

INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 47 NUMBER 2 MARCH 2007



CMS makes a grand descent

J-PARC

Linac reaches beam energy of 181 MeV p5

LHC FOCUS

A super solenoid is ready to go p22

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The amazing value of accelerators p50

Hard coded logic?

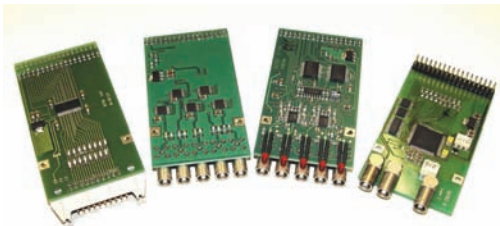
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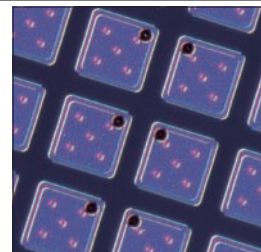
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The EEE Project: big science goes to school

Antonino Zichichi talks about his cosmic-ray initiative for schools.

Axions create excitement and doubt at Princeton

A workshop focuses on the possible discovery of a new particle.

CMS: a super solenoid is ready for business

The powerful superconducting magnet passes commissioning tests.

CMS collaboration takes on a cosmic challenge

Cosmic rays test the performance of the CMS detector systems.

PSI pixels spin off into research with X-rays

Detectors developed for CMS find applications in other sciences.

LUMI'06 takes strides towards LHC upgrade

Experts review scenarios for increasing the LHC's luminosity.

String theory meets heavy ions in Shanghai

QM2006 saw first attempts to link heavy-ion data with string theory.

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Viewpoint

Cover: The 880 t YE+2 endcap disc descends into the CMS cavern. Before the descent underground the detector underwent a successful "Magnet test and cosmic challenge" (p22 and p26). (For a time-lapse film of the descent see http://cmsinfo.cern.ch/outreach/CMStimes/2006/12_18/)

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ACCELERATORS

J-PARC linac accelerates hydrogen ions up to 181 MeV design value

On 24 January the linac for the Japan Proton Accelerator Research Complex (J-PARC) successfully accelerated a beam of negative hydrogen ions up to 181 MeV, the design energy for Phase I of the project. The acceleration to the full energy is three months earlier than scheduled.

J-PARC, which is a joint project between the High Energy Accelerator Research Organization (KEK) and the Japan Atomic Energy Agency (JAEA), is being built at Tokai, approximately 120 km north of Tokyo. The accelerator system will comprise a 400 MeV proton linac (181 MeV at the first stage of Phase I), a 3 GeV, 25 Hz Rapid-Cycling Synchrotron (RCS), and a 50 GeV Main Ring Synchrotron. The RCS provides the Materials and Life Science Experimental Facility with a 1 MW beam to generate pulsed muons and pulsed spallation neutrons. Every 3 s, the beam from the RCS is injected four times into the Main Ring, where it is ramped up to 50 GeV (40 GeV at Phase I). Fast extraction then provides a beam for neutrino production and slow extraction sends beam to the Hadron Experimental Facility (HDF). The neutrinos travel to the Super-Kamiokande detector located 295 km to the west, while the slowly extracted beam will produce secondary beams for hyper-nuclei experiments, rare-decay experiments with kaons, hadron-spectroscopy experiments and so on, or will serve primary beam experiments in the HDF.

Construction of J-PARC started in April 2001, and beam commissioning began some five years later. The radio-frequency quadrupole (RFQ) linac accelerated beam up to 3 MeV on 20 November 2006, the very



The J-PARC team celebrate their success at reaching the 181 MeV Phase I design energy.

day that the beam commissioning started. A month later, on 19 December, the team accelerated the beam up to 20 MeV using the first tank of the drift-tube linac (DTL), and up to 50 MeV using the second and third tanks the next day. Then at midnight on 19 January all of the 30 separated-type DTL (SDTL) cavities, which are driven by 15 klystrons, were ready for acceleration up to 181 MeV. First, the commissioning team performed a phase scan with each pair of the SDTL cavities driven by one klystron before finally completing the scan through 15 pairs on 24 January.

In each scan the team measured the beam energy by the time-of-flight method. For the initial beam study, the peak current, the beam pulse length and the repetition rate were set at 5 mA, 20 μ s and 2.5 Hz, respectively, to avoid possible damage in accelerator components should something go wrong at high beam power. During the commissioning, both the RF power source and cavity system proved to be very stable. This stability together with a very accurate alignment of all of the magnets, especially

in the drift-tube linac, were the two major elements that allowed a rapid tuning of the linac, three months before schedule.

Klystrons drive the J-PARC DTL, but it also has quadrupole electromagnets, which are variable-focusing elements. To meet the conflicting requirements of these two systems, the researchers chose an RF acceleration frequency of 324 MHz rather than the widely used 350 MHz; the compact quadrupole electromagnets were developed with the full use of electroforming and wire-cutting techniques; and industry developed the 324 MHz klystrons with a pulsed power of 3 MW (500 μ s and 50 Hz) in close collaboration with the J-PARC linac team.

The combination of the 3 MeV RFQ linac and the 324 MHz RF source is now being considered as a best choice for the front end of the proton linac by many future projects at Fermilab, the ISIS spallation neutron source in the UK, the Facility for Antiproton and Ion Research at GSI and the Chinese Spallation Neutron Source. This is partly because 324 or 325 MHz, 3 MW pulsed klystrons are now available, and partly because the frequency is a quarter of L-band frequency, which would be used in a future superconducting International Linear Collider.

The RCS beam commissioning will start in autumn 2007, while the beam commissioning of the Main Ring and the muon and neutron production targets together with their beam transports will start in May 2008. By the end of 2008, the complex will be ready for the J-PARC users. The success of the linac beam commissioning earlier than scheduled is encouraging news.

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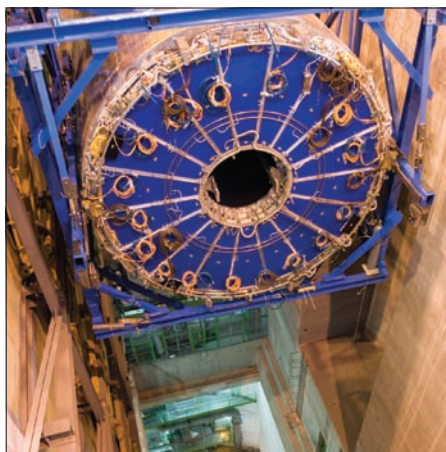
Le linac de J-PARC atteint la valeur nominale de 181 MeV	5	U70 engage l'extraction stochastique	7
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LHC NEWS

ALICE's TPC arrives at experiment cavern...

In early January ALICE's time projection chamber (TPC) moved 300 m from the assembly hall to the experiment cavern, taking four days to complete the journey. This 5 m wide, 5 m diameter cylinder weighs 8 tonnes and is extremely fragile.

The first steps included lifting the TPC with an overhead crane from the cleanroom in the assembly hall and positioning it onto four hydraulic jacks, which raised the TPC to 80 cm. Then a flatbed truck gently slid under the structure and carefully carried it to the entrance of the cavern, making sure not to tilt it more than 2°. The next step was to lower the cylinder 50 m into the ALICE cavern. This proved challenging, with just 10 cm of leeway



ALICE's TPC descends 50 m into the cavern.

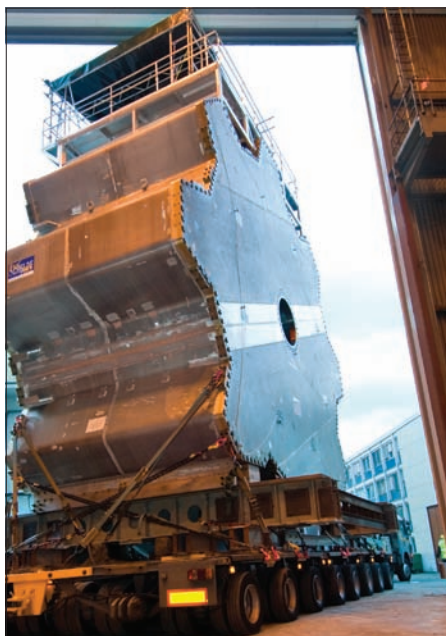
between the delicate TPC and the shaft walls. Finally, a gantry crane moved the TPC close to its final position within the solenoid magnet, where work will begin on installing the internal tracking system.

The TPC consists of very light, fragile carbon-fibre. The surface structure, or field cage, is covered with 30 000 mylar strips secured with the utmost precision. The two endcaps carry electronic read-out channels. These are connected by several thousand flat cables to two service support wheels, which provide support for the electrical, electronic and gas-supply systems. In May, the TPC will be tested in its underground location using cosmic rays.

...while ATLAS toroid takes a steady trip

The first End-Cap Toroid (ECT) for the ATLAS experiment at the LHC has begun the last stage of its journey to the underground cavern. Now that the assembly of the cold mass, integration in the vacuum vessel and connection to the vacuum pumps, cryogenic lines and current leads are all complete, the toroid will undergo a cooling test on the surface before being lowered into the cavern.

The 5 m wide, 11 m diameter, 240 t structure is one of two similar ECTs, the last large magnets to be installed inside ATLAS. Moving at about 1 km/h on a special transport trailer, it left the assembly hall on the Meyrin site in preparation for cold-testing at a nearby outdoor location. The transport operation was extremely delicate: the slightest wrong turn or movement could have caused the tall structure to sway at an angle that would cause serious damage to the fragile parts inside. The toroid cold mass is suspended inside the vacuum



The first of the End-Cap Toroids leaves the assembly hall before it is cold-tested.

vessel by four gravity rods and tipping the ECT at too large an angle could have damaged these rods.

During the surface test, the ECT is being cooled to 80 K using the cryogenic plant in a nearby building. Tests will check for cold leaks in the cooling circuits and verify the electrical insulation of the coils under thermal stress. During the 300–80–300 K thermal cycling, all of the crucial components as well as the magnet's instrumentation will be thoroughly checked to make sure that it will function properly once installed underground.

The test will last until mid-March. The toroid will then be lowered into the ATLAS cavern in early June for final commissioning, when it will be cooled to 4.5 K using the ATLAS cryogenic plant and charged up to the nominal current of 20.5 kA. The second ECT is scheduled for lowering in early July, just in time for closure of the LHC beam pipe in August.

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

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

ACCELERATORS

U70 proton synchrotron goes ahead with stochastic extraction

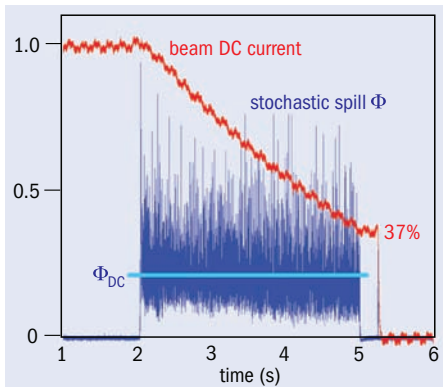


Fig. 1. Beam current (red curve) and spill current Φ (blue) from the stochastic extraction tests at the 50 GeV plateau in the U70. About 63% of the beam is slowly extracted during a period of 2.9 s.

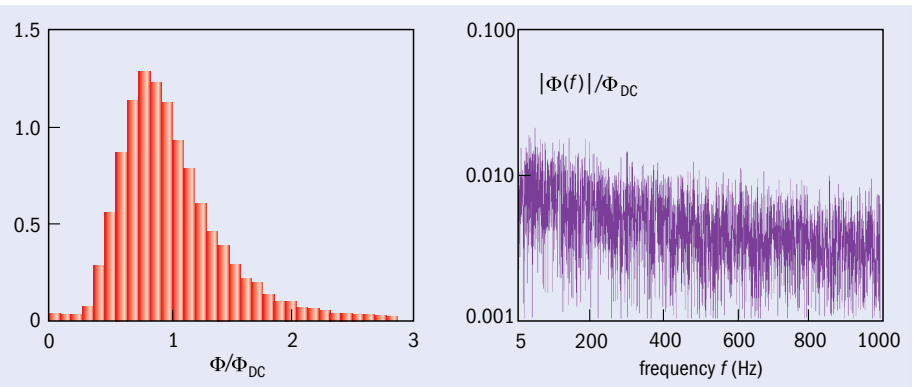


Fig. 2. Left: Distribution of the spill ripple magnitude about the average value of spill current Φ_{DC} , recorded at a sampling rate of 50 kS/s. The standard deviation is 0.40 and the spill duty factor $\langle \Phi \rangle^2 / \langle \Phi^2 \rangle$ is 0.86. Right: The amplitude Fourier spectrum of the spill ripple signal, which is relatively continuous and free from the pronounced discrete lines previously observed, which arise as a result of mains harmonics.

The new advanced slow stochastic extraction (SSE) system at the U70, the 70 GeV proton synchrotron at the Institute for High Energy Physics (IHEP) in Protvino, has operated successfully during normal running in 2006. The aim is to use the technique to produce longer, more uniform spills than can be achieved with the standard extraction, which uses magnetic optics to move particles to the transverse resonance.

The first feasibility tests for SSE at the U70 took place in late 2004 (*CERN Courier* March 2005 p10). These tests yielded natural stochastic spills, which were superimposed by radiofrequency noise with power spectra kept invariant through the extraction time. Such spills inherently had no flat-top in their DC content, however, and so were not useful

for users. Since then, the beam physicists and engineers at IHEP have continued their efforts towards an operational SSE scheme and have developed some sophisticated dedicated circuitry, which they beam-tested during runs in 2005–2006.

The core of the new system consists of a feedback loop that modulates the amplitude of the operational noise in response to the spill current signal, which is monitored by a beam-loss monitor located downstream of the electrostatic septum deflector. Being a DC-coupled feedback system with a finite base-band bandwidth, it is designed both to flatten and to smooth the stochastic spills.

The team has now used this system at the U70. The figures show that it has achieved the primary design goal of obtaining low-

ripple flat-topped spills lasting 2–3 s, with noticeable progress in the quality of slow spills. The persistent AC ripple observed in the past in the extracted current now shows up as a random signal. It turns out that it cannot be suppressed via the feedback control used owing to the limited base-band bandwidth of the 3rd-order transverse resonance transfer-function involved in the overall closed-loop gain product.

The new SSE scheme routinely serviced the U70 during the entire run of 2006 yielding slow spills 1.1 s long, and exhibited a relatively robust and reliable behaviour consistent with the design aims. Further improvements of the SSE set-up promise a better functioning of the U70 for external fixed-target experiments in the near future.

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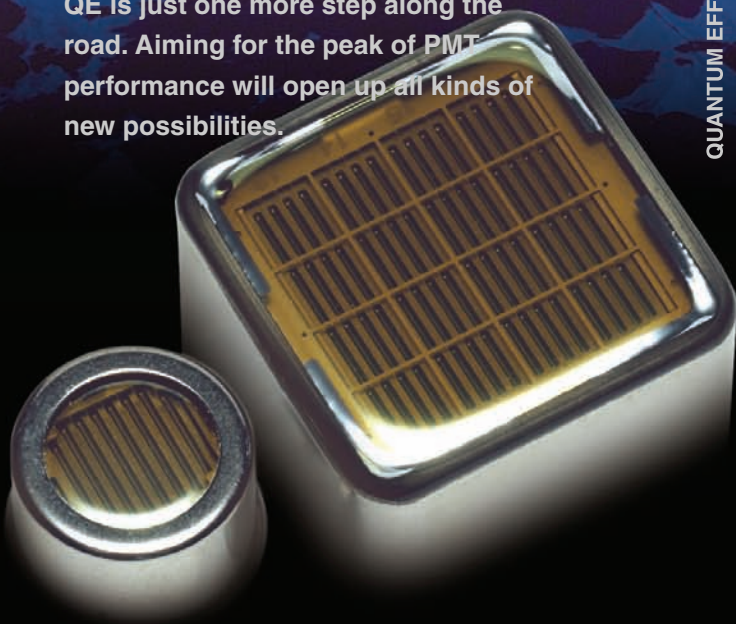
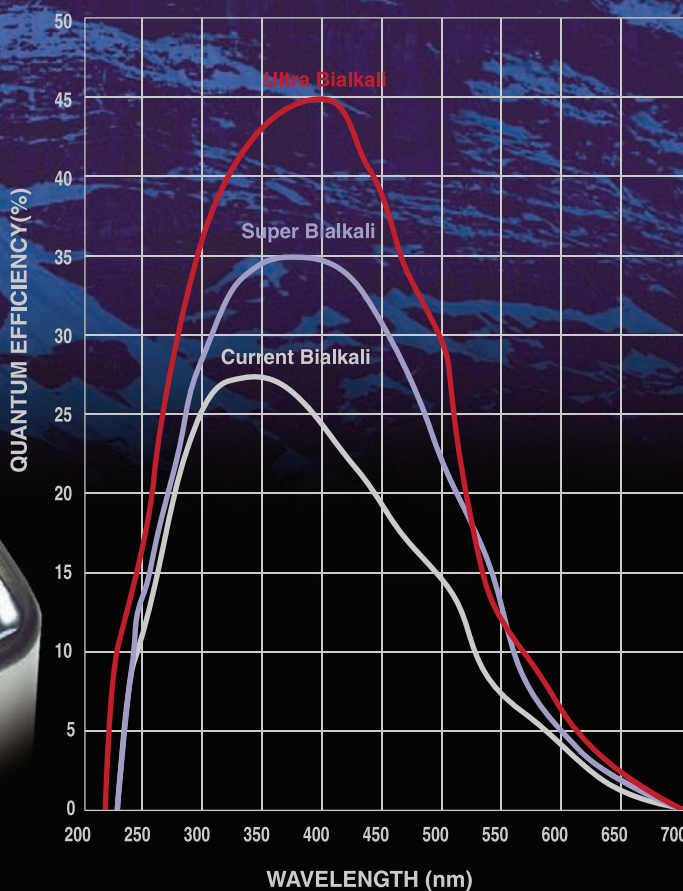
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Compiled by Steve Reucroft and John Swain, Northeastern University

Silicon creates ball lightning



Successive video frames in which a luminous ball squeezes under an electrical conductor.

Ball lightning has long been mysterious and difficult to study owing to a lack of ways to produce it in the laboratory. Now it looks as though Antonia Pavão and colleagues at the Federal University of Pernambuco and the Instituto Nacional de Pesquisas Espaciais in Brazil may have tamed this elusive phenomenon. The team passed 100–140 A through layers of silicon 0.35 mm thick to create an arc, which tossed out blobs of molten silicon, but occasionally also produced glowing spheres the size of table-tennis balls. The balls lasted up to 8 s and their colour – blue-white or orange-white – suggests that their temperature was around 2000 K.

The researchers found that the luminous balls they generated exhibited some of the

behaviour reported in eye-witness accounts of ball lightning. For example, they recorded one ball as it passed through a gap smaller than its apparent diameter (see figure), and observed balls bounce from the ground. Earlier laboratory models of ball lightning needed to be sustained by an external source of microwaves and winked out in a few milliseconds, so this research represents a huge leap in lifetime for something that could be ball lightning in the laboratory.

Further reading

G S Paiva *et al.* 2007 *Phys. Rev. Lett.* **98** 048501.

See also www.espacociencia.pe.gov.br/multimedia/multimedia_video.php.

Atom interferometry helps measure G

Newton's constant, G , is notorious for being poorly measured and any new technique to pin it down is welcome. The surprise now is that a quantum technique offers a new handle on it with completely different systematics. JB Fixler of Stanford University and colleagues have used an interferometer based on laser-cooled caesium atoms. Depending on the placement of a 540 kg lead weight, they measured G to be $6.697 \pm 0.027 \pm 0.021 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$, which is consistent with existing measurements.

The current best value for G has an uncertainty some 30 times smaller, but this new technique could, in principle, yield much more precise values in the future. It also offers a direct measurement of the effects of gravity on a quantum-mechanical system.

Further reading

JB Fixler *et al.* 2007 *Science* **315** 74.

Nuclear-waste storage takes a blow

A material that was looking good as a matrix in which to hold radioactive waste may not be up to the job. With worries that glasses might not be stable enough, attention has focused on ceramics and minerals such as zircon. Now Ian Farnan of the University of Cambridge and colleagues have shown that damage from alpha particles can produce defects that cause swelling and dramatically weaken the crystal structure.

For example, crystalline zircon with 10% plutonium in it by weight will become amorphous (glass-like) after 1400 years. This is a far cry from the 250 000 years that experts hoped zircon's crystalline structure would trap and immobilize plutonium. Even worse, leakage due to partial damage of the crystalline structure could start in just 210 years. This could be yet another good argument for Carlo Rubbia's energy amplifier.

Further reading

I Farnan, H Cho and WJ Weber 2007 *Nature* **445** 190.

