Facility, which was equipped to test the individual sectors and for the integration and pre-commissioning of the full detector, including the cooling plant and the full-scale configuration of power supplies and services. This strategy proved invaluable for debugging the system before installation in the experimental area.

In June 2007 the SPD was finally installed in the ALICE experimental area at Point 2 in the LHC ring, with connection to services possible in November, when the mini-frame carrying service interfaces was put in place.

Commissioning of the SPD started in January 2008 with the aim of being fully ready by the time that the LHC delivers the first proton–proton collisions, scheduled for later this summer. Indeed, the SPD



A close view of the details of wire-bonding of ladders on the pixel bus.

is one of the ALICE sub-detectors to contribute to the measurement of the charged-particle multiplicity, which is the common objective of "day-one" studies for all of the LHC experiments.

Since May the SPD has been collecting cosmic data triggered by the Fast-OR trigger signal produced by the SPD itself. The events are selected by requiring at least one hit in the outer layer of the top half-barrel in coincidence with at least one hit in the outer layer of the bottom half-barrel. These data samples are being used for a preliminary alignment of the SPD components. More recently the same signal is being used to trigger other ALICE subdetectors: first the other two ITS systems – the drift and double-sided microstrip detectors – and then the TPC, thus exercising the combined TPC-plus-ITS tracking.

On the evening of 15 June, while preparing the detector for the cosmic run, the triggered events from the SPD showed a puzzling pattern never seen before. It took a while for the team working in the control room to realize that the SPD was observing one of the first signs of life of the LHC at Point 2: muon tracks produced in the beam dump during the injection test in transfer line TI 2 (p30).

● It is unfortunately impossible in this short article to give the well deserved credit to all of those who have deployed a relentless effort over nearly a decade to lead to completion this complex and exciting detector successfully to completion. For more information about the SPD project, see the ALICE website http://aliceinfo.cern.ch.

Résumé

ALICE : un détecteur à pixels innovant

L'expérience ALICE du LHC va se consacrer à l'étude de collisions d'ions lourds, qui créent de la matière à interaction forte, dense et chaude. La très grande quantité de particules produites est une des caractéristiques importantes de ces collisions : environ 100 fois plus que dans une collision typique proton–proton. Ces très nombreuses particules imposent des fortes contraintes de construction du détecteur, particulièrement au niveau de la trajectographie des particules. L'un des éléments les plus importants d'ALICE est le détecteur à pixels au silicium, clé de voûte de la mesure des trajectoires des particules.

Vito Manzari, *INFN/Bari and CERN, and* **Giorgio Stefanini**, *CERN, on behalf of the ALICE SPD collaboration.*

Lisa Randall: dreams of warped space-time

Antonella Del Rosso talks to Lisa Randall, and finds a straight-talking physicist who not only puts her mind to a rather warped universe but can also write popular science.

Lisa Randall is the first female tenured theoretical physicist at Harvard University. This alone would probably be enough to raise the interest of most science journalists who are all too often confronted with the endless search for a female face who would look good in their newspapers, and make science somehow more human to non-scientific readers. Search her name in Google and read articles about her, then read her most recent book, and you realize that she is also one of the small band of physicists who can write popular science books. Then meet her, as I did at CERN, and you discover a no-nonsense person who finds it "normal" to deal with extra-dimensions and parallel universes, as well as hidden gravitons and quantum gravity.

Randall has visited CERN many times, staying for several months in 1992 to 1993, when she worked on B physics and also on ideas in supersymmetry and supersymmetry breaking. These ideas have since evolved, and she is now one of the world's experts in the theory of extra dimensions, one of the solutions proposed for the puzzling question of quantum gravity. According to these theories, our universe could have extra dimensions beyond the four that we experience – three of space and one of time.

The idea of an extra dimension is simple to state, but how can we picture extra dimensions in our three-dimensional minds? As Randall concedes, explaining the extra dimensions is possible primarily through analogies, such as, Edwin Abbot's analogy of Flatland. If you lived on a two-dimensional surface and could see only two dimensions, what would a three-dimensional object become for you? "In order to answer, you would have to explore your object in your two-dimensional view," she explains. "The slice would be two dimensional but the object would still be three dimensional." This is to say that, although extra dimensions are difficult to imagine in our limited three-dimensional world, we can nevertheless explore them.

Warping in a universe with extra dimensions would be an amazing discovery, but does Randall expect to find any evidence? The LHC, she explains, could hold the key. "The LHC will allow us to explore an energy scale never reached before – the TeV scale. We know there are questions about this particular scale. We know the simple Higgs theory is incomplete, so there should be something else around. That's why people think it should be supersymmetry or extra dimensions, something just explaining why the Higgs boson is as light as it is," she explains. Randall works in particular on the idea of warped geometry. If this is true, experiments at the LHC should see particles that travel in extra dimensions, the mass of which is around the tera-electron-volt scale that the LHC is studying.

Lisa Randall (right) together with Nobel laureate T D Lee (centre) and ATLAS spokesperson, Peter Jenni, during a vist to CERN in August 2007.

One fascinating area of modern physics linked to extra dimensions is that of quantum gravity. Gravity is the best known among the forces that we experience every day, yet there is no theory that can describe it at the quantum level. Gravity also still holds secrets experimentally, because its force-carrying particle, the graviton, remains hidden from view, but Randall's theories of extra dimensions could shed light here, too.

Could the graviton be found in the additional dimensions, and therefore in the proton–proton collisions at the LHC? "We don't know for sure," says Randall, "but the Kaluza–Klein partner of the ▷

graviton – the partner of the graviton that travels in extra dimensions – might be accessible." It seems that even for the theorists leading the field, the theory is a little tricky to understand. "You have one graviton that doesn't have any mass," she explains, "and it acts just as a graviton is supposed to act in four dimensions. And you have another graviton that has momentum in the extra dimensions: it will look like a massive graviton according to four-dimensional physics. The particle will have momentum in the fifth dimension and this is the part that we will be able to see."

The quantum effects of gravity have also led theorists to talk of the possibility that black holes could be formed at the LHC, but Randall remains sceptical. "I don't really think we will find black holes at the LHC," she says. "I think you'd have to get to even higher energy." It is more likely in her opinion that experiments will see signs of quantum gravity emerging from a low-energy quantum gravity scale in higher dimensions. However, she admits: "If we really were able to have enough energy to see a black hole, it would be exciting. A black hole that you could study would be very interesting."

Interesting, indeed, but also scary, because black holes have always been described as "matter-eaters". However, there is nothing to fear. Massive black holes can only be created in the universe by the collapse of massive stars. These contain enormous amounts of gravitational energy, which pull in surrounding matter. Given the collision energy at the LHC, only microscopic and rapidly evaporating black holes can be produced in the collisions. Even if this does occur, the black holes will not be harmful: cosmic rays with energies much higher than at the LHC would already have produced many more black holes in their collisions with Earth and other astrophysical objects. The state of our universe is therefore the most powerful proof that there will be no danger from these high-energy collisions, which occur continuously on Earth.

So much for black holes, but I am still full of curiosity about Randall. What, for example, originally sparked her interest in physics? "I actually liked math first more than physics," she says, "because when I was younger that is what you got introduced to first. I loved applying math a little bit more to the real world – at least what I hope is the real world." Now, as a leading woman in a male-dominated research field, and as the author of a popular book, *Warped Passages* (*CERN Courier* December 2005, p51), she is the focus of media attention. She finds some of this surprising but notes that it's not just attention to her but to the field in general. One of the motivations she had for writing her book, was that people are excited about the LHC. She saw the chance to give them the opportunity to find out more about what it will do. "These are difficult concepts to express. You could give an easy explanation or you could try to do it more carefully in a book. One of the very rewarding things is that a lot of people who have read my book have said they can't wait for the LHC; they can't wait to see what they are going to find. So it is exciting when you give a lecture and thousands of people are there – it's exciting because you know that so many people are interested." On the other hand, she finds some of the specific types of reporting disturbing, because it shows how far society still has to go: "We haven't reached the point where it's usual for women to be in the field."

In addition to her work on black holes, gravity and so on, Randall is currently working on ideas of how to look for different models at the LHC, and how to look for heavier objects, such as the graviton, that might decay into energetic top quarks. She is also trying to explore alternative theories. "I'm not sure how far we'll go in things like supersymmetry," she says, "I'm playing around with models and ways to search for it at the LHC."

Randall with Fabiola Gianotti (right), deputy spokesperson at ATLAS.

Yes, physics is about playing around with ideas – ideas that nobody has ever had before but that have to be tested experimentally. The LHC will shed light on some of the current mysteries, and Randall, who like many others has played around with ideas for years, can't wait for this machine to produce the experimental answers.

● For Lisa Randall's lectures at CERN in March 2008 on Warped Extra-Dimensional Opportunities and Signatures, see http://indico.cern.ch/conferenceDisplay.py?confId=28978, http://indico.cern.ch/conferenceDisplay.py?confId=28979 and http://indico.cern.ch/conferenceDisplay.py?confId=28980.

Résumé

Lisa Randall et les dimensions inconnues

*Lisa Randall fait partie des spécialistes mondiaux des dimensions supplémentaires et de la gravité quantique. Elle compte aussi parmi les rares auteurs d'ouvrages scientifiques à succès. Dans cet entretien, la physicienne évoque avec Antonella Del Rosso l'univers intriguant des dimensions supplémentaires. Elle aborde en particulier la possibilité de découvrir des gravitons ou des mini-trous noirs au LHC. Elle nous parle aussi des réactions de la presse et du public à son livre « *Warped Passages* », dans lequel elle prend le pari d'expliquer des concepts compliqués à un large public.*

Antonella Del Rosso, *CERN*.

