INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERNCOURIER

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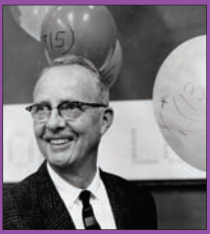
ALICE follows the J/ψ trail



ALVAREZ

Commemorating the centenary of a great ideas man **p21**

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LUMINOSITY UPGRADE

Exploiting the LHC's full capacity **p19**

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MONITOR BOARD

also useable for programming of HV and LV modules manually

Contents

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

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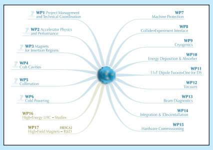


On the cover: The muon spectrometer and its tracking chambers (seen here during installation) play a key role in detecting J/Ψ particles in ALICE, while the particles are proving to have their own special role in studying the medium created in heavy-ion collisions at the LHC (p14). (Image credit: A Saba for CERN.)

COSYLAB
CONTROL SYSTEM LABORATORY

News

LIGHT SOURCES

Cornell sprints past milestones towards hard X-ray source

Synchrotron X-ray sources have become essential tools across the sciences, medicine and engineering. To continue the rapid pace of advances in these fields, researchers need much better high-intensity sources of short-wavelength X-rays to capture ultrafast phenomena and probe materials with atomic resolution. Existing continuous-duty synchrotrons fall short because they produce mostly incoherent light, so there is now a worldwide race to build coherent, high-flux hard X-ray sources.

Cornell University has for some time received funding to conceive, design and prototype innovative superconducting technology for an energy-recovery linac (ERL) as a basis for a next-generation source. Towards the end of 2011, the team at Cornell surpassed three important milestones on the road towards a coherent source and is now within striking distance of delivering performance that matches theoretical limits.

The goal of an ERL light source is to create ultralow-emittance electron bunches, accelerate them in a superconducting linear accelerator and then circulate them only once through a series of small-gap undulators to produce ultrabright, short pulses with a high fraction of transversely coherent, hard X-ray light. The electron's energy is then recovered to accelerate a new, high-brightness beam. Three of the biggest R&D challenges are to prove that it is possible to build an electron injector with sufficient current and sufficiently small emittances, as well as a superconducting linac with sufficiently small energy consumption.

Cornell's prototype injector has achieved the first milestone by delivering a continuous-duty current of 35 mA. This is the world record for any laser-driven photocathode electron gun and is above the specification for one of the proposed operating modes. The team is now ramping up the current to even higher levels.

Cornell's first ERL cavity during its vertical test showing the required small energy loss. (Image credit: Cornell/LEPP.)

The normalized emittance goals at Cornell are around 0.1 mm mrad for a bunch charge of about 20 pC and 0.3 mm mrad at some 80 pC, i.e. for a 100 mA beam of 1.3 GHz bunches. The emittances achieved for the bunch cores (the central 2/3 of the bunch) are <0.15 mm mrad at 20 pC and 0.3 mm mrad at 80 pC. The team expects even better values as the injector voltages are ramped up. For comparison, at 5 GeV a 0.1 mm mrad emittance yields a geometric horizontal emittance of 10 pm mrad. The current world-record storage-ring source, PETRA-III at DESY, operates with a geometric horizontal emittance of 1 nm mrad.

Finally the energy requirement for the first prototype cavity of Cornell's X-ray ERL has been shown to be as small as proposed in a vertical cryogenic test ($Q_0 = 2 \times 10^{10}$ at 16 MV/m), thus reaching the third milestone.

While much remains to be done, these achievements show that even this first prototype injector, when coupled with a linac and long undulators in a full-scale ERL light source, would already produce continuous-duty (1.3 GHz) pulses of hard X-ray beams of unprecedented coherence and pulse length.

- For more details, contact Georg.Hoffstaetter@cornell.edu or see http://erl.chess.cornell.edu.

Sommaire en français

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

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

SPIN PHYSICS

Results from SPIN@COSY may bode well for RHIC

The SPIN@COSY polarized-beam team has found unexpectedly strong higher-order spin resonances when using 2.1 GeV/*c* polarized protons stored in the COSY COoler SYnchrotron at the Forschungszentrum Jülich. These results may help to increase the polarization in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven when it is used as a 250 GeV/*c* polarized proton collider. The data were taken in April 2004 and presented in part at the International Spin Physics Symposium at Trieste the following September. However, the many partly overlapping data points had an unusually large scatter, so they allowed no firm conclusions to be reached. Now, after a challenging reanalysis, the team has published results that may spell good news for the work at RHIC.

In all of the other experiments by SPIN@COSY, the data showed the expected spread when beam parameters were varied upwards, e.g. in steps of 2, 4, 6, 8, 10 and then downwards, e.g. in steps of 9, 7, 5, 3, 1. However, this was not true for the April 2004 data. Indeed, when several of the sweeps were repeated for the second and third times, the data-spread increased. Clearly, these data needed a reanalysis, which began in 2009 after the other data from SPIN@COSY had been published.

The team obtained data for each resonance by measuring the polarization after sweeping COSY's vertical (and later horizontal) betatron tunes slowly through the resonance with a narrow tune range of 0.002 in 2s, giving a tune sweep-rate of 0.001/s. The sweep-rate through all of the other resonances was made about 250 times faster by sweeping through a much larger range in a shorter time, typically a range of 0.125 in 0.5s. This reduced the effect of all of the other resonances by about 250-fold.

One possible cause of the spread in the data was a variation in the polarization stability of the polarized H$^-$ ion source. Polarized ion-sources are sensitive devices, with several sextupoles and RF transition units, whose fields and frequencies must be precisely matched to maximize the polarization. The source polarization at COSY is measured by a low-energy polarimeter (LEP) and the values stored on a nearby computer; but in 2004 this computer was not connected to the computers in the main control room, where the 2.1 GeV/*c* data were stored. Fortunately, however, the stored LEP data from 2004 were still available in 2009, so that several gigabytes of data could be transferred from COSY to Michigan. There, a small team of two post-docs and four undergraduate students matched the LEP data from the source in time with the corresponding 2.1 GeV/*c* data. When the 2.1 GeV/*c* polarization data were renormalized to the LEP polarization data, much of the spread disappeared.

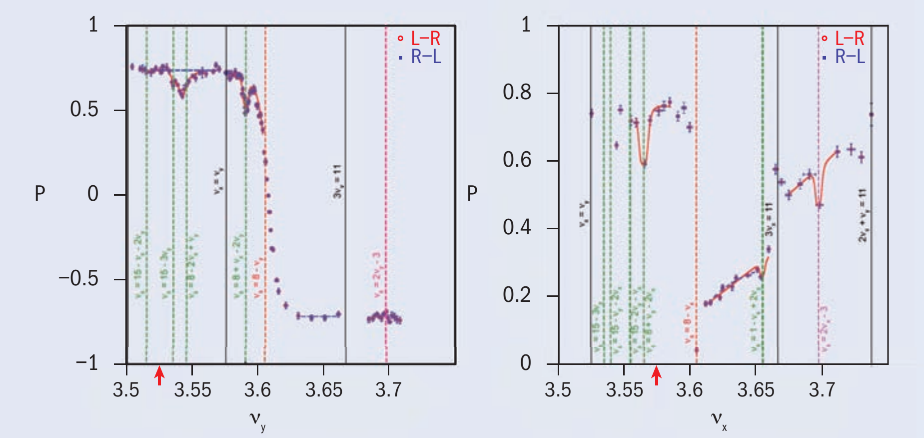


Fig. 1. The measured vertical polarization of 2.1 GeV/c polarized protons is plotted against the vertical betatron tune ν_y on the left and against the horizontal betatron tune ν_x on the right. The coloured dashed vertical lines show the calculated positions of the 1st-, 2nd- and 3rd-order spin resonances. The solid black vertical lines show the positions of the beam blow-up resonances. The final low-to-high recombined data points are shown by open red circles, while the high-to-low points are shown by smaller blue squares. (Note that both sets of points are identical for these final recombinations.) The red vertical arrows show the betatron tunes before the fast tune sweep.

The team then refined the vertical betatron-tune data further by using what is possibly a new technique for combining many partly overlapping data points in an unbiased manner. Thirty-six pairs of data points were sequentially recombined, whenever both lay within a sequentially increasing (in 0.001 steps) range in betatron tune. This recombination continued for 76 steps until the results of recombining the data from low-to-high vertical betatron tunes and from high-to-low tunes were all identical. In the horizontal data only five pairs of overlapping points needed to be recombined.

Figure 1 shows the results of this two-step reanalysis. The data clearly revealed that the long-held belief that lower-order spin resonances always caused more depolarization than higher-order resonances, and vertical spin resonances always caused more depolarization than horizontal resonances, was not correct for the 2nd- and 3rd-order resonances. The results showed that the single 2nd-order vertical resonance was far weaker than two of the 3rd-order vertical resonances (figure 2).

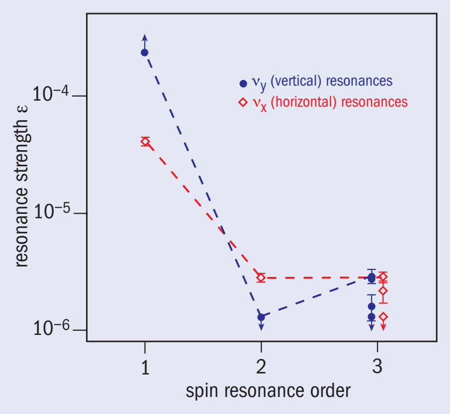


Fig. 2. The measured spin resonance strengths obtained from figure 1 are plotted against the resonance order. The up arrow indicates a lower limit on the resonance strength, while the down arrows each indicate an upper limit.

They also showed that, while the 1st-order vertical resonance was so much stronger than the 1st-order horizontal resonance that it fully flipped the spin direction, this was certainly not true for the 2nd- and 3rd-order resonances. These unexpected results may help the RHIC polarized collider to increase its 250 GeV level of polarization further towards the 100 GeV level.

● Further reading

M A Leonova *et al.* 2012 *Phys. Rev. Letts.* in press.

ASTROPARTICLE PHYSICS

EXPLORER's life comes to a fruitful end

After 20 years of continuous operation, the EXPLORER gravitational-wave detector has come to the end of its long life as an experiment and left CERN. On 23 January it set off for a new existence at the European Gravitational Observatory (EGO) in Cascina, near Pisa, where it will become the main attraction in a new museum area. The detector's main results span from the first modern upper limits on signals for gravitational waves bathing the Earth to the measurement of the dynamic gravitational field generated by an artificial source; from correlations with γ-ray and neutrino bursts to the acoustic detection of cosmic rays.

EXPLORER was the first gravitational-wave detector to reach the sensitivity and stability needed to perform long-term observations. Built and operated by INFN's gravitational-wave groups at Rome and Frascati – first led by Edoardo Amaldi and Guido Pizzella and then by Eugenio Coccia – it was based on a cryogenic mechanical resonator, in the shape of a 3-m long aluminium cylindrical bar cooled to 2 K. It could be driven by a gravitational wave with spectral components at the bar's resonant frequency, that is, about 1 kHz, and made use of superfluid helium to reduce thermal and vibrational noise and to allow the exploitation of high-sensitivity transducers and superconducting amplifiers. The experiment was able to detect changes as small as 10^{-19} m in the bar's vibrational amplitude – a real achievement.