Egyptians may have invented concrete

Some of the stone that went into making the great pyramids at Giza may not be natural limestone, but rather some sort of ancient concrete. This controversial idea proposed in the mid-1980s has recently gained support from the work of Michel Barsoum and Adrish Ganguly from Drexel University in Philadelphia, and Gilles Hug of the Laboratoire d'Etudes des Microstructures, LEM ONERA-CNRS.

Barsoum and colleagues used scanning and tunnelling electron microscopy to look at 15 samples of stone and six different limestones from the area. They found ratios of magnesium and calcium that are not consistent with the value for the limestone samples. They also found evidence of particles of minerals that appear to have been artificially hydrated in a strongly basic solution. In other words, the Egyptians may have used a form of concrete to build the only



Research suggests that the Egyptians may have used concrete in the pyramids at Giza. (Copyright V Georgievsky/Dreamstime.)

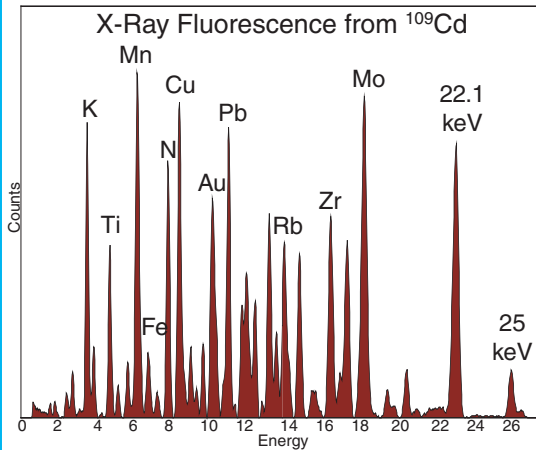
survivor of the seven wonders of the ancient world, some 2500 years before the Romans introduced their own brand of concrete.

Further reading

MW Barsoum, A Ganguly and G Hug 2006 *J. Am. Ceram. Soc.* **89** 3788.

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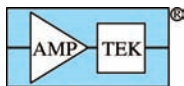


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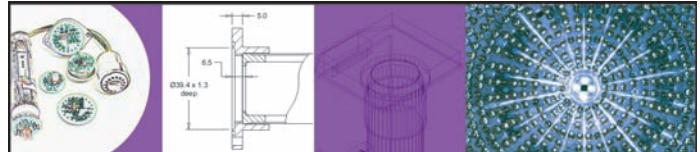
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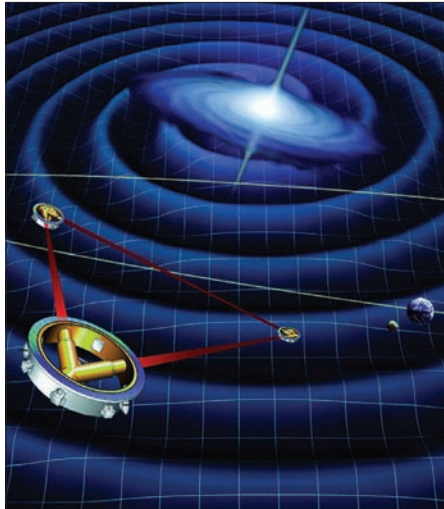


Gravitational waves could probe inflation

“In the beginning was the Word,” opens the gospel of John, and this finds some resonance in the possibility of detecting gravitational waves from the Big Bang itself at frequencies typical of sound waves. Careful listening to this background signal would probe the inflation phase of the very early universe.

Astronomy is a science based on photons. First limited to visible light and then broadening to include radio waves, the field of investigation has exploded during recent decades. Windows on the sky at new wavelengths have opened one by one thanks to the use of satellites to avoid absorption by the Earth’s atmosphere. However, at any wavelength, the quest towards the beginning of time stops abruptly 380 000 years after the Big Bang, when the emission of the cosmic microwave background (CMB) occurred. This is when the universe became transparent and there is no hope of looking further back in time via electromagnetic radiation. Although earlier events like inflation may leave some imprint in the map of the CMB (*CERN Courier* May 2006 p12), a direct messenger from the very early universe must be of a different nature.

Primordial neutrinos from the time of Big Bang nucleosynthesis would be a good candidate for such a messenger, but their very low energy and interaction cross-section makes them currently undetectable. Gravitational waves are another candidate attracting a great deal of interest as a possible witness of the very early universe.



Artist’s view of LISA, a joint ESA and NASA project to be the first space mission to detect gravitational waves. (Courtesy ESA.)

Einstein’s general theory of relativity predicts that these distortions of space–time propagate with the speed of light. Although studying the change of period of tight double-pulsar systems has demonstrated their existence (*CERN Courier* March 2004 p12), direct detection is still to be achieved despite the great effort invested to detect these subtle disturbances of space–time.

A theoretical study by Juan Garcia-Bellido and Daniel Figueroa from the Universidad Autonoma de Madrid, Spain, sheds a new light on the expected amplitude and spectral property of primordial gravitational waves. The study focuses on the violent reheating of

the universe after hybrid inflation. According to the researchers, many extensions of the Standard Model of particle physics expect this process, both in string and supersymmetric theories.

They suggest that such a process would lead to the formation of high-energy bubble-like structures, which would collide and generate a stochastic background of gravitational waves. Taking into account the expected downshift of this radiation by 24 orders of magnitude due to the cosmic expansion since that time, their calculation predicts a maximum intensity of gravitational waves at frequencies from about 1 Hz for a low-scale inflation model up to about 10 MHz for a high-scale model.

This frequency range is too high to be accessible to the future Laser Interferometer Space Antenna (LISA), a joint mission of ESA and NASA, but there is hope to detect the expected signal with other projects, on the ground with the Advanced Laser Interferometer Gravitational Wave Observatory or in space with NASA’s proposed Big Bang Observer. There is no doubt that the detection of gravitational waves from the first 10^{-34} s of the universe would be a new milestone in science, allowing physicists to confront their models with observations.

Further reading

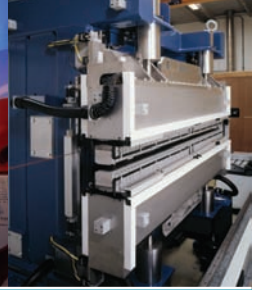
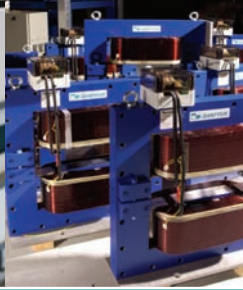
J Garcia-Bellido and DG Figueroa 2007 *Phys. Rev. Lett.* in press [<http://arxiv.org/abs/astro-ph/0701014>].

Picture of the month



This beautiful false-colour infrared view of the Eagle Nebula (Messier 16) located 7000 light-years away in the Serpens constellation was taken by NASA’s Spitzer Space Telescope (*CERN Courier* January/February 2004 p19). The famous “Pillars of Creation” captured by the Hubble Space Telescope in 1995 are overlaid and their location is shown on the background image. The other dust column observed by Hubble 10 years later is also visible to the left of the image (*CERN Courier* June 2005 p12). Careful analysis of the reddish central area reveals an excess of heat thought to be due to a supernova explosion, which could have been seen to explode 1000–2000 years ago and would destroy the majestic pillars, from our point of view, 1000 years from now. (Courtesy NASA/JPL-Caltech/N Flagey [IAS/SSC] and A Noriega-Crespo [SSC/Caltech].)

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Photo: P. Frigola, Climber: H. Badakov, Buttermilks boulders near Bishop



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CERN COURIER ARCHIVE: 1964

A look back to *CERN Courier* vol. 4, March 1964, compiled by Peggie Rimmer

NEWS FROM CERN

On the brink of a breakthrough

For most of the year at CERN, work goes on normally and the fact that one or other of the experimental groups is discovering something new goes relatively unnoticed. In February, however, a number of events combined to provide the kind of excitement that more than makes up for the long periods of monotony.

Clues had, in fact, been available in the library for a week or two, in "preprints" of two theoretical papers, one by M Gell-Mann, of the California Institute of Technology, US, and the other by G Zweig, of the same institute but at present a visiting scientist at CERN. Produced independently, both papers put forward a new way of looking at the theory of "unitary symmetry" known as SU3, part of a set of algebras developed by Norwegian mathematician Sophus Lie nearly a hundred years ago.

Application of this theory, notably in the form known as the "eightfold way", has brought a considerable amount of order into the chaos created by the discovery of so many new, supposedly "fundamental", particles during the past few years. Specific properties of particles can be represented by quantum numbers which can take only certain values, and applying the algebraic rules to these number groups all strongly interacting particles in a definite way.

Unfortunately, the parallel between physically observed particles and mathematical theory is not exact. In SU3 all positions in the groups arise from a set of three fundamental entities; in physics the proton and neutron belong to a set of eight particles. Both Gell-Mann and Zweig suggested that strongly interacting particles could be made from combinations of just three basic units, similar to the proton, neutron and lambda particle but with electric charges of $2/3$, $-1/3$ and $-1/3$ respectively. It was this property that caused the stir.

From the time of Millikan's classic experiments in 1911 it has been accepted that the charge of the electron is the smallest one possible. The idea of

fractionally charged particles seemed quite preposterous. Even those who suggested it seemed to share the doubts; Gell-Mann called his new particles "quarks" with a reference to *Finnegans Wake*, Zweig turned to card games for inspiration and called his particles "aces". One anonymous versifier, finding the whole situation too much, posted the following on CERN's Theory Division notice board:

Think of the words that our subject is fraught with,
Words that old Webster would never be caught with,
Ladders and tadpoles and majorization,
Bootstraps and buddahs and peratization,
Haffnians, pfaaffians, some think it's drollish,
Why, half of the world speaks Regge Polish!
Things are so bad that I must protest it,
From Joycean footnotes, please give us some respite!

Oh, horrible thought if in nature 'tis observed,
That the quarks and the aces,
Keep changing their places,
And charge seems never conserved!

For experimentalists, the excitement lay in the prediction that at least one of the new particles would be stable. This quark, or ace, if produced with one-third the charge of a proton, would have an ionizing power (and therefore bubbles per centimetre along its track in a bubble chamber) of only one-ninth for the same apparent momentum. Of course, the mass of aces (which could not be predicted theoretically) might be too high for them to be produced with present-day accelerators. Nonetheless, the Electronics Experiments Committee, on 11 February, decided that the particles should be taken seriously. That same afternoon G Zweig explained his theory at the weekly Experimental Physics Discussion and two proposals for experiments, from groups led by G Cocconi and A Zichichi, were described.

Some people felt that if aces existed they ought to have been seen in at least one of the millions of bubble-chamber pictures already scanned, though they could have been missed if the scanners were not specifically looking for them. In any case, it quickly became clear that the combination

of a bubble chamber and the o_2 beam in the PS East hall provided the quickest way of looking for them. Some time in March the o_2 beam will be set to accept high-energy negative particles (mostly pions) from the internal target and direct them into the 81 cm Saclay/Ecole Polytechnique bubble chamber.

While working on this proposal, DRO Morrison realized that the same kind of bubble-chamber exposure had in fact been carried out with the CERN 32 cm chamber in 1960. The photographs were got out and a team of physicists and scanners looked through 10 000 of them in one night. No aces were found. The group working with the Ecole Polytechnique heavy-liquid bubble chamber scanned 100 000 photographs. Again the result was negative. The possibility was raised that aces might be formed in weak interactions rather than in the strong ones investigated in these two searches. Accordingly, photographs of about 300 neutrino events in the CERN heavy-liquid bubble chamber were looked at again, but no tracks with too few bubbles could be found.

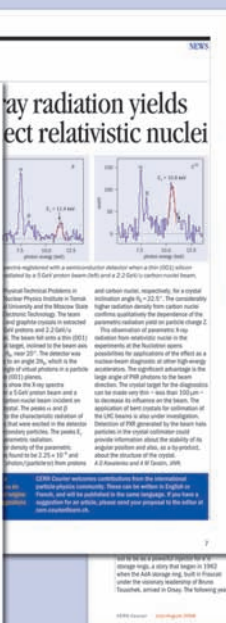
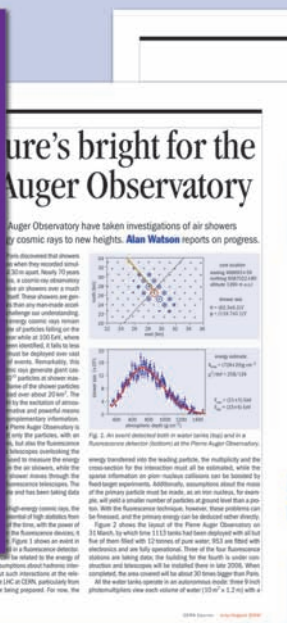
Adding point to the discussion was the news from Brookhaven in the middle of the month that two examples of the omega-minus particle had been discovered in their new 80 inch (200 cm) bubble chamber. This particle, predicted by the "eightfold-way", was the last one needed to complete a group of 10 particles. At CERN, the satisfaction of knowing that the omega really existed was tempered with a certain disappointment, not to say envy, as two bubble-chamber runs last year and another in January had been carried out here to look for the particle, but several hundred thousand pictures had so far provided no trace of it.

Zweig's aces and Gell-Mann's quarks may or may not be found, but their ideas have triggered off a new series of moves in this search for an explanation of the occurrence of the so-called fundamental particles.

● Compiled from Last Month at CERN pp26-27.

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The EEE Project: big science goes to school

Antonino Zichichi tells **Bob Swarup** about his initiative to bring frontier research in physics into the heart of Italian schools and to encourage the next generation of physicists.



High-school students at CERN prepare the multigap resistive plate chambers, which are used in schools in the EEE Project.

In May 2004, a major webcast linked CERN and high schools all over Italy to inaugurate the Extreme Energy Events (EEE) Project. Launched on the occasion of the visit to CERN of the Italian Minister of Education, University and Research, the project is the initiative of Antonino Zichichi from Bologna University and CERN.

What is the main idea behind the project?

This project is meant to be the most extensive experiment to detect muon showers induced by extremely energetic primary cosmic rays (protons or nuclei) interacting in the atmosphere. Ultimately, it will cover a million square kilometres of Italian and Swiss territory. It would have been very expensive to implement such a large project without involving existing structures, namely schools all over Italy and part of Switzerland. This “economic” strategy also has the advantage of bringing advanced physics research to the heart of the new generation of students.

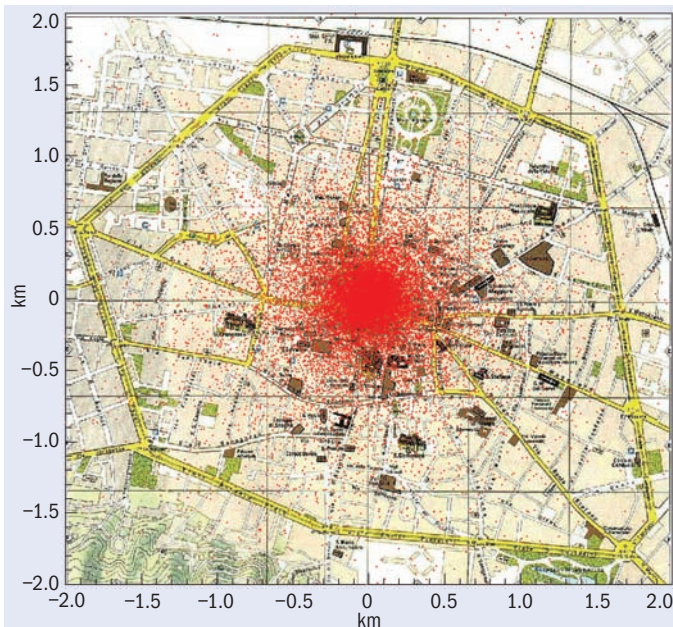
How will the experiment detect cosmic-ray showers?

The EEE telescopes, distributed over an immense area, will be tracking devices, capable of reconstructing the trajectories of the charged particles traversing them. These particles are the secondary cosmic rays produced in the showers, and are mostly muons

at sea level. The project is based on a very advanced detector unit: the multigap resistive plate chamber (MRPC) (Cerron-Zeballos *et al.* 1996). An EEE telescope comprises three layers of MRPCs. We have developed these chambers for the ALICE time-of-flight detector at CERN's LHC (Akindinov *et al.* 2004). Their performance in terms of detection efficiency and time resolution is outstanding.

However, the EEE Project also aims to bring science into high schools (Zichichi 2004). This is why the plan was for all of the MRPCs to be built by teams of school pupils supervised by their teachers at CERN or in the nearest laboratory (located in the closest university or research institute). After the MRPC construction phase, school pupils participate in the installation, testing and start-up of the EEE telescope in their school, then in its maintenance and data-acquisition, and later in the analysis of the data. Of course the scientific and technical staff of the universities and research institutes collaborating in the project coordinate and guide everything.

The telescopes will be coupled to GPS units and interconnected via a network. A dedicated PC will locally acquire the MRPC signals produced by each telescope and will then transfer them to the largest Italian computer centre in Bologna for analysis using Grid middleware. ▶



Monte Carlo simulation of an air shower generated in the high atmosphere (15 km altitude) by a 10^{17} eV primary cosmic proton. The red points represent muons impinging on Bologna. About a million muons in this shower reach the ground over an area of more than 10 million square metres.

How much does the project cost and how is it funded?

The cost is minimal because we install our detectors at existing structures (schools). The EEE Project was funded in 2005 by the Italian Ministry of Education, University and Research, and by Italian research institutes such as INFN and the Enrico Fermi Centre. The cost of an EEE unit (that is, a complete telescope, including PC, laboratory equipment, cables, gas system, etc.) is about €50 000. CERN, the World Federation of Scientists, the Italian National Research Council and many Italian universities are also participating in the project. Owing to the success of the project and to its undoubted impact on education and research potential, we expect more funding in the coming years.

What is the status of the project? How many schools are involved so far and what is the next step?

In one year, pupils from more than 20 high schools have built more than 70 MRPCs at CERN. Nine pilot sites are equipped with EEE telescopes: at CERN, at the INFN Gran Sasso Laboratory, at the INFN Frascati Laboratory and in the INFN sections in Bologna (central Italy), Cagliari (Sardinia, central-western Italy), Catania (Sicily, southern Italy), Lecce (south-east Italy) and Turin (north-west Italy). The remaining MRPCs are currently moving from Geneva to Italy for the other high schools that are involved so far. We foresee that all of these telescopes should soon be collecting data. Meanwhile the construction of other MRPCs at CERN continues, thanks to a new wave of pupils from other Italian high schools. More than 50 schools are already queuing up to be part of the EEE Project.

The next stage of the project is to continue expanding, increasing its coverage and involving as many high schools as possible in this frontier experimental research in fundamental physics.

What do you believe the project contributes to education?

The direct involvement of young pupils in the project is the most efficient way to contribute to their learning while doing advanced research in physics. The pupils will be personally involved in advanced research and will acquire a deeper knowledge of particle and astroparticle physics, experimental tools, data-acquisition systems, software, networks, etc. They will gain direct access to the data and to the working methods typical of modern research work.

How does EEE differ from schools projects in other countries?

When I started to speak about the project I knew of no other proposals. Now some educational cosmic-ray projects have been proposed in other countries. The detectors are groups of scintillation counters, typically on the school's roof, and not in the building as with the EEE telescopes. These projects don't use tracking devices.

What will the project contribute to research?

There are short- and long-range time coincidences between close (within the same city) and distant telescopes, and the tracking capabilities of the telescopes will determine with good precision the direction of the incoming primary cosmic ray. Therefore, the EEE Project can study not only large showers of muons originating from a common vertex, but also correlations between separated showers that might be produced by bundles of primaries. The project thus allows a large variety of studies, from measuring the local muon flux in a single telescope, to detecting extensive air showers producing time correlations in the same metropolitan area, to searching for large-scale correlations between showers detected in telescopes tens, hundreds or thousands of kilometres apart. When complete – that is, equipped with at least 100 telescopes – the EEE Project will compete strongly with other high-energy cosmic-ray experiments searching for extreme-energy extended air showers.

Further reading

AN Akimov *et al.* 2004 *Nucl. Inst. Meth.* **A533** 74.

E Cerron-Zeballos *et al.* 1996 *Nucl. Inst. Meth.* **A374** 132.

A Zichichi 2005 *Progetto "la Scienza nelle Scuole", EEE – Extreme Energy Events*, Società Italiana di Fisica.

Résumé

Projet EEE: la Mégascience à l'école

En mai 2004, une importante webémission a associé le CERN et des écoles secondaires de toute l'Italie pour marquer le coup d'envoi du projet «Extreme Energy Events» (EEE). Ce projet, imaginé par Antonino Zichichi, a l'ambition de mener la plus étendue des expériences de détection des gerbes de muons créées par des rayons cosmiques primaires extrêmement énergétiques (protons ou noyaux) interagissant dans l'atmosphère. Elle couvrira un million de kilomètres carrés en Italie et en Suisse, en utilisant des trajectographes construits, montés et exploités par des étudiants d'écoles secondaires sur une vaste superficie. Dans cette interview, Zichichi explique comment il entend instiller l'intérêt pour la recherche de pointe dans les écoles italiennes.