CERN

Merkel sees preparations for LHC…

As CERN prepares for the start of the LHC, Angela Merkel, the Chancellor of the Federal Republic of Germany, paid a visit to the laboratory on 29 April, making her the first German chancellor ever to come to CERN.

On arrival she was warmly welcomed by Robert Aymar, CERN's director-general, and introduced to the next director-general, Rolf-Dieter Heuer, along with members of CERN's upper management. The first stop on the subsequent tour was the ATLAS control room, where she was greeted by ATLAS spokesperson Peter Jenni, before travelling 100 m underground to the ATLAS experimental cavern and the LHC tunnel. The chancellor asked questions and showed a strong interest in what she saw throughout the visit, undoubtedly aided by her PhD in physics.

Merkel also met with 13 young German scientists working at CERN. The laboratory is an important centre for the training of future scientists and technical experts; every year between 50 and 100 doctoral theses prepared in the framework of CERN projects are completed at German universities.

German physicists have made important contributions to the construction of the LHC experiments. There are about 200 German scientists and engineers among CERN's personnel and of all the member states, Germany pays the largest contribution, 20% of the total budget. Of the 9000 or so scientific users at CERN, around 900 are German.

German Chancellor Angela Merkel and members of CERN's upper management. From left to right: Maximilian Metzger, secretary-general; Robert Aymar, director-general; Angela Merkel; Rolf-Dieter Heuer, future director-general; Jos Engelen, chief scientific officer; Sigurd Lettow, chief financial officer.

Angela Merkel (right) in the LHC tunnel with CERN's director-general, Robert Aymar (left).

…and German and Swiss ministers follow suit

Merkel was followed four weeks later by the German Federal Minister of Education and Research, Annette Schavan, and the Head of the Swiss Federal Department of Foreign Affairs, Micheline Calmy-Rey. The two ministers paid a joint visit to CERN on 23 May. After an introduction from director-general, Robert Aymar, the ministers signed the guest book. They then took the opportunity to tour the ATLAS experiment and the underground LHC tunnel, where they were guided by ATLAS spokesperson Peter Jenni.

German Federal Minister of Education and Research Annette Schavan (centre left) and the Head of the Swiss Federal Department of Foreign Affairs, Micheline Calmy-Rey (centre right), in front of the ATLAS experiment, accompanied by (left to right) Jos Engelen, Rolf-Dieter Heuer, Robert Aymar and Peter Jenni, ATLAS spokesperson.

WORKSHOP

Elba provides a view of the top

Participants at the 2008 International Workshop on Top Quark Physics in a good mood on a sunny day – finally. (Courtesy INFN-Pisa.)

After a successful start in 2006 on the Atlantic coast of Portugal, the International Workshop on Top Quark Physics moved to a location a little farther away from the "home of the top quark" (Fermilab, where it was discovered in 1995) and a little closer to CERN, where the LHC is expected to become a "top factory". In May the island of Elba provided the setting for the second meeting in the series. The format of plenary talks only, with an almost equal time devoted to discussions as to presentations, was optimal for a rich exchange of ideas, as much as for dealing with a number of hot topics on both the experimental and the theoretical sides. The following few highlights give a taste of the meeting.

While the CDF and D0 experiments at Femilab's Tevatron provided the bulk of the results, speakers from the ATLAS and CMS collaborations at the LHC put forward many ideas for new measurements. With one top-pair per second in the low-luminosity phase (10^{33} cm^{-2} s^{-1}), the LHC experiments will have the chance to explore many new areas, although it was evident that some, which are already studied at the Tevatron (e.g. the top mass), will present a challenge.

The production cross-section for top-antitop with its current accuracy is challenging not only the next-to-leading-order calculations available but also our understanding of the parton distribution functions. The large uncertainties in the predictions for the LHC call for a new programme of measurements aimed at improving our understanding of those quantities.

Doug Glenziski of Fermilab presented the new measurements of the top mass from the Tevatron. The accuracy of this measurement, which approaches the level of 0.8 % (1.4 GeV/c^2), spurred a hot debate both on its interpretation on the theoretical side and on which observables are best suited to provide the top quark mass. Scott Willenbrock's summary talk provided a short introduction to this subject.

Another hot topic was the elusive electroweak production of the top quark. The evidence for single top, which is still an effect of about 3σ after seven years of running the Tevatron collider, will have to wait a little longer to become an observation. In the meantime its naïve interpretation as directly related to the V_{tb} element of the Cabibbo–Kobayashi–Maskawa (CKM) matrix has been challenged, because the exploitation of the third family as a probe for new physics calls for relaxing many assumptions that are true within the Standard Model. Not surprisingly, the possibility of improving direct measurements of the CKM elements involving the top quark was one of the highlights of the workshop. Despite the large uncertainties, a few brave souls are already using the determination of the CKM elements involving top to set limits on new physics. Does this mean that there is room for a new UTfit collaboration? It should at least provide more food for thought for the existing one.

Many speakers stressed the need for better Monte Carlo (MC) simulations in order to go to new physics, and a whole session was devoted to top-specific MC tools. The lively discussions showed that we need more data from the Tevatron and, of course, the LHC.

Statistics was one topic under discussion so, a few statistics on the meeting are not out of place. There were 117 participants, most of them students or postdocs, including a number of theoreticians. All of this calls for a third workshop, to be held in 2010 in a place still to be discovered (unlike top quark) but for which we have some evidence (like for single top). Now, 13 years after its discovery, this quark as heavy as gold has found its "home".

COLLABORATION

CERN and Turkey agree on cooperation…

On 14 April, Okay Cakiroglu, president of the Turkish Atomic Energy Authority (TAEK), visited CERN, accompanied by Ahmet Uzumcu, the permanent ambassador of Turkey to the United Nations in Geneva, and by Ali Tanrikut, the deputy director of TAEK. During the visit, Cakiroglu and CERN's director-general, Robert Aymar, signed an international cooperation agreement.

At the signature, Cakiroglu expressed his hopes that this agreement will enhance the cooperation between TAEK and CERN, and added that it will motivate Turkish scientists and engineers. He also noted that this is an important milestone towards Turkey's membership of CERN. Turkey has been an observer state of CERN since 1961, and has participated in the CHARM, SMC and CHORUS experiments. Turkish physicists are now actively involved in the CMS, ATLAS, ALICE experiments at the LHC and in the CERN Axion Solar Telescope.

Signature of the cooperation agreement between Turkey, represented by the president of the Turkish Atomic Energy Authority, Okay Cakiroglu, and CERN, represented by the director-general, Robert Aymar.

…while Saudi Arabia signs up to new protocol

Mohammed I Al-Suwaiyel, president of King Abdulaziz City for Science and Technology, shakes hands with CERN's Robert Aymar, on signing a protocol to the 2006 international cooperation agreement.

On 9 May, Mohammed I Al-Suwaiyel, president of the King Abdulaziz City for Science and Technology, representing the Government of Saudi Arabia and accompanied by members of the Saudi Arabian Government, visited CERN. Al-Suwaiyel and CERN's director-general, Robert Aymar, signed a protocol to the 2006 international cooperation agreement between CERN and Saudi Arabia defining the operational framework needed to carry out various specific tasks provided for in the cooperation agreement. These tasks will help promote the development of a high-energy particle physics community in Saudi Arabia, as well as providing an illustration of the visible participation of Saudi Arabia as a member of the global CERN community.

APPOINTMENTS

Achim Richter (right) will take over at ECT from Jean-Paul Blaizot. (Courtesy ECT*.)*

ECT* selects Richter as its next director

Achim Richter, former chairman of CERN's ISOLDE experiments committee, will be the next director of ECT*, the Centre for Theoretical Studies in Nuclear Physics and Related Areas located in Trento. He is currently director of the Institut für Kernphysik at Technische Universität Darmstadt and will succeed Jean-Paul Blaizot as director of ECT* on 1 November. After four years in office Blaizot will return to the Theory Division of CEA Saclay.

Richter's scientific interests span a range of physics, including nuclear structure and reactions, atomic physics, accelerator physics, symmetries, invariance principles and nonlinear dynamics.

Merminga takes charge of accelerator division at TRIUMF

TRIUMF, Canada's national laboratory for particle and nuclear physics, has announced the appointment of Lia Merminga as the new head of its Accelerator Division. She moves to TRIUMF from Jefferson Lab, where she has been director of the Centre for Advanced Studies of Accelerators since May 2002.

Merminga, who has degrees from the University of Athens and the University of Michigan in Ann Arbor, is widely recognized for expertise in identifying problems and solutions associated with the push for higher-energy, higher-quality accelerator beams, and developing concepts for new accelerators. She has worked in advanced accelerator physics for 20 years, specializing in the physics and technology of energy-recovery linacs, high average power free-electron lasers, linac-ring colliders, multibunch instabilities in recirculating linacs, RF control and modelling, and nonlinear dynamics. She is internationally known for her contributions to the design of potential applications of energy-recovery linacs.

Lia Merminga (Courtesy Jefferson Lab.)

INAUGURATION

NTU launches a new centre for cosmology

The National Taiwan University (NTU) in Taipei has inaugurated the Leung Center for Cosmology and Particle Astrophysics (LeCosPA). The centre has been made possible through a donation of NT$205 million (around US$7 million) from Chee-Chun Leung, co-founder and vice president of the Taiwan-based company, Quanta Computers Inc.