EXPLORER in situ *in Hall 171 at CERN.*

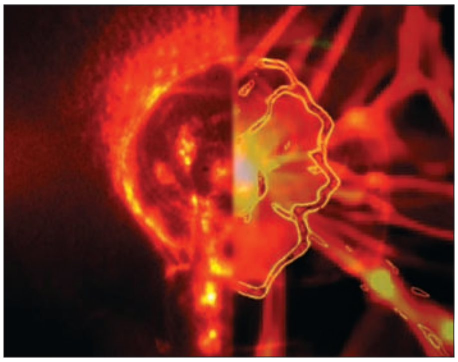
EXPLORER's gravitational-wave sensitivity was limited to the strongest sources in the Galaxy. Now, the future of the field is represented by the network of large interferometers: the Laser Interferometer Gravitational-Wave Observatory with two interferometers in the US, Virgo at the EGO site in Italy, GEO in Germany and the Large-scale Cryogenic Gravitational wave Telescope in Japan. This network, which will comprise advanced versions of the instruments, should start detecting signals from many thousands of galaxies from the year 2015; typical sources of gravitational waves include supernovae, pulsars, and collisions of neutron stars and black holes. In the mean time, for the next three years, the Galaxy will be monitored by two modern cryogenic bars – Nautilus in INFN's Frascati Laboratory and Auriga in INFN's Legnaro Laboratory and by the GEO interferometer in Hanover.

- For more information, see http://gwic.ligo.org.

Experiment recreates 'seeds' of the universe's magnetic fields

How did magnetic fields arise in the universe? An experiment using a high-power laser to create plasma instabilities may have glimpsed the processes that created magnetic fields during the period of galaxy formation.

Magnetic fields pervade the cosmos. Measurements of synchrotron emission at radio frequencies from cosmic rays and of Faraday rotation reveal that they exist in Galaxy clusters on the megaparsec scale, with strengths that vary from a few nanogauss to a few microgauss. Intergalactic magnetic fields weave through clusters of galaxies forming even larger-scale structures. In these clusters the temperatures can often be greater than 10^8 K, making them strong X-ray emitters. It is possible that the energy to heat the plasma comes from the magnetic field through some plasma instability. In general, wherever intergalactic hot matter is detected, magnetic fields with strengths greater than 10^{-9} G are also observed – with weaker magnetic fields tending to occur outside galaxy clusters. The magnetic field therefore appears to play a role in the structure of the universe.



This composite picture shows on the left an image of a laser-produced shock wave; the right side is a simulation of a collapsing shock-wave arising during the pregalactic phase of the universe. Brighter colours correspond to regions of higher density or temperature. (Image credit: F Miniati /ETH.)

The only way to explain the observed magnetization is through a magnetic dynamo mechanism in which it is necessary to invoke a "seed" field – but the origin of this seed field remains a puzzle. Prior to galaxy formation, density inhomogeneities would drive violent motions in the universe, forming shock waves that would generate vorticity on all scales. In 1997 Russell Kulsrud suggested that the "Biermann battery effect" could create seed magnetic fields as small as 10^{-21} G that would be amplified by the protogalaxy dynamo. In this effect, proposed by astrophysicist Ludwig Biermann in 1950, electric fields can arise in a plasma as the electrons and the heavier protons respond differently to external pressure and tend to separate. The Biermann battery acts to create the seed magnetic fields whenever the pressure and density gradients are not parallel.

Now, an international team of scientists has performed an experiment to recreate the conditions similar to those in the pregalactic epoch where shocks and turbulent motions form. They used a high-power laser at the Laboratoire pour l'Utilisation des Lasers Intenses in Paris to explode a rod of carbon surrounded by helium gas in a field-free environment. Magnetic induction coils monitored the magnetic fields created in the resulting shock waves. The team found that the explosion generated strong shock waves around which strong electric currents and magnetic fields formed, through the Biermann battery effect, with fields as high as 10–30 G existing for 1–2 μs at 3 cm from the blast. When scaled through 22 orders of magnitude, the measurements matched the predynamo magnetic seeds predicted by theory prior to galaxy formation.

- **Further reading**

Gianluca Gregori *et al.* 2012 *Nature* **481** 480.

LHC PHYSICS

Looking at the top for new physics

Last year one of the properties of top-quark production, the $t\bar{t}$ charge asymmetry, attracted much interest with the publication of measurements by the CDF and DØ collaborations at Fermilab's Tevatron (T Aaltonen *et al.* 2011, V M Abazov *et al.* 2011). They reported results that were 2σ above the predicted values. This deviation can be explained by several theories that go beyond the Standard Model by introducing new particles that contribute to top-quark production. The CMS collaboration has now measured this top-quark property for the first time at the LHC – and finds a different result.

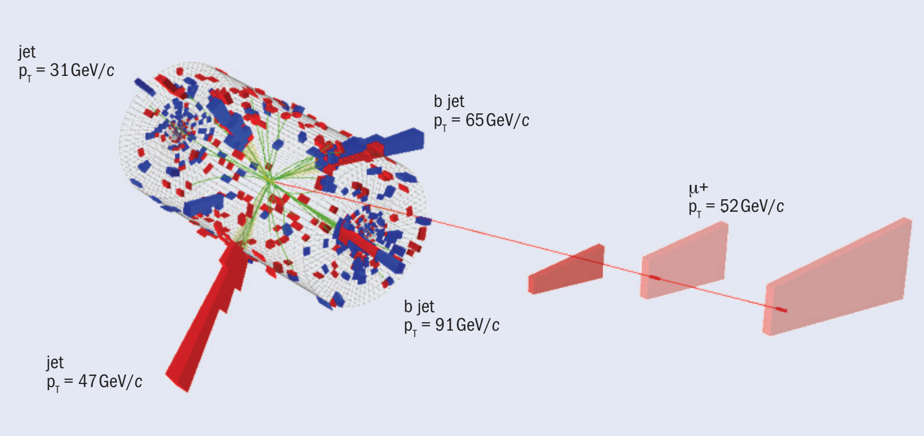


Fig. 1. Event display of a $t\bar{t}$ candidate event. The t is reconstructed in the forward direction; the $\bar{t}$ is reconstructed from the three central jets. The difference in pseudorapidity Δ|η| is 2.7.

In the Standard Model, a difference in angular distributions between top quarks and antiquarks (commonly referred to as the charge asymmetry) in $t\bar{t}$ production through quark–antiquark annihilation appears in QCD calculations at next-to-leading order. It leads to there being more top quarks produced at small angles to the beam pipe, while top antiquarks are produced more centrally (figure 1). As a consequence, the pseudorapidity distribution of top quarks is broader than that of top antiquarks, which makes the difference of the respective pseudorapidities, $\Delta|\eta| = |\eta_t| - |\eta_{\bar{t}}|$, a suitable observable for measuring the charge asymmetry (figure 2). The Standard Model predicts a small asymmetry of $A_C = 0.0136 \pm 0.0008$, which translates into an excess of about 1% of events with $\Delta|\eta| > 0$ compared with events with $\Delta|\eta| < 0$ (Kuhn and Rodrigo 2011). The existence of new sources of physics could enhance this asymmetry.

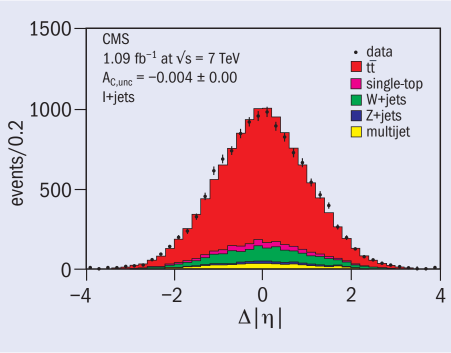


Fig. 2. The reconstructed distribution of the difference of the absolute values of the top quark and antiquark pseudorapidities.

CMS has measured the $t\bar{t}$ charge asymmetry using data corresponding to an integrated luminosity of 1 fb^{-1} (CMS collaboration 2011). A total of 12 757 events were selected in the lepton+jets channel, where one top quark decays into a b quark, a charged lepton (electron or muon) and the corresponding neutrino, while the other top quark decays into three quarks. The background contribution to this dataset is about 20%. The measurement of the charge asymmetry is based on the full reconstruction of the four-momenta of the top quarks, which have to be reconstructed from the observed leptons, jets and missing transverse energy. The dependency of the selection efficiency both on the Δ|η| value and on the smearing of the momenta of the top-quark decay products, because of finite detector resolution, are accounted for when calculating the final result.

The measured value of $A_C = -0.017 \pm 0.032$ (stat.)$^{+0.025}_{-0.036}$ (syst.) is consistent with the Standard Model prediction and does not provide any indication for a new physics contribution. CMS also measured the uncorrected charge asymmetry as a function of the invariant mass of the top-quark pair, $m_{t\bar{t}}$. Previous measurements by the CDF collaboration had found an asymmetry that was more than 3σ above the predicted value for large values of $m_{t\bar{t}}$. However, the current analysis by CMS dampens the excitement that the CDF result caused because it reveals no hints for a deviation from the Standard Model predictions.

● Further reading

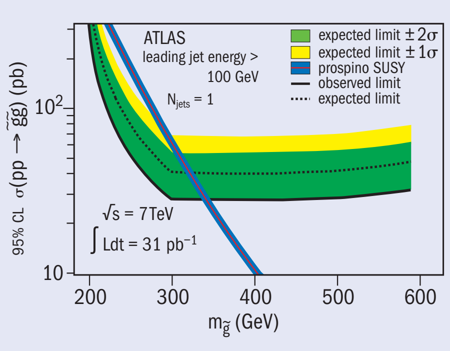
T Aaltonen *et al.* (CDF collaboration) 2011 *Phys. Rev. D* **83** (2011) 112003.
V M Abazov *et al.* (DØ collaboration) 2011 *Phys. Rev. D* **84** (2011) 112005.
CMS collaboration 2011 arXiv:1112.5100v2.
J H Kuhn and G Rodrigo 2011 arXiv:1109.6830.

The hunt for long-lived exotic beasts

The hunt for exotic massive long-lived particles is an important element in the ATLAS collaboration's programme of searches. The signatures associated with such long-lived objects are particularly striking and experimentally challenging. At the LHC they could appear as slow-moving and highly ionizing objects that could slip into the next bunch-crossing, saturate the read-out electronics and confound the event reconstruction software. An alternative approach to the direct detection of moving long-lived particles is to search for those that stop in the detector and subsequently decay.

This is the method used in a recent search by the ATLAS collaboration.

The new search looks for metastable R-hadrons that would be formed from gluinos and light quarks (ATLAS collaboration 2011a). If produced, some R-hadrons would stop in the dense calorimeter material – following electromagnetic and hadronic interactions. Within the scenario of split-supersymmetry, an R-hadron could decay to a final state of jets and a neutralino. During 2010, the experiment used jet triggers to record candidate decays in empty bunch crossings when no proton–proton collisions were intended. With the subsequent analysis, which required estimations of cosmic and beam-related backgrounds along with the uncertainties on R-hadron stopping rates, ATLAS has set upper limits on the pair-production cross-section for gluinos with lifetimes in the range 10^{-5}–10^{3} s. From this, the collaboration has obtained a lower mass limit for the gluino of around 340 GeV at the 95% CL (see figure). Although the search was inspired by split-supersymmetry, the results are generally applicable for any heavy object decaying to jets.



Observed (solid line) and expected (dashed line) cross-section limits on the pair-production of gluinos as a function of the gluino's mass. The predicted cross-section is also shown, as the red line with blue band, allowing a lower mass limit to be inferred from the intersection of the observed cross-section limit with the predicted cross-section.

This complex work complements other, more conventional, searches for long-lived particles that interact or decay in the ATLAS detector. These results allow stringent limits to be set on topical models of new physics. Moreover, the collaboration is performing experimentally driven searches up to the limits of the detector's capability to detect long-lived objects. For example, a search based on early collision data sought exotic particles with large electric charge (up to 17*e*).

With more data and a continually improving knowledge of the detector response, the ATLAS collaboration is aiming at a set of comprehensive searches for long-lived objects, which possess a range of colour, electric and magnetic charges, and appear as stable objects or decay to a variety of final states.