Bob Swarup interviewed Antonino Zichichi for *Physics World* (October 2006 p8).

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Diamond and Solet smoothly commissioned their Libera equipped storage rings

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What was the challenge? The commissioning of the storage rings at Diamond and Solet was a major project, and it was essential to have a reliable and efficient storage ring system. The challenge was to commission the rings in a way that was safe, reliable, and efficient.

What was the solution? The solution was to use the Libera storage ring system. Libera is a highly reliable and efficient storage ring system that has been used successfully at many other facilities. It was chosen for its proven reliability and its ability to handle high currents.

What were the results? The commissioning of the storage rings at Diamond and Solet was completed successfully. The rings are now operating at their design currents, and the facilities are ready for use. The use of Libera was a key factor in the success of the commissioning process.

What are the benefits? The benefits of using Libera are many. It is a highly reliable and efficient storage ring system that has been used successfully at many other facilities. It is also a cost-effective solution that can be used in a wide range of applications.

What are the next steps? The next steps are to continue to improve the performance of the storage rings and to explore other applications for Libera. The teams at Diamond and Solet are committed to making the most of the facilities and to providing high-quality services to their users.

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Brookhaven National Laboratory chooses SAES® Getters' new NEG thin-film technology to coat the RHIC machine

Brookhaven National Laboratory (BNL) has chosen SAES® Getters' new NEG thin-film technology to coat the RHIC machine. The technology is a significant improvement over the current technology used for coating the machine. *By SAES® Getters.*

What was the challenge? The challenge was to find a coating technology that could provide a high-quality, long-lasting coating for the RHIC machine. The coating had to be able to withstand the high temperatures and vacuum conditions of the machine.

What was the solution? The solution was to use SAES® Getters' new NEG thin-film technology. This technology provides a high-quality, long-lasting coating that is able to withstand the harsh conditions of the RHIC machine.

What were the results? The coating of the RHIC machine with SAES® Getters' new NEG thin-film technology was completed successfully. The coating is now in place and is providing excellent performance.

What are the benefits? The benefits of using SAES® Getters' new NEG thin-film technology are many. It provides a high-quality, long-lasting coating that is able to withstand the harsh conditions of the RHIC machine. It is also a cost-effective solution that can be used in a wide range of applications.

What are the next steps? The next steps are to continue to improve the performance of the coating and to explore other applications for SAES® Getters' new NEG thin-film technology. The teams at BNL are committed to making the most of the machine and to providing high-quality services to their users.

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Axions create excitement and doubt at Princeton

A workshop at the Institute for Advanced Study paid much attention to a small-scale experiment that might have found the first direct indication of a new particle.



Workshop participants pose in the sunshine outside of the Institute for Advanced Study at Princeton in October 2006.

The lightweight axion is one of the major candidates for dark matter in the universe, along with weakly interacting massive particles. It originally arrived on the scene about 30 years ago to explain CP conservation in QCD, but there has never been as much theoretical and experimental activity in axion physics as there is today. Last year, the PVLAS collaboration at INFN Legnaro reported an intriguing result, which might indicate the detection of an axion-like particle (ALP) and which has triggered many further theoretical and experimental activities worldwide. The international workshop Axions at the Institute for Advanced Study, held at Princeton on 20–22 October 2006, brought together theorists and experimentalists to discuss current understanding and plans for future experiments. The well organized workshop and the unique atmosphere at Princeton provided ideal conditions for fruitful discussions.

In 2006, the PVLAS collaboration reported a small rotation of the polarization plane of laser light passing through a strong rotating magnetic dipole field. Though small, the detected rotation was around four orders of magnitude larger than predicted by QED (Zavattini *et al.* 2006). One possible interpretation involves ALPs produced via the coupling of photons to the magnetic field.

Combining the PVLAS result with upper limits achieved 13 years earlier by the BFRT experiment at Brookhaven National Laboratory (Cameron *et al.* 1993) yields values of the ALP's mass and its coupling strength to photons of roughly 1 meV and $2 \times 10^{-6} \text{ GeV}^{-1}$, respectively (Ahlers *et al.* 2006). If the PVLAS result is verified, these two values challenge theory because a standard QCD-motivated axion with a mass of 1 meV should have a coupling constant seven orders of magnitude smaller. Another challenge

to the particle interpretation of the PVLAS result comes from the upper limit measured recently at CERN with the axion solar helioscope CAST, which should have clearly seen such ALPs. However this apparent contradiction holds true only if such particles are produced in the Sun and can escape to reach the Earth.

So far there is no direct experimental evidence for conventional axions. The first sensitive limits were derived about two decades ago from astrophysics data (mainly from the evolution of stars, where axions produced via the Primakoff effect would open a new energy-loss channel so stars would appear older than they are), and also from experiments searching for axions of astrophysical origin (cavity experiments and CAST for example) and accelerator-based experiments. The conclusions were that QCD-motivated axions with masses in the micro-electron-volt to milli-electron-volt range seem to be most likely – if they exist at all.

The combined PVLAS–BFRT result would fit well into these expectations if the coupling constant were not too large by orders of magnitude. Theoreticians have tried to deal with this problem and develop models in line with the ALP interpretation of the PVLAS data and astrophysical observations. There may be some possibilities involving “specifically designed” ALP properties. However, to the authors' understanding, such attempts fail if the conclusion announced at the workshop persists: according to preliminary new PVLAS results, the new particle is a scalar, whereas conventional axions are pseudoscalars. Consequently either the interpretation of the data or the experimental results must be reconsidered.

Although the PVLAS collaboration has measured the Cotton–Mouton effect – birefringence of a gas in a dipole magnetic \triangleright

Table 1

name	place	magnet (field length)	laser wavelength power	P_{PVLAS}	photon flux at detector
ALPS	DESY	5T 4.21 m	1064 nm 200 W cw	$\approx 10^{-19}$	10/s
BMV	LULI	11T 0.25 m	1053 nm 500 W 4 pulses/day	$\approx 10^{-21}$	10/pulse
LIPSS	Jefferson Laboratory	1.7T 1.0 m	900 nm 10 kW cw	$\approx 10^{-23.5}$	0.1/s
OSQAR (preliminary phase)	CERN	9.5T 1.0 m 9.5T 3.3 m	540 nm 1 kW cw	$\approx 10^{-20}$	10/s
PVLAS (regeneration)	INFN Legnaro	5T 1 m 2.2T 0.5 m	1064 nm 0.8 W cw $N_{pass} = 5 \times 10^5$	$\approx 10^{-23}$	10/s

Table 1. Planned “light shining through a wall” experiments to detect axion-like particles (ALPs), indicating the most important characteristics for the magnet and laser. PVLAS and later OSQAR will use optical cavities to generate more ALPs. P_{PVLAS} denotes the probability of photon-ALP-photon conversion for the different experimental set-ups and the coupling constant derived from the PVLAS measurement and BFRT limits. The last column gives the expected signal rate of reconverted photons.

field – for various gases with unprecedented sensitivity, the workshop openly considered possible systematic uncertainties. While experimental tests rule out many uncertainties, others are still to be checked. For example, the relatively large scatter of individual PVLAS measurements and the influence of the indirect effects of magnetic fringe fields remain to be understood. The PVLAS collaboration is therefore planning further detailed analyses.

In search of ALPs

One clear conclusion is the need for more experimental data. A “smoking gun” proof of the PVLAS particle interpretation would be the production and detection of ALPs in the laboratory. In principle the BFRT collaboration has already attempted this in an approach called “light shining through a wall”. In the first part of such an experiment, light passes through a magnetic dipole field in which ALPs would be generated; a “wall” then blocks the light. Only the ALPs can pass this barrier to enter a second identical dipole magnet, in which some of them would convert back into photons (figure 1). Detection of these reconverted photons would then give the impression of light shining through a wall. The intensity of the light would depend on the fourth power of the magnetic field strength and the orientation of the light polarization plane with respect to the magnetic dipole field.

The PVLAS collaboration and other groups are planning a direct experimental verification of the ALP hypothesis. Table 1 provides an overview of some of the approaches presented at the workshop. Besides PVLAS the ALPS, BMV and LIPSS experiments should take data in 2007. BMV and OSQAR (as well as the Taiwanese experiment Q&A) will confirm directly the rotation of the light

polarization plane that PVLAS claims. The BMV collaboration aims for such a measurement in late 2007.

Research during the coming year should therefore clarify the PVLAS claim in much greater detail. The measurement of a new axion-like particle would be revolutionary for particle physics and probably also for our understanding of the constituents of the universe. However, considering the theoretical difficulties described above, a different scenario might emerge. Within a year from now we might be confronted both with an independent confirmation of the PVLAS result on the rotation of the light polarization plane, and simultaneously with only upper limits on ALP production by the light shining through a wall approaches. This situation would require new theoretical models.

The planned experiments listed in Table 1 do not have the sensitivity to probe conventional QCD-inspired axions. In the near future, CAST will be the only set-up to touch the predictions for solar-axion production. The workshop in Princeton, however, heard about other promising experimental efforts to search directly for axions or other unknown bosons with similar properties. These studies use state-of-the-art microwave cavities – for example, as in ADMX in the US, which is looking for dark-matter axions – or pendulums to search for macroscopic forces mediated by ALPs.

On the theoretical side, as we mentioned above, attempts to interpret the PVLAS result have generated some doubts on the existence of a new ALP. Perhaps micro-charged particles inspired by string theory might provide a more natural explanation of the PVLAS result. Researchers are thus discussing novel ideas of how to turn experimental test benches for accelerator cavity development into sensitive set-ups to test for micro-charged particles. How-

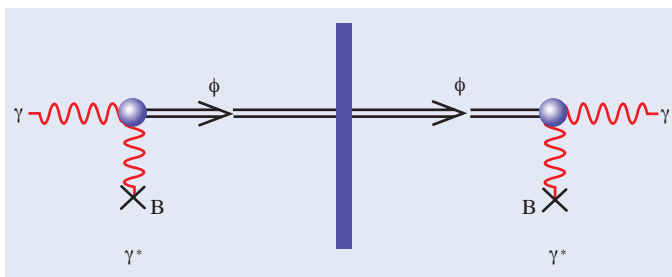


Fig. 1. The principle of "light shining through a wall".

ever, as Ed Witten explained in the workshop summary talk, string theories also predict many ALPs, so perhaps we are on the cusp of discovering an entire new sector of pseudoscalar particles.

In summary, it is clear that small-scale non-accelerator-based particle-physics experiments can have a remarkable input to particle physics. Stay tuned for further developments.

• The authors wish to thank the Princeton Institute for Advanced Study for the warm hospitality, and especially Raul Rabadan and Kris Sigurdson for their perfect organization of the workshop.

Further reading

For more about the workshop see www.sns.ias.edu/~axions/axions.shtml.

For an overview on production and detection of very light bosons see www.desy.de/~ringwald/axions/axions.html.

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Résumé

Physique des axions: espoirs et doutes à Princeton

Les axions, très légers, sont, tout comme les particules massives interagissant faiblement, des candidats très sérieux pour la matière noire de l'Univers. L'an dernier, la collaboration PVLAS du laboratoire Legnaro de l'INFN a communiqué un résultat surprenant, compatible avec la détection d'une particule ressemblant à l'axion, encourageant aussitôt de nombreuses activités théoriques et expérimentales dans le monde entier. L'atelier international sur les axions à l'Institut for Advanced Study, qui s'est tenu à Princeton du 20 au 22 octobre 2006, a rassemblé des théoriciens et des expérimentateurs pour faire l'état de l'art et envisager de futures expériences. La bonne organisation de l'atelier et l'atmosphère unique de Princeton offraient un cadre rêvé pour des discussions fécondes.

Axel Lindner, DESY, and **Konstantin Zioutas**, University of Patras.

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CMS: a super solenoid is ready for business

The powerful superconducting solenoid for the CMS experiment has passed its commissioning tests with flying colours and is now ready for routine operation.

For seven years, Point 5 on the LHC has been the site of intense activity, as the CMS detector has taken shape above ground at the same time as excavation of the experimental cavern below. Last year saw an important step in the preparations on the surface, as the huge CMS superconducting solenoid – the S in CMS – was cooled down, turned on and tested.

The CMS coil is the largest thin solenoid, in terms of stored energy, ever constructed. With a length of 12.5 m and an inner diameter of 6 m, it weighs 220 tonnes and delivers a maximum magnetic field of 4T. A segmented 12500t iron yoke provides the path for the magnetic flux return. Such a complex device necessarily requires extensive tests to bring it into stable operation – a major goal of the CMS Magnet Test and Cosmic Challenge (MTCC) that took place in two phases between July and November in 2006.

From the start, the idea was to assemble and test the CMS magnet – and the whole detector structure – on the surface prior to lowering it 90 m below ground to its final position. The solenoid consists of five modules that make up a single cylinder (figure 1), while the yoke comprises 11 large pieces that form a barrel with two endcaps. There are six endcap disks and five barrel wheels, and their weight varies from 400t for the lightest to 1920t for the central wheel, which includes the coil and its cryostat.

The CMS solenoid has several innovative features compared with previous magnets used in particle-physics experiments. These are necessary to cope with the high ampere turns needed to generate the 4T field – 46.5 MA around a 6 m diameter. The most distinctive feature is the four-layer coil winding, reinforced to withstand the huge forces at play. The niobium titanium conductor is in the form of Rutherford cable co-extruded with pure aluminium and mechanically reinforced with aluminium alloy (figure 2). The layers of this self-supporting conductor bear 70% of the magnetic stress of 130 MPa while the cylindrical support structure, or mandrel, takes the remaining 30%.

Constructing the coil has been a *tour de force* in international collaboration involving suppliers in several countries. The basic element, the superconducting wire, originated with Luvata in Finland, and passed to Switzerland, where Brugg Kabelwerk made



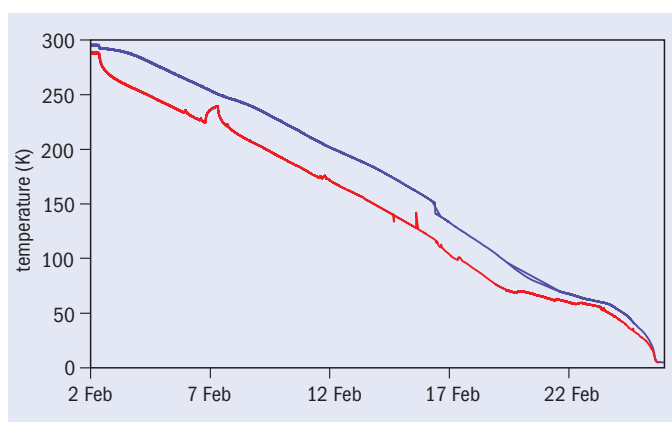
Fig. 1. The assembly of the solenoid nears completion at CERN.

the Rutherford cable, and Nexans co-extruded it with pure aluminium. The cable then went to Techmeta in France for electron-beam welding onto two sections of high-strength aluminium alloy to allow the conductor to support the high magnetic stress. Finally ASG Superconductors in Italy wound the coils for the five sections of the solenoid, which travelled individually by sea, river and land to Point 5 for assembly into a single coil. The division into sections, and the chosen outer diameter of 7.2 m, ensured that transport could be by road without widening or rebuilding.

By August 2005 the solenoid was ready to be inserted into the cryostat that keeps it at its operating temperature of 4.5 K (figure 3). Cooling requires a helium refrigeration plant with a capacity of 800 W at 4.5 K and 4500 W in the range 60–80 K. The cryoplant was first commissioned with a temporary heat load to simulate the coil and its cryostat, and then early in 2006 the real



Fig. 2 (above) A model of the CMS solenoid coil, showing its four-layer coil-winding structure. Fig. 3 (above right). The solenoid, right, about to be inserted into the cryostat barrel. Fig. 4 (right). The first cool-down of the solenoid during three weeks in February 2006 was a complete success.



coil was ready for cool-down. In an exceptionally smooth operation the temperature of the 220 t cold mass was lowered to 4.5 K over 28 days (figure 4).

The next stage was to close the magnet yoke in preparation for the MTCC. The massive elements of the yoke move on heavy-duty air pads with grease pads for the final 100 mm of approach. Once an element touches the appropriate stop it is pre-stressed with 80 t to the adjacent element to ensure a good contact before switching on the magnet. To assure good alignment, a precise reference network of some 70 points was set up in the assembly hall, with the result that all elements could be aligned to within 1 mm of the ideal coil axis. The first closure of the whole yoke took some 30 days, and was completed on 24 July (*CERN Courier* September 2006 cover and p7). The MTCC could now begin.

Testing the magnet took place in two phases, with the initial tests in August 2006 and further tests and field mapping in October. The cosmic challenge, to test detectors and data-acquisition systems with cosmic rays, took place simultaneously (p26). Figure 5 (p24) shows the cycles in which the magnet reached increasing current levels during Phase I, remaining for longer periods of high current, and hence high magnetic field, during Phase II. Each step in current ended with a fast discharge into external dump-resistor banks. Depending on the current level at the time of the fast discharge, it could take up to three days to re-cool the coil.

A key feature with any superconducting magnet system is to

protect against high thermal gradients occurring in the coil if the system switches suddenly from being superconducting to normally (resistively) conducting with a sudden loss of magnetic field and release of stored energy – a quench. The aim is to dissipate the energy into as large a part of the cold mass as possible. For this reason the CMS solenoid is coupled inductively to its external mandrel, so that in the case of a quench eddy currents in the mandrel heat up the whole coil, dissipating the energy throughout the whole cold mass.

The tests showed that when the magnet discharges the dump resistance warms up by as much as 240°. At the same time the internal electrical resistance of the coil increases, up to as much as 0.1 Ω after a fast discharge at 19 kA. Figure 6 (p24) shows the effect of the magnet's increasing resistance with current on the time constant for the discharge.

The tests also showed that after a fast discharge at 19 kA the average temperature of the whole cold mass rises to 70 K, with a maximum temperature difference of 32.3° measured between the warmest part, on the inside of the central section of the coil, and the coldest part, on the outside of the mandrel. It then takes about two hours for the temperature to equalize across the whole coil. About half of the total energy (1250 MJ) dissipates as heat in the external dump resistor, which takes less than two hours to return to its normal temperature.

Monitoring the magnet's mechanical parameters was also ▷

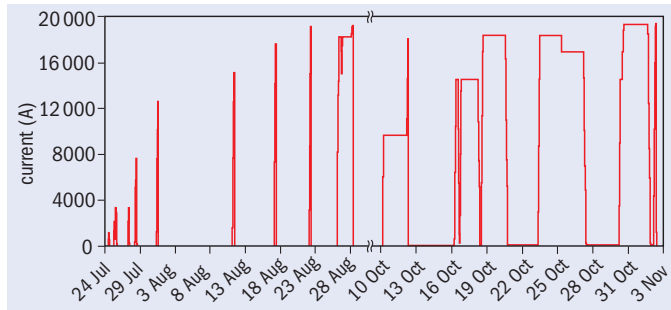
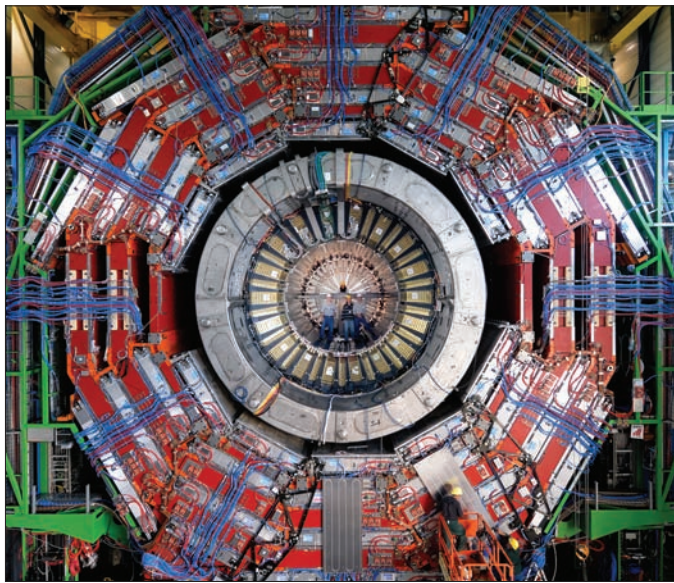


Fig. 5. During the two phases of tests, the magnet was powered to increasing current levels, and then for longer periods.



an important feature of the tests, to check for example the coil shrinkage and the stresses on the coil-supporting tie rods during cool-down. The measured values proved to be in excellent agreement with calculations. Powering the cold mass step-by-step allowed also for measurements of any misalignment of the coil. This showed that the axial displacement of the coil's geometric centre is less than 0.4 mm, indicating a magnetic misalignment of less than 2 mm in the positive z direction.