Leung studied physics at NTU, together with Pisin Chen, the cosmologist who is the first director of LeCosPA and NTU C C Leung Prof. of Cosmology. Chen, formerly of the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) at Stanford University, has recently joined the faculty of NTU.

Leung became fascinated by high-energy physics and astrophysics when he was an undergraduate at NTU, but eventually entered the electronics industry. When his fellow student and friend Chen decided to join NTU to help promote cosmology and particle astrophysics, he resolved to provide the additional resources for Chen to realize his dream.

NTU has recently enjoyed an increasing number of major donations. At the inauguration, the president of NTU, Si-Chen Lee, stressed the uniqueness of Leung's donation, being the first for pure science. Moreover, the donation will be used mainly for the operation of LeCosPA rather than for its buildings.

Chee-Chun Leung and NTU president Si-Chen Lee sign the LeCosPA donation contract, with (from left to right) Yee Bob Hsiung (NTU physics department chair), Ming-Je Tang (NTU vice-president of finance), Mrs Leung, Tai-Jen George Chen (NTU academic vice-president), Pisin Chen (LeCosPA director) and Pauchy W-Y Hwang (chairman of ceremony) observing. (Courtesy Yu-Chung Chen.)

International experts in cosmology and particle astrophysics attended the inauguration ceremony. In addition to Leung and Lee, distinguished speakers at the ceremony included the president of the National Central University, Luo-Chuan Lee, the Pehong and Adele Chen Director of KPIAC, Roger Blandford, and Joseph Silk the Savilian Prof. of Astronomy at Oxford University.

At the inauguration, Chen recalled the time when he and Leung founded an astronomy society at NTU. They bought a piece of window glass from the nearby Kee-Lung harbour, which had became a centre for the disintegration of retired ocean liners, and ground it night and day to build Taiwan's first eight-inch telescope.

Now Chen has the opportunity to turn LeCosPA into an important active centre of cosmology and particle astrophysics. Blandford has already proposed that KIPAC and LeCosPA should develop special ties for collaboration.

● For more about LeCosPA see the web: http://lecospa.ntu.edu.tw.

MEETINGS

NNN08, the **2008 International Workshop on Next Generation Nucleon Decay and Neutrino Detectors**, will be held at Paris 7 University Denis Diderot campus on 11–13 September. Hosted by the AstroParticle and Cosmology Laboratory, it will be the eighth in a series of workshops to discuss future large underground detectors, as well as the theoretical work that motivates and describes such advances. New detectors will explore proton decay lifetimes and advance understanding of the neutrino sector, including

AWARDS

Art Poskanzer receives the Bonner prize from the APS

The Tom W Bonner prize is the only American award in experimental nuclear physics, and for the first time it has been given for work in relativistic nuclear collisions. Art Poskanzer received the prize at the April Meeting of the American Physical Society (APS) "in recognition of his pioneering role in the experimental studies of flow in relativistic heavy-ion collisions". In his acceptance talk, he stressed the important contributions of his colleagues, especially Sergei Voloshin of Wayne State University and Hans Georg Ritter of Lawrence Berkeley National Laboratory (LBNL).

Poskanzer, who is now a distinguished senior scientist emeritus at LBNL, was the first scientific director of the Berkeley Bevalac, the first relativistic nuclear accelerator. At the Bevalac he was co-discoverer of the collective flow of nuclear matter, the phenomenon in which nuclear matter, compressed to a state of high temperature and density, exhibits a fluidic motion.

Poskanzer also has connections with CERN, dating back to 1971 when he collaborated in a PS experiment with the Orsay group. He participated in work at ISOLDE, WA80, NA35 and NA49. He helped to initiate the heavy-ion programme at the SPS and was deputy spokesperson of NA49. He then became co-founder of the STAR collaboration at Brookhaven's Relativistic Heavy Ion Collider.

Art Poskanzer (left) receives the 2008 Tom W Bonner prize from Arthur Bienenstock, president of the American Physical Society. (Courtesy APS.)

Poskanzer's work on collective flow in NA49 led to similar work in the STAR experiment, where large elliptic flow has been found (*CERN Courier* March 2007 p35). Here the experimental observations have provided important evidence for the existence of strongly coupled quark–gluon plasma with the characteristics of a perfect liquid.

IUPAP recognizes young researchers in particle physics

The International Union of Pure and Applied Physics (IUPAP) has announced the award of its first Young Scientist Prizes in Particle Physics to Yasaman Farzan of the Institute for Research in Fundamental Sciences (IPM), Tehran, and Kai-Feng Chen of the National Taiwan University, Taipei. The prize was recently established by IUPAP to recognize the scientific achievements of outstanding young experimental and theoretical particle physicists.

Yasaman Farzan receives the prize for her highly regarded theoretical contributions to neutrino and lepton physics. She has made several innovative conjectures, including the measurement of CP violation in the lepton sector, the extraction of neutrino mixing parameters from high-energy neutrinos, and supernova cooling processes involving new, weakly interacting particles. Many of her predictions will be addressed by future experiments in neutrino and lepton physics.

Kai-Feng Chen has made creative and innovative contributions to the analysis of B-meson decays with the Belle experiment at KEK. Among them is the very important measurement of time-dependent CP violation in $b \rightarrow s$ transitions and polarization measurements in B-decays. His contributions resulted in highly cited publications of the Belle experiment. He has recently started work with CMS.

mass hierarchy, more oscillation parameters, CP violation, supernova dynamics and high-energy cosmic neutrino sources. For more information, see http://nnn08.in2p3.fr/.

The **Pixel 2008 Workshop** will take place at FermiLab in Batavia, Illinois, on 23–26 September. The event will cover pixel electronics and sensors, high-density detector processing and interconnect technologies, hybridization techniques, particle tracking and imaging applications. All sessions will be plenary and will consist of invited overview talks followed by shorter presentations. The workshop is open to anyone interested in pixel technology, but participation will be limited to 160 delegates. For further information, see http://conferences.fnal.gov/pixel2008 or contact Cynthia Sazama; fax +1 630 840 8589; e-mail sazama@fnal.gov.

LCWS08, the **2008 Linear Collider Workshop**, and **ILC08**, the **International Linear Collider Meeting**, will be held in Chicago on 16–20 November. Hosted by Argonne National Laboratory, Fermilab, Illinois Institute of Technology, Northern Illinois University, Northwestern University, University of Chicago, University of Illinois at Urbana Champaign and University of Illinois at Chicago (UIC), the meetings will be on the campus of UIC. The workshop will consist of plenary and parallel sessions for developing the physics case and reviewing detector and accelerator designs for an electron–positron linear collider. For more information, see http://linearcollider.org/lcws or e-mail: lcws08@uic.edu.

Arkani-Hamed receives the Sackler Prize

Tel Aviv University has announced that the 2008 Raymond and Beverly Sackler Prize in the Physical Sciences, this year awarded in the field of "Physics beyond the Standard Model in the LHC era", has been presented to Nima Arkani-Hamed of the Institute for Advanced Study, Princeton, New Jersey. He received it on 19 May during the annual session of Tel Aviv University's Board of Governors.

Arkani-Hamed has been rewarded "for his novel, deep and highly influential contributions to new paradigms for physics beyond the Standard Model at the TeV energy scale, especially the ideas of large extra dimensions and of the large hierarchy of strengths of fundamental forces in nature, including gravity; supersymmetry model-building; theories of flavour and neutrino masses; and models of the cosmological constant".

Nima Arkani-Hamed explores large extra dimensions and natural forces. (Courtesy Tel Aviv University.)

Friedrich-Wilhelm Büßer, chair of the Association of the Friends and Sponsors of DESY, congratulates Niklaus Berger (right) on the PhD thesis award. (Courtesy DESY.)

DESY prize for track trigger work

The 2008 PhD thesis prize of the Association of the Friends and Sponsors of DESY has been awarded to Niklaus Berger from the Swiss Federal Institute of Technology Zurich.

He received the prize for his thesis, entitled "Measurement of Diffractive Φ Meson Production at HERA with the H1 Fast Track Trigger". In his work, Berger measured the cross section for the diffractive photoproduction of Φ mesons at HERA with the H1 detector. He contributed substantially to the set-up, programming and commissioning of the new fast track-trigger, which carried out a quick and precise track reconstruction online. This annual PhD thesis prize acknowledges the best doctoral thesis on DESY physics every year.

CORRECTION

An extra letter unfortunately found its way in to the name Shirkov in the headline of the article to celebrate the 80th birthday of Dmitri Shirkov on p27 of the May issue. Many apologies to all concerned.

CENTENARY

Artem Alikhanian: the father of Armenian physics

Artem Alikhanian was born 100 years ago on 24 June 1908. With Piotr Kapitsa, Lev Landau, Igor Kurchatov, Abraham Alikhanov (Artem's elder brother) and others, he laid the foundations of nuclear physics in the USSR. His role as a founder of a large-scale physics research centre in Armenia – the Yerevan Physics Institute – is especially notable.

Alikhanian's research focused mainly on nuclear physics, cosmic rays and elementary particle physics, accelerator physics and technology. In 1934, with Alikhanov and Michael Kozodaev, he discovered the production of electron–positron pairs by internal energy conversion. Then in 1936, with Alikhanov and Lev Artsimovich, he experimentally confirmed energy conservation in positron annihilation. Together with Alikhanov, he conducted precision measurements on the beta spectra of a large number of radioactive elements and discovered the dependence of spectral shape on the atomic number. He also proposed the experimental method to prove the existence of neutrinos through nuclear recoil in electron capture in ^{7}Be.