● Further reading

ATLAS collaboration 2011a CERN-PH-EP-2011-188, arXiv:1201.5595[hep-ex].
For other searches see:
ATLAS collaboration 2011b, arXiv:1102.0459 [hep-ex].
ATLAS collaboration 2011c, arXiv:1103.1984 [hep-ex].
ATLAS collaboration 2011d, arXiv:1106.4495 [hep-ex].
ATLAS collaboration 2011e, arXiv:1109.2242 [hep-ex].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Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Blurred vision helps spiders see better

People estimate distance using binocular vision and many animals do so by moving their heads round. However, jumping spiders, which need to be excellent judges of distances (as the name suggests, they jump!), use neither method. Remarkably, as Takashi Nagata of Osaka University in Japan and colleagues have recently shown, they make use of blurry vision.

Jumping spiders have two pairs of forward-facing eyes: the principal, more central eyes; and the anterior, lateral eyes. In studies of the *Hasarius adansoni* species, the researchers found that the principal eyes provide the depth perception and that these eyes have an unusual structure. Rather than having a single layer of photoreceptors, they have four, and it turns out that the first two are maximally sensitive to green light, the other two to ultraviolet. The effects of chromatic aberration mean that green images are focused clearly only on the first layer. The spiders jump accurately in green light but in other spectra they consistently underestimate distances. This appears (no pun intended) to be a genuinely new mechanism of depth perception.

● **Further reading**

T Nagata *et al.* 2012 *Science* **335** 469.

Blurred vision helps the jumping spider Hasarius adansoni *to get to its prey. (Image credit: Nicholashan/dreamstime.com.)*

An optical diode

Electrical diodes, which conduct electricity in one direction only, are commonplace. Now, Li Fan of Purdue University in Indiana and colleagues have made a diode for light. Naively, it might seem that such a device should be impossible because of the time-reversal invariance of matter–light interactions, but the trick here is to use nonlinear optics to make a complex, effective index-of-refraction. The unidirectionality then comes from coupling two different modes – in effect, the colour going in is not quite the same as the colour going out.

While this means that the "diode" cannot be used as a linear optical isolator, it is made from a pair of silicon rings and is compatible with standard CMOS technology. With a forward–backward transmission ratio of 28 dB, it could find a range of applications and herald a new approach to optical information processing.

● **Further reading**

L Fan *et al.* 2012 *Science* **355** 447.
See also *Science* **355** 38-b and 38-c.

Seeing clearly in the infrared

A big problem in infrared (IR) astronomy is that the night sky is not dark. Hydroxyl molecules in the atmosphere emit a range of bright, narrow IR lines, which is why astronomers have had to launch their telescopes into space – or at least seek out mountains that are high enough for the air above to be clear and dry.

Now, J Bland-Hawthorn of the University of Sydney in Australia and colleagues have found another way.

A sophisticated filter based on Bragg gratings made from fibres selectively reflects back the unwanted lines and acts as a notch filter to give a clear view in the rest of the infrared spectrum. This new technology could open up the possibility for vastly improved infrared astronomy using Earth-based telescopes.

● **Further reading**

J Bland-Hawthorn *et al.* 2011 *Nature Communications* **2** doi:10.1038/ncomms1584.

The thinnest wire

Worries that quantum effects at small scales lead to a breakdown of Ohm's law and higher electrical resistance in small wires appear to be unfounded. Hoon Ryu of Purdue University in Indiana and colleagues made wires just four atoms wide and one atom high by embedding phosphorus atoms in a silicon crystal. Contrary to expectations, the resistivity of the material turned out to be very low – about 0.4 mΩ-cm – with a current-carrying ability similar to copper. Moreover, it still obeyed Ohm's law even at this tiny scale. This is good news for Moore's law, which could go all of the way down to device sizes of a few atoms across, and it could represent the limit for classical scaling down of electronics.

● **Further reading**

B Weber *et al.* 2012 *Science* **355** 64.

Eyeball quantum mechanics

Quantum systems tend to be small, but now quantum states large enough to be seen with the naked eye have been made. Gab Christmann of the University of Cambridge and colleagues made microscopic cavities in which a quantum fluid of polaritons can be manipulated with laser light.

Quantum mechanics forces the flow of this fluid to be quantized in vortices that can be seen with the naked eye (albeit with the help of a microscope). It is hoped that these remarkable states could be created at room temperature with standard electrical circuits for a new approach to making sensitive gyroscopes and quantum circuits.

● **Further reading**

G Tosi *et al.* 2012 *Nature Physics* doi:10.1038/nphys2182.
S Braz *et al.* 2012 *Science* **355** 303.

Solar cells that are more than 100% efficient

If a photon enters a solar cell and produces multiple excitons, then the overall quantum efficiency achievable can be more than 100%. Arthur Nozik of the National Renewable Energy Laboratory in Golden, Colorado, and colleagues have made this mechanism work in lead-selenide quantum-dot photocells, obtaining on average 1.14 electrons for each incident photon. The work could lead to more efficient methods to harnessing solar power.

● **Further reading**

O E Simonin 2011 *Science* **334** 1530.

Astrowatch

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

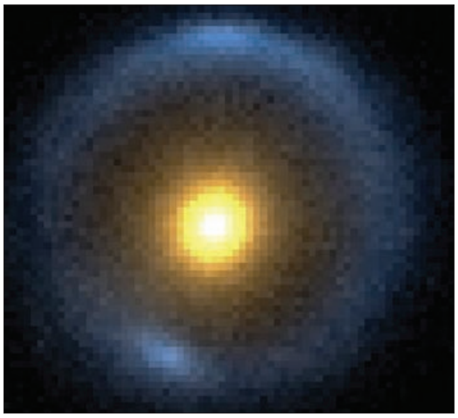
Einstein ring reveals dwarf dark-matter galaxy

If a remote galaxy is located exactly behind another galaxy then it can be seen deformed by gravitational lensing as an "Einstein ring". The careful analysis of such an effect has recently revealed the presence of an invisible dwarf galaxy contributing to the gravitational lens. It could be one of the many dark-matter satellites expected by simulations of cold dark matter.

Playing hide-and-seek is not easy for galaxies: they appear even bigger and brighter when they hide behind each other. When two galaxies are perfectly aligned on the line-of-sight, the image of the remoter one can even be deformed into a complete annulus around the nearer source. This strong gravitational lensing effect is called an "Einstein ring" because it is described by Albert Einstein's general theory of relativity. The gravity of the closer galaxy acts like a magnifying glass. It bends the light paths around it by deforming space–time locally.

According to standard cosmology, the universe is composed of about 5% ordinary matter (baryons), 23% dark matter and 72% dark energy. This result is derived from fluctuations of the cosmic microwave background (CMB) with additional constraints from type Ia supernovae and from the large-scale distribution of galaxies (*CERN Courier* May 2008 p8). Because dark-matter particles are still of unknown nature, they are distinguished as "cold" or "hot", where "hot" means that they are moving with a highly relativistic speed, like neutrinos, for instance.

If dark matter is cold, small-scale galaxies should form first and subsequently merge to form larger galaxies; if it is hot, large halos would form first and then fragment into galaxies of various sizes. Numerical simulations of the formation of large-scale structures from CMB fluctuations suggest that dark matter should be dominated by a cold component to account for the observed distribution of galaxies. There are, however, several problems with cold dark matter. One of them is that such simulations greatly over-predict the number of small galaxies orbiting fully fledged spiral or elliptical galaxies. While cold dark matter should result in thousands of dwarf satellite galaxies around the Milky Way, astronomers have so far observed only about 30 of them. So either the models are missing a key ingredient or there should be many dark-matter galaxies around the Milky Way – but too scarcely populated with stars to be detectable.



False-colour image of the gravitational lens B1938+666. The background galaxy (blue) is made into an Einstein ring by the lensing effect of gravity of a galaxy closer to Earth (yellow). (Image credit: Chris Fassnacht/UC Davis graphic.)

While some astronomers search for dark galaxies around the Milky Way, others try to detect their presence around distant galaxies using gravitational lensing. Simona Vegetti, a postdoctoral researcher at the Massachusetts Institute of Technology, belongs to the second group and was lucky enough to detect the signature of one such elusive galaxy at cosmological distance. Together with her colleagues in the Netherlands and US, she studied the B1938+666 lens system, in which the gravitational lensing effect of a massive elliptical galaxy at a redshift of $z \simeq 0.9$ is making a background galaxy ($z \simeq 2.1$) appear as an almost perfect Einstein ring. The study is based on infrared observations obtained both with the Keck 10 m telescope on Mauna Kea, Hawaii, and with the Hubble Space Telescope.

The team found a slight deformation of the Einstein ring that would be the imprint, according to their modelling, of a small companion to the lensing elliptical galaxy. The dwarf galaxy's weight was estimated at 190 million solar masses and its luminosity has an upper limit of 54 million solar luminosities. This means that its mass-to-light ratio is at least 3.5 times higher than that of the Sun. Such a ratio is typical of dwarf galaxies orbiting the Milky Way, such as Fornax and Sagittarius, but it is still an order of magnitude below the expectation of numerical simulations. As long as the Galaxy remains invisible even to future facilities, the discovery of this object will support the cold dark-matter scenario, although many more such small dark galaxies must be discovered to be consistent with simulations.

Further reading

S Vegetti *et al.* 2012 *Nature* **481** 341.

Picture of the month

This near-infrared view of the Helix Nebula (NGC 7293) was captured by the Visible and Infrared Survey Telescope for Astronomy (VISTA) of the European Southern Observatory (ESO). The image reveals filaments of cold gas that radiate out of the centre of this famous planetary nebula (*CERN Courier* July/August 2003 p13). Located about 700 light-years away, in the constellation Aquarius, the Helix Nebula was formed from the ejection of the outer gas layers by a Sun-like star at the end of its life. The tiny blue dot at its centre is the remaining core of the dying star that collapses into a white dwarf. The shape of the ejecta with a diameter of about two light-years resembles a giant eye with an apparent size of about a third of the Moon. (Image credit: ESO/VISTA/J Emerson, with acknowledgments to Cambridge Astronomical Survey Unit.)

CERN Courier Archive: 1969

A LOOK BACK TO CERN COURIER VOL. 8, MARCH 1969, COMPILED BY PEGGIE RIMMER

COMMENT

Opening up the Particle Zoo

In 1935 Julian Huxley was elected Secretary of the Zoological Society of London, with responsibility for the London Zoo. He opened the doors of the Zoo to the public and the number of visitors rocketed. This helped to generate an awareness and love of animals which may well have been vital in providing a climate of opinion in which wild-life conservation schemes could be promoted and get political backing.

Huxley's policy did not go unopposed. The more conservative zoologists resented the public intrusion into what had been virtually exclusively their domain and they manoeuvred Huxley out of power in 1942. But by then the doors of the Zoo could not be closed.

Particles are not as accessible as animals but it is possible to get across much of the fascination of particle physics. There is almost a moral obligation to open the doors of the Particle Zoo to the people who pay for the research.

But perhaps a more telling argument is one of self-interest. At present there are indications of a widespread and growing disenchantment with science and a rapid drift away from science among young people. Another sensitive sign is the declining amount of space given to science by newspapers. Political decisions and budgets often reflect situations like this. Unless scientists are prepared to come out of the ivory tower onto the soapbox they may find out too late that the foundations of the tower are crumbling.

- Compiled from texts on pp62–63.

The large superconducting coil (BIM) being operated at Saclay to gain experience in superconductivity techniques.

SACLAY

Superconducting coil

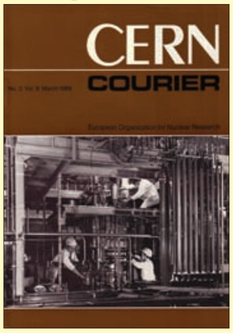
At the end of February a large superconducting coil (called BIM) was operated at Saclay. It may eventually be incorporated in experimental equipment but its initial purpose is to confront the problems of construction and operation of large superconducting coils.