A major goal of Phase II of the MTCC was to map and reconstruct the central field volume with 5×10^{-4} precision. The measurements took place in three zones, with flux-loop measurements in the steel yoke, check-point measurements near the yoke elements, and a detailed scan of the entire central volume of the detector – essentially the whole space inside the hadron calorimeter.

Measuring the average magnetic flux density in key regions of the yoke by an integration technique involved 22 flux loops of 405 turns installed around selected plates. The flux loops enclosed areas of 0.3–1.58 m² on the barrel wheels and 0.48–1.1 m² on the endcap disks. The flux loops measure the variations of the magnetic flux induced in the steel when the field in the solenoid is changed during the fast (190 s time constant) discharge. A system of 76 3D B-sensors developed at NIKHEF measured the field on the steel–air interface of the disks and wheels to adjust the 3D magnetic model and reconstruct the field inside the iron yoke elements, which are part of the muon absorbers.

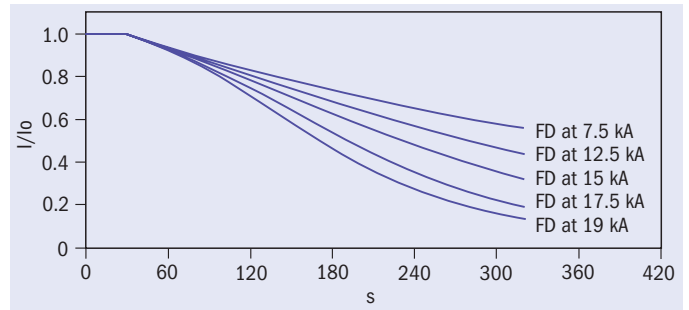


Fig. 6. The normalized magnet current during a fast discharge triggered at $t=30$ s for several initial currents.

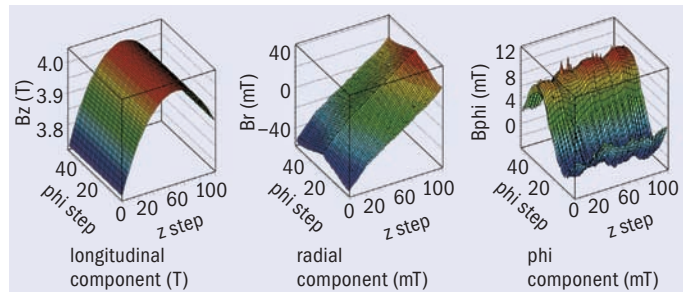


Fig. 7 (left). The solid steel yoke (red) comprising three concentric layers interspersed with muon chambers (silver) surround the superconducting solenoid (silver-coloured ring). The field mapper is installed across the centre of the hadron calorimeter (gold coloured). Fig. 8 (above). Graphical representation of the magnetic field measured by sensors on one of the two arms of the mapper. The two arms were at different z values; this one maps from the most negative z step (0), while the other reaches the most positive z step.

A special R&D programme with sample disks made of the CMS yoke steel from different melts investigated if the measurements of the average magnetic flux density in the yoke plates could be done with accuracy of a few per cent using flux loops. These studies showed that the contribution of eddy currents to the voltages induced in the test flux loop is negligible.

The precise measurement of the magnetic field in the tracking volume inside the CMS coil used a field-mapper designed and produced at Fermilab. This incorporated 10 more 3D B-sensors, developed at NIKHEF and calibrated at CERN to 5×10^{-4} precision for a nominal field of 4T. To map a cylindrical volume inside the coil, this instrument moved along the rails installed inside the hadronic barrel calorimeter, stopping in 5 cm steps at points where the sensor arms could be rotated through 360°, and at predefined angles with azimuth steps of 7.5°. Figure 7 shows the final position of the mapper before closure of the positive endcap. It mapped a cylindrical volume 1.724 m in radius and 7 m long.

The CMS magnet has six NMR probes near the inner wall of the superconducting coil cryostat to monitor the magnetic field. These were also used in the field-mapping to measure the field on the coil axis and on the cylindrical surface of the measured volume.

The actual field-mapping in October involved a series of measurements at 0T, 2T, 3T, 3.8T (twice to study systematics), 3.5T and 4T. The flux-loop measurements were made during fast-discharges of the coil at various current values. While the detailed

analysis of the data is still ongoing, preliminary studies are very encouraging. The field distribution behaves very much as the simulation predicted – though more detailed simulation of the extra iron in the feet of CMS is necessary to account for it fully.

Figure 8 represents the magnetic field measured by sensors on the negative z arms of the mapper. The longitudinal component varies, as predicted, from 4T at the point (0, 0, 0) to 3.75T close to the endcap region of the electromagnetic calorimeter. The two arms of the mapper were at different z values, hence one maps from the most negative z step (0), and the other reaches the most positive z step (121). As a natural consequence of the flux return in the iron, the radial component is zero at (0, 0, 0) rising to about 40 mT near the nose region of the endcap.

The azimuthal component of the field is nominally zero, but as the plot shows it takes on small values with a sinusoidal dependence on the rotation angle. This is now fully understood as coming from small tilts of the plane in which the mapper moves with respect to the nominal z axis of the magnetic field; this couples the magnetic field components and also gives rise to the small variations seen in the radial component. In addition, the team now understands some even smaller variations in the sinusoidal behaviour of the azimuthal field as a function of the z step following a careful survey of the tilts induced on the mapper arms as it traversed the length of the coil on its (almost) straight rails.

The electrical tests of the solenoid have demonstrated its excellent performance, as well as the functioning of its ancillary systems, and its readiness for smooth operation. The detailed mapping was equally successful and final analysis is now underway to ensure that the best possible parameterization of the field for analysis of real data in autumn 2007. As soon as the tests were over, the huge sections of yoke were pulled apart again, and the descent to the cavern (see cover) could at last begin.

• Many institutes participating in CMS took part in the design, construction and procurement of the magnet, as members of the CMS Coil Collaboration, including CEA Saclay, ETH Zurich, Fermilab, INFN Genoa, ITEP Moscow, the University of Wisconsin and CERN.

Résumé

CMS: un solénoïde supraconducteur prêt à fonctionner

L'année dernière, une étape importante a été franchie dans les préparatifs de l'expérience CMS du LHC: l'immense solénoïde supraconducteur (le S de CMS) a été refroidi, mis sous tension et testé. Jamais jusqu'ici un solénoïde fin n'avait pu stocker autant d'énergie. De 12,5 m de longueur et de 6 m de diamètre intérieur, il pèse 220 tonnes et crée un champ magnétique pouvant atteindre 4 T. Une culasse en fer segmentée de 12 500 t permet le retour du flux magnétique. Ce dispositif complexe doit être soumis à des essais approfondis. C'était le but de «l'épreuve de l'aimant et du défi des cosmiques» (MTCC), qui se sont déroulés en deux étapes entre juillet et novembre 2006 et ont exigé la cartographie de précision de la région centrale du champ magnétique.

Domenico Campi, CERN, and **David Stickland**, Princeton University. CMS would like to dedicate this article and the following one to the memory of colleagues and friends, Vitaly Kaftanov, Jean-Claude Lottin, Xavier Lagrue and Rich Smith.

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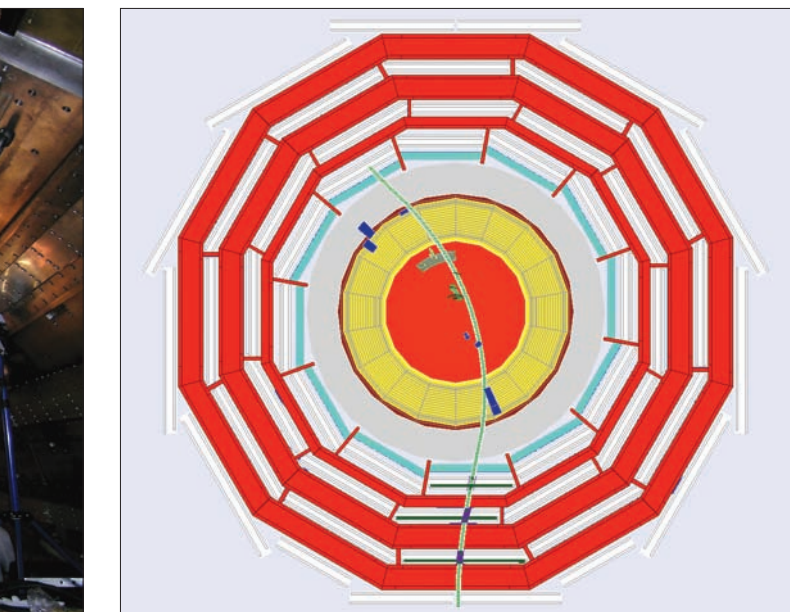
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S on a cosmic challenge

collaboration took advantage of the near-complete assembly of the detector, from support systems through to data-acquisition.



Left: a “gold plated” event, reconstructed online, from the CMS cosmic challenge. Right: preparing for the cosmic challenge. Muon chambers fill the detector. Two sectors of these chambers were fully equipped and used for the cosmic challenge. The ECAL supermodules used are visible behind the person working on the HCAL; gold coloured) and the solenoid cryostat (silver ring).



Right: a “gold plated” event, reconstructed online, from the CMS cosmic challenge. Participating in the run: the drift tubes (between the red layers of the magnet) and the ECAL (between the tracker and the HCAL). The muon track was reconstructed taking account of the magnetic field. (Courtesy Ianna Osborne.)

test combined sub-detectors in 20° slice(s) of CMS with the magnet, using as near as possible final readout and auxiliary systems to check noise and interoperability; and last but not least, trigger and record cosmic muons and try out operational procedures.

In addition, the cosmic tests had to make no significant impact on progress in assembling the detector, and had to take place in the shadow of the work on commissioning and field-mapping the magnet. The tests also had to complement the trigger-system (high rate) tests taking place in the electronics-integration centre. Moreover, the aim was to use final systems as far as possible, that is with no (or very few) specific developments for the cosmic test. Another important aspect was to build a fully functional commissioning and operations team of experts from a collaboration that brings together more than 2000 people from laboratories worldwide, transcending linguistic and cultural backgrounds.

In order not to interfere with assembly work, electronics racks and control rooms for the tests were installed just outside the surface-assembly building in a large control barrack recovered from the OPAL experiment at LEP. Substantial investments were nonetheless needed in the surface hall, general and sub-system infrastructure, the triggering system, some temporary power supply systems, and in the tracker “slice” that was specially made for the cosmic challenge within a full replica of the final containment tube.

As the project progressed, the collaboration began to recognize its importance as a first test of intra-collaboration communication and remote participation, and the original scope expanded to include more substantial objectives for offline as well as online systems. A series of Run Workshops, culminating in a readiness review in June 2006, established the final objectives of the project. Weekly Run Meetings open to all CMS, eventually becoming daily, also ensured coordination. Ultimately the diligent work of hundreds of people aided by a little good fortune transformed the cosmic challenge into a cosmic success for CMS.

Four sub-detectors took part in the challenge. The silicon tracker system comprised 75 modules of the Tracker Inner Barrel in two partially populated layers, 24 modules of the Tracker Outer Barrel, and 34 modules of the Tracker Endcap system in two partially populated “petals”. By normal standards these 133 modules were a substantial system, comparable to any silicon detector used at LEP. It is worth remarking that this represents only 1% of the final CMS system, by far the largest ever built using silicon detectors. In addition, there were two barrel supermodules comprising 3400 lead tungstate crystals of the ECAL, or about 5% of the total; eight barrel sectors (22%), four endcap sectors (11%), and four sectors of the outer barrel section of the HCAL. For muon detection there were three (out of 60) muon barrel sectors, ▷



The crowded control room in the "Green Barrack" at Point 5 during the CMS cosmic challenge (G Franzoni).

consisting of drift tube (DT) and resistive plate chambers (RPC), together with cathode strip chambers (CSCs) forming endcap muon chambers – in all, 8% of the total system.

As was the case for the sub-detectors, all common support systems were tested in close to final versions, using in most cases production hardware and software. The first priority was the definition and implementation of elements of the Detector Safety System. The teams had also to integrate sub-detectors with the central Detector Control System and a scaled-down version of the trigger system. The tests used the central DAQ with its final architecture and approximately 1% of the final computing power, and successfully operated the integrated run control, event builder, event filter, data storage and transfer to the CERN Advanced Storage manager (CASTOR). Throughout the whole exercise a fully functional event display enabled a simple and quick feedback on the status of different sub-detectors.

Other important organizational components of the operations were the consistent use of an electronic logbook, webcams, video-conferencing tools and Wiki-based documentation, as well as web-based monitoring, which was extensively tested. The challenge involved data transfers from Tier-0 (at CERN) to some Tier-1 centres (at CNAF/Bologna, PIC/Madrid and Fermilab) through the Physics Experiment Data Export (PHEDEX) protocol exercising the fast offline analysis and remote monitoring at the Meyrin CERN site as well as at the Fermilab Remote Operations Center.

There were two distinct phases of the cosmic challenge: the first phase in July and August 2006 was parasitic to the commissioning of the magnet (p22). During this phase around 25 million "good" events were recorded with, at least, DT triggers and the ECAL and Tracker slice in the readout. Of these, 15 million events were at a stable magnetic field of at least 3.8T – close to the maximum field of 4T. A few thousand of the events corresponded to the benchmark where a cosmic ray was recorded in all four CMS sub-detector systems – Tracker, the ECAL, the HCAL and muon system – with nominal magnetic field. The image of the first of these events rapidly became a symbol of the success of the cosmic challenge and the demonstration of the CMS detector "as built". During the challenge, data-taking efficiency reached more than 90% for extended periods. Data transfer to some Tier-1 centres, online event display, quasi-online analysis on the Meyrin site, and fast offline data-checking at Fermilab were some of the

highlights of Phase I, which in this way offered a first taste of the full running experience. One example of an encouraging result was the good agreement between the predicted and measured cosmic muon spectra, both in momenta and angular distributions, using the new CMS software, CMSSW.

Phase II took place during October and November, after an efficiently executed "cosmic shutdown", during which the tracker slice and the ECAL were removed and replaced with a field-mapper. While not as glamorous as the first phase, Phase II provided a wealth of solid information relevant to commissioning and operating CMS as an instrument for physics. For this phase, the team corrected and tested several minor faults found in Phase I in the magnet, detectors and central systems, and took more data with the HCAL and muon systems. Phase II recorded about 250 million events for studies of calibration, alignment and efficiency. The measurements made of the effect of the magnetic field on the response of the HCAL and on the drift paths in the muon barrel DTs were particularly crucial. Integration work on aspects of the trigger also allowed data to be recorded with some final systems.

Less than two weeks after the end of the magnet tests, the CMS detector was fully re-opened so the major elements could begin to be lowered into the experiment cavern. Meanwhile, work on analysing the millions of cosmic-ray events recorded in the cosmic challenge continues in many of the institutes in the collaboration. Now, as attention turns to completing the remaining assembly and installation of the muon, tracking and ECAL systems, the whole collaboration is looking forward eagerly, and with confidence, to re-assembling the detector underground and repeating the exciting and successful accomplishments of 2006, but this time with tracks from collisions of LHC beams.

Résumé

La collaboration CMS relève un défi cosmique

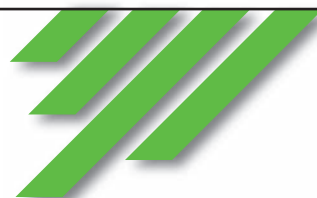
Comparé aux trois autres grandes expériences LHC, CMS a déployé une stratégie toute personnelle pour la construction de son détecteur au CERN. La collaboration a décidé dès le début d'assembler les grands éléments des détecteurs dans un hall de surface avant de descendre des sections complètes dans la caverne souterraine. En été et en automne 2006, la collaboration CMS a tiré parti de la présence en surface du détecteur presque entièrement achevé pour tester ses performances (des systèmes de support à l'acquisition des données) avec des rayons cosmiques. Quatre sous-détecteurs ont participé au «défi des cosmiques», qui a permis d'enregistrer des millions d'événements avec un champ magnétique proche de sa valeur maximale.

Austin Ball and **Archana Sharma**, CERN.



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PSI pixels spin off into research with X-rays

The countdown to the LHC start-up has begun, but even before the first protons have collided, pixel detectors designed for the CMS experiment are being used in other areas.

When the CMS experiment begins recording data at the LHC the first components to detect particles produced in the head-on proton-proton collisions will be those in the layers of silicon pixels that form the inner part of the CMS tracker (figure 1). The pixel detectors in the barrel part of the cylindrical tracker are the responsibility of a Swiss collaboration based at the Paul Scherrer Institute (PSI). These specially developed detectors have to fulfil extreme requirements. In addition, their high performance in tests has resulted in similarly designed but simpler detectors for investigations into protein crystallography at the Swiss Light Source and radiography at the Swiss Spallation Neutron Source. These detectors are already in operation and a start-up company has been formed to supply them to other synchrotron light sources.

Researchers at PSI began developing a hybrid pixel detector system 12 years ago that would be suitable for the very high rates of particle tracks expected at the LHC. Roland Horisberger, project manager of the pixel project, recalls that at the time such a pixel system appeared very futuristic and posed many questions. Nevertheless, researchers from PSI, the universities of Basel and Zurich, and the ETH Zurich gathered together and formed a pixel competence centre to develop a pixel vertex detector for CMS.

Pixels at work

This new detector is in essence a very large digital camera for recording the tracks of ionizing particles. It comprises 65 million silicon pixels, each $100\ \mu\text{m} \times 150\ \mu\text{m}$, which are micro-bump-bonded to special complementary metal-oxide semiconductor (CMOS) read-out chips. This enables researchers to record precisely the position and time of a penetrating particle track. The read-out chip detects the hit pixels and records their analogue pulse height. It is then possible, using charge division, to achieve an excellent position resolution of $10\text{--}15\ \mu\text{m}$, while limiting the data transfer to the hit pixels only. For this purpose each pixel is equipped with a fast charge-sensitive amplifier with an analogue sample-and-hold circuit and a discriminating comparator circuit to perform the hit “decision”.

The pixel barrels contain as many as 768 silicon sensor modules, each of which has a sensitive area of about $10\ \text{cm}^2$ and consists of a matrix of $160\ \text{pixels} \times 416\ \text{pixels}$. The charge produced by the



Fig. 1. Holding a 16 chip hybrid pixel detector unit developed for CERN, PSI's project manager Roland Horisberger stands at the centre of the CMS experiment close to where the detectors will be positioned. (All images courtesy of HRBramaz/PSI.)

66560 pixels is conducted through an equal number of micro-bump-bonded contacts to 16 read-out chips, each containing 4160 cells, where the charge signals are amplified and processed.

These “hybrid” pixel detectors depend on a special high-density connection technique, which was developed in co-operation ▷

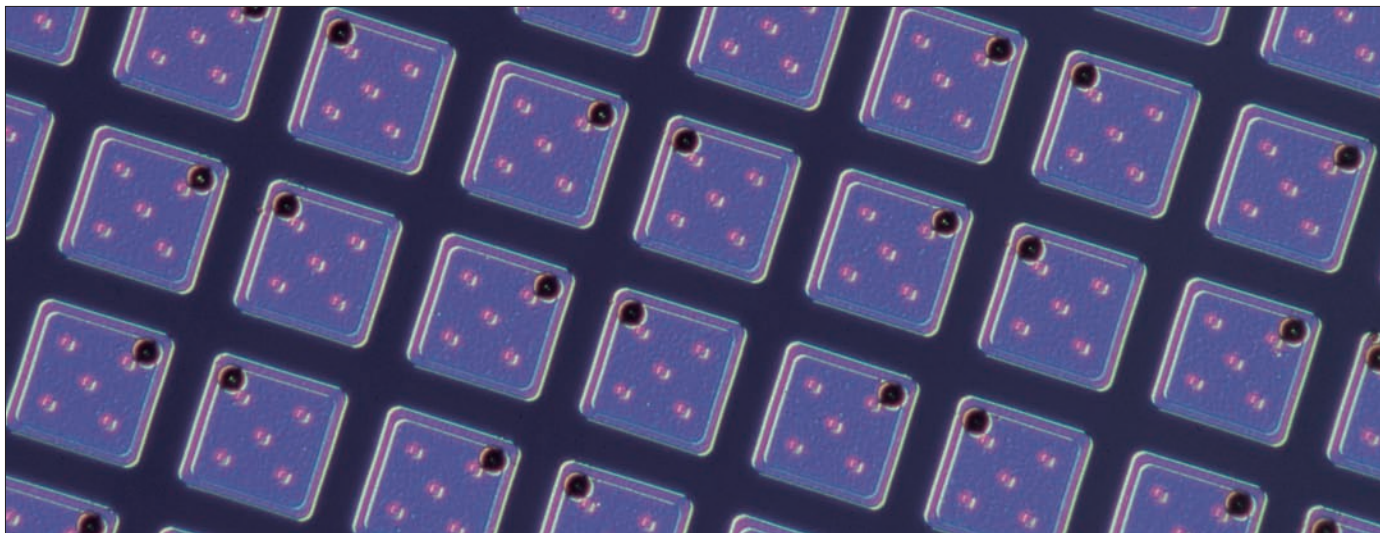


Fig. 2. Pixel detectors depend on the bump-bonding technique, which PSI adapted and miniaturized. The contact between pixel and microchip is a 17 μm solder ball of indium. This microscope image shows pixels with the indium balls (dark points).

with the Laboratory for Micro- and Nanotechnology at PSI. The contact between pixel and microchip – the bump – is a 17 μm solder ball of indium, a metal with a low melting point. The technique, known as bump-bonding, was taken from industry and miniaturized further to achieve the desired small bump ball size (figure 2). The work requires that the bump-bonding is achieved with a precision of 1–2 μm .