In 1942 Alikhanian and his co-workers began their well known research on cosmic rays on mount Aragats near Yerevan. They discovered streams of fast protons in the cosmic rays; the intense production of protons by fast neutrons; a new type of shower (the so-called narrow shower); and the first hints of particles with masses ranging between those of the muon and the proton. Alikhanian also made significant contributions to the development of methods for the detection of high-energy particles, in particular the Alikhanian–Alikhanov mass spectrometer, wide-gap spark chambers, and X-ray transition radiation detectors.

As one of the founders and the first director of the Yerevan Physics Institute, Alikhanian led the development and construction of the 6 GeV Yerevan electron synchrotron. He also promoted the training of young physicists and from 1961 to 1975 organized the International Schools of High Energy Physics at Nor-Amberd, of which he was director. A staunch supporter of the international co-operation of scientists, his fidelity to science, his personality, and his great erudition captivated everyone.

Artem Alikhanian, 1908–1978. (Courtesy Yerevan Physics Institute.)

LEARNED SOCIETIES

Sissakian elected academician, Foster FRS

Academician Alexei Sissakian (left) and Brian Foster FRS. (Courtesy JINR and J Liebeck.)

At its meeting in Moscow on 26 May – 2 June, the General Assembly of the Russian Academy of Sciences (RAS) elected Alexei Sissakian, director of JINR, as RAS full member (academician) and member of the RAS Presidium. This followed soon after Brian Foster, European regional director for the International Linear Collider (ILC) and head of particle physics at Oxford University, was elected Fellow of the Royal Society (FRS) in the UK.

Sissakian started his scientific career in 1968 at the Bogoliubov Laboratory of Theoretical Physics of JINR, and he became JINR vice-director in 1989. He has been director since 2006. Under his direct leadership for the past decade, JINR has implemented the research programme for the Nuclotron Accelerator Complex, including activities in the design and development of the Nuclotron-based Ion Collider Facility to collide heavy-ions at high energies. In addition to his many scientific accomplishments, Sissakian has contributed much to the development of JINR as an open international scientific centre, co-operating with other national and world scientific centres, in particular CERN.

Meanwhile, Brian Foster has been elected FRS on the basis of his leadership in the development of particle accelerators and detectors. Before becoming part of the core management for the ILC Global Design Effort, he was spokesman of the ZEUS experiment at DESY and chairman of the European Committee for Future Accelerators. The Royal Society recognizes Foster's role as an "international leader in the development of accelerators, instrumentation and physics analysis of electron–positron and electron–proton colliders", and it stresses that his "vision of a strong UK contribution to this effort and to accelerator science is reflected in his founding the Adams Institute for Accelerator Science in Oxford and Royal Holloway University of London, of which he was the first director."

NEW PRODUCTS

OBITUARIES

Frank Krienen 1917–2008

Frank Krienen, one of the pioneers of CERN, was killed in a tragic road traffic accident in Amsterdam on 20 March.

Frank was one of the first recruits for CERN's 600 MeV Synchrocyclotron, in 1952. He became a respected and inspiring leader throughout the construction period of the accelerator and, at the same time, an older brother and an exacting mentor. He later devoted himself to developing particle detectors, in particular spark wire chambers using different types of readout.

His next major involvement at CERN was his contribution to the last g-2 experiment at CERN in 1969–1977, which was based on many innovative solutions. In particular he was in charge of the construction and operation of the electric quadrupoles necessary to provide the vertical focusing of the muon beam in the storage ring. His colleagues working on g-2 appreciated not only his technical competence but also his originality in proposing new solutions, and his strong personality. He was a great friend.

The cooling of antiprotons using an intense electron beam à la Budker was his next project. Although not used in the first version of the antiproton source at CERN, this was later incorporated in the low energy antiproton ring.

The later stages in his long and fruitful career, after leaving CERN, took him to Stanford and Brookhaven, where he continued his involvement in the latest g-2 programme. Frank made an important contribution to the design of the inflector that proved to be a real breakthrough in the experiment.

After being based first in California and then in New England, Frank lived for years in Florida, from where he travelled regularly to follow his many scientific and personal interests. He was a regular visitor to Europe and to CERN, and was always welcomed by his colleagues.

Gifted with a curious, inquisitive mind, Frank had an excellent training both in physics and in engineering. He remained active to the last, well beyond his 90th birthday. His many friends remember him, thankful for having been close to such an exceptional person and our thoughts are with Anneke, his wife, and Fenna and Frankie, his two children.

His friends at CERN. For more about Frank's contributions to particle physics, see p25.

Hugh Bradner 1915–2008

Particle physicist turned oceanographer Hugh Bradner passed away on 5 May aged 92.

After receiving his PhD from Caltech in 1941, Bradner was recruited by Robert Oppenheimer to join the Manhattan Project, where he worked on a variety of activities, including developing instrumentation to study high explosives and planning the nascent laboratory and town of Los Alamos.

After the war, Bradner moved to the Lawrence Berkeley Laboratory and UC Berkeley, where he developed instrumentation used in atomic tests. He also took up high-energy physics, using photographic emulsion to study particle production at the 184-inch cyclotron. Among other things, he measured the cross-section for pion interactions in emulsion, establishing that they interacted strongly. He also worked on a device to analyse bubble chamber photographs and performed some of the first experiments with polarized proton beams, studying the scattering of 285 MeV polarized protons in different targets.

Hugh Bradner, (Courtesy Scripps Institute of Oceanography.)

In the early 1950s, Bradner developed instrumentation for Operation Greenhouse atomic tests in the Marshall Islands. Installation required some underwater diving, and this stimulated an interest in diving equipment. Although the aqualung had simplified underwater work, ocean diving was still a very cold activity. Bradner experimented with neoprene, a synthetic rubber, and discovered that it would hold water well; this water would gradually warm up to body temperature. By 1954, he and his colleagues were marketing the EDCO Sub-Mariner suit, which was designed to keep divers warm. Although there is still considerable dispute about who invented the wetsuit first, it seems indisputable that Bradner was the first to develop it for underwater diving.

On the basis of this experience, in 1960 Bradner was recruited to the Scripps Institute of Oceanography in San Diego. There, he put his high-energy physics experience to work, developing a variety of instrumentation. Among other things, he worked on using seismographs to detect earthquakes caused by nuclear tests, but did not abandon particle physics. One article that he wrote in 1964 was on the generation of heat by neutrino interactions in the Earth. He later became a member of the DUMAND and NESTOR collaborations.

Although Bradner formally retired in 1980, he remained active in a variety of pursuits.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel +44 (0)117 930 1027 Fax +44 (0)117 930 1178 E-mail sales@cerncourier.com
Please contact us for information about rates, colour options, publication dates and deadlines.

LIP

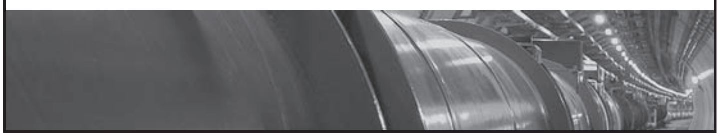
Laboratório de Instrumentação e Física Experimental de Partículas

LIP Lisbon opens 5-year research positions for experimental particle physicists, GRID Computing and Medical Physics. Applicants with a solid CV and at least three years experience after their PhD will be considered. These positions may be converted into staff positions at the end of the first three years.

The present activities of LIP-Lisbon cover the participation in experiments and R&D at CERN (ATLAS, CMS, COMPASS) and in astroparticle experiments (AUGER, GAW, SNO/SNO+).
For details, see **http://www.lip.pt**

Until the 31st August 2008, candidates should send their CVs and letters of reference to the
LIP Directorate, Av. Elias Garcia,
14 – 1, P-1000-149 Lisboa, Portugal.

Further information can be requested from Sandra Dias
sandra@lip.pt.



UNIVERSITY OF CALIFORNIA IRVINE POSTDOCTORAL POSITION IN EXPERIMENTAL PARTICLE PHYSICS

The experimental particle physics group at the University of California, Irvine has one or more postdoctoral positions available immediately in each of three groups. One position is with the group of W. Molzon participating in the MEG $\mu \to e\gamma$ search experiment at the Paul Scherrer Institut and possibly in a new experiment at Fermilab based on the MECO muon to electron conversion proposal. A second is with the group of A. Lankford, A. Taffard, and D. Whiteson working on the ATLAS experiment with focus on physics analysis and commissioning of the muon cathode strip chamber system or high level trigger. A third is with the UCI group led by H. Sobel and D. Casper, with work on the T2K, Super-Kamiokande and Minerva experiments. All positions allow the possibility of being based in part at the experiment. A PhD in experimental physics is required. Candidates should address inquiries to hep-postdoc@uci.edu and send an application, CV, and arrange for letters of recommendation submitted to **http://www.physics.uci.edu/UCI-Particle-Postdoc.html**. *UCI is an equal opportunity employer committed to excellence through diversity.*

MC PAD

FP7 Marie Curie Initial Training Network on Particle Detectors

MARIE CURIE ACTIONS

The MC-PAD training network comprises 14 partners, including 3 industrial, from 9 European countries. It provides excellent training opportunities to young researchers in the field of radiation detectors for the next generation of particle physics experiments and applications in related fields.

The project is being coordinated by CERN.