The coil is in two halves each 0.4 m high, with an internal diameter of 1 m and external diameter of 1.3 m, separated by a gap of 0.2 m. The superconducting ribbon, 10 mm wide by 1.8 mm thick, is made of niobium-titanium filaments (about 0.25 mm in diameter) embedded in copper. It is coated with epoxy 50 μm thick to withstand 1500 V while still allowing good heat conduction.

The coil is designed for a critical current of 1750 A. During tests, which began at the end of February, the current was raised without problem to 1360 A – corresponding to a magnetic field at the centre of the coil of 36.5 kG and a stored energy of 8.5 MJ. At this current a low resistance appeared in a section of the coil (involving about 30 m of ribbon). This 'normal' zone did not spread to the rest of the coil and the superconducting state could be completely recovered by slightly reducing the current. Further tests are under way to correct the fault and to push the performance higher.

- Compiled from texts on p76.

Compiler's Note



Well, particle physicists have certainly come out of their ivory towers. Media headlines regularly feature Higgs bosons, speedy-neutrinos and all that they entail; even the $\chi_b(3P)$ made it. The opening salvo of a recent *Times* (UK) editorial on CERN's political as well as scientific achievements indicates how times have changed: "At a time when more than half a century of European co-operation may seem to be in peril, those in need of some good cheer would do well to raise their eyes from Brussels and look south to Geneva." Let's hope that this kind of publicity prevents scientists from becoming an endangered species.

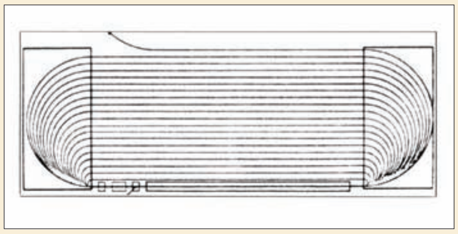
ILLINOIS

Superconducting microtron

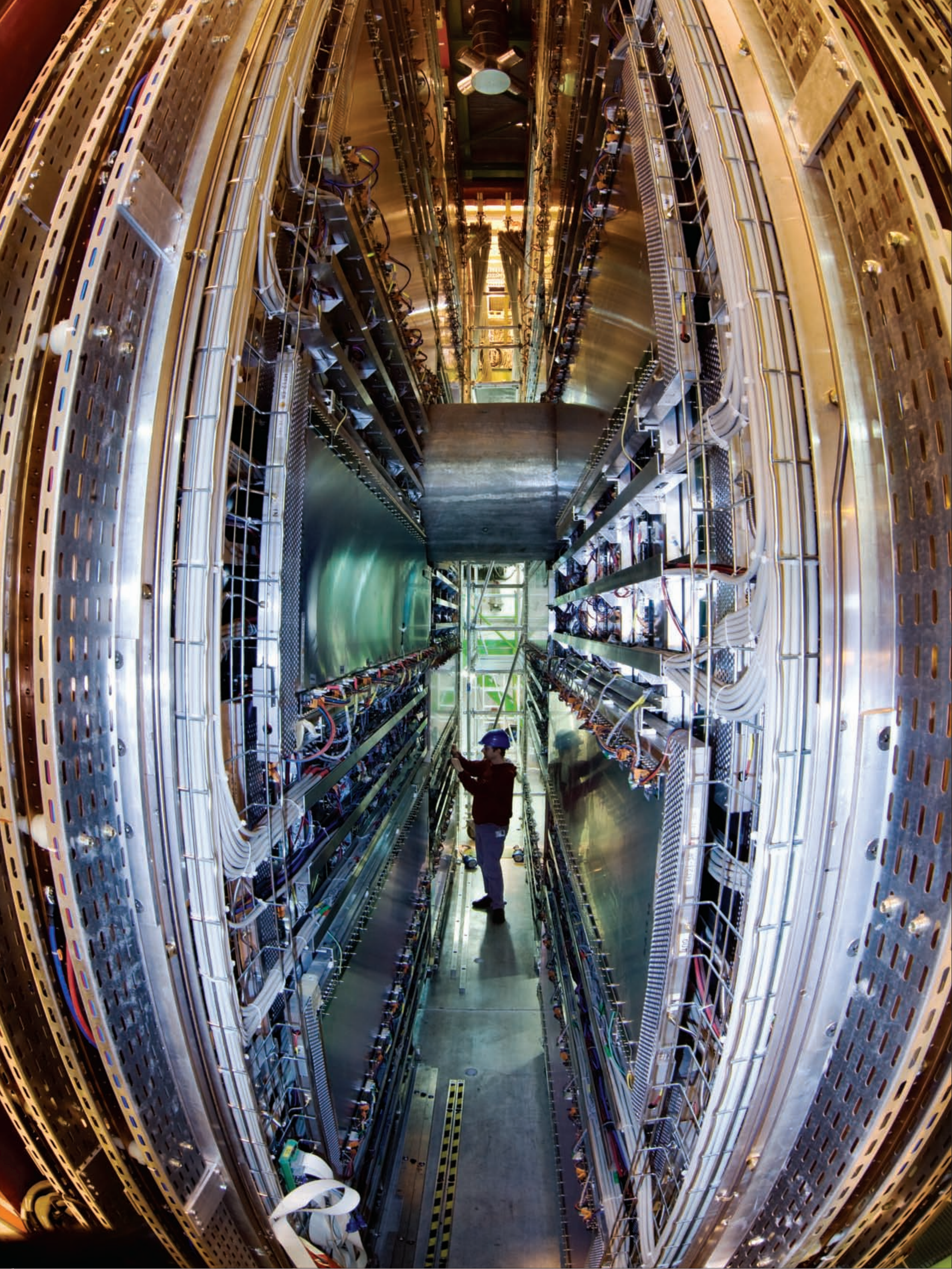
At the 1969 Particle Accelerator Conference at Washington in March, the design of a 600 MeV superconducting microtron for the University of Illinois was presented. The machine, intended for nuclear physics research, involves several novel features.

The first stage of the project is a 30 MeV superconducting electron linac. The main advantage of superconducting machines for physics experiments is the high duty-cycle (the percentage of time for which the machine is providing particles) made possible by the dramatic drop in power consumption. In some cases, duty-cycle is more important than beam intensity. Compared with a conventional linac duty-cycle of about 0.2%, Illinois will have 100%. Tests are underway with single lead and niobium cavities to find a satisfactory method of fabricating and assembling superconducting cavities into a linac.

- Compiled from texts on pp78–79.



Schematic diagram of the 600 MeV racetrack microtron. The boxes at each side represent magnets, about 7 m apart, bending the electrons back to pass a total of 20 times through the 30 MeV superconducting linac, represented by the long thin rectangle at the bottom. The magnets will be about 3 m wide and have slots of a few centimetres aperture between the pole faces where the beams travel.



ALICE unveils mysteries of the J/ψ

Analysis of early results from both nucleus–nucleus and proton–proton collisions at the LHC indicate that a final answer on the fate of the J/Ψ inside a hot QGP seems to be within reach.

The J/ψ meson, a bound state of a charm (c) and an anticharm ($\bar{c}$) quark, is unique in the long list of particles that physicists have discovered over the past 50 years. Found almost simultaneously in 1974 – at Brookhaven, in proton–nucleus collisions, and at SLAC, in e^+e^- collisions – this particle is the only one with two names, given to it by the two teams. With a mass greater than 3 GeV it was by far the heaviest known particle at the time and it opened a new field in particle physics, namely the study of "heavy" quarks.

The charm quark and its heavier partners, the bottom and top quarks (the latter discovered more than 20 years later, in 1995), have proved to be a source of both inspiration and problems for particle physicists. By now, thousands of experimental and theoretical papers have been published on these quarks and the production, decay and spectroscopy of particles containing heavy quarks have been the focus of intense and fruitful investigations.

However, despite a history of almost 40 years, the production of the J/ψ itself still represents a puzzle for QCD, the standard theory of strong interactions between quarks and gluons. On the one hand, the creation of a pair of quarks as "heavy" as charm ($m_c \approx 1.3\ \mathrm{GeV}/c^2$) in a gluon–gluon or quark–antiquark interaction is a process that is "hard" enough to be treated in a perturbative way and therefore well understood by theory. On the other hand however, the binding of the pair is essentially a "soft" process – the relative velocity of the two quarks in a J/ψ is "only" about 0.5 c – and this proves to be much more difficult to model.

J/Ψ production

About fifteen years ago, the results obtained at Fermilab's Tevatron collider first showed a clear inconsistency with the theoretical approach adopted at the time to model J/ψ production, the so-called colour-singlet model. This unsatisfactory situation led to the formulation of the more refined approach of nonrelativistic QCD (NRQCD), which brought a better agreement with data. However, other quantities such as the polarization of the produced J/ψ, i.e. the extent to which the intrinsic angular momentum of the particle is aligned with respect to its momentum, were poorly reproduced. This uncomfortable situation also arose partly because of controversial experimental results from the Tevatron, where the CDF experiment's results on polarization from Run1 disagreed with those from Run2. Considerable hope is therefore placed on the results that the LHC can obtain for this observable (more on this later).

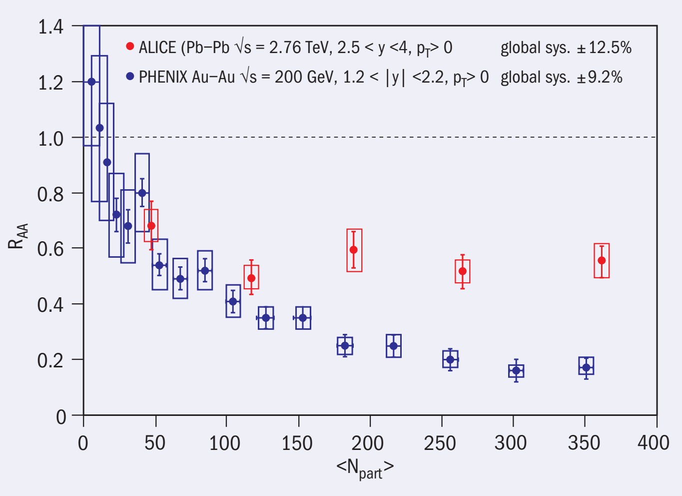


Fig. 1. A comparison of the J/ψ suppression between RHIC (PHENIX) and the LHC (ALICE). The ALICE results show a strikingly smaller suppression, in particular for head-on collisions (large N_{part}), despite the much larger centre-of-mass energy.

Nevertheless, despite these unresolved mysteries surrounding its production, the J/ψ has an important "application" in high-energy nuclear physics and more precisely in the branch that studies the formation of the state of (nuclear) matter where quarks and gluons are no longer confined into hadrons: the quark–gluon plasma (QGP). If such a state is created, it can be thought of as a hot "soup" of coloured quarks and gluons, where colour is the "charge" of the strong interaction. In the usual world, quarks and gluons are confined within hadrons and colour cannot fly over large distances. However, in certain situations, as when ultrarelativistic ▷

A view of the trigger chambers of the ALICE Muon Spectrometer, which are used to select events with muon pairs from J/ψ decays.

heavy-ion collisions take place, a QGP state could be formed and studied. Indeed, such studies form the bulk of the physics programme of the ALICE experiment at the LHC.

The J/ψ is composed of a heavy quark–antiquark pair with the two objects orbiting at a relative distance of about 0.5 fm, held together by the strong colour interaction. However, if such a state were to be placed inside a QGP, it turns out that its binding could be screened by the huge number of colour charges (quarks and gluons) that make up the QGP freely roaming around it. This causes the binding of the quark and antiquark in the J/ψ to become weaker so that ultimately the pair disintegrates and the J/ψ disappears – i.e. it is "suppressed". Theory has shown that the probability of dissociation depends on the temperature of the QGP, so that the observation of a suppression of the J/ψ can be seen as a way to place a "thermometer" in the medium itself.