At CMS the pixel modules are placed close to the beam pipe at radii of 4, 7 and 11 cm. They provide the three innermost charged-particle tracking points of the experiment and should enable the reconstruction of the secondary displaced vertices arising from b-quark decays, a crucial signature for the discovery of new physics processes. At the design luminosity of the LHC the enormous particle flux of nearly 10^{10} particles per second will create 120 GB of data every second. The intensive bombardment creates an extreme radiation load on the detectors and the associated on-board electronics. Yet tests at the PSI proton accelerator have shown that this does not significantly affect the functioning of the detectors.

From the LHC to protein crystals

The detector technology developed for CERN measures particle tracks for high-energy particle physics, but at the Swiss Light Source the same technology operates as a very sensitive digital X-ray camera known as the PILATUS 6M detector (for “Pixel Apparatus for the SLS”; figure 3). It consists of 60 modules with 6 million pixels, making up an active area of 43 cm \times 45 cm. Adapted to the needs of experiments at synchrotrons, the detector operates in single-photon counting mode – each incoming photon is counted and the number for each pixel is stored digitally.

The process has no electrical background interference, so it achieves an extremely high dynamic range. Very weak and very intense signals can therefore be measured at the same time in a single image, and exposure times can be selected freely between 1 ms and several hours. The CMOS chips and the sensors are radiation tolerant, and the PILATUS 6M detectors have a dynamic range of 20 bits, a highest sensitivity in the energy range of 3–30 keV

and a read-out time of a few milliseconds.

When this equipment was being developed the focus was on its application for protein crystallography. Understanding the molecular structure of a crystal requires knowing the intensities of all the reflections as accurately as possible. Researchers can use this information to calculate the actual arrangement of the atoms and molecules in the protein, but the quality of data used to decode the molecular structure is crucial.

In these experiments the researchers fire a tightly bundled X-ray beam onto a protein crystal. This results in images that are patterns formed by thousands of scattered Bragg reflections. The advantage of pixel detectors is that they can deal with the incoming data in the most efficient way. The rate of more than 1 million X-ray photons per second hitting just a few pixels means that the reflections at the centre of the image are extremely intense; at large scattering angles towards the edge there are far fewer reflections from a few dozen photons. Molecular biologists are excited about the excellent data quality they have obtained so far with the PILATUS 6M detector.

The PILATUS 100K detector is a smaller system that was developed in parallel. This system consists of a matrix of approximately 500 pixels \times 200 pixels and enables information to be recorded even faster and with greater precision than with comparable commercial detectors. The system is currently used for material science research at synchrotrons and improves insight in several research areas such as the surface properties of materials. To meet growing demands, a spin-off company was recently founded and the CEO, Christian Broennimann, leads a team of four. The market for these detectors lies mainly in the field of synchrotron radiation.

Meanwhile, the precision work on the individual modules for the CMS experiment continues. The barrel pixel modules are currently being fabricated at PSI at a rate of four to six a day, with a total of 720 modules to be delivered ready for service in late autumn 2007. The PSI pixels will then be on the look-out for passing particles and playing their part in the search for new physics at the LHC.

Fig. 3. The PILATUS 6M detector is a highly sensitive digital X-ray camera that consists of 60 modules with 6 million pixels, making up an active area of 43 cm x 45 cm. A spin-off company has been created to meet the growing demands in the field of synchrotron radiation. Members of the team are reflected here. Left to right: Christian Broennimann, Markus Naef and Eric Eikenberry.



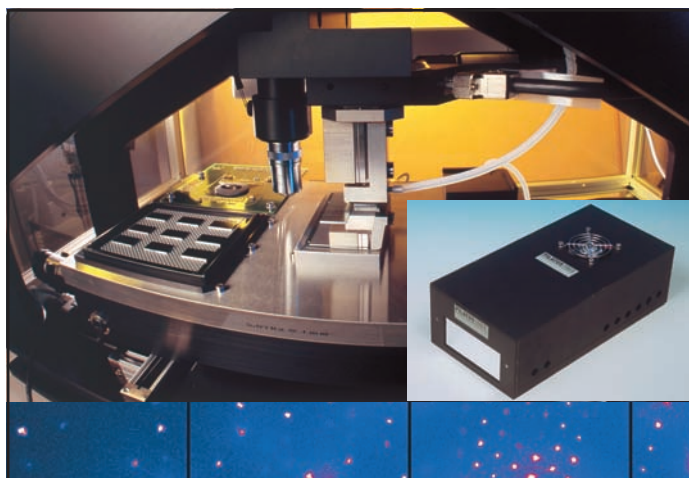
Résumé

Retombées des pixels du PSI dans les applications des rayons X

Lorsque la collaboration CMS commencera à enregistrer des données au LHC, les premiers éléments qui détecteront des particules produites par les collisions frontales proton-proton seront les couches de pixel au silicium formant la partie centrale du détecteur. Les pixels de la partie tonneau du trajectographe cylindrique relèvent de la responsabilité d'une collaboration

suisse à l'Institut Paul Scherrer. Ces détecteurs spécialement conçus doivent répondre à des exigences extrêmes et leurs performances élevées lors des essais ont permis de concevoir des détecteurs plus simples mais de conception similaire, qui sont déjà utilisés pour les recherches en cristallographie des protéines menées à la source de lumière suisse (SLS) et en radiographie à la source suisse de neutrons de spallation.

Juanita Schläpfer-Miller, Paul Scherrer Institute.



Next Generation X-Ray Detectors

DECTRIS, a spin-off company of the Paul Scherrer Institute (PSI), is the first company to sell complete X-ray detector systems based on the outstanding properties of the newly developed "single photon counting" technology.

Key features of the PILATUS 100K detector system:

- High dynamic range: 20 bits/pixel
- Short readout time: 2.6 ms
- High framing rate: 200 Hz
- High counting rate: 3×10^9 /s/pixel
- Very simple operation

Applications:

- Synchrotron radiation
- Laboratory X-ray diffraction
- Non-destructive testing



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LUMI'06 takes strides towards LHC upgrade

The LUMI'06 workshop, which took place in Valencia, brought together experts from Europe, Japan and the US to review scenarios for increasing the LHC's luminosity.



Participants at LUMI'06 in front of the Institut de Fisica Corpuscular in Valencia, which hosted the workshop.

Over the past two years, studies to upgrade the LHC have made great progress under the joint auspices of the European CARE accelerator network on High-Energy High-Intensity Hadron Beams (HHH) and the US LHC Accelerator Research Program (US-LARP). These efforts recently culminated in the third topical workshop of the CARE-HHH-APD network, LUMI'06, which was held in Valencia on 16–20 October 2006. About 70 members of CARE and LARP and their associated institutes attended, including 13 participants from major US laboratories and two from KEK in Japan.

LUMI'06 was devoted to the beam dynamics of the LHC luminosity upgrade and to high-intensity effects limiting the performance of both the LHC accelerator complex at CERN and the Facility for Antiproton and Ion Research (FAIR) at GSI. More specifically, the double objective of LUMI'06 was to establish a forward-looking baseline scenario for the LHC luminosity upgrade and to concur on a scientific rating of alternative scenarios for the upgrade of the CERN accelerator complex, while also assessing the performance of the GSI FAIR synchrotrons.

The workshop concluded an exciting year of intense HHH networking activity, in which several other workshops and conferences were devoted to various LHC upgrade issues, treating topics such as crystal collimation and channelling, rapid switching devices, superconducting magnet design, magnet optimiza-

tion, super-ferric storage-ring approaches and beam dynamics in high-brightness hadron beams. Throughout the year, in preparing for LUMI'06, there had also been great progress made on the development of a web repository for accelerator physics codes, code benchmarking and on the construction of a database for superconducting cables and magnets.

Accomplishing key goals

A highlight of experimental studies just before the workshop was the first successful test of crystal reflection with a 400 GeV proton beam at CERN in the SPS North Area by the H8-RD22 collaboration. The demonstration of an extremely high effective field, together with more than 95% extraction efficiency, opens up a new perspective for the upgrade of the LHC collimator system. Such an improvement is certainly welcome, in view of the known obstacles on the way to reaching the nominal LHC performance.

Several speakers at LUMI'06, including CERN's Ralph Assmann, Rüdiger Schmidt and Gianluigi Arduini, surveyed the various difficulties and limitations of the nominal LHC and of the existing CERN complex – related, for example, to collimation, machine protection and the injectors – and they pointed out the challenges that need to be overcome to reach the LHC design luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. Nevertheless, after five days of intense discussions,

the workshop participants displayed great optimism about the upgrade goal of boosting the LHC peak luminosity by another factor of 10 beyond nominal towards $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$.

A key objective that LUMI'06 successfully accomplished was to select the most promising upgrade paths and, possibly, improve them or identify new ones. The workshop considerably reduced the number of alternative scenarios for the upgrade of the interaction region by arguing against all layouts with strong separation dipoles between the collision points and the low-beta quadrupoles closest to them. A primary argument in favour of the “quadrupole-first” solutions is the different level of difficulty and implied development timescale. In particular, at present nobody in the world is actively prototyping strong superconducting dipole magnets.

In considering the technology on which to base the new low-beta quadrupoles there are two alternatives – namely “pushed” NbTi and Nb₃Sn – that the workshop decided to pursue in parallel until the first results become available from long Nb₃Sn prototype magnets to be built in the US. This should be within the next two or three years. CERN's Tom Taylor in particular proposed an intriguing “hybrid” solution, combining both NbTi and Nb₃Sn technologies.

Two novel concepts that would greatly enhance the luminosity potential of an LHC upgrade foresee complementing the interaction-region upgrade with additional slim superconducting dipole magnets (DO) or quadrupole doublets (QO), which would be embedded deeply inside the upgraded detectors. Together with other measures, such elements may allow squeezing the beta functions at the collision point by a factor of seven, as opposed to two, beyond nominal, down to a β^* of around 8 cm. Extensive studies are needed for the accelerator and detectors before these novel schemes can be soundly judged for viability.

The compensation of long-range beam-beam effects by a current-fed metre-long wire running parallel to the beam is by now almost established as a valuable and inexpensive complementary tool for enhancing performance. At LUMI'06, Fermilab's Vladimir Shiltsev proposed the additional use at the LHC of electron lenses both for head-on beam-beam compensation and as a halo collimator. Large-angle “crab” cavities for interaction-region layouts with large crossing angles were rejected in view of numerous technical challenges, which several speakers identified, including Brookhaven's Rama Calaga and Ramesh Gupta, and CERN's Rogelio Tomas and Joachim Tuckmantel. Participants appreciated the high risk involved with choosing a crossing geometry that would fully rely on their functionality. In contrast, simpler small-angle crab cavities were recognized as a potentially powerful tool for realizing very small beta functions in conjunction with the detector-integrated dipole DO. KEK's Kazuhito Ohmi presented simulations of LHC emittance-growth with crab cavities and feedback. The results of the first-ever crab cavity operation in a collider at the KEKB electron-positron machine will be the next milestone. Expected soon, these results will have a big impact on the further pursuit of using crab cavities at hadron colliders.

Figure 1 shows two example layouts of an upgraded LHC interaction region, accommodating several of the advanced elements discussed during the workshop. Advantages of the first scheme, with a detector-integrated slim dipole located about 3 m from the interaction point, are the reduced number of long-range collisions

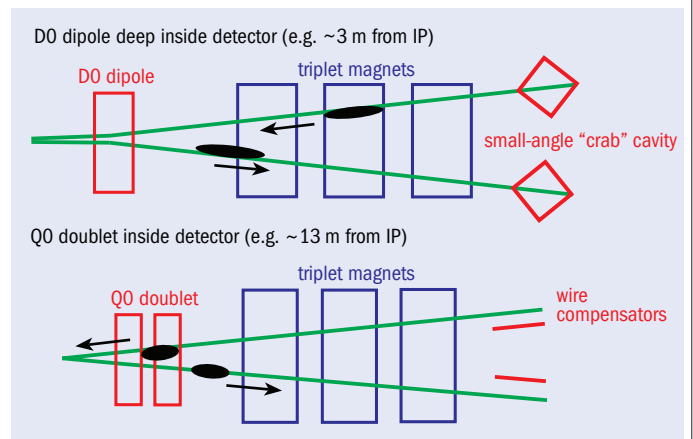


Fig. 1. Examples of layouts for a “quadrupole first” interaction region for an LHC upgrade, featuring detector-integrated dipoles (DO) or quadrupoles (QO) together with large-aperture quadrupole triplets and small-angle “crab” cavities or long-range beam-beam wire compensators, respectively.

and the absence of geometric luminosity loss. The second scheme relaxes the triplet quadrupole requirements and decreases the chromaticity. A combination of the two schemes – that is an interaction region layout containing both DO and QO – is another possibility, which combines all the advantages.

Tackling the beam-parameter frontier

The workshop also made significant progress at the beam-parameter frontier. In the past, parameter sets suffered either from an unacceptable number of events per crossing or from an electron-cloud heat load that by far exceeded the available cooling capacity. LUMI'06 approved two compromise solutions with 25 ns and 50 ns bunch spacing, which the authors presented (table 1). For these new sets of beam parameters the number of events per crossing stays near the maximum acceptable value, while the predicted electron heat load remains safely below the projected cooling capability.

The 25 ns option is accompanied by an 8 cm β^* , which requires a DO magnet inside the detector, Nb₃Sn large-aperture quadrupoles and a low-angle crab cavity. The 50 ns option has $\beta^* = 25$ cm, for which optics solutions exist based on either technology for the quadrupoles. In addition it needs only the wire compensation of long-range beam-beam effects. Since LUMI'06, the two biggest LHC experiments, CMS and ATLAS, have indicated a preference for the scenario with 50 ns spacing. LUMI'06 rejected the original baseline upgrade scenario with 12.5 ns bunch spacing – half the nominal – since accelerator physicists, cryogenics experts and detector physicists now generally agree that this spacing will produce an insurmountable heat load. Indeed, at this bunch spacing the well-known heating from image currents in the resistive wall and from synchrotron radiation already require the entire local cooling capacity, leaving zero reserve for the electron cloud, which is predicted to be the dominant heat source.

For the LHC injector upgrade, LUMI'06 has endorsed the Linac4/Superconducting Proton Linac upgrade, as well as PS2, a normal-conducting replacement for CERN's venerable Proton Synchrotron (PS) with twice the PS circumference. However, the workshop also made it clear that these new accelerators alone may not ▷

Table 1

parameter	symbol	nominal	ultimate	25 ns, low beta*	50 ns, long bunches
number of bunches	n_b	2808	2808	5616	1404
protons/bunch	$N_b [10^{11}]$	1.15	1.7	1.7	4.9
bunch spacing	$\Delta t_{\text{sep}} [\text{ns}]$	25	25	25	50
average current	$I [\text{A}]$	0.58	0.86	0.86	1.22
longitudinal profile		Gaussian	Gaussian	Gaussian	uniform
rms bunch length	$\sigma_z [\text{cm}]$	7.55	7.55	7.55	11.8
beta at IP1 & IP5	$\beta^* [\text{m}]$	0.55	0.5	0.08	0.25
crossing angle	$\theta_c [\mu\text{rad}]$	285	315	0	381
Piwinski parameter	$\theta_c \sigma_z / (\sigma^* 2)$	0.64	0.75	0.60	2.5
peak luminosity	$L [10^{34} \text{cm}^{-2}\text{s}^{-1}]$	1.0	2.3	15.5	10.7
optimum average luminosity for 10 h turnaround time	$\langle L \rangle [10^{34} \text{cm}^{-2}\text{s}^{-1}]$	0.46	0.91	2.4	2.5
optimum run length with 10 h turnaround time	$\tau_{\text{opt}} [\text{h}]$	21.2	17.0	6.6	9.5
total heat load on beam screen (max SEY=1.4)	dP/ds [W/m]	1.39	1.62	1.62	1.50
peak number of events/crossing		19	44	294	403

Parameters of LHC upgrade options with 25 ns and 50 ns bunch spacings compared with nominal and ultimate LHC design values.

overcome existing intensity limits in the Super Proton Synchrotron (SPS) and that complementary SPS “enhancements” are likely to be required. Several participants challenged the alternative to the normal-conducting PS2, namely a fast cycling superconducting PS2+. Issues of concern here include the distributed beam losses in a cold machine, heating from the fast ramp, technological development risks, missing physics arguments and lack of human resources. In addition, preliminary simulations presented by Miguel Furman of LBNL indicate that the electron cloud could be a serious problem for new superconducting injector rings.

In summary, the LUMI'06 workshop developed novel scenarios for the upgrade of the LHC interaction regions, while eliminating a number of previous options and proposed novel sets of beam parameters better tailored to a higher-luminosity LHC. The workshop also discussed the supporting upgrades to the CERN accelerator complex, including replacement of the PS, which may be necessary for boosting the integrated LHC luminosity, as well as the peak luminosity. With a substantial participation from US-LARP, the European and US upgrade activities could successfully be re-aligned and a general consensus emerged on the future steps to be taken. According to the present schedule, the LHC interaction regions will be upgraded by around 2014. The interaction region and beam-parameter upgrades should increase the peak luminosity several times. However, harvesting the full gain in the integrated luminosity as well will almost certainly require accompanying upgrades to the CERN injector complex, improving turnaround time and removing intensity bottlenecks.

- The HHH Networking Activity is supported by the European Community Research Infrastructure Activity under the European Union's Sixth Framework Programme “Structuring the European Research Area” (CARE, contract number RII3-CT-2003-506395).

Further reading

<http://care-hhh.web.cern.ch/CARE-HHH/LUMI-06>.

Résumé

LUMI'06 en route pour l'augmentation de la luminosité du LHC

Ces deux dernières années, les études sur l'augmentation de la luminosité du LHC ont beaucoup progressé sous les auspices conjoints du programme européen CARE sur les faisceaux hadroniques de haute intensité et de haute énergie (HHH) et du Programme de recherche sur les accélérateurs LHC des Etats-Unis (US-LARP). Leurs travaux ont récemment débouché sur le troisième atelier du réseau CARE-HHH-APD consacré à ce thème, LUMI'06, tenu à Valence en octobre 2006. Cet atelier avait deux buts: esquisser un scénario de base pour l'augmentation de la luminosité du LHC et s'entendre sur la valeur scientifique respective des divers autres scénarios pour l'amélioration du complexe d'accélérateurs du CERN, tout en évaluant les performances des synchrotrons pour le projet FAIR du GSI.

Walter Scandale and Frank Zimmermann, CERN. Dedicated to the memory of Francesco Ruggiero (p41).

String theory meets heavy ions in Shanghai

The latest experimental results from the heavy-ion programmes at RHIC and CERN's SPS were the focus of attention at QM2006 in Shanghai. For the first time there were discussions about attempts to connect these data with string theory.

The field of ultra-relativistic heavy-ion collisions held its 19th international quark-matter conference, QM2006, in Shanghai on 14–20 November 2006. More than 600 physicists discussed the latest experimental and theoretical advances in the study of quantum chromodynamics (QCD) at extreme values of temperature, density and low parton fractional momentum (“low- x ”).

The wealth of data from the six years of operation of the RHIC collider at Brookhaven, together with that from the fixed-target programme at CERN, is leading to a developing paradigm of the matter produced in high-energy nucleus–nucleus collisions as a “perfect liquid” with negligible viscosity. Far from the ideal parton-gas limit, the lattice QCD calculations for several quantities, such as the equation of state and the quarkonia spectral functions, reveal a non-trivial structure up to temperatures three times higher than the critical QCD temperature – the region that experiments are studying. The current theoretical and experimental efforts centre on characterizing in detail the unanticipated properties of this strongly interacting medium.

Strings and the perfect fluid

One of the most important indications of the formation of thermalized collective QCD matter in heavy-ion collisions is the observation of hydrodynamic flow fields in the form of large anisotropies in the final particle yields with respect to the reaction plane. If the medium expands collectively, the pressure gradients present in non-central collisions – with an initial lens-shaped overlap area – result in momentum anisotropies in the final state. Fluid-dynamics calculations indicate that such gradients must develop very early in the collision, during the high-density partonic phase, in order to reproduce the strong “elliptic flow” seen in the data.