We are looking for young experimental physicists and electronics engineers, ready to participate in research training as

Early-Stage Researchers (3-year positions)

The research work may lead to the award of a PhD.

Experienced Researchers (2-year positions)

Experienced researchers should have a PhD.

In total, 22 positions are available. Contracts awarded in the first round of recruitment are scheduled to start on 1 November 2008; the application deadline is 31 August 2008.

For full information about MC-PAD, the posts and the application procedure, see http://cern.ch/mc-pad

MC-PAD: CERN (CH) - DESY (D) - GSI (D) - INFN-Frascati (I) - U Hamburg (DE) - AGH-UST Krakow (PL) - JSI Ljubljana (SLO) - NIKHEF (NL) - PSI (CH). Associated partners: NIMP Bucharest (RO) – IFJ PAN Krakow (PL) - Photonis SAS (F) - Micron Ltd. (UK) - Evatronix (PL).

TECHNISCHE UNIVERSITÄT DRESDEN

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

At the **Faculty of Science** in the **Institute for Nuclear and Particle Physics** we have an opening for a

Postdoctoral Fellow for Experimental Particle Physics (E 13 TV-L)

on a fixed-term position for an initial period of two years. The contract may be extended by a second period until 30. 6. 2012. The period of employment is governed by the Fixed Term Research Contracts Act (Wissenschaftszeitvertragsgesetz - WissZeitVG).
Duties: playing a leading rôle in the analysis efforts and detector development activities of the local ATLAS group. The current research activities of our group comprise data analysis and tool development for the search for Higgs Bosons beyond the Standard Model as well as commissioning of the ATLAS Liquid Argon Calorimeter. An active participation in the planned research and development of fast readout electronics for the Liquid Argon calorimeters at the upgraded sLHC and for the forward calorimeters at the International Linear Collider ILC is desired. The post is supported within the Helmholtz-Alliance "Physics at the Terascale" – a research network supported by the Helmholtz Association and comprises the research centres DESY and FZ Karlsruhe, 17 German Universities, and the Max-Planck-Institute for Physics (http://www.terascale.de). Participation in project-oriented teaching is possible.
Qualification: Ph.D. in Experimental High Energy Physics or equivalent experience, great potential for outstanding achievements as an independent researcher and experience within the above-mentioned activities.

Applications from women are particularly welcome. The same applies to disabled people.
Please submit your application by **August 1, 2008** (Deadlines refer to the date on the postmark of the University's Post Room Service) including your CV, summary of research interests, list of publications with own contributions, a copy of the certificate of your highest academic degree and three names of referees to **TU Dresden, Fakultät Mathematik und Naturwissenschaften, Fachrichtung Physik, Institut für Kern- und Teilchenphysik, Herrn Jun. Prof. Dr. A. Straessner, 01062 Dresden**, Germany or to straessner@physik.tu-dresden.de, (Please note: We are currently not able to receive electronically signed and encrypted data).

cerncourier.com

Foundation for Fundamental Research on Matter

The Foundation for Fundamental Research on Matter (FOM) promotes, co-ordinates and finances fundamental research of international standard/calibre in The Netherlands. It is an autonomous foundation responsible to the physics division of the national research council NWO. FOM employs about 900 people, primarily scientists (including PhD students) and technicians, who work at FOM research institutes and research groups at universities. FOM is chiefly financed by the NWO (Netherlands Organisation for Scientific Research) Governing Board and NWO Physics and can be considered as the Physics Division of NWO. In addition to the government funds of NWO, FOM acquires financial means from the European Union and through collaboration with the industry and universities. For additional information see www.fom.nl.

FOM

Nikhef is the national institute for subatomic physics in the Netherlands with ca. 250 employees of which about 120 are physicists. It is a collaboration of four universities and the funding agency FOM. The institute coordinates and supports major activities in experimental subatomic physics in the Netherlands such as the preparation of experiments at the LHC at CERN, notably ATLAS, LHCb and ALICE. The scientific programme also includes several astroparticle physics projects, in particular participation in the ANTARES neutrino telescope, the AUGER cosmic-ray observatory and the VIRGO gravitational-wave interferometer.

Within the Physics Data Processing group, Nikhef pursues a programme on Grid computing. The primary focus of this programme is to provide the best possible computing (software and hardware) infrastructure for high-energy physics. The group consists of nine full-time and a similar number of part-time staff. Together with the Dutch national computing center SARA, Nikhef houses and operates one of the Tier-1 centers for the LHC Computing Grid. This center is part of the Dutch "BiG Grid" e-science infrastructure, a 30 M€ project with Nikhef as one of the three core partners. The PDP group contains also two R&D components: grid-computing techniques for data-intensive sciences (also non-HEP) and design and engineering of security-related grid software and policy infrastructures. Nikhef has a tenure-track position for an

experimental physicist

with substantial expertise and experience in data-intensive computing. The candidate will pursue a programme within the general R&D areas described above, as well as participate in our current programmes, and play an active role in our external collaborations.

The successful candidate must possess a track record reflecting the desired expertise and experience, and should also be a skilled communicator, excelling at presentation, negotiation, and document construction. He or she should be a team player, capable of motivating and inspiring colleagues and collaborators, and possess the skills to attract new funding.

The candidate must have at least postdoctoral-level experience; experience with high-energy physics is preferred. Interest, affinity and especially active experience with other data-intensive sciences is also advantageous. Nikhef offers the successful candidate a stimulating work environment in a world-class grid computing group at the frontiers of science.

Information

Information about the scientific and educational activities at Nikhef can be found at the web site www.nikhef.nl. For questions specific to this position, please contact the leader of our Grid programme, dr. J.A. Templon, either by phone +31 20 5922092 or by e-mail: templon@Nikhef.nl.

Job interviews are foreseen in the period August 25th. 2008 until September 6th 2008.

Applications

Candidates are invited to send their application, including curriculum vitae, list of publications as well as three letters of reference before August 16th, 2008 to: Nikhef, att. Mr. T. van Egdom, P.O. Box 41882, NL-1009 DB Amsterdam or by email: teus.van.egdom@Nikhef.nl.

Please quote vacancy: PZ-080160.

All qualified individuals are encouraged to apply.

NIKHEF

We are one of the largest interdisciplinary research centres in Europe and are a member of the Hermann von Helmholtz Association of National Research Centres. We work in the fields of "Health", "Energy and the Environment," and "Information Technology". To support these research activities, we have top-class supercomputers at our disposal.

For our Institute of Nuclear Physics (IKP) we are seeking a

MASTER OF PHYSICS (PhD)

– ref. 112/2008 –

The Nuclear Physics Institute (IKP-1) has taken a lead role in the development of the PANDA experiment, which is one of the key experiments of the new research facility FAIR in Darmstadt. The task of the PANDA experiment is to investigate of the strong interaction in the transition region between perturbative and non-perturbative QCD. The main focus lies on the physics with of hadrons charm quarks.
Together with other members of the PANDA collaboration the IKP-1 is in charge for the development of the central tracker based on straw tubes, the development and production of the Micro-Vertex-Detector (MVD) as well as the development of the beam and target pipe in the interaction region.
The design and development of the Micro-Vertex-Detector is technollogically one of the most challenging tasks, because the MVD has to cope with very high spatial resolution, extreme data rates and very stringent requirements on the maximum radiation length.

The position offers you:

The main tasks in this position are the development, tests and production of the readout electronics of the MVD. The analysis of the detector design to optimize the resolution and the radiation length, and development of the analysis software of the sub detector within the existing PANDARoot software framework are also aspects of this position. In addition, you will consult the international PANDA collaboration with your leading role in the development of the readout electronics and intensify the scientific cooperations.

Qualifications required:

You have completed your PhD in physics preferably in the field of experimental nuclear or particle physics. You are experienced in the development of complex experimental setups including readout electronics.

Candidates should preferably have:

Experience with experimental nuclear or particle physics in particular with hybrid silicon pixel detectors, complex readout systems and the computer languages C++ and VHDL as well as the analysis software ROOT.

The position is initially for a fixed term of three years.

The implementation of equal opportunities is a cornerstone of our staff policy at Forschungszentrum Jülich; for this we have received the „TOTAL E-QUALITY" Award. Applications from women are therefore particularly welcome. We also welcome applications from disabled persons.

Salary and social benefits will conform to the provisions of the Collective Agreement for the German Civil Service (TVöD).

Please submit your application with the reference number given above to:

Forschungszentrum Jülich GmbH
Geschäftsbereich Personal
– Personalentwicklung –
52425 Jülich
Germany
Tel. +49 2461 61-2110

Further information at:
www.fz-juelich.de

JÜLICH
FORSCHUNGSZENTRUM

FAIR

Facility for Antiproton and Ion Research Darmstadt, Germany

The international research laboratory FAIR (Facility for Antiproton and Ion Research) with its accelerator and experimental complex to be built in Darmstadt, Germany, will open up new horizons for research into the structure of matter, especially including hadron, nuclear, atomic, and plasma physics. The FAIR project will involve scientific and technical cooperation of presently fourteen countries. Its construction, with a total cost of € 1.2 billion, will be carried out by a limited liability company, FAIR GmbH. The project was started in 2008 and is expected to be completed by 2015. When completed, FAIR will provide the European science communities dealing with accelerator based physics with a world wide competitive and in many aspects superior facility.