Such a screening of the colour interaction, and the consequent J/ψ suppression, was first predicted by Helmut Satz and Tetsuo Matsui in 1986 and was thoroughly investigated over the following years in experiments with heavy-ion collisions. In particular, Pb–Pb interactions were studied at CERN's Super Proton Synchrotron (SPS) at a centre-of-mass energy, $\sqrt{s}$, of around 17 GeV per nucleon pair and then Au–Au collisions were studied at $\sqrt{s}$=200 GeV at Brookhaven's Relativistic Heavy-Ion Collider (RHIC).

As predicted by the theory, a suppression of the J/ψ yield was observed with respect to what would be expected from a mere superposition of production from elementary nucleon–nucleon collisions. However, the experiments also made some puzzling observations. In particular, the size of the suppression (about 60–70% for central, i.e. head-on nucleus–nucleus collisions) was found to be approximately the same at the SPS and RHIC, despite the jump in the centre-of-mass energy of more than one order of magnitude, which would suggest higher QGP temperatures at RHIC. Ingenious explanations were suggested but a clear-cut explanation of this puzzle proved impossible.

At the LHC, however, extremely interesting developments are expected. In particular, a much higher number of charm–anticharm pairs are produced in the nuclear interaction, thanks to the unprecedented centre-of-mass energies. As a consequence, even a suppression of the J/ψ yield in the hot QGP phase could be more than counter-balanced by a statistical combination of charm–anticharm pairs happening when the system, after expansion and cooling, finally crosses the temperature boundary between the QGP and a hot gas of particles. If the density of heavy quark pairs is large enough, this regeneration process may even lead to an enhancement of the J/ψ yield – or at least to a much weaker suppression with respect to the experiments at lower energies. The observation of the fate of the J/ψ in nuclear collisions at the LHC constitutes one of the goals of the ALICE experiment and was among its main priorities during the first run of the LHC with lead beams in November/December 2010.

The ALICE experiment is particularly suited to observing a J/ψ regeneration process. For simple kinematic reasons, regeneration can be more easily observed for charm quarks with low transverse-momentum. Contrary to the other LHC experiments, both detector systems where the J/ψ detection takes place – the central barrel (where the $J/\psi \to e^+e^-$ decay is studied) and the forward muon spectrometer (for $J/\psi \to \mu^+\mu^-$) – can detect J/ψ particles down to zero transverse momentum.

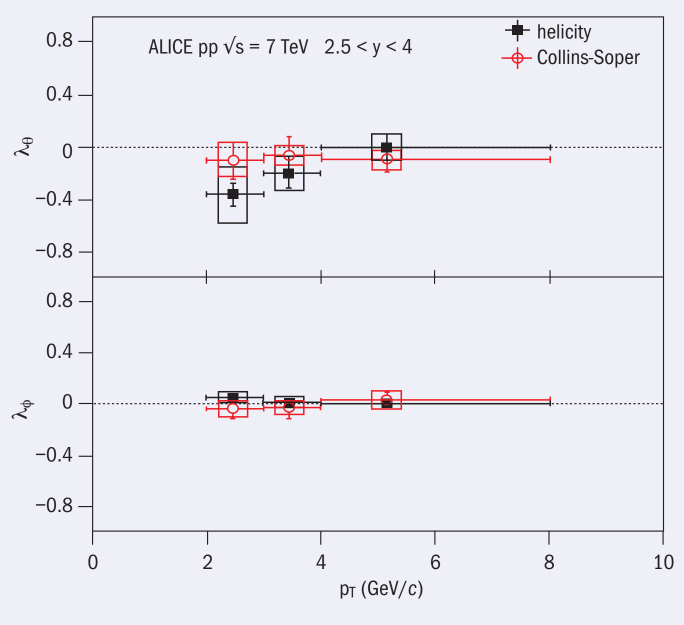


Fig. 2. The two parameters, λ_θ and λ_φ, that express the degree of polarization of the J/ψ, as a function of its transverse momentum, in the helicity and Collins-Soper frames. The values obtained by ALICE are, within errors, compatible with zero, showing an unpolarized J/ψ production at LHC energy.

As the luminosity of the LHC was still low during its first nucleus–nucleus run, the overall J/ψ statistics collected in 2010 were not huge, of the order of 2000 signal events. Nevertheless, it was possible to study the J/ψ yield as a function of the centrality of the collisions in five intervals from peripheral (grazing) to central (head-on) interactions.

The J/Ψ and its suppression can be seen as a thermometer in the medium created in the collision.

Clearly, suppression or enhancement of a signal must be established with respect to a reference process. And for such a study, the most appropriate reference is the J/ψ yield in elementary proton–proton collisions at the same energy as in the nucleus–nucleus data-taking. However, in the first proton run of the LHC the centre-of-mass energy of 7 TeV was more than twice the energy of 2.76 TeV per nucleon–nucleon collision in the Pb–Pb run. To provide an unbiased reference, the LHC was therefore run for a few days at the beginning of 2011 with lower-energy protons and J/ψ production was studied at the same centre-of-mass energy of Pb–Pb interactions.

The Pb–Pb and p–p results are compared using a standard quantity, the nuclear modification factor R_{AA}. This is basically a ratio between the J/ψ yield in Pb–Pb collisions, normalized to the average number of nucleon–nucleon collisions that take place in the interaction of the two nuclei and the proton–proton yield. Values smaller than 1 for R_{AA} therefore indicate a suppression of the J/ψ yield, while values larger than 1 represent an enhancement.

The results from the first ALICE run are rather striking, when compared with the observations from lower energies (figure 1, p15). While a similar suppression is observed at LHC energies for peripheral collisions, when moving towards more head-on collisions – as quantified by the increasing number of nucleons in the lead nuclei participating in the interaction – the suppression no longer increases. Therefore, despite the higher temperatures attained in the nuclear collisions at the LHC, more J/ψ mesons are detected by the ALICE experiment in Pb–Pb with respect to p–p. Such an effect is likely to be related to a regeneration process occurring at the temperature boundary between the QGP and a hot gas of hadrons ($T \approx 160$ MeV).

The picture arises from these observations is consistent with the formation, in Pb–Pb collisions at the LHC, of a deconfined system (QGP) that can suppress the J/ψ meson, followed by a hadronic system in which a fraction of the charm–anticharm pairs coalesce and ultimately give a J/ψ yield larger than that observed at lower energies. This picture should be clarified by the Pb–Pb data that were collected in autumn 2011. Thanks to an integrated luminosity for such studies that was 20 times larger than in 2010, a final answer on the fate of the J/ψ inside the hot QGP produced at the LHC seems to be within reach.

ALICE is also working hard to help solve other puzzles in J/ψ production in proton–proton collisions, in particular by studying, as described above, the degree of polarization. A first result, recently published in *Physical Review Letters*, shows that the J/ψ produced at not too high a transverse momentum are essentially unpolarized, i.e. the angular distribution of the decay muons in the $J/\psi \rightarrow \mu^+\mu^-$ process is nearly isotropic (figure 2). Theorists are now working to establish if such behaviour is compatible with the NRQCD approach that up to now is the best possible tool for understanding the physics related to J/ψ production.

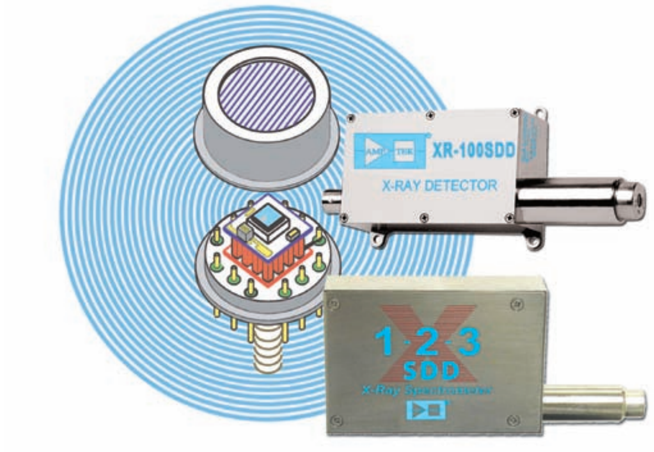
In conclusion, a particle that has been known for almost half a century continues to be a source of inspiration and progress. However, even if particle and nuclear physicists working at the LHC are confident of being able finally to understand its multifaceted aspects, the future often brings the unexpected. So stay tuned and be ready for surprises.

Résumé

ALICE dévoile les mystères du J/ψ

L'analyse des premiers résultats de l'expérience ALICE auprès du LHC semble indiquer qu'on pourra bientôt se prononcer définitivement sur le sort du J/ψ dans un plasma chaud quark–gluon. Le nombre énorme de charges de couleur libres (quarks et gluons) pourrait affaiblir la liaison du quark et de l'antiquark dans le J/ψ, si bien que celui-ci finirait par disparaître (il serait éliminé). La théorie montre que la probabilité de cette dissociation dépend de la température du plasma quarks–gluons, de sorte que l'observation de cette élimination du J/ψ revient à placer un thermomètre dans la matière elle-même

Enrico Scomparin, INFN Torino, on behalf of the ALICE collaboration.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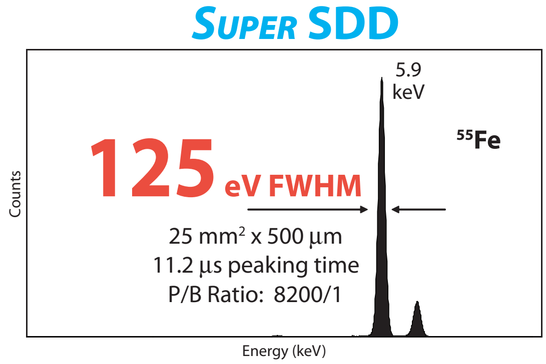
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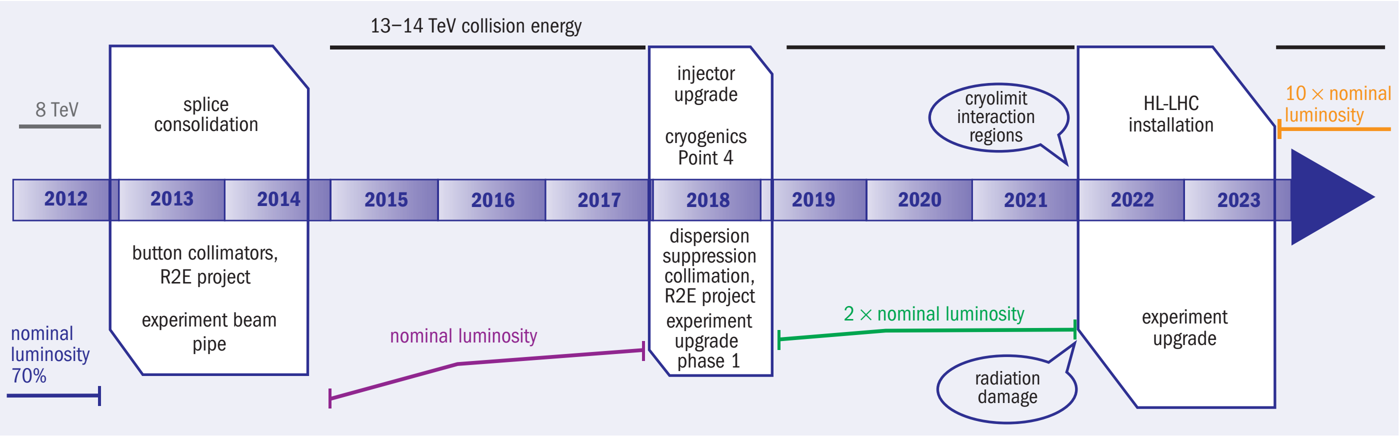


Fig. 1. Long-term programme of the LHC in terms of energy of the collisions (upper black lines) and of luminosity (lower coloured lines). The first long shutdown, in 2013–2014, will allow the design parameters of beam energy and luminosity to be reached. The second shutdown, in 2018, will secure luminosity up to about two times the nominal design value and enable an injector upgrade.