Two new experimental results presented at the conference supported this theoretical expectation. The PHOBOS and STAR collaborations at RHIC have observed large dynamical fluctuations of the elliptic-flow strength, which are fully compatible with those

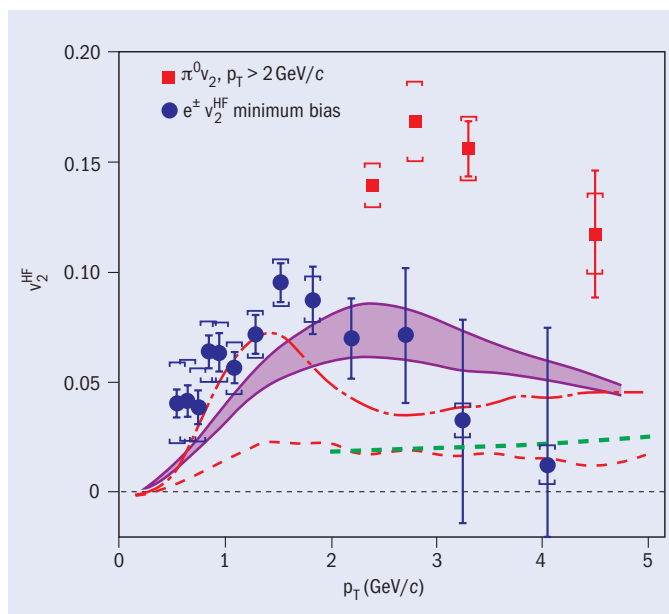


Fig. 1. The large azimuthal anisotropy (v_2 parameter) of heavy-flavour (HF) decay electrons is an indication that charm quarks participate in the collective flow of the medium.

expected from event-by-event variations in the initial collision geometry alone. These results confirm that the strength of the collective flow is driven by the initial spatial anisotropy of the medium. The PHENIX collaboration presented data on the azimuthal anisotropy of electrons coming from the decay of charm and beauty mesons (figure 1). They have observed momentum anisotropies as large as 10%, indicating that charm quarks interact collectively and participate in the common flow of the medium. Both results clearly suggest a robust hydrodynamical response developing during the early partonic phase of the reaction.

On the theory side, progress was reported on hydrodynamical approaches including computationally expensive descriptions of the full three-dimensional evolution of the plasma, as well as, for the first time, viscosity corrections. These calculations indicate that the dimensionless viscosity-to-entropy-density ratio, η/s , has to be very small in order to reproduce the liquid-like properties seen in the data. If the viscosity is negligibly small then the produced medium is the most perfect fluid ever observed, in striking contrast with the ideal-gas behaviour at high temperatures that asymptotic freedom predicts. Determining the transport properties of such a medium in the region not far from the critical \triangleright

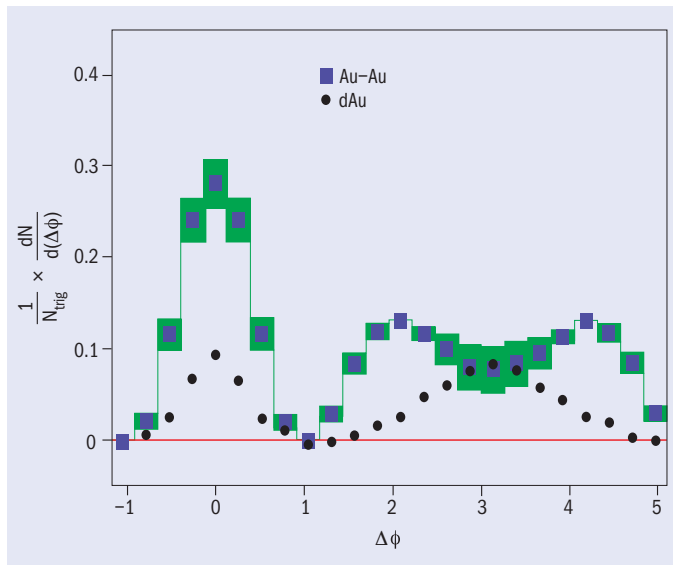


Fig. 2. Azimuthal angle correlations with respect to a semi-hard trigger hadron at $\Delta\phi=0$ in central gold-gold (Au-Au) collisions. The origin of the conical-like structure in the away-side hemisphere is one of the hottest topics of discussion.

temperature is, however, a difficult task: perturbative expansions break down in this region while finite-temperature lattice techniques are not well adapted for studying real-time quantities.

Techniques developed in the context of string theory, where strong coupling regimes are accessible to computation, can help to circumvent this difficulty. The meeting in Shanghai heard of new approaches that make use of the correspondence between anti-de Sitter (AdS) and conformal-field theories (CFT) to estimate the properties of strongly coupled systems in $N=4$ super-symmetric Yang-Mills theory from calculations in dual weakly coupled gravity. The somewhat controversial hope is that these theories, though different from QCD, capture the relevant dynamics in the range of interest for phenomenology at RHIC. One of the first observables computed by these methods is the η/s ratio, which is conjectured to exhibit a universal lower bound of $1/4\pi$.

The conference also reviewed results on the heavy-quark diffusion coefficient, the jet-quenching parameter, and photon and dilepton emission rates. The application of AdS/CFT techniques, which the field has received with both enthusiasm and criticism, is nonetheless providing new insight into dynamical properties of strongly interacting systems that cannot be directly treated by either perturbation theory or lattice methods. At the same time this approach is opening novel directions for phenomenological studies and experimental searches.

Jet quenching

The study of hadron spectra at high-transverse momentum in heavy-ion collisions – the apparent modifications of which are generically known as jet quenching – was again one of the main conference topics. Speakers from experiments at both RHIC and CERN's SPS presented new results on inclusive high- p_T hadron suppression and two- and three-particle correlations between a leading trigger particle and the associated hadrons. Two clear experimental facts summarize the findings: the strong suppres-



TD Lee (left), honorary chair of the conference, and Bill Zajc, former spokesperson for the PHENIX collaboration, both celebrated their birthdays in Shanghai during QM2006.

sion of the yields of leading-hadrons indicates that fast quarks and gluons lose a sizeable amount of energy when traversing dense matter; and the two- and three-particle correlations studies indicate that this energy reappears as softer particles far from the initial parton direction both in azimuth and rapidity space.

When the transverse momentum of the trigger and the associated particles are both similar and of the order of a few gigaelectron-volts, the two-particle-correlation signal around the direction opposite to the trigger particle presents a dip in central collisions, in striking contrast with the typical Gaussian-like shape observed in proton-proton and deuteron-gold collisions (figure 2). The three-particle-correlation data indicate a cone-like emission rather than a deflected jet topology. One proposal is that conical structures result from shock waves or Cherenkov radiation produced by highly energetic partons traversing the medium. Such observations could thus help to constrain the value of the speed of sound or the dielectric constant of the plasma. A more conservative explanation proposes one-gluon exclusive bremsstrahlung radiation at the origin of the enhanced “Mercedes-like” topologies that experiments observe. The differential studies of the transverse-momentum and the centrality dependencies presented at the conference further constrain the models.

Interesting intrajet correlations also appear in the near side, that is at angles in the trigger particle hemisphere. Owing to the trigger bias the near-side signal is sensitive to interactions that originate close to the surface of the hot dense fireball, while the opposite-side particle production reflects the most probable longer path through this medium. The data from the STAR collaboration (up to $p_T^{\text{trig}}=9$ GeV/c) show that, although the near-side azimuthal correlations remain basically unchanged from proton-proton to central gold-gold collisions, the pseudo-rapidity distribution is substantially broadened in the gold-gold case and presents a ridge structure above which an almost unaffected Gaussian shape appears. The dynamical origin of this effect is not yet understood but, interestingly, it indicates a coupling of the longitudinally expanding underlying event with the jet development.

With increased integrated luminosities, heavy-quark probes are becoming more and more important at RHIC. The latest PHENIX data indicate a large suppression of decay electrons from high- p_T charm and beauty mesons. The amount of suppression is very

similar to that of the light-quark mesons, which is difficult to accommodate in most jet-quenching models since QCD distinctly predicts a lower gluon radiation probability for heavy-quarks compared with massless quarks or gluons.

There are also new results for direct photon production in gold-gold collisions up to transverse momenta of 20 GeV/c. Comparison of the gold-gold and proton-proton yields indicates that the QCD factorization theorem also holds for hard scatterings with heavy ions. The quality of the data is such that small deviations from the proton-proton reference can be traced back to isospin corrections and nuclear modifications of the parton distribution function in the nucleus. With improved statistics it will certainly be possible to use such data in global-fit analyses to constrain the nuclear parton distributions.

Last but not least, the conference saw the first measurements of direct photons emitted back-to-back with high- p_T hadrons. With reduced uncertainties such correlations will provide an important calibrated measure of the energy lost by the original parton.

J/ψ melting and lattice QCD

The suppression of charmonium bound states, in particular the J/ψ , was proposed 20 years ago as a smoking-gun signature for quark-gluon plasma formation, and this is still the experimental observable that offers the most direct connection with lattice QCD. The first high-statistics results from RHIC were presented in Shanghai. Surprisingly, they show that the amount of suppression is almost identical to that found at the SPS (figure 3). The medium created at RHIC is expected to be much denser and hotter than that at the SPS and most models predicted a stronger depletion.

A natural explanation of the similarity of the suppression at the two energies ($\sqrt{s_{NN}} = 17$ and 200 GeV) is put forward by recent lattice data that indicate that the J/ψ (but not the χ_c and ψ') survives up to temperatures twice the critical one. The increase in the temperature from the SPS to RHIC would not be enough to dissolve the J/ψ , which is then only indirectly suppressed due to the lack of feed-down contributions from the dissolved χ_c and ψ' states. Alternative explanations point out that the recombination of charm and anticharm quarks in the thermal bath (up to 10 charm-anticharm pairs are produced in central gold-gold collisions at RHIC) could compensate almost exactly for the additional suppression. The influence of initial-state effects, those present already in proton-nucleus collisions, are not yet completely settled. More proton-nucleus (at the SPS) and deuteron-gold (at RHIC) reference data, as well as the study of different charmonium states in gold-gold, will be needed to unravel the origin of the suppressed J/ψ yields.

Towards the LHC

The emerging picture in ultra-relativistic heavy-ion collisions is that of the formation of a strongly interacting medium with negligibly small viscosity – a perfect liquid – and with energy densities as high as 30 GeV/fm³. These characteristics emerge from the ideal hydrodynamics description of collective elliptic flow, and the large energy loss suffered by energetic quarks and gluons traversing the system respectively. The detailed study of the transport properties of this medium and the potential observation of the anticipated weakly interacting quark-gluon plasma will require key measure-

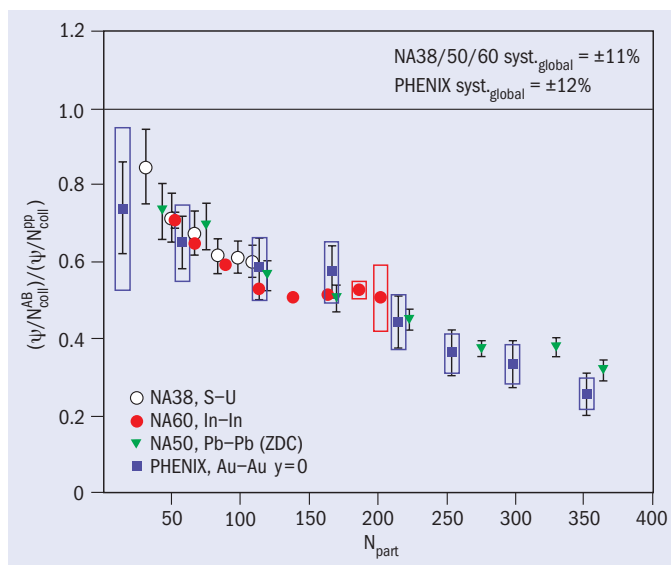


Fig. 3. Suppression of J/ψ in lead-lead (Pb-Pb) collisions at the SPS ($\sqrt{s_{NN}} = 17$ GeV) and in gold-gold (Au-Au) at RHIC ($\sqrt{s_{NN}} = 200$ GeV) as a function of the reaction centrality (the number of participant nucleons).

ments in lead-lead collisions at 5.5 TeV at the LHC. The higher initial temperatures, the greater duration of the quark-gluon plasma phase and the much more abundant production of hard probes expected at the LHC are likely to result in indisputable probes of the deconfined medium that depend much less on details of the later hadronic phase.

A whole morning session at the conference looked at “Heavy-Ion Physics in the Next 10 Years”. The imminence of the LHC start-up – with an active nucleus-nucleus programme being developed by the ALICE, CMS and ATLAS collaborations – guarantees an exciting future for the physics of high-density QCD.

Further reading

More information about the conference, as well as the talks presented, is available at www.sinap.ac.cn/qm2006/.

Résumé

La théorie de cordes rencontre des ions lourds à Shanghai

Les collisions d'ions lourds ultrarelativistes étaient à l'ordre du jour de la 19^e conférence internationale sur la matière quarkonique, QM2006, à Shanghai en novembre 2006. Plus de 600 physiciens y ont discuté des toutes dernières avancées expérimentales et théoriques des études de chromodynamique quantique aux valeurs extrêmes de température, de densité et des faibles fractions de l'impulsion du parton (petit x). Les tout derniers résultats expérimentaux des programmes d'ions lourds du RHIC et du SPS ont été au centre des débats et, pour la première fois, les tentatives de lier ces données à la théorie des cordes ont fait l'objet de discussions animées. La réunion s'est aussi tournée vers l'avenir et les attentes à l'égard du LHC.

David d'Enterria and **Karel Safarik**, CERN, and **Carlos A Salgado**, University of Rome La Sapienza.

INTERNATIONAL RELATIONS

CERN opens its doors to its first collaborators from Saudi Arabia

With its physics programmes carried out with the help of the world's largest accelerator complex, CERN has become a magnet for high-energy particle physicists, currently hosting some 7500 scientists from more than 60 countries worldwide. In addition to co-operation with its 20 European member states, the organization has signed formal co-operation agreements with the governments of more than 40 non-member states, as well as memoranda of understanding with a large number of funding agencies that provide support to CERN's user community.

More recently, and in response to the rising interest of a new generation of young scientists from North African and Middle Eastern countries to work in fundamental science, CERN has established formal ties with governments of countries such as Egypt, Iran, Jordan, Morocco, Pakistan, Saudi Arabia and the United Arab Emirates. Saudi Arabia, for example, increasingly realizes the importance of higher education as a long-term investment, not only to develop its growing agriculture and industry, but also to allow its own population to participate in fundamental science and research at an international level.

A number of young Saudis have already participated in CERN's Summer Student programme, but more recently CERN's director-general welcomed two of the first long-term visitors from Saudi Arabia, Ibtesam S Badhrees and Nader S Alharbi, who was Saudi Arabia's first visitor to CERN. Both Badhrees and Alharbi are preparing a PhD thesis, under the supervision of the Université de Genève and the Technische Universität in Vienna, respectively (CERN does not award academic degrees). Badhrees works on silicon detectors as a member of the ATLAS Collaboration, while Alharbi is in the study team for a superconducting proton linac, which would serve as the new injector as required for a luminosity upgrade of the Large Hadron Collider (p32).



From right to left: Robert Aymar, CERN's director-general, Ibtesam S Badhrees, Nader S Alharbi and Deither Blechschmidt, advisor to the director-general.

More recently, CERN has agreed with HRH Turki Al-Saud, vice-president of the King Abdulaziz City for Science and Technology (KACST) in Riyadh, that Alharbi (also from KACST) will design a model of the drift-tube linac structure at CERN, and then have it manufactured in Saudi Arabia. Later, KACST will provide a full-scale section of the linac structure – a key element of the SPL – as Saudi Arabia's participation in CERN. KACST is a governmental organization that promotes scientific and technological research, in particular in national resources and environment, space science, astronomy and geophysics, information technology,

petro-chemistry, atomic energy, mathematics and physics (including particle physics).

This development, only a few months after Saudi Arabia and CERN signed a Co-operation Agreement in Riyadh, opens the prospect of a mutually beneficial participation between Saudi Arabia and CERN, providing valuable opportunities for young Saudi scientists to participate in a cutting-edge fundamental-research endeavour of the international science community hosted by CERN. Moreover, a successful collaboration between Saudi Arabia and CERN will help to build new bridges between the West and the Arab world.

CELEBRATION

Khriplovich hits 70



Iosif Khriplovich, a prominent theorist from the Budker Institute of Nuclear Physics (BINP), was 70 on 23 January. His career has been closely related to the institute, which he joined in 1959. He is known for his contributions to the gauge field theory of fundamental interactions, violation of fundamental symmetries in atoms and nuclei, and the physics of black holes and general relativity.

In 1968 Khriplovich performed the first correct calculation of the charge renormalization in Yang–Mills theory and clearly explained an unusual sign of the effect. In 1974 he suggested an experiment to search for the optical activity of atomic bismuth vapours, which L Barkov and M Zolotarev carried out at BINP. This resulted in the first observation of macroscopic parity violation and the discovery of the weak interaction of electrons with nucleons via neutral currents.

In the 1980s, together with his students, Khriplovich predicted that atomic parity violation depending on nuclear spin was in the main due not to neutral currents, but rather to the electromagnetic interaction of electrons with a so-called anapole nuclear moment arising from parity-violating nuclear forces. These calculations were later confirmed by the discovery of the anapole moment by Carl Wieman's group at JILA, University of Colorado, Boulder.

Working closely with experimentalists, during recent years Khriplovich has been actively involved in preparing a deuteron EDM experiment. For many years he has also taught at Novosibirsk State University, giving lectures on quantum mechanics, general relativity and the history of physics.

APPOINTMENTS

Dylla leave Jefferson Lab to take the reins at the AIP

Frederick Dylla will be the next executive director and CEO of the American Institute of Physics (AIP). On 1 April he will succeed Marc Brodsky, who will retire after more than 13 years at AIP's helm.

Dylla has worked at Jefferson Lab in Newport News, Virginia, since 1990. He concurrently held an adjunct professorship at the College of William and Mary in Virginia. While at Jefferson Lab he served as the chief technology officer and associate director for the Free-Electron Laser (FEL) programme funded by the US Office of Naval Research. He was responsible for initiating, building and operating the FEL, which generates high-power light in many regions of the electromagnetic spectrum. Before moving to Jefferson Lab, he held various research and management positions from 1975 to 1990 at Princeton University's Plasma Physics Laboratory, where he helped to develop technology for nuclear-fusion reactors, particle accelerators and materials processing.

Dylla is a past president of the American Vacuum Society: Science & Technology of Materials, Interfaces and Processing,



Frederick Dylla, who will take over at the AIP.

where he was elected a fellow in 1998 and is currently a distinguished lecturer. He is also a fellow of the American Physical Society and founding member of its Forum on Industrial and Applied Physics. He has served on many advisory committees for US agencies such as the Department of Energy, the Department of Defense, and the National Science Foundation.

AWARDS

Bogoliubov prize goes to Barrau for black-hole research



Alexei Sissakian, left, presents the 2006 Bogoliubov prize to Aurélien Barrau.

Aurélien Barrau from the Laboratory for Subatomic Physics and Cosmology, and Joseph Fourier University, Grenoble, has won the 2006 Bogoliubov Prize for young scientists, established by the Joint Institute for Nuclear Research (JINR) in 1999. He receives the prize for a series of papers on astrophysics and cosmology.

Barrau studies quantum physics in the vicinity of black holes, one of the most fascinating fields of physics (*CERN Courier* November 2004 p27). He visited Dubna to receive his prize and gave a seminar on Black holes and quantum fields: from paradox to paradigm at the Bogoliubov Laboratory of Theoretical Physics, JINR. Barrau received the prize from JINR director Alexei Sissakian on 15 December at the meeting of the JINR Directorate with the CNRS delegation.

OBITUARIES

Aaldert Hendrik Wapstra 1922–2006

It is with great sadness that we say adieu to our colleague Aaldert Wapstra, “grand inquisitor of the atomic masses”, who passed away at home in Amsterdam on 4 December 2006.

Aaldert Wapstra’s career in nuclear physics spanned five decades from 1953 when he received his doctorate from the University of Amsterdam and became professor at Delft Technical University in 1955. In 1963, he joined the executive board of the Institute of Nuclear Physics Research (IKO), which later became the premier subatomic physics institute of the Netherlands: NIKHEF. Succeeding Godfried Van Lieshout in 1971, he was director of NIKHEF until 1982. Though he retired in 1987, his active contribution to the “Atomic Mass Evaluation” (AME) continued through 2005.

The mass of an atom, when measured accurately enough, yields the nuclear binding energy, which in turn has important implications in subatomic physics. Because masses can be determined via the different techniques of decay spectroscopy, reactions or mass spectrometry, the production of a mass table requires a meticulous and rigorous evaluation procedure. Aaldert first provided such an evaluation at the first international conference dedicated to atomic masses. With F Everling, LA König and JHE Mattauch, he established the



procedure for producing – and testing the consistency of – the different results.