At present, the FAIR project is represented by the FAIR International Steering Committee (ISC) with delegates from all States having signed the memorandum of understanding. In this capacity, the FAIR ISC is inviting applications for the appointment of the position of the

FAIR Scientific Director

The FAIR GmbH is now being established with the FAIR Member States acting as its shareholders. It will be located on the premises of GSI, Darmstadt, the German Helmholtz center for ion research, thereby using the existing GSI accelerator complex, its infrastructure, and expertise for the FAIR project.

The FAIR Scientific Director is the Chief Executive Officer of the FAIR GmbH and, together with the FAIR Administrative Director, its legal representative. He/she reports to the FAIR Council as the governing body of the future FAIR GmbH.

The Scientific Director's responsibilities will involve the coordination and supervision of the construction of the facility, and implementation of the approved scientific programme at FAIR, as well as the development of its long-term strategic options. Candidates therefore are expected to have outstanding expertise in leading positions in international projects of research in the above-mentioned fields, as well as in science and laboratory management. The position will be appointed for a five-years term of office starting on January 1, 2009.

Applicants are requested to address a letter of interest, with a complete resume, to the
Chairperson of the Search Committee,
Dr. Jacek T. Gierliński,
and send it by surface mail or email to
c/o Dr. Beatrix Vierkorn-Rudolph, BMBF, Directorate 71:
Large Facilities, Energy, Basic Research,
Heinemannstr. 2, 53175 Bonn, Germany,

Beatrix.Vierkorn-Rudolph@bmbf.bund.de
with the annotation "Confidential" **before August 31, 2008**.

www.fair-center.org

Ruhr-Universität Bochum

The **Faculty for Physics and Astronomy** invites applications for a

Full Professor (W3-Chair) position for theoretical physics in the field of hadron and particle physics

(successor to Prof. Goeke)

We are looking for an outstanding physicist in the field of theoretical hadron and particle physics to complement the local theoretical and experimental activities. The new chaired professor will find an excellent research environment with the institute infrastructure of a large internationally recognized chair.

The successful applicant is expected to demonstrate a strong commitment to excellence in teaching physics on all levels, managerial and leadership skills, and willingness to participate in the self-administration of the University.

Applicants are expected to have a Ph.D. in physics and the "Habilitation" or an equivalent scientific qualification. Candidates at the level of Assistant Professor ("Juniorprofessor") will also be considered.

The Ruhr-University Bochum wishes to increase the proportion of female faculty in physics and therefore welcomes especially applications from qualified women. Handicapped persons with the same qualifications will be given preference.

Qualified candidates are invited to submit an application including C.V., publication list, list of teaching and research activities and copies of degree certificates by September 30, 2008 to **Dekan der Fakultät für Physik und Astronomie der Ruhr-Universität Bochum, D-44780 Bochum, Germany**.

NSCL at MICHIGAN STATE UNIVERSITY

Advancing Knowledge. Transforming Lives.

Physicist position in Superconducting Radio Frequency (SRF)

National Superconducting Cyclotron Laboratory (NSCL) is searching for a physicist with experience and interest in Superconducting Radio Frequency (SRF). The position can be filled in the Continuing Appointment system at NSCL or in the NSCL Faculty system. A strong scientific and technical background with organizational skills is desired.

NSCL is building a superconducting linac to re-accelerate radioactive ions. A vigorous research program is in place including electromagnetic and mechanical cavity design, cavity fabrication and testing, and cryomodule fabrication. We are also involved in Nb material research in collaborations with the School of Engineering as well as cavity design and fabrication techniques with other major National Laboratories. The SRF group consists of physicists, engineers, technicians and graduate students.

Application information available at

http://www.nscl.msu.edu/ourlab/employment.

MSU is committed to achieving excellence through cultural diversity. The university actively encourages applications and/or nominations of women, persons of color, veterans and person with disabilities.

MSU is an affirmative action, equal opportunity employer.

Laurentian University
Université Laurentienne

Postdoctoral Research Positions at SNOLAB for the SNO+ and DEAP Experiments

Three Postdoctoral Research positions are available in the experimental particle astrophysics group at Laurentian University, for two experiments under development at SNOLAB in Sudbury, Ontario, Canada. SNOLAB is Canada's new state-of-the-art international facility for particle astrophysics and an expansion of the highly successful Sudbury Neutrino Observatory (SNO), located two kilometers underground at Vale Inco's Creighton Mine. For information on the laboratory and the experimental program please see **www.snolab.ca.**

The SNO+ experiment will refill the SNO detector with a custom liquid scintillator to extend SNO's solar neutrino measurements to lower energies as well as to study geo-neutrinos and reactor neutrinos. It also plans to load the scintillator with Neodymium to search for neutrino-less double beta decay with high sensitivity. Two postdoctoral associates would lead research in the SNO+ topics planned at the SNOLAB site and at Laurentian University. These include the establishing of purification and radio-assay techniques for the SNO+ metal-loaded liquid scintillator, and the study of detector backgrounds. Other topics include developing the SNO+ supernova neutrino burst trigger, Monte Carlo modeling, and other DAQ and data analysis tools.

The third postdoctoral associate will participate in the DEAP/CLEAN experimental program which uses single-phase liquid-argon as the detecting medium to search for WIMP dark matter. The collaboration is developing detectors at several mass scales including DEAP-1, a 7kg detector, MiniCLEAN a 360 kg detector and DEAP/CLEAN a 3600 kg detector. DEAP-1 is currently operating underground at SNOLAB while MiniCLEAN and DEAP/CLEAN are proposed to be installed at SNOLAB in 2009 and 2010 respectively. The successful candidate will take a lead role in the operation and analysis of data from DEAP-1 and will participate in the development of DEAP/CLEAN including the implementation of the calibration systems.

We seek applicants with a PhD in experimental particle astrophysics, nuclear or particle physics or a closely related field. The candidates should have demonstrated ability to lead efforts in hardware development and data analysis. These positions are based at the SNOLAB site in Sudbury and administered through Laurentian University. The initial appointments will be for two years. Salary will be commensurate with qualifications and experience. Applicants should send a detailed CV and a statement of research interests, as well as arranging for three letters of reference to be forwarded to (please include the reference "SNO+/DEAP application"):

Ms. Shari Moss, SNOLAB Project Office, P.O. Box 159,
Lively ON Canada P3Y 1M3
or by e-mail to **jobs@snolab.ca**

A review of applications will begin on July 27, 2008, but applications will be accepted until the positions are filled. We thank all who express interests in these positions and advise that only those selected for an interview will be contacted. For further information contact **Dr. Clarence Virtue (cjv@snolab.ca)**.

Laurentian University is committed to equity in employment and encourages applications from all qualified applicants including women, aboriginal peoples, members of visible minorities and persons with disabilities.

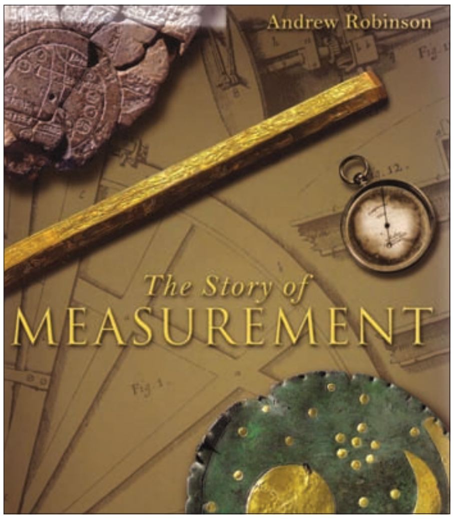
ADVERTISER'S INDEX

This index is provided as a service and, while every effort is made to ensure its accuracy, *CERN Courier* accepts no liability for error.

BOOKSHELF

Summer Bookshelf

This year many of the world's particle physicists will be spending the summer months hard at work on preparations for the LHC's first collisions. Undoubtedly there will be little time for holidays, but to provide some ideas for more relaxed reading, this Bookshelf reviews a selection of books away from mainstream particle physics.



The story of measurement by Andrew Robinson, Thames & Hudson. Hardback ISBN 9780500513675, £13.97 ($25.51).

Try to imagine civilization without measurement. In addition to length, weight, height, or any of the other obvious scalar quantities that we use in our daily lives, time and language also require standards to make sense. Current quantification includes concepts inconceivable to the earliest humans – gigabytes, body-mass index, radioactivity, and even beam intensity ... Without accurate measurements our society would become chaos. On the other hand, some measurements are far from accurate, but still give a very clear idea of the described quantity: "a scourge of mosquitoes", "a run of salmon," or "a handful of children" are all something we can easily visualize.

The story of measurement by Andrew Robinson, former literary editor of *The Times Higher Education Supplement* and the author of the bestselling *The Story of Writing*, consists of a series of chapters that can be read independently; it can also be read from cover to cover. However, by simply leaving the book on your coffee table you can enjoy it in silent moments in small doses every evening – and, I'm willing to wager, most of your guests will do the same, as they wait while coffee is being brewed.

Most people, perhaps with the exception of particle physicists who are used to aiming for "5σ detection" while doing their measurements, do not necessarily think about how measurements are going to be interpreted. Or maybe more subtle: who else is clear as to what accuracy means versus precision and error versus uncertainty? One chapter has been devoted to this interesting issue, and having originally trained as a survey engineer, this discussion brings back a lot of good memories for me.

The book has received mixed reviews, but it is not obvious which scale has been used for measuring the quality – after all it remains a coffee-table book and should be judged as such. I found it entertaining. Its potential popularity is also well reflected in that it exists in several language editions. *Das Abenteuer der Vermessung* and *La storia della misurazione* are already available in the bookshops. Read it yourself and make your own judgment, while, of course, applying all the rules that have to be taken into account for making a good measurement.