Designs on higher luminosity

The HiLumi LHC Design Study is drawing on expertise from around the world in setting the scope for a high-luminosity upgrade.

The Large Hadron Collider (LHC) has been exploring the new high-energy frontier since 2009, attracting a global user-community of more than 7000 scientists. At the start of 2011, the long-term programme for the LHC had a minimum goal of an integrated luminosity (a measure of the number of recorded collisions) of at least 1 fb^{-1}. Thanks to better-than-anticipated performance, the year ended with almost six times this amount delivered to each of the two general-purpose experiments, ATLAS and CMS.

The LHC is the pinnacle of 30 years of technological development. Set to remain the most powerful accelerator in the world for at least two decades, its full exploitation is the highest priority in the European Strategy for Particle Physics, adopted by the CERN Council and integrated into the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap (*CERN Courier* September 2006 p37). However, beyond the run in 2019–2021, halving the statistical error in the measurements will require more than 10 years of running – unless the nominal luminosity is increased by a considerable amount. The LHC will need a major upgrade after 2020 to maintain scientific progress and exploit its full capacity. The aim is to increase its luminosity by a factor of 5–10 beyond the original design value and provide 3000 fb^{-1} in 10 to 12 years.

From a physics perspective, operating at a higher luminosity has three main purposes: to perform more accurate measurements on the new particles discovered at the LHC; to observe rare processes that occur at rates below the current sensitivity, whether predicted by the Standard Model or by the new physics scenarios unveiled by the LHC; and to extend exploration of the energy frontier, to increase the discovery reach with rare events in which most of the proton momentum is concentrated in a single quark or gluon.

Technological challenges

The LHC will also need technical consolidation and improvement. For example, radiation sensitivity of electronics may already be a limiting factor for the LHC in its current form. Transferring equipment such as power supplies from the tunnel to the surface requires a completely new scheme for "cold powering", with a superconducting link to carry some 150 kA over 300 m with a vertical step of 100 m – a great challenge for superconducting cables and cryogenics.

With such a highly complex and optimized machine, an upgrade must be studied carefully and will require about 10 years to implement (figure 1). This has given rise to the High-Luminosity LHC (HL-LHC) project, which relies on a number of key innovative technologies, representing exceptional technological challenges, such as cutting-edge 12 T superconducting magnets with large aperture, compact and ultraprecise superconducting cavities ▷

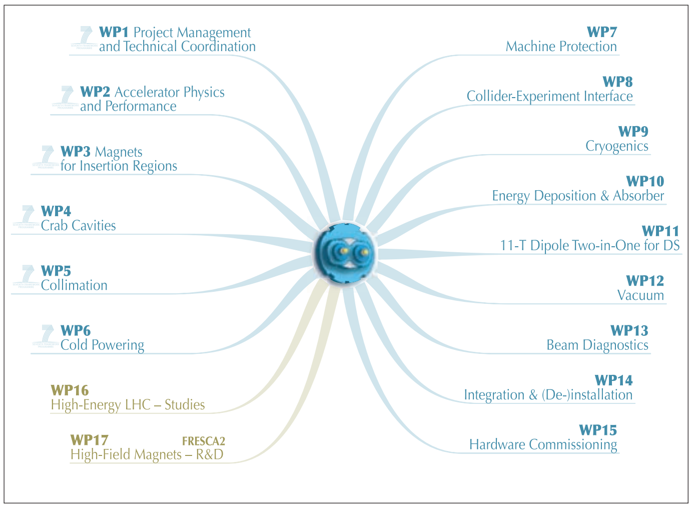


Fig. 2. Work Packages of the HiLumi LHC FP7 Design Study (WP1-WP6) within the High-Luminosity (HL-LHC) project.

for beam rotation, new types of collimators and 300-m long, high-power superconducting links with almost zero energy dissipation.

The high-luminosity upgrade therefore represents a leap forward for key hardware components. The most technically challenging aspects of these cannot be done by CERN alone but will instead require strong collaboration involving external expertise. For this reason part of the HL-LHC project is grouped under the HiLumi LHC Design Study, which is supported in part by funding from the Seventh Framework programme (FP7) of the European Commission (EC).

Six work packages

HiLumi LHC comprises six work packages (WP), which are all overseen by the project management and technical co-ordination (WP1). Accelerator physics (WP2) is at the heart of the design study and it relates closely to the WPs that are organized around the main equipment on which the performance of the upgrade relies (figure 2). The first aim is to reduce β^* (the beam focal length at the collision point), so the insertion-region magnets (WP3) that accomplish this function are the first set of hardware to consider. Crab cavities (WP4) will then make the decreased β^* really effective by eliminating the reduction caused by geometrical factors; they will also provide levelling of the luminosity during the beam spill. Collimators (WP5) are necessary to protect the magnets from the 500 MJ stored energy in the beam – a technical stop to change a magnet would take 2–3 months. Superconducting links (WP6) will avoid radiation damage to electronics and ease installation and integration in what is a crowded zone of the tunnel. The remaining WPs of HL-LHC are not included in the FP7 Design Study as they refer to accelerator functions or processes that will be carried out within CERN (with the exception of the 11 T dipole project for collimation in the cold region of the dispersion suppressor, which is the subject of close collaboration with Fermilab).

The 20 participants within the HiLumi LHC Design Study include institutes from France, Germany, Italy, Spain, Switzerland and the UK, as well as organizations from outside the European Research Area, such as Russia, Japan and the US. As well as providing resources, participants are sharing expertise and responsibilities for the intellectual challenges.

The Japanese and US contributions constitute roughly one third of the manpower for the design study and are well anchored in existing partnerships formed during the construction of the LHC, namely the CERN-KEK collaboration and the US LHC Accelerator Research Program (LARP). Japan participates as a beneficiary without funding and the US laboratories are associates connected to the project via a memorandum of understanding. The participation of leading US and Japanese laboratories enables the implementation of the construction phase as a global project. The proposed governance model is tailored accordingly and could pave the way for the organization of other global research infrastructures.

The four-year HiLumi LHC Design Study was launched last November with a meeting attended by almost 160 participants, half of whom were from institutes beyond CERN (*CERN Courier* January/February 2012 p9). The meeting was held jointly with LARP because HL-LHC builds on both US and European activities. It included a meeting of the collaboration board, during which Michel Spiro, president of the CERN Council, presented the necessary steps for inclusion in the updated European Strategy for Particle Physics. CERN Council will discuss the updated strategy in March 2013 and plans to adopt it in a special session in Brussels in early summer 2013. Spiro's presentation showed that with respect to the initially proposed timeline of HiLumi LHC, the *Preliminary Design Report* will now need to advance by one year to be ready by the end of 2012.

The FP7 HiLumi LHC Design Study thus combines and structures the efforts and R&D of a large community towards the ambitious HL-LHC objectives. It acts as a catalyst for ideas, helping to streamline plans and formalize collaborations. When evaluated by the EC, the design study proposal scored 15 out of 15 and was ranked top of its category, receiving funding of €4.9 million. "The appeal of the HiLumi LHC Design Study is that it goes beyond CERN and Europe to a worldwide collaboration," stated Christian Kurrer, EC project officer of HiLumi LHC at the meeting in November. "This will further strengthen scientific excellence in Europe."

● For more details about the High Luminosity upgrade and the HiLumi LHC Design Study, see http://cern.ch/HiLumiLHC.

Résumé

Vers une luminosité plus élevée

Le LHC devrait rester l'accélérateur le plus puissant du monde pendant au moins deux décennies. Toutefois, au-delà de 2019-2021, il faudra faire tourner la machine plus de dix ans pour diviser par deux l'erreur statistique des mesures auprès du collisionneur, à moins d'augmenter sensiblement la luminosité nominale. Pour poursuivre le progrès scientifique et exploiter ses pleines capacités, il faudra considérablement améliorer la machine après 2020. Le but est d'accroître la luminosité d'un facteur 5 à 10 au-delà de la valeur nominale initiale et de fournir une luminosité intégrée de 3000 fb^{-1} en l'espace de 10 à 12 ans

Kate Kahle and **Lucio Rossi**, CERN.

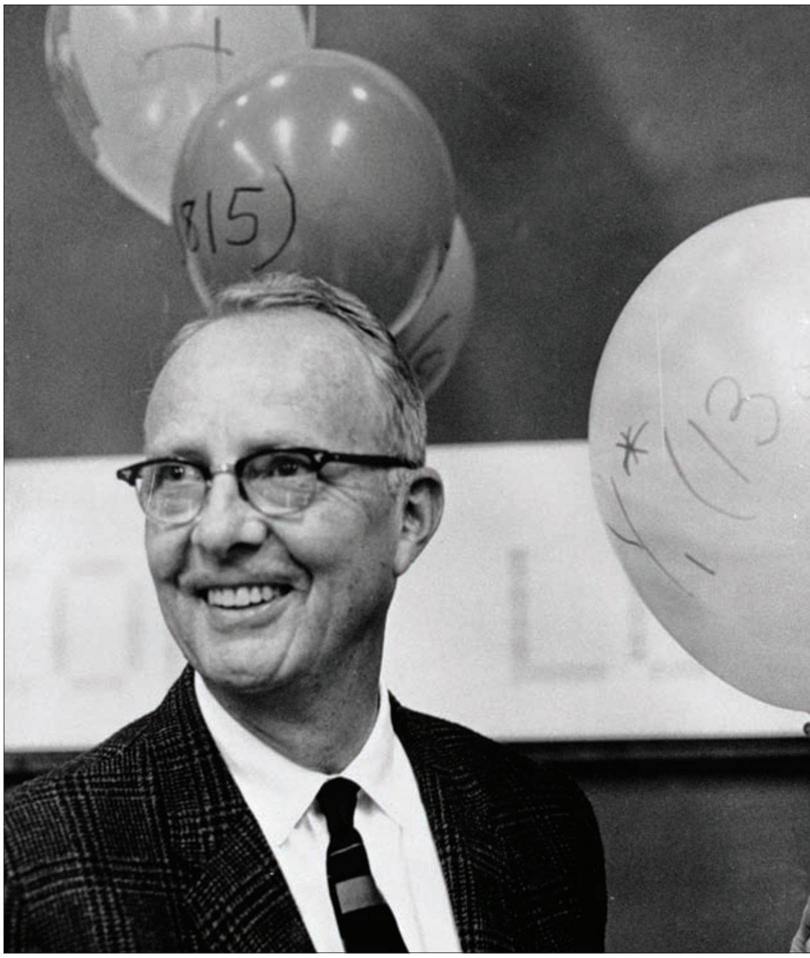
Luis Alvarez: the ideas man

The years from the early 1950s to the late 1980s came alive again during a symposium to commemorate the birth of one of the great scientists and inventors of the 20th century.

Luis Alvarez – one of the greatest experimental physicists of the 20th century – combined the interests of a scientist, an inventor, a detective and an explorer. He left his mark on areas that ranged from radar through to cosmic rays, nuclear physics, particle accelerators, detectors and large-scale data analysis, as well as particles and astrophysics. On 19 November, some 200 people gathered at Berkeley to commemorate the 100th anniversary of his birth. Alumni of the Alvarez group – among them physicists, engineers, programmers and bubble-chamber film scanners – were joined by his collaborators, family, present-day students and admirers, as well as scientists whose professional lineage traces back to him. Hosted by the Lawrence Berkeley National Laboratory (LBNL) and the University of California at Berkeley, the symposium reviewed his long career and lasting legacy.

A recurring theme of the symposium was, as one speaker put it, a "Shakespeare-type dilemma": how could one person have accomplished all of that in one lifetime?