Since that time, the AME has been updated at regular intervals with the 2003 evaluation, the most recently published, comprising reliable masses for some 3000 nuclides. It is the most cited reference in nuclear physics and forms a unique, common benchmark for nuclear theory. The evaluation requires great fluency in the technical methods of measuring masses. In this regard, Aaldert was extremely interested in various breeds of mass spectrometers, and offered such pearls of wisdom as: “My experience, in the course of 55 years in evaluating data, has been that precision measurements with non-focusing instruments should be considered with a healthy distrust.”

Aaldert also helped to formulate the definition of the mass unit, designated as u for “unified” unit, equal to a twelfth the mass of ^{12}C . He liked to joke about its singular

name: “Let us be firm in retaining the u , let us even make it a double- u !”, as a reference to the initial letter of his last name.

At the 2004 conference of Exotic Nuclei and Atomic Masses – 44 years after attending the original conference on masses – Aaldert received the SUNAMCO medal of the Symbols, Units, Nomenclature, Atomic Masses and fundamental Constants commission of the International Union of Pure and Applied Physics, in recognition of his long commitment and numerous achievements in the field. It was fitting that he received an award that he himself had presented to others on previous occasions.

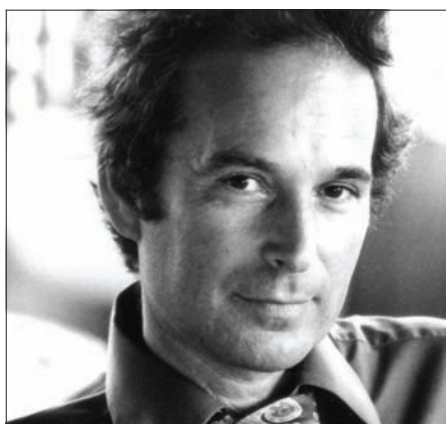
In addition to his technical and scientific skills, Aaldert loved culture. An accomplished pianist, he was particularly fond of music and had very modern taste, with the work of Messiaen figuring prominently. He was also a dedicated family man, composing poems for his grandchildren for the feast of St Nicholas each year.

Aaldert’s fine blend of culture and scientific acumen made it a pleasure to receive him in Orsay, where he visited regularly for discussions concerning the evaluation. His experience and authority were less impressive only than his profound modesty. It will be difficult to carry on without him. *Georges Audi and David Lunney, CSNSM-Orsay.*

Geoff Manning 1929–2006

Geoff Manning, director of the Rutherford Appleton Laboratory between 1979 and 1986, died on 21 December 2006, aged 77.

Geoff was born on 31 August 1929 in Hackney, London. His father Jack Schwartz, a Russian Jewish émigré, was a gambler and his mother Ruby had little formal education. When Schwartz abandoned the family less than a year after Geoff’s birth, Ruby struggled to raise her children alone. Despite this unpromising start, Geoff gained places first at Tottenham Grammar School and then (following a brief stint in the RAF) at Imperial College London. He read physics



at Imperial and went on to study for a PhD in nuclear physics under Sam Devons. Geoff married his schoolgirl sweetheart Anita in 1951 and after his PhD emigrated with his young family in 1956 to work for the Canadian Atomic Energy Co in Chalk River, later moving to the California Institute of Technology, where he worked with many leading physicists, including Dick Feynman.

Returning to the UK in 1960, Geoff joined the Atomic Energy Research Establishment at Harwell. He moved into the exciting new field of particle physics in 1965, joining the Rutherford Laboratory as group leader. Over

the next two decades he took on successively the roles of head of High Energy and Atlas Divisions, deputy-director and finally director in 1979, the year in which the laboratory merged with the Appleton Laboratory to form the Rutherford Appleton Laboratory (RAL). A distinguished experimental physicist, he continued to take an active interest in the laboratory's scientific output throughout the administrative phase of his career.

While director of RAL he ushered in a new era of wider research, attracting Japanese, German and Indian funding, and overseeing the design and construction of a world-class neutron source, ISIS, opened by Prime Minister Margaret Thatcher in October 1985.

The following year he received a CBE, and the Glazebrook Medal and Prize from the Institute of Physics for services to science. That RAL's future remains bright is in no small part a result of Geoff's carefully considered broadening of research and expertise.

Always happiest with a new project or interest in hand, after more than 20 years at RAL he left to pursue a career in industry, as chair of Active Memory Technology Ltd from 1986 to 1992. He never fully retired, however, spending his last years making silverware, building furniture, inventing a novel DIY product and teaching his eight grandchildren DIY and business skills.

Single-minded determination and a belief

in the power of will to overcome obstacles made Geoff successful at almost everything he undertook, in work, in leisure and in play. Fiercely rational and intellectually powerful, he could be uncompromising in argument and impatient with those slower or less sure than himself. But it was perhaps the difficulty of his early years that underpinned the other great driving force of his life; devoted to his children and grandchildren, he took immense pride in their achievements.

He will be missed by his extended family and wide group of friends, and in particular by his wife Anita, their three children Howard, Ian and Karen, and their spouses and children.

Francesco Ruggiero 1957–2007

Francesco Ruggiero, a brilliant accelerator physicist, an inventive researcher, a great collaborator, an excellent mentor and a true gentleman, passed away on 17 January.

Of Neapolitan origin and following diploma studies on gravitational waves, Francesco received his PhD in accelerator physics from the Scuola Normale Superiore di Pisa in 1985. After participating in the commissioning of LEP at CERN, he made numerous invaluable contributions to the design of the LHC, in particular on collective effects, machine impedance and beam-beam interaction. In 1997, he recognized the potential danger from an electron cloud in the LHC and he launched an important remedial crash programme.

Later Francesco became leader of the accelerator-physics group in the former SL Division. Since 2000 he drove the LHC accelerator upgrade studies, for example, by



coordinating the CARE-HHH network (p32). Under his wonderful and caring guidance many bright young accelerator physicists were trained or recruited at CERN.

A member of the EPS Accelerator Group, Francesco helped to prepare the programmes for several EPAC conferences. He contributed to *PRST-AB*, the refereed journal for accelerator physics and technology, as associate editor for Europe, and he was on

the editorial board of the Springer series on *Particle Acceleration and Detection*.

His interests in physics extended beyond accelerators. In 2005, his article in *La Gazzetta dello Sport* explained to a general audience why boat weights measured in Valencia and Malmo differ by some 35 kg, thus addressing a mystery that arose during the weighing of boats between different races of the America's Cup. He was especially fascinated by Einstein and by quantum-mechanical paradoxes.

Francesco was full of passion and energy, often working until dawn. We will never forget his open mind, his love for physics, his friendliness and his humour. During his long fight with cancer, he never gave up hope that he would recover and return to work. Francesco will be greatly missed by the accelerator community worldwide. *His colleagues and friends.*

MEETINGS

A workshop on **Small-x and Diffractive Physics** will be at Fermilab on 28–31 March to discuss experimental, phenomenological and theoretical progress in high-energy diffractive interactions. It will present results from the Tevatron, HERA and RHIC and cosmic-rays. The focus will be on measuring exclusive Higgs bosons, vector boson pairs and phenomena beyond the standard model at the LHC with forward proton spectrometers. For more information see

www-d0.fnal.gov/~royon/smallx/ or contact Michael Albrow, e-mail albrow@fnal.gov.

The **Second CERN–Fermilab Hadron Collider Physics Summer School** will be at CERN on 6–15 June. The school will focus on the technology and physics of the LHC experiments, emphasizing the first years of data-taking and the discovery potential of the programme. In-depth discussion sessions will support the lectures. The

deadline for applications is 9 March. For more information see <http://cern.ch/hcpss> or e-mail cern-fnal-school-sec@cern.ch.

The next **Crimean Summer School and Conference on New Trends in High-Energy Physics** will be on 15–22 September in Yalta, Ukraine. Apply to Crimea-2007, BITP, Kiev-143, 03680 Ukraine, e-mail crimea@bitp.kiev.ua, or fax +38 044 5265998. For more information see <http://crimea2007.bitp.kiev.ua/>.

INTERNATIONAL COLLABORATION

CERN builds relations with Korea and Algeria

CERN has signed a co-operation agreement with the government of the Republic of Korea, thereby formalizing Korea's participation in the laboratory's experimental-physics programme. On 25 October, the ambassador of the Republic of Korea to Switzerland, Won-Hwa Park, visited CERN to sign the agreement, witnessed by Joo-Han Kim of the Korean Ministry of Science and Technology. The agreement covers the development of scientific and technical co-operation in high-energy physics. At least 18 post-docs, supervising a large number of students and technicians from 14 Korean universities have registered at CERN and these numbers are still expected to grow.

This was one of three official Korean visits to CERN within the space of two weeks. On 23 October Won-Hwa Park accompanied Myung-Bak Lee, the former Mayor of Seoul, members of Lee's staff and Korean journalists. The third official visit was on 3 November, when CERN welcomed a delegation of the Permanent Mission of the Republic of Korea, led by ambassadors Hyuck Choi, Tae-yul Cho and Dong-hee Chang.



Won-Hwa Park, ambassador of the Republic of Korea to Switzerland, left, with CERN's director-general at the signature ceremony to mark Korea as an official collaborator.

Later in November it was the turn of the Algerian Minister of Higher Education and Scientific Research, Rachid Haraoubia, to visit CERN. On 14 November he toured the ATLAS experiment and the LHC tunnel, and met Algerian scientists working at CERN.



Algerian Minister of Higher Education and Scientific Research, Rachid Haraoubia, right, with Robert Aymar, during his visit to CERN.

Some 15 Algerian physicists attached to European and US institutes are participating in the LHC experiments, in particular ATLAS. A formal collaboration agreement between Algeria and CERN is expected to be drawn up in the near future.

NEW PRODUCTS

Aerotech has announced new ALAR large aperture rotary stages with smooth cog-free brushless direct-drive motors. The stages also offer backlash-free fast and ultra-precise positioning. The range features compact space-saving apertures with sizes from 100 to 325 mm. For further information contact Cliff Jolliffe, tel +44 118 940 9400, e-mail cjolliffe@aerotech.co.uk or see www.aerotech.co.uk.

AMS Technologies are now providing the new series of high-voltage fast-pulse capacitors from General Atomics Energy Products. The range of 8–100 nF capacitors is for use at up to 100 kV and 25 kA peak current. It is for low repetition rate, fast-discharge applications. For more details contact André Geiger, tel +49 89 89 577 500, e-mail electronic@ams.de, or see www.ams.de.

Andor Technology has launched the iKon-M CCD camera range and the iDus InGaAs detector-array system. The iKon M delivers high quantum efficiency and low noise performance for light-starved imaging. The new iDus detector offers 512 or 1024 element linear photodiode arrays, with high sensitivity and resolution at 800–2200 nm. For details contact Emma McClintock, tel +44 28 9023 7126 or see www.andor.com.

Burle Electro-Optics Inc has released its low-cost CEM 4899 replacement electron multiplier for the Sciex API-2000 and API-3200 mass spectrometers. It uses cartridge technology to reduce costs and speed up replacements, features no-alignment optics and meets high dynamic-range requirements. For more information tel +1 800 648 1800 or +1 508 347 400, e-mail sales@burle-eo.com, or see www.burle.com.

CeramTec North America Corporation has announced a new family of hermetic high-voltage feedthroughs with mating air-side cable assemblies. The range includes 40 kV and 50 kV feedthroughs, each with 10 A capacity. The air-side cable assembly has a threaded connection. For further information, tel +1 864 682 3215, fax +1 864 682 1140, e-mail sales@ceramtec.com or see www2.ceramtec.com.

Narda Safety Test Solutions has developed a new portable broadband field meter, the NBM-550, to make electric and magnetic field measurements from RF to microwave wavelengths. Its features include a large graphical display, memory for logging up to 5000 results and a GPS interface for positional data. For further information, tel +49 7121/9732 777, e-mail support@narda-sts.de or see www.narda-sts.com.

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Studentships on the MCnet network

MCnet is an EU-funded Marie Curie Research Training Network, dedicated to developing, validating and tuning the next generation of Monte Carlo event generators for high energy particle physics and training future event generator authors and the event generator user base.

MCnet will create two novel forms of studentship:

Joint long term studentships: two PhD positions to be held jointly: one at Karlsruhe followed by Durham; one at Durham followed by University College London. Each will begin in October 2007, move to the second university in April 2009 and be completed in September 2010. Closing date: March 31st 2007.

Short term visiting studentships: open to anyone registered for a PhD in experimental or theoretical particle physics to receive additional training in one of our research groups for three to six months during 2008. Applications should include a research proposal. Closing date: June 30th 2007.

More details and links to application forms can be obtained from www.montecarlonet.org

Studentships are subject to the usual conditions of Marie Curie fellowships. Applications are particularly encouraged from women, nationals of New Member States and residents of Less Favoured Regions.

MCnet is a collaboration of CERN, the Universities of Durham, Karlsruhe and Lund and University College London; all are committed to providing equality of opportunity.

Marie Curie Actions
Human resources and mobility



Agilent Technologies

Agilent Technologies, global leader in test and measurement solutions, has recently acquired Acqiris, a leading company developing high-end digitizer and signal analyzers in PCI/cPCI and VME format. The analyzer product with FDK (firmware design kit) gives our customers the capability of developing real time analysis firmware that will be programmed into the analyzer's FPGA.

There is an immediate opening in the R&D group located in Geneva Switzerland for a

R&D Software / Firmware Engineer

The main responsibility is to support customers using the FDK, as well as to develop firmware and/or software for new FDK products. The successful candidate will also be in charge of writing the FDK user manuals. He will participate actively to improve our design efficiency, as well for firmware design than for firmware verification.

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- Proficiency in troubleshooting and debugging code.
- Good working knowledge of software and firmware development principles.
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If you believe your motivation and experience would be an asset in our challenging environment, please apply online through www.jobs.agilent.com, requisition number 2016325.

In case of problems you can send it to: human.ressources@acqiris.com

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RELAX... JOB HUNTING DOESN'T NEED TO BE STRESSFUL

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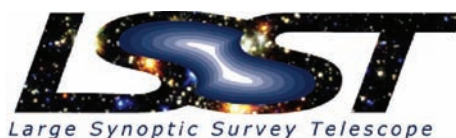
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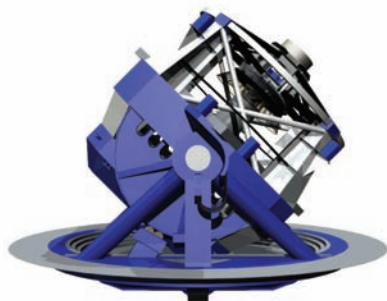
Associate Project Manager LSST Corporation



The LSST Corporation, which will build and operate the Large Synoptic Survey Telescope, seeks an engineer or scientist experienced in project management to join the LSST team as Associate Project Manager. In keeping with the LSST Corporation's commitment to succession planning, the successful candidate will be expected to prepare to assume the role of Project Manager in due course.

The Associate Project Manager will help to develop and construct a World-class astronomical facility to be built in Northern Chile. The LSST project includes an 8.4-meter, 3.5 degree wide-field telescope, a 3.2 gigapixel camera and a data management system to process, archive, and distribute the 22 Terabytes of data that will be produced every night. The project is currently in its design and development phase, with both public and private sponsorship. Plans call for a close collaboration between the NSF and Department of Energy laboratories in construction. Commissioning is scheduled for 2014. The LSST Corporation includes over 20 universities, government laboratories, and private corporations.

The Associate LSST Project Manager, reporting directly to the Project Manager, will assist in managing all business and technical activity on the project. In particular, he or she will have day-to-day responsibility for directing technical tasks, monitoring contracts and awards, and will chair the change control board. The Associate Project Manager will support the Project Manager in representing and justifying all project activity to the LSST Board of Directors and funding agencies. The LSST Corporation is searching for a highly motivated, self-directed individual with experience in large construction projects, control systems, data management, and standard project management tools and methods. Experience with DOE and/or NSF projects and management processes is highly desirable. The successful candidate will be expected to relocate to Tucson.



The LSST Corporation is an Affirmative Action and Equal Employment Opportunity employer. Qualified candidates are invited to submit a resume, a letter describing experience and interests, and the names of three references to:

hrnoao@noao.edu (preferred) or postal mail to: **LSSTC/NOAO Human Resources, PO Box 26732, Tucson, AZ 85726-6732.** Make reference to the **Attn: Associate Project Manager, LSST Corporation, Job #822** when submitting materials.

All personnel services are administered by the National Optical Astronomy Observatory (NOAO) on behalf of the LSSTC, under a business service agreement.

Online-only opportunities

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RESEARCH ASSOCIATES FOR T2K and MINOS

The Particle Physics Department at RAL has two immediate vacancies for three-year fixed term Research Associates to work on the T2K (<http://neutrino.kek.jp/hfnu>) and MINOS (<http://www.numi.fnal.gov/>) projects. These vacancies are available as a possible job share.

A postdoctoral physicist (ref: SPBU029) is sought to work on the development, commissioning and calibration of the T2K 280m near detector electronics, software tools, neutrino data analysis and to participate in test beam activities. Candidates are expected to have a PhD in experimental particle physics and experience in analysis, hardware and software for particle physics experiments. Further details on this post may be found at <http://www.clrc.ac.uk/Activity/VNInfo;SECTION=9957>; For additional information, contact Dr. Alfons Weber (Tel: +44 (0)1235 445092, email: A.J.G.Weber@rl.ac.uk).

A physicist or physicist programmer (ref: SPBU030) is sought to work on both the MINOS and T2K projects. The post will involve developing and commissioning the data acquisition system for the T2K 280m near detector, assisting with operational support for the MINOS data acquisition and participating in the analysis of data. Applicants will have a degree or equivalent in a physical or computer science, and ideally, a PhD in experimental particle physics, with experience of data acquisition on a large-scale experiment. Further details on this post may be found at <http://www.clrc.ac.uk/Activity/VNInfo;SECTION=9958>; For additional information, contact Dr. Geoff Pearce (Tel: +44 (0)1235 445676, email: G.F.Pearce@rl.ac.uk).

The starting salary for both posts is in the range £24,638 to £27,998 (pay award pending), dependent on experience. In addition we offer an index-linked, final-salary pension scheme and generous leave allowance. If suitable working patterns can be agreed between relevant parties, these roles offer an ideal opportunity for two individuals to job share.

Closing date for applications is 23 March 2007.

Interviews will be held on 10 & 11 April 2007.

CCLRC operates a no-smoking policy and is committed to Equal Opportunities.

Application forms may be obtained from Valerie Gilbert, Science Programmes, CCLRC, Chilton, Didcot, Oxfordshire OX11 0QX, telephone +44 (0)1235 445658, or e-mail recruit-spbu@rl.ac.uk
Please quote the relevant SPBU reference number. More information about CCLRC is available from <http://www.clrc.ac.uk>



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DESY is world-wide one of the leading accelerator centres exploring the structure of matter. The main research areas range from elementary particle physics over various applications of synchrotron radiation to the construction and use of X-ray lasers.

For the experiments H1, ZEUS and HERMES at the ep collider HERA, the experiments ATLAS and CMS at LHC, and for the preparations of the International Linear Collider ILC (accelerator and experiments) several

DESY Fellowships

at Hamburg and Zeuthen are announced. Scientists who have completed their Ph.D. within the last 4 years are invited to submit their application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degree). They should arrange for three letters of recommendation to be sent to the personnel department of DESY.

The DESY Fellowships are awarded for a duration of 2 years with the possibility for prolongation by one additional year. Salary and benefits are commensurate with public service organisations. DESY is an equal opportunity, affirmative action employer and encourages applications from women. DESY has a kindergarten on site.

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Max Planck Institute for Physics

(Werner Heisenberg Institute)



MAX-PLANCK-GESELLSCHAFT

The Max Planck Institute for Physics and the Cluster of Excellence *Origin and Structure of the Universe* invite applications for a

Junior Research Group Leader (tenure track)

in the field of

Detector Development in Particle Physics (Experiment)

The Cluster of Excellence *Origin and Structure of the Universe* has recently been installed on the Garching Campus near Munich as part of the Excellence Initiative of the Federal Government of Germany. The cluster is operated jointly by the physics departments of the two Munich Universities, several Max Planck Institutes and the European Southern Observatory. It aims at a deeper understanding of the fundamental forces and dynamics that drive the expansion of our universe, the creation of the elements, and the growth of large-scale structure. As part of this effort, 10 new research groups will be created to work in key areas of the relevant science.