Jens Vigen, CERN.

Il fisico che visse due volte by Fabio Toscano, Sironi Editore. Paperback ISBN 9788851800963, €18.

Il fisico che visse due volte – the physicist who lived twice – is Lev Davidovich Landau, the iconoclastic physicist and 1962 Nobel Laureate. One of the greatest theorists of the Soviet Union, he made significant contributions to almost all fields in physics, from superfluidity to the properties of ferromagnetic bodies, from the absorption of sound in solids to the theory of phase transitions. This biography by Fabio Toscano, an Italian theorist with a broad experience in communicating science, nicely guides the reader through all aspects of this rich scientific production, never neglecting to present it primarily as a human adventure.

The main focus, as I expected, is on Landau's attitude to physicists and people in general, and thanks to this book I discovered his rather peculiar personality. Unpleasant to most of the people with whom he interacted, he was loved by some of his colleagues and friends who had a great admiration for his broad knowledge and his courage always to say what he thought, regardless of constraints from politics, society or academic authority. His straight-talking attitude caused serious problems to both his career and his private life (he spent one year in prison) at a time when the Soviet Union was under Stalin's dictatorship.

In addition to his written contributions and original articles, one of Landau's main legacies for Russian science is the "Landau school". To be admitted to the school, students had to pass a comprehensive exam, the "Theoretical Minimum", designed personally by Landau. As Toscano explains, Landau kept personal contact with all his students until he died in 1968, six years after a car accident that brought him close to death. In the accident "not even the eggs Vera [the driver's wife] had in her hands broke", but Landau's brain suffered from serious injuries that left him in a coma for three months. He never fully recovered, and was afterwards much less creative.

This book certainly shows Landau with all his humanity, even emphasizing some of the scientific traps into which he fell. However, the details about Russia's history and social situation that the author likes so much sometimes make the reading hard and the focus too distant. When "stuck" in such pages, I was eager to come back to Landau's real life in Moscow or Baku or Karkhov and

follow him, for example in meeting Bohr and quantum mechanics. Having studied some of the volumes of the *Course of Theoretical Physics* that Landau wrote with Evgeny Lifshitz and other colleagues, I appreciated this biography. Toscano's account is very accurate – even scientific – and describes well Landau's personality, the *raison-d'être* of the book.
Antonella Del Rosso, CERN.

Nets, Puzzles and Postmen, an exploration of mathematical connections, by Peter M Higgins, Oxford University Press. Hardback ISBN 97801992184214, £15.99 ($29.95).

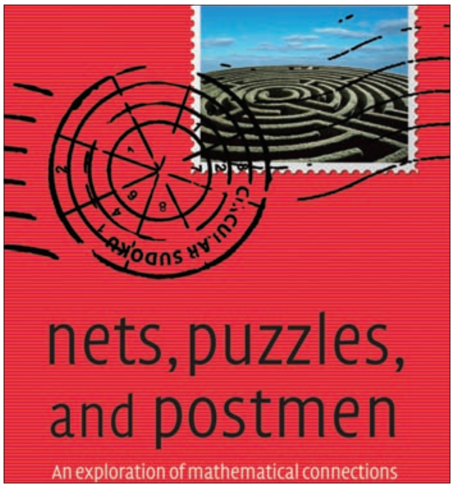
This book, written in "accessible" language, is not an easy read. The author, inventor of Circular Sudoku, purports that the first 200 pages are for readers who have no "familiarity with mathematical ideas and notation" (let's call one of them Hilary), followed by 40 pages for connoisseurs.

Well, Hilary had better be a fast learner. After an introduction to the basic properties of networks, namely nodes and edges, by page seven there are already paths, walks, cycles, circuits, multiple edges, isolated nodes, and more besides. Hilary has no idea why, whether or how much of this has to be absorbed, nor how to fast-forward safely. And so it is throughout the book.

The real show stopper comes on page 150. "One of the greatest unsolved problems in all of mathematics is whether or not P = NP. Some say yes, some no, some say they have no idea (Hilary is probably one of these), while still others suspect that the question can never be answered at all". Gosh! After two pages of suspense Hilary is told that P is a class of algorithms operating in polynomial time and two more pages pass before is it revealed that NP does not, as you might expect, mean Not Polynomial but Nondeterministic Polynomial. Oh dear! Is our novice supposed to be familiar with this MIT Clay Institute Millennium Problem carrying its million-dollar prize? I wasn't. Should I really be reviewing this book?

The book flips between "he" and "she", randomly attributing gender to the reader. Or is it random? I began to wonder why the reader, female several pages ago, is now male? This irritating and distracting political correctness is almost always avoidable. What gender is Hilary?

Having said all of that, the book treats a fascinating variety of puzzles and



applications: museum guards, automata, cryptography, instant insanity cubes, one-way traffic systems, dancing partners, critical paths, and more. It is an excellent introductory textbook for would-be pure(ish) mathematicians. I wish it had been available when I was contemplating my choice of career. I shall enjoy it much more the second time around – the book, that is.
Peggie Rimmer, Satigny.

ATLAS : Le nouveau défi des particules élémentaires par François Vannucci, Éditions Ellipses. Broché ISBN 9782729834432, €7.50.

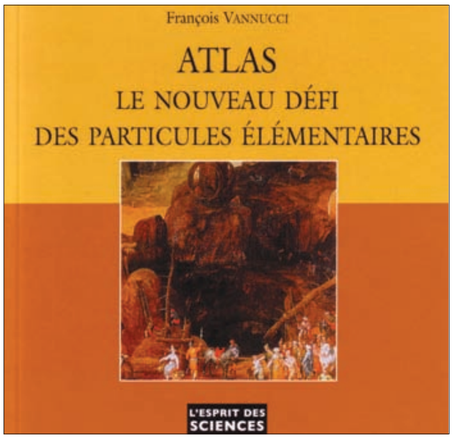
Ce livre se présente délibérément comme un ouvrage de vulgarisation. Il incarne effectivement un effort réel pour présenter au non-initié une des expériences du LHC, ATLAS. Tout son intérêt est de replacer l'expérience dans plusieurs perspectives, pour certaines assez inhabituelles. Perspective historique, scientifique, mais aussi économique, politique et humaine surtout. ATLAS est notamment présenté comme un outil, certes colossal, unique au monde, mais qui reste une étape dans la quête de connaissance de l'Homme.

La première partie permet d'embrasser le projet ATLAS dans sa globalité tout en portant un regard original sur lui. L'auteur file une métaphore assez savante tout au long de sa description. Il compare les physiciens travaillant dans la caverne d'ATLAS aux hommes du mythe de la caverne de Platon. Cachés au fond de celle-ci, ils sont aveugles ou presque à la lumière de la connaissance, et ne perçoivent que les ombres de la réalité, ombres qui constituent néanmoins toute leur réalité, puisqu'ils n'en connaissent pas d'autre! Métaphore savante et habile, qui rejoint élégamment une des tensions propres à la physique des particules; comment, en construisant des machines et en analysant ses résultats avec des programmes élaborés pour trouver un objet attendu, peut-on s'attendre à découvrir quelque chose d'inconnu?

Les analogies sont nombreuses, tant pour parler de la machine elle-même que des physiciens, qui sont par exemple comparés aux compagnons des chantiers de construction des cathédrales médiévales. Des citations de philosophes et d'écrivains, Pascal, Rabelais, Thomas Mann, Céline..., ponctuent régulièrement les propos de François Vannucci et donnent à la physique un éclairage inhabituel. Ces ouvertures vers la philosophie, l'histoire et la littérature sont autant d'appréciables confrontations de la physique avec d'autres sciences, humaines cette fois-ci!

Autre intérêt pour le novice: la collaboration est présentée de l'intérieur, anecdotes à la clef. Elles rendent la physique des particules plus vivante, plus humaine, plus amusante. L'auteur nous donne l'impression d'être dans le secret d'ATLAS, avec entre autres l'évocation du colloque de Stockholm, primordial dans l'histoire d'ATLAS, raconté par le menu. Il évoque aussi la culture de la démocratie présente dans la collaboration.

Si la première partie est très accessible au non-physicien, la deuxième l'est moins. Du point de vue de la vulgarisation, il est dommage que l'effort mené s'essouffle quelque peu dans l'explication de la physique du LHC. On regrette également le peu d'illustration et de schémas qui auraient pu venir en renfort. La richesse de l'écriture



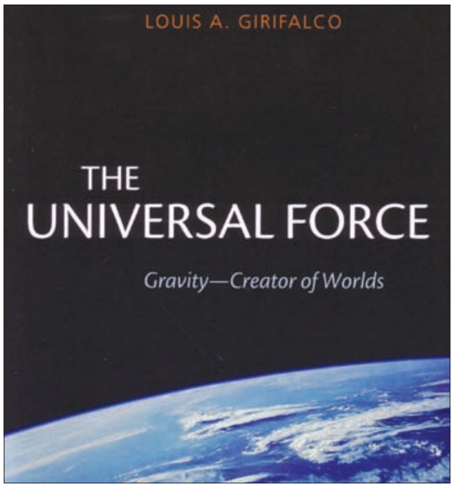
permet quoi qu'il en soit de se frotter au monde de la physique même si un bon niveau de culture générale est requis pour se sentir à l'aise avec ces jeux intellectuels.