Beyond his own initiatives, Alvarez created a culture around him that inspired others to, as George Smoot put it, "think big," as well as to "think broadly and then deep" and to take risks. Combined with Alvarez's strong scientific standards and great care in executing them, these principles led directly to the awarding of two Nobel prizes in physics to scientists at Berkeley – George Smoot in 2006 and Saul Perlmutter in 2011 – in addition to Alvarez's own Nobel prize in 1968.



Luis Alvarez celebrating the announcement of his 1968 Nobel prize. (Image credit: University of California, Lawrence Berkeley National Laboratory.)

Invaluable talents

Rich Muller, who was Alvarez's last graduate student, described some of his mentor's work during the Second World War. Alvarez's talents as an inventor made him invaluable to the war effort. Among his contributions was the ground-controlled approach (GCA) that allowed planes to land at night and in poor visibility. For the rest of his life, at least once a year, Alvarez would bump into someone who thanked him for GCA, explaining: "I was a pilot in the Second World War and you saved my life." In 1948, when the Soviets imposed a blockade of Berlin, GCA allowed the Berlin Airlift to succeed by assuring the cargo planes' safe landing in difficult circumstances.

In the early post-war period, Alvarez's inventions included the proton linear accelerator (with Wolfgang Panofsky) and a tandem Van de Graaff accelerator. Over his lifetime he was granted more than 40 US patents. He applied for his first in 1943 and his last in 1988, the year he died. He was one of the first inductees to the Inventor's Hall of Fame. He loved thinking and, heeding the advice of his physiologist father, frequently made time to sit and think. ▷

The lunch crowd included many alumni of the Bubble Chamber Group. (Image credit: Lightspree Photography.)

Three of the day's speakers. Left to right: Lina Galtieri, physicist in the Bubble Chamber Group; Walter Alvarez, Luis' geologist son; Jack Lloyd, engineer in the Bubble Chamber Group. (Image credit: Paolo Galtieri.)

Muller recalled that Alvarez told him that only one idea in 10 is worth pursuing, and only one in 100 might lead to a discovery. Considering how many of his ideas bore remarkable fruit, Muller concluded that Alvarez must have had thousands of them.

One such idea originated from his interactions in 1953 with Don Glaser, who invented the bubble chamber. Alvarez thought that a large liquid-hydrogen bubble chamber was needed to solve all of the puzzles generated by the many particles that had been recently discovered. He immediately put his two graduate students, Frank Crawford and Lynn Stevenson, and a number of his technicians to work on the project. The first tracks in a hydrogen bubble chamber were seen in the summer of 1954.

A succession of chambers then culminated in the 72-inch bubble chamber, which began operating in 1959. Jack Lloyd, an engineer in the Alvarez group at the time, believes that it was probably one of the largest tanks of liquid hydrogen ever made (400 l), interfaced with the most enormous piece of optical glass ever made. As Lloyd recalled: "It had to work at around 60 or 70 psi and it pulsed every 6 s, with about a 10 psi pulse, which is a frightening thing to an engineer because of potential fatigue problems."

Observation of the traces left by particles in the bubble chamber needed additional equipment for scanning the photographs and measuring the tracks. In the end, it was necessary to use computers to handle the wealth of information coming from the measurements. The latter task was assigned to Art Rosenfeld, who came to the Alvarez group as a post-doc on the recommendation of Enrico Fermi. Fermi said that, given the politics of the two men, they would be on speaking terms about 80% of the time. "That was right," Rosenfeld recalled. Keeping the peace was not among Alvarez's strengths.

By 1967 the Alvarez group was analysing more than a million events a year. An army of scanners examined the films for events of interest and a battalion of computer programmers wrote code to analyse them. The bubble-chamber team was at that time the largest high-energy physics group in the world, totalling several hundred people. The development of the chamber and the analysis systems resulted in an explosion of new particle discoveries that helped to establish the quark model. It was this work that earned Alvarez the Nobel Prize in Physics in 1968.

Among his other attention-grabbing ideas was the use of cosmic rays to search for secret chambers in Chephren's pyramid in Giza. Jerry Anderson, who collaborated on the project in the late 1960s, told of Alvarez's work in assembling a team of Egyptian and US scientists to design and carry out the experiment. After pointing detectors in several different directions they found no evidence of any voids in the solid pyramid. Afterwards, if anyone commented that the team had not found any hidden chambers, Alvarez would respond, "We found that there were no hidden chambers" – an important distinction.

Around that same time he became interested in a film taken with a home-movie camera that captured the assassination of President John F Kennedy. Charles Wohl, a student in his group, described Alvarez's careful analysis of the film and his conclusions, which clarified some of the uncertainties in the official investigation of the assassination.

The Alvarez philosophy

More than one speaker quoted this passage from Alvarez's autobiography: "I'm convinced that a controlled disrespect for authority is essential to a scientist. All of the good experimental physicists I have known have had an intense curiosity that no 'Keep Out' sign could mute." Yet, Alvarez had a perfect safety record while building and operating the huge bubble chamber. Stanley Wojcicki, who was a graduate student in the group, said that when Alvarez was retiring as the head of the bubble-chamber group and a new head was about to be appointed, someone asked him about the replacement's responsibilities. "He's the person who talks to the widows after an accident," was Alvarez's response.

Saul Perlmutter, who was Muller's graduate student, felt Alvarez's influence keenly when he came to LBNL in 1982. He characterized it as a "can-do, cowboy spirit". He explained: "As a physicist, you had the hunting licence to look at any problem whatsoever and also you had the arrogance to think you were going to be able to solve that problem – or at least be able to make a measurement that might be relevant to the problem. And if there was equipment around, you would use it; and if there was not equipment around, you would invent it. And you had the wealth of talent around you, of the engineers, mechanical and electrical, who knew how to put these things together and how to make them work." That was fertile ground for discovery.

Perlmutter also benefited from Alvarez's philosophy in another way. When he and Carl Pennypacker wanted to start looking for supernovae at greater distances, Muller was sceptical about their prospects for success. However, he had learnt from Alvarez that part of the job of a group leader is to support people in trying things even if you are not sure that they are the right things to do. This is what he did – and Perlmutter's Nobel prize for that work attests to Muller's (and Alvarez's) wisdom.

In the final decade of his life, Alvarez's "hunting licence" led him into geology and palaeontology. His son, Walter Alvarez, a geologist studying the Cretaceous-Tertiary boundary in an outcropping in Italy, gave his father a rock showing the clay boundary separating a layer of limestone with abundant fossils of diverse species and a layer largely devoid of signs of life. Luis was intrigued and eventually conceived of a way of determining how long it took for this clay layer to accumulate. This would signal whether the mass extinction was sudden or gradual. Neutron activation analysis showed an anomalous abundance of iridium in the clay layer, a result that led eventually to the Alvarez's theory that an impact from a comet or asteroid caused the dinosaurs and other species to die out. The announcement stirred a controversy that was only recently settled in their favour.

Other speakers during the day attested to Luis Alvarez's inventive spirit and his fearlessness in asking original and important questions in far-flung fields in which he had no previous experience. He eagerly embraced new ideas and unhesitatingly took on new challenges throughout his career. The lively and enlightening day ended with a reception and dinner, where more family members and colleagues related their recollections of this icon of 20th-century science and technology.

● Further reading

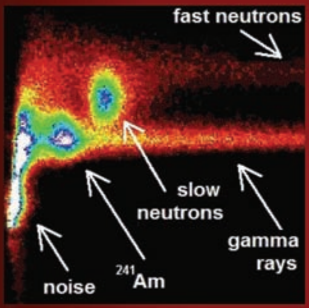
See the symposium website for videos and slides of the presentations, historical photos and more, at http://luis-alvarez-symposium.lbl.gov.

Résumé

Luis Alvarez : l'homme des idées

Luis Alvarez, l'un des grands physiciens expérimentateurs du XX^{e} *siècle, avait l'âme d'un scientifique, d'un inventeur, d'un détective et d'un explorateur. Il a laissé sa marque dans des domaines tels que les radars, les rayons cosmiques, la physique nucléaire, les accélérateurs de particules, les détecteurs, l'analyse de données à grande échelle, les nouvelles particules et l'astrophysique. Le 19 novembre, quelque 200 personnes étaient présentes à un colloque destiné à célébrer le centenaire de sa naissance. D'anciens collègues et d'anciens étudiants ont fait revivre la période du début des années 50 à la fin des années 80, rendant hommage aux travaux d'un savant qui voyait et pensait grand*

Lina Galtieri and **Jeanne Miller**, Lawrence Berkeley National Laboratory.



DIRAC observes dimeson atom

Hydrogen-like atoms consisting of a charged meson pair – such as the $\pi^+\pi^-$ and πK atoms – provide a unique tool for exploring low-energy hadron–hadron interactions.

The study of nonstandard atoms has a long tradition in particle physics. Such exotic atoms include positronium, muonic atoms, antihydrogen and hadronic atoms. In this last category, mesonic hydrogen in particular has been investigated extensively in different experiments at CERN, PSI and Frascati. Dimeson atoms also belong to this category. These electromagnetically bound mesonic pairs, such as the $\pi^+\pi^-$ atom (pionium, $A_{2\pi}$) or the πK atom ($A_{\pi K}$), offer the opportunity to study the theory of the strong interaction, QCD, at low energy, i.e. in the confinement region.

This strong interaction leads to a broadening and a shift of atomic levels, and dominates the lifetime of these exotic atoms in their s-states. The $\pi\pi$ interaction at low energy, constrained by the approximate chiral symmetry SU(2) for two flavours (u and d quarks), is the simplest and best understood hadron–hadron process. Since the bound-state physics is well known, a measurement of the $A_{2\pi}$ lifetime provides information on hadron properties in the form of scattering lengths – the basic parameters in low-energy $\pi\pi$ scattering.

Moreover, the low-energy interaction between the pion and the next lightest, and strange, meson – the kaon – provides a promising probe for learning about the more general three-flavour SU(3) structure (u, d and s quarks) of hadronic interactions, which is a matter not directly accessible in pion–pion interactions. Hence, data on πK atoms are valuable because they provide insights into the role played by the strange quarks in the QCD vacuum.

The experiment

The mesonic atoms $A_{2\pi}$ ($A_{\pi K}$) are produced by final-state Coulomb interactions between oppositely charged $\pi\pi$ (πK) pairs that are generated in proton–target reactions (Nemenov 1985). In the DImeson Relativistic Atom Complex (DIRAC) experiment at CERN, they are formed when a 24 GeV/*c* proton beam from the Proton Synchrotron hits a thin target, typically a 100 μm-thick nickel foil (figure 1). After production, the mesonic atoms travel through the target and some of them are broken up (ionized) as they interact with matter. This produces "atomic pairs", which are characterized by their small relative momenta, $Q < 3$ MeV/*c*, in the centre of mass of the pair. These pairs are detected in the DIRAC apparatus. The remaining atoms mainly annihilate into $\pi^0\pi^0$ pairs, which are not detected, or they survive and annihilate later. The number of "atomic pairs" from the break-up of atoms, n_A, depends on the annihilation mean-free-path, which is given by the atom's lifetime, τ, and its momentum. Thus, the break-up probability, P_{br}, is a function of the $A_{2\pi}$'s lifetime, τ.