We are seeking candidates for a Junior Research Group (JRG) leader who will focus on the development of detector technologies for particle physics experiments. The JRG-leader will get a tenure track position (salary scale TVöD-14) at the Max-Planck-Institut für Physik for initially 5 years. The evaluation for tenure (salary scale TVöD-15) will start after three years. The JRG leader will also obtain a 'Lecturer position' (Lehrauftrag) from the faculty of the Technische Universität München. The Max Planck Institute for Physics has a long history of developing detectors for particle physics experiments, including silicon vertex detectors, time projection chambers, and liquid Argon calorimeters. The capabilities of the mechanical and electronics engineering departments at the Max Planck Institute for Physics and other institutes participating in the cluster would be available to the Junior Research group. The proposed area of development should match the capabilities available as well as fit into the existing programs of research in the Cluster. Active participation in the teaching program of the Cluster and the Technische Universität München is welcome.

Formal requirements for this position are a PhD and several years of experience in the field of experimental particle physics.

The Max Planck Society is an equal opportunity employer. The goal is to enhance the percentage of women in the areas where they are underrepresented. Women, therefore, are especially encouraged to apply. The Society wants to employ more disabled people. Applications of disabled persons are particularly welcome.

Applicants should complete the following web-form
<http://universe-cluster.de/jobs/RA4a> before March 31, 2007.

Max-Planck-Institut für Physik

Prof. Dr. Allen Caldwell
Föhringer Ring 6
80805 München
caldwell@mppmu.mpg.de

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RESEARCH ASSOCIATE for LHCb (SPBU031)

The Particle Physics Department at the Rutherford Appleton Laboratory (RAL) has an immediate vacancy for a three-year Research Associate position to work on the LHCb experiment at the CERN Large Hadron Collider.

The RAL LHCb group has a pivotal role in the development of the Ring-Imaging Cherenkov detectors and the software of the experiment since the initial stages of the design and construction. The group is now ramping up the physics analysis effort in preparation for the beginning of the data-taking, building on the group members' extensive experience of CP violation studies in the B system and expert knowledge of the LHCb detector and software.

We are looking for a highly motivated individual to make leading contributions to the LHCb physics analysis programme and to take on responsibilities in the commissioning and operation of the LHCb detector. The successful candidate will have the opportunity to help shaping the group's physics analysis strategy and to support the supervision of graduate students. Applicants should have a Ph.D. in physics and experience with the data analysis and the software of high energy physics experiments. A willingness to travel within the UK and overseas is essential. Long term attachment to CERN is a possibility.

The starting salary is in the range of £24,638 to £27,998, dependent on experience. An index-linked pension scheme and a generous leave allowance are also offered.

Further information can be found at <http://hepwww.rl.ac.uk/lhcb>

For enquires about this post, please contact Dr Stefania Ricciardi, Tel: +44(0)1235 445213, email: s.ricciardi@rl.ac.uk

Application forms may be obtained from Valerie Gilbert, Science Programmes, CCLRC, Chilton, Didcot, Oxfordshire OX11 0QX, telephone +44 (0)1235 445872, or e-mail recruit-spbu@rl.ac.uk Please quote the relevant SPBU reference number.

More information about CCLRC is available from <http://www.clrc.ac.uk>

Closing date for application is 16 March 2007.

Interviews will be held in the week commencing 16 April 2007.

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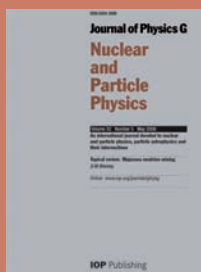
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The **Department 08 - Physics, Mathematics, and Computer Science** - of the Johannes Gutenberg-University Mainz (Germany), invites applications for the position of

University Professor of Experimental Physics

(Full Professor, Bes.Gr. W 3 BBesG)
(succession of Prof. Konrad Kleinknecht)

which is **opening April 1, 2008** at the Institute of Physics.

We seek an internationally renowned researcher to take a leading role in the "Experimental Particle and Astroparticle Physics" group. A central activity of the candidate should lie in the area of LHC physics. The research group has taken on long-term responsibilities with the ATLAS experiment. In order to guarantee the breadth of research in the long run, future activities in other areas of particle or astroparticle physics are desired.

Applicants are expected to have a Ph.D. in physics, a proven first rate research record and to have interest in and aptitude for teaching. Lectures are usually given in German. The Johannes Gutenberg-University promotes a concept of intensive tutoring and requests a high rate of presence at the University. Participation in all teaching activities and academic administration duties of the Faculty is expected.

The Johannes Gutenberg-University Mainz aims at increasing the percentage of women in academic positions and strongly encourages women scientists to apply.

The University is an equal opportunity employer and particularly welcomes applications from persons with disabilities.

Qualified candidates are asked to submit their applications **by April 16, 2007**, including curriculum vitae, lists of publications, lists of teaching experience, and reprints of up to five of their most important publications to the



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DESY is one of the leading laboratories for the development of novel technologies for detectors at the future International Linear Collider (ILC). Within the EU supported Integrated Infrastructure Initiative EUDET we have an immediate opening for a

Physicist

The research topics are the design of special calorimeters for the instrumentation of the forward region and the development and test of a prototype. The research activities are performed in an international collaboration with strong European participation.

We expect from you a Ph.D. in experimental particle physics, experience in the construction and operation of detectors and in data analysis. For further information, please contact Dr. Wolfgang Lohmann (wolfgang.lohmann@desy.de).

Please send your application by indication the code number to personal.abteilung-zeuthen@desy.de.

The position is limited to 2 years.

Salary and benefits are commensurate with public service organizations. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

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BOOKSHELF

Histoire de la radioactivité par

René Bimbot, Vuibert. Broché ISBN 9782711771943, €35.

Dans son Histoire de la radioactivité, René Bimbot s'adresse à un très large public dans un style limpide et son livre se lit aisément, cela d'autant plus que de nombreux graphiques et illustrations facilitent la compréhension. Au fil du texte, le lecteur peut aussi s'attarder sur des encadrés expliquant certaines notions simples de physique, accessibles dès la fin du secondaire, qui, au prix d'un effort minime, permettent d'approfondir la compréhension du sujet traité.

Des vignettes présentent en quelques paragraphes les chercheurs qui ont écrit les pages les plus remarquables de cette histoire ou y sont étroitement associés, c'est le cas successivement de Röntgen, Becquerel, Marie Curie, Pierre Curie, JJ Thomson, Planck, Einstein, Rutherford, Bohr, de Broglie, Chadwick, Fermi, Yukawa, Frédéric et Irène Joliot, Lawrence, Gentner, Seaborg et Charpak.

Trop souvent, sous différents prétextes, les physiciens présentent de façon caricaturale le développement historique de leur sujet de prédilection; ici au contraire René Bimbot s'attache à suivre en grand détail le cheminement des idées en faisant ressortir les influences réciproques des acteurs ayant joué les premiers rôles dans les découvertes sur la radioactivité.

Curieusement ce livre semble combler un vide; en effet, une recherche rapide montre qu'il n'existait pas d'ouvrage dans la langue de Becquerel traitant complètement du sujet. En anglais on note le récent ouvrage de G I Brown (2003) intitulé *Invisible Rays: A History of Radioactivity* qui traite des mêmes sujets. L'auteur a joué un rôle très actif dans certaines des célébrations des divers centaines remarquables de la physique que nous avons connu au cours de la dernière décennie, une bonne préparation pour l'élaboration de son *Histoire*.

Le livre comporte trois parties intitulées «De la radioactivité naturelle au noyau de l'atome», «De la radioactivité artificielle à l'énergie de fission» et «Rayonnements et radioactivité aujourd'hui».

Les sept chapitres de la première partie s'attachent aux premiers travaux de Becquerel, puis de Marie et Pierre Curie, et guident ensuite le lecteur à travers les



bouleversements de la physique qui ont caractérisé le début du 20^e siècle jusqu'à l'élucidation par Gamow de la radioactivité alpha en 1928 (expliquée par l'effet tunnel permis par la mécanique quantique) et la théorie de Fermi de la radioactivité bêta en 1933. En résolvant les énigmes posées par la radioactivité, les physiciens nucléaires ont enrichi la physique de deux nouvelles forces, la force forte et la force faible. Ils ont ainsi légué à leurs successeurs de la physique des particules deux sujets essentiels dont l'élucidation théorique a pris plusieurs décennies pour arriver à l'unification électrofaible et à la chromodynamique quantique.

La deuxième partie traite en sept chapitres du sujet associé du positon et de l'antimatière, puis de la radioactivité dite artificielle et des diverses applications de la radioactivité. Parmi celles-ci, René Bimbot souligne bien sûr le rôle toujours croissant en médecine nucléaire des multiples radionucléides à usage médical et de l'imagerie avant de passer au domaine de la datation, en particulier par la méthode du carbone-14. Il consacre trois chapitres à la fission, aux armements nucléaires, aux diverses filières électronucléaires (sans éluder l'accident de Tchernobyl) et à la question des déchets.

Plus courte, la troisième partie du livre

discute des détecteurs puis des deux faces contrastées des rayonnements: leurs dangers mais aussi leurs bienfaits en radiothérapie. Le chapitre final aborde des manifestations plus rares de la radioactivité, comme la capture électronique, l'émission de un ou de deux protons et aussi d'un neutron post-bêta. René Bimbot insiste par ailleurs sur le fait qu'il reste des radioactivités à découvrir après celle des ions lourds (comme le carbone-14) et que la sensibilité croissante des méthodes de détection promet la découverte de radioactivités ultrafaibles par des nucléides considérés comme stables. Ce chapitre considère aussi la désintégration bêta au niveau des quarks, après les niveaux moins élémentaires du noyau et du proton présentés auparavant.

On peut regretter l'omission de la double désintégration bêta qui aurait particulièrement intéressé les lecteurs du *CERN Courier*. De plus, un index analytique des sujets traités aurait utilement complété celui des scientifiques cités dans le livre.

Le livre de René Bimbot remplit donc de façon convaincante l'objectif annoncé par le titre et il intéressera en particulier le lecteur recherchant une perspective historique sur un sujet qu'il connaît déjà.

François Siohan, Collex, Suisse.

Maverick Mathematician: The Life and Science of J E Moyal by Ann Moyal, ANU E Press. Online ISBN 1920942990, free. Paperback ISBN 1920942580, AU\$19.95.

Most physicists may recall the "culture shock" of their first exposure to quantum mechanics: the sensible advice to suspend temporarily their intuition, built on classical mechanics, and to plunge instead into Hilbert space and learn how to get the answers. Only after some control of the subject had mitigated that shock did they gradually return to connect to the classical limit, and, as clarity grew on hindsight, to appreciate Paul Dirac's association of quantum commutators with Poisson brackets, and develop intuition in negotiating the semiclassical subtleties of \hbar .

But this routine unfolding of the story may well be a historical accident, predicated on the precedence and dominance of the standard Hilbert-space formulation of quantum mechanics over an intriguing alternative formulation in phase space.

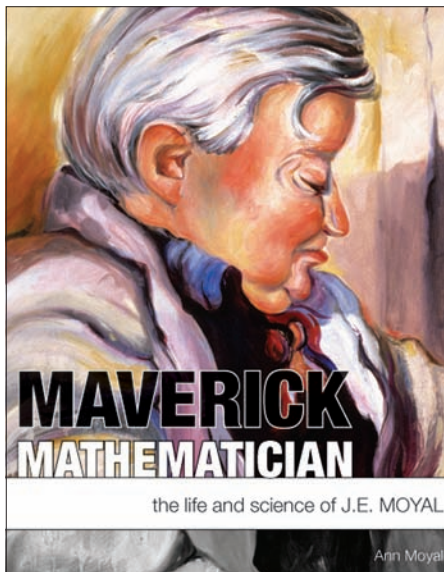
This phase-space formulation merges more directly and intuitively with the classical theory, since it works with the same variables as the classical theory, with essentially the same interpretation, avoiding the traditional disorienting switch to operators.

This compelling formulation is often dubbed “deformation quantization”, or “Moyal quantization”, after Joe Moyal, the central among the four principal contributors to its development; the other three being Hermann Weyl (1927), Eugene Wigner (1932) and Hip Groenewold (1946). With Moyal’s classic 1949 paper, the formulation was firmly in place. But why did it take so long for it to become appreciated and popular (more than 1300 citations), and to spawn applications? And who was Moyal? It is hard to check a measure of curiosity, given the magnitude of the achievement.

Moyal’s widow, Ann Moyal, an eminent historian of science, has now written a brisk, absorbing biography of him. *Maverick Mathematician: the life and science of J.E. Moyal* covers the striking and thought-provoking phase-space quantization story. It outlines his exceptionally adventurous life and career, with plenty of sociocultural tidbits. It focuses on his highly original mind, intrepid spirit, wit and exuberance in living.

Born in British-mandate Palestine and educated in France and England, he worked in England, Northern Ireland, Australia and the US. His inventive innovations span engineering, applied physics, theoretical physics, and statistics. Moyal’s statistical common sense and intuition managed to cut through much of the confusion of the insiders. He effectively reorganized our understanding of the subject, all the while developing the novel mathematical structures required, such as the celebrated Moyal bracket – the true equivalent to quantum commutators, properly completing Dirac’s Poisson bracket proposal.

A possible clue to the question posed concerning the slow acceptance of the formulation emerges in the book. What comes as a revelation is Moyal’s long and doughty defence of his vision of phase-space quantization against Dirac’s dogged criticism of it, as Moyal (an inspired academic outsider) was developing, refining and striving to have it published for the better part of a decade (1940–1949),



through world war and contentiousness. Appendix II contains excerpts of their invaluable 18 month correspondence. At times technical, poignant and spirited, it sheds light on how insistent reservations about the classical–quantum correspondence and the uncertainty principle prevented Dirac from accepting the essential legitimacy of phase-space quasi-probability distributions, and the formal equivalence of Hilbert space to phase space, regardless of the theory discussed.

In the end, Moyal’s paper could not be kept hidden under a bushel; it was published and asserted itself. Posterity has validated Moyal’s interpretation of the “negative probability” implicit in the Wigner distribution as a linchpin of the quantum statistical picture where it is shielded by the uncertainty principle, which restricts measurability of observables. It took all but a quarter of a century for universal uncontested acceptance of the fact, however.

What is special about Moyal’s daring vision, in some contrast to that of the other three co-founders of the formulation, is the following. More than they, beyond working out the basic formalism, he championed its conceptual autonomy from the Hilbert-space picture, even though he ultimately conceded that it was equivalent to this picture, and even, in principle, the logical possibility of supplanting that picture under suitable circumstances.

A particular treat in many biographies written by a spouse comes from the unique

glimpses into the book’s subject – as well as instinctive avoidance of the inessential. With this book, the reader is doubly fortunate, on account of the author’s lifelong professional expertise in the history of science. Moyal was a committed all-out scientist, and thus fortunate to have the central thread of his life and his originality documented with insight and liveliness.

Cosmas Zachos, Argonne National Laboratory.

Books received

Problems and Solutions in Quantum Computing and Quantum Information (2nd edition) by Willi-Hans Steeb and Yorick Hardy, World Scientific. Hardback ISBN 9812567402 £45 (\$78).

Quantum computing and quantum information are two of the fastest growing and most exciting research fields in physics. This book supplies a collection of problems in quantum computing and quantum information together with their detailed solutions, which will be invaluable to students and researchers. All the important concepts and topics are here, such as quantum gates and quantum circuits, entanglement, teleportation, Bell inequality, Schmidt decomposition, von Neumann entropy, quantum cryptography, quantum error correction and squeezed states. The topics range in difficulty from elementary to advanced. Almost all of the problems are solved in detail and most are self-contained.

Physical Realizations of Quantum Computing: Are the DiVincenzo Criteria Fulfilled in 2004? by Mikio Nakahara, Shigeru Kanemitsu, Martti M Salomaa and Shin Takagi (eds), World Scientific. Hardback ISBN 981256473X, £45 (\$78).

The contributors to this volume work at the forefront of various realizations of quantum computers. They survey the recent developments in each realization, in the context of the DiVincenzo criteria, including nuclear magnetic resonance, Josephson junctions, quantum dots and trapped ions. There are also theoretical contributions relevant to the physical realizations of a quantum computer. The book fills the gap between elementary introductions and highly specialized research papers, so allowing graduate students to understand this cutting-edge research in the shortest possible time.

Amazing particles and light

Swapan Chattopadhyay reflects on the extraordinary fundamental value of accelerators.

Five years ago, I wrote in this column when I had just made the transition to Jefferson Lab (*CERN Courier* October 2002 p46). Promising developments in hadronic physics, microwave superconductivity, free-electron lasers and efficient energy-recovery techniques in accelerators were beckoning me – after 25 colourful years at Berkeley, including two spent at CERN. I was also concerned about the longevity of a profession in which I had personally invested. I had seen the attrition of talents, many of whom I mentored, to other professions, driven by socio-economic realities of large particle accelerators. This inspired me to motivate accelerator-science practitioners to diversify their portfolio by developing the small and mezzo-scale engines that would drive emerging nano- and bio-sciences. Today, on the eve of another personal transition as I prepare to take the helm at the UK's Cockcroft Institute, new developments and challenges once again invite comment.

I observe a few key developments contributing at the frontier of “discovery”, while others attest to “innovation” and “diversification”. These include: development of electron, proton and ion beams of unprecedented precision based on normal and superconducting material technology and advanced feedback control; diversification and growth of synchrotron radiation sources worldwide; evolution of sophisticated table-top laser-plasma acceleration techniques with necessary control to produce giga-electron-volt electron beams; demonstration of self-amplified spontaneous emission for the planned X-ray free-electron lasers; demonstration of efficient energy use and recovery in superconducting linacs; and production of ultra-short femtosecond flashes of electrons, infrared light and X-rays for studies of ultra-fast phenomena – to name but a few.

I also admit to occasional sombre worries that perhaps accelerators will be just a passing moment in history. But I was always awakened by the realization that particle



accelerators have been and must continue to be singularly distinctive instruments of discovery and innovation, in various measures. What we are witnessing is a mere partitioning of the balance between these values in the context of the evolving human condition. We have consolidated the “discovery” sector and diversified the “innovation” sector. The fundamental value of accelerators, articulated in my 2002 Viewpoint, remains invariant: they package and focus energy and information in patterns of space-time bursts to serve a multitude of human pursuits – hence their universal, timeless appeal. Amazing particles and light, carrying focused energy and information in special scaccato-fashion, beam into matter and life, illuminating what our eyes do not see and manipulating what our hands cannot.

Throughout the 20th century, fundamental discoveries were enabled by bold conception and realization of ever-larger particle accelerators, which today must be consolidated into just a few carefully selected facilities so large that they can only be supported internationally. Hence the emergence of but a few grand future

machines: the Large Hadron Collider, the X-ray free-electron lasers, a potential International Linear Collider (ILC- or CLIC-based), and neutrino/muon facilities. This consolidation is a must for mastering the global resources necessary to discover fundamentals at the core of the physical world: hidden dimensions, symmetries and structures; origins of mass, dark matter and dark energy; unification of gravity; and exotic states of matter.

In parallel with that consolidation, we continue to anticipate tremendous diversification in the innovation sector of clever techniques and merger of technologies in creating unique bursts of particles and light. These efforts will lead not only to novel affordable scientific devices (for example, energy-recovery and laser-plasma-based compact high-brightness particle and light sources), but also to an increasing set of affordable instruments and processes that more directly enrich our everyday lives (such as novel medical imaging, diagnostics, therapy and radiation oncology; micro-machined instruments for use in medicine, scientific research, information technology and space exploration; designer nano-materials; and knowledge of complex protein structures for drug discovery).

The vision is one of discovering the secrets of the hidden energy and matter in the universe's evolution; of understanding the protein as the molecular engine of life through studying its energetics and structural folding; of innovating new eco- and bio-friendly materials for human use; and of eliminating radioactive waste and dependence on fossil fuels. Extraordinarily clever particle accelerators drive this at all scales from “small” to “mezzo” to “grand”.

Is this just a dream? Inspired by US poet Carl Sandburg, I respond: “Nothing happens, unless first a dream.”

Swapan Chattopadhyay, inaugural director of the Cockcroft Institute, Sir John Cockcroft Chair of Physics, Universities of Liverpool, Manchester and Lancaster, and associate director emeritus, Jefferson Lab.



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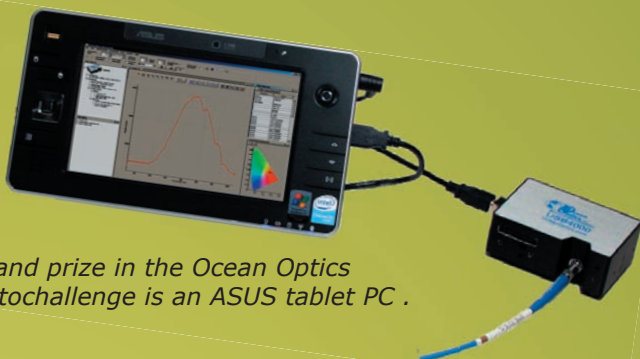
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- One FPGA per Channel
- Optical link for high data throughput
- CAENscope software included