Enfin, l'effort de recul de l'auteur sur ATLAS est appréciable, même s'il ne parle en son propre nom qu'une seule fois à la fin de l'ouvrage, dans une conclusion brillante où l'on comprend indirectement pourquoi une expérience de physique peut évoquer la Tour de Babel (d'ailleurs en couverture) de par sa complexité, les multitudes de compétences nécessaires, la nécessité de trouver un langage commun pour tenter, en construisant un édifice unique et immense, d'approcher les secrets de la création de l'Univers. Pourtant là où la Tour de Babel symbolise l'échec, la prétention et la désorganisation humaines, l'expérience ATLAS et celles du LHC en général peuvent et doivent faire mentir cette vision en montrant ce dont l'humanité est parfois capable.
Juliette Davenne, CERN.

The Universal Force: Gravity – Creator of Worlds by Louis A Girifalco, Oxford University Press. Hardback ISBN 9780199228966, £19.99 ($49.95).

Four hundred years after Galileo's pioneer measurements on falling bodies, gravity – the "predominant presence of daily existence" – remains enigmatic, according to author Louis Girifalco. The question: "Which falls faster – a kilo of lead or a kilo of feathers?" can still be problematic. He cites personal experience.

Gravity is the mighty brush that painted the landscape of our universe. Girifalco is passionate about science, and it shows. However, his spirited description omits important aspects only recently uncovered. But first the history. The emergence of gravity from the fog of ignorance parallels that of physical science itself. Newton changed our picture of the world, but stood "on the shoulders of giants". Girifalco explains well how these giants transformed science from abstract philosophy to experimental study, and how gravity brought mathematics, previously the domain of astronomers, down to Earth. He is effusive about the other gravitational heavyweight, Einstein. However, while special relativity is easy to grasp, it is only an overture to gravity. General relativity is more elusive, especially without equations, and some readers might emerge from the book with their relativities confused.



It is in the latter half of the 20th century that Girifalco loses focus. There is no mention of the startling mismatch between the observed motion of galaxies and the amount of visible matter – stars – that they contain. To make everything come out right, galaxies have also to contain invisible "dark matter". In fact there has to be more of this than anything else; the ultimate gravitational enigma is that we now know how much we do not know.

Classically, gravity is always attractive; it pulls the different parts of the universe together and slows down the Big Bang expansion. However new measurements of supernovae have shown that distant parts of the universe are accelerating away from us. This gravity that pushes rather than pulls – the mysterious "dark energy" – is only mentioned in passing.

If gravity is indeed the "Creator of worlds", there is little on how this happens. Cosmological inflation and the continual quest to synthesize gravity with quantum field theory are unvisited. Otherwise, Girifalco's passionate book is a good introduction to the ancient history of cosmology, the personalities involved, and the experimental method. There are just two equations.
Gordon Fraser, is author of Cosmic Anger: Abdus Salam*, the first Muslim Nobel Scientist (Oxford University Press).*

Das Miniatom-Projekt: Ein Wissenschafts- und Kriminalroman by Richard M Weiner, Verlag Literaturwissenschaft.de. Paperback ISBN 3936134146, €14.90.

"A genius sees what others do not see. So does a madman." This quote at the beginning of the book sets the scene. Trevor McCallum is a physicist who discovers that changes in the values of certain natural "constants" could lead to smaller atoms. This evokes not only the interest of fellow scientists but also of various intelligence agencies, who want to keep a close eye on this development. To test his theory, he needs powerful computers – with which he develops an almost schizophrenic love-hate-relationship. One day he is found dead in front of a computer terminal. Is it murder or suicide?

Going back, the reader gets to know the young Trevor: how he grew up, how he became fascinated by physics and especially how from an early age he skirted between genius and madness. Other people are introduced as well – a physicist who visits an institute in Russia, a colleague there who comes to see her several years later in Paris, a German physicist who testifies before a US committee – all of whose tales are interwoven with McCallum's story, directly or indirectly.

The crime story is injected with science and science fiction, love and envy, secrets and secret agents. The author, a well known physicist, knows the locations and the scientific community first-hand and this authenticity can be felt throughout the book. On the other hand, you can tell that this is his first novel and that he is not a linguist. The text sometimes appears convoluted, and the chronology is sometimes not clear.

Nevertheless it is an interesting read, where you learn about chain reactions and chaos along the way. And not only in theory; maybe the detectives would have come to different conclusions if they had initially had other information.
Hannelore Hämmerle, Munich.

VIEWPOINT

Will the LHC reveal the unexpected?

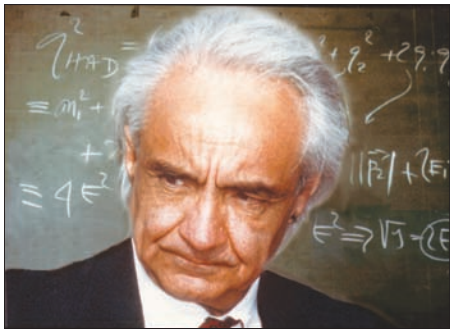
Davide Patitucci describes the view of the new energy frontier at the LHC as seen by last year's International School of Subnuclear Physics in Erice, Sicily.

This autumn, commissioning should be in full swing on the LHC at CERN, the world's largest laboratory for the study of subnuclear physics. So it is entirely appropriate that the 46th Course of the International School of Subnuclear Physics, the oldest of the 123 schools of the Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC) in Erice, will look at what may come from the LHC – both the expected and the unexpected.

This year's course, directed by Antonino Zichichi and Gerardus 't Hooft, is to be held in Erice in September. It will provide the perfect opportunity to focus on the highlights from CERN, and in particular the goals of the LHC. This was also the theme of the 45th in the series, held in 2007, when CERN's director-general, Robert Aymar, stated that these goals "could determine the future course of high-energy physics and should allow us to go beyond the Standard Model".

Physics beyond the Standard Model first appeared before the Standard Model itself, when Raymond Davis observed neutrinos from the Sun in the 1960s. At Erice last year, Alessandro Bettini from the Galileo Galilei physics department at Padua University pointed out: "From 1962 neutrinos were used to look into the Sun's core, but their behaviour was totally unexpected." This led to the case for neutrino oscillations – a phenomenon that the Italian Laboratori Nazionali Gran Sasso (LNGS) is studying through the CERN Neutrinos to Gran Sasso project, which started in August 2006. "The observation of neutrino oscillations has now established beyond doubt that neutrinos have mass and mix," claimed Eugenio Coccia, director of LNGS, during his talk. "This existence of neutrino masses is the first solid experimental fact requiring physics beyond the Standard Model."

The physics of neutrinos is also linked to the unseen matter of the universe. In 1933, Fritz Zwicky, on measuring the mean quadratic velocity of galaxies, proposed the existence of a kind of "invisible matter" – he named it dark matter – that could have



Antonino Zichichi, founder of the EMFCSC and the schools in Erice. (Courtesy EMFCSC.)

neither electromagnetic nor strong nuclear interactions. Neutrinos became the obvious candidates for dark-matter particles, but the study of the evolution of large-scale structures in the universe has unexpectedly shown that the contribution of neutrinos must be extremely small, if it exists at all. Indeed, no Standard Model particle can be considered as the dominant component of dark matter. One new particle candidate is the sterile neutrino, as Lisa Randall from Harvard University explained last year. "This new 'flavour' of neutrino could be trapped, like gravitons, in a different brane from the one we live on," she said. "For this reason we have not observed it directly so far. But the LHC should manage to see many particles that were created during the dawn of the universe and disappeared soon after the Big Bang."

There are many questions in particle physics that the LHC could help to solve, which the 46th course will again discuss this year. A key question is whether the expectations from the LHC predictable.

To answer this, during his talk at the 45th course, Zichichi recalled a front-line scientist of the 20th century, whose birth centenary was celebrated last year at the World Nuclear Physics Conference in Tokyo. In 1935 Hideki Yukawa proposed the existence of a particle with a mass between that of the light electron and the heavy nucleon – the first meson. "No-one was able to predict the 'gold mine' hidden in the production, decay and intrinsic structure of the Yukawa particle," said Zichichi. "This gold mine is still being explored today, and its present frontier is the quark–gluon-coloured world." Zichichi also pointed out: "It is considered standard wisdom that nuclear physics is based on perfect theoretical predictions, but people forget the impressive series of unexpected events with enormous consequences [UEEC] discovered inside the Yukawa gold mine." (*CERN Courier* September 2007 p43).

Such UEEC events are a common feature of the greatest scientific discoveries and the most important historical facts. However, there is a difference. Analysing history on the basis of "what if?" leads historians to conclude that the world would not be as it is if one or any number of "what if?" events had not occurred. This is not the case for science, as Zichichi underlines: "The world would have exactly the same laws and regularities, even if Galileo Galilei or somebody else had not made their discoveries."

UEEC events will be crucial evidence for understanding the existence of complexity at the elementary level. "No one could predict a UEEC event on the basis of present knowledge," Zichichi pointed out. "In fact predictions are based on the mathematical description of UEEC events, so they come only after a UEEC event. Moreover, we should be prepared with powerful experimental instruments, technologically at the frontier of our knowledge, to discover all the pieces of the Yukawa gold mine."

With the advent of the LHC at CERN, a new supercollider will study the properties of a "new world" produced in collisions between heavy nuclei ($^{208}Pb^{82+}$) at the maximum energy so far available (1150 TeV). This world is the quark–gluon-coloured world, totally different from all that we have so far been dealing with.

As Aymar underlined: "If new physics is there, the LHC should find it." There is nothing left for us but to await the unexpected.

Davide Patitucci, Enrico Fermi Centre, Rome.

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