The interactions between the protons and the target also produce oppositely charged free $\pi\pi$ pairs, both with and without final-state Coulomb interactions, depending on whether or not the pairs are produced close to each other. This gives rise to "Coulomb pairs" and "non-Coulomb pairs". The latter includes meson pairs in which one or both mesons come from the decay of long-lived sources. Furthermore, two mesons from different interactions can contribute as "accidental pairs". The total number of atoms produced, N_A, is proportional to N_C, the number of Coulomb pairs with low relative momenta, $N_A = kN_C$, where the coefficient, k, is precisely calculable. DIRAC measures the break-up probability

A general view of the downstream part of the DIRAC experiment (upper image) beyond the magnet (orange), with the yellow boxes of the Cherenkov counters in the foreground. The lower image shows the section between the beam shielding and the magnet, with the vacuum chamber (blue), the beginning of the flat chamber (yellow) and the magnetic screen (orange) in front of the magnet. The beam pipe for the primary protons (silver) lies beneath the blue vacuum chamber.

ns and measures their lifetime

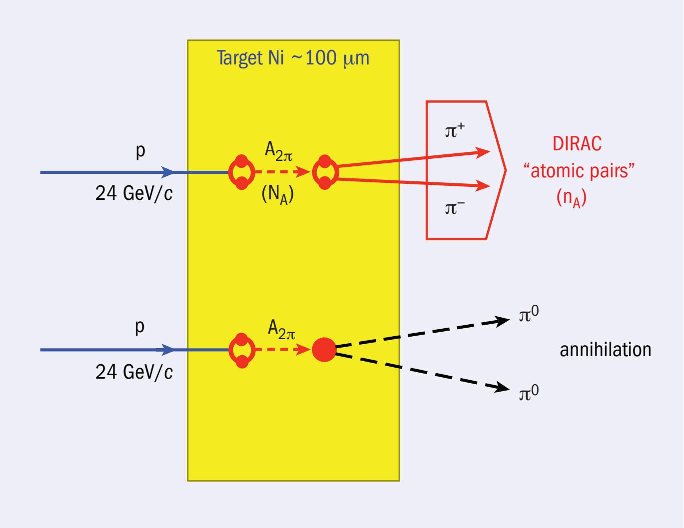


Fig. 1. Pionium ($A_{2\pi}$), produced in nickel, is detected through its break-up (ionization). Alternatively, the $A_{2\pi}$ annihilates (decays). N_A denotes the total number of produced atoms, whereas n_A is the number of “atomic pairs” from atom break-up.

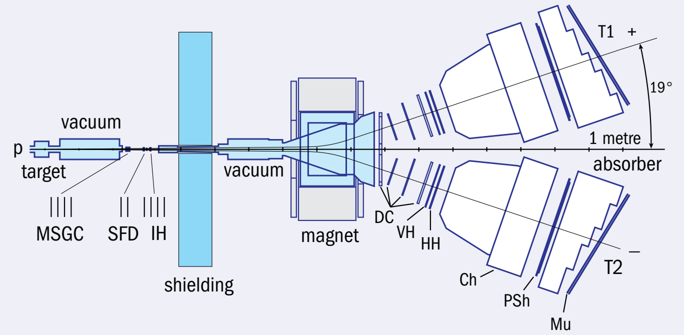


Fig. 2. The DIRAC double-arm spectrometer. The microstrip gas chambers (MSGC), the scintillating-fibre detector (SFD) and the scintillation-ionization hodoscope (IH) provide initial track data. Downstream of the spectrometer magnet, drift chambers (DC) measure final tracks to determine momenta. The vertical and the horizontal-scintillation hodoscopes (VH and HH) are used for trigger purposes and time measurement. Cherenkov detectors (Ch) containing nitrogen, preshower detectors (PSh) and scintillation muon detectors (Mu) behind the iron absorber help to distinguish pions from electrons and muons.

for the $A_{2\pi}$, which is defined as the ratio of the observed number of “atomic pairs” to the number of produced atoms: $P_{br}(\tau)=n_A/N_A$. N_A is calculated from the number of “Coulomb pairs”, N_C, obtained from fits to the data.

The purpose of the DIRAC set-up is to record oppositely charged ππ (πK) pairs with small relative momenta, Q. As figure 2 shows, the emerging pairs of charged pions travel in vacuum through the upstream part where co-ordinate and ionization detectors provide initial track data, before they are split by the 2.3 Tm bending magnet into the “positive” (T1) and “negative” (T2) arms. Both arms are equipped with high-precision drift chambers and trigger/time-of-flight detectors, as well as Cherenkov, preshower and muon counters. The relative time resolution between the two arms is around 200 ps.

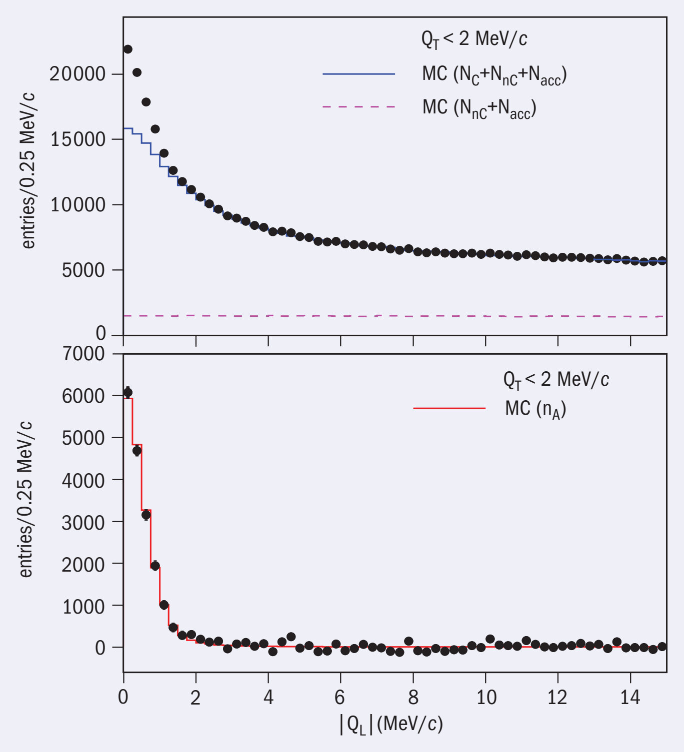
The momentum reconstruction in the double-arm spectrometer uses the drift chamber information from both arms as well as the measured hits in the upstream co-ordinate detectors. The resolution on the longitudinal (Q_L) and transverse (Q_T) components of the relative momentum of the pair, Q, defined with respect to the direction of the total momentum of the pair in the laboratory, is 0.55 MeV/*c* and 0.1 MeV/*c*, respectively. A system of fast-trigger processors selects the all-important events with small Q.

Observing and measuring lifetimes

The observation of the $A_{2\pi}$ was reported from an experiment at Serpukhov nearly 20 years ago. This was followed at CERN 10 years later with a measurement of the $A_{2\pi}$ lifetime by DIRAC (Adeva *et al*. 2005). Last autumn, DIRAC presented the most recent value for the $A_{2\pi}$ lifetime in the ground state, $\tau = 3.15\times10^{-15}$ s, with a total uncertainty of around 9%, based on the statistics of 21 200 “atomic pairs” collected with the nickel target in 2001–2003 (Adeva *et al*. 2011). Figure 3 (overleaf) shows the characteristic accumulation of events at low Q_L from the break-up of the $\pi^+\pi^-$ atom: the $A_{2\pi}$ signal appears as an excess of pairs over the background spectrum in the low Q region.

S-wave ππ scattering is isospin-dependent, so this lifetime can be used to calculate a scattering-length difference, $|a_0-a_2|$, where a_0 and a_2 are the S-wave ππ scattering lengths for isospin 0 and 2, respectively. The measured lifetime yields a result of $|a_0-a_2| = 0.253\ (m_\pi^{-1})$ with around 4% precision, in agreement with the result obtained by the NA48/2 experiment at CERN (Batley *et al*. 2009). The corresponding theoretical values are $0.265\pm0.004\ (m_\pi^{-1})$ for the scattering-length difference (Colangelo *et al*. 2000) and $(2.9\pm0.1)\times10^{-15}$ s for the lifetime (Gasser *et al*. 2001). These results demonstrate the high precision that can be reached in low-energy hadron interactions, in both experiment and theory.

The first evidence for the observation of the πK atom, $A_{\pi K}$, was published by the DIRAC collaboration in 2009 (Adeva *et al*. 2009). In this case, the mesonic atoms were produced in a 26 μm-thick platinum target and the DIRAC spectrometer had been upgraded for K identification with heavy-gas (C_4F_{10}) and aerogel Cherenkov detectors. An enhancement observed at low relative momentum corresponds to the production of 173 ± 54 πK “atomic pairs”. From this first data sample, the collaboration derived a lower limit on the πK atom lifetime of $\tau_{\pi K} > 0.8\times10^{-15}$ s (90% CL), to be compared with the theoretical prediction of $(3.7\pm0.4)\times10^{-15}$ s ▷



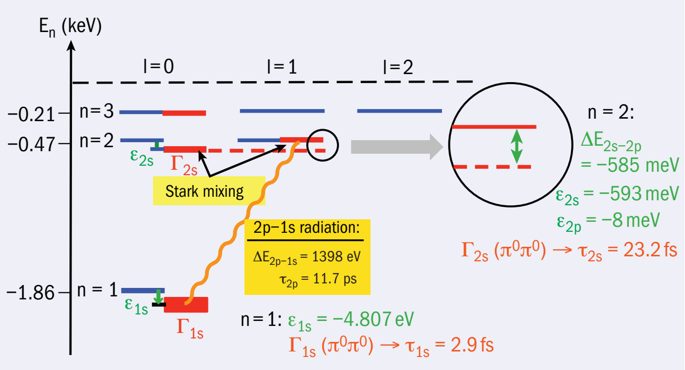


Fig. 4. (above) Pionium energy-level scheme and 2s–2p energy splitting. The decay widths (Γ_{1s}, Γ_{2s}) and the energy shifts (ε_{1s}, ε_{2s}, ε_{2p}) are presented for the states with principal quantum numbers n=1 and 2.

Fig. 3. (left) Q_L distributions of $\pi^+\pi^-$ pairs from data (black dots) and simulation (solid line). Top: the experimental spectrum in comparison with the simulated background components of "Coulomb" (N_C), "non-Coulomb" (N_{nC}) and "accidental" (N_{acc}) pairs. Bottom: the residuals for the "atomic pairs" (n_A) – the pionium signal – after background subtraction and the corresponding simulation.

(Schweizer 2004). The ongoing detailed analysis of a much larger data sample aims first to extract a clear signal for the production of the $A_{\pi K}$ atom and then to deduce from these data a value for the $A_{\pi K}$ lifetime.

Future investigations

Pionium is an atom like hydrogen and the properties of its states vary strongly with their quantum numbers. An illustration of this is the 2s→1s two-photon de-excitation in hydrogen ($\tau_{2s} \approx 0.1$ s), which is many orders of magnitude slower than the 2p→1s radiative transition ($\tau_{2p} = 1.6$ ns). In pionium, the situation is similar but opposite: the decay $A_{2\pi}$ (2s-state)→$2\pi^0$ ($\tau_{2s} = 23.2$ fs) is roughly three orders of magnitude faster than the 2p→1s radiative transition (τ_{2p} = 11.7 ps). The DIRAC collaboration aims to measure Lamb shifts in pionium by exploiting the properties of these specific states and in 2010 started to study the possibility of observing long-lived $A_{2\pi}$ states (Nemenov *et al.* 2002).

The energy shifts, ΔE_{ns-np}, for levels with the principal quantum number, n, and orbital quantum number, l, are another valuable source of information. These shifts contain a dominant strong contribution, $\Delta E^{\text{strong}}_{ns-np}$, together with minor QED contributions, $\Delta E^{\text{QED}}_{ns-np}$, from vacuum polarization and self-energy effects. The strong s-state energy shift, $\Delta E^{\text{strong}}_{ns-np}$, is proportional to $(2a_0+a_2)$, i.e. it depends on the same scattering lengths, a_0 and a_2, as the pionium lifetime. As figure 4 shows, for the principal quantum number n=2, the strong and electromagnetic interactions shift the 2s level below the 2p level by $\Delta E_{2s-2p} = \Delta E^{\text{strong}}_{ns-np} + \Delta E^{\text{QED}}_{2s-2p} = -0.47\text{ eV} - 0.12\text{ eV} = -0.59\text{ eV}$ (Schweizer 2004).

By studying the dependence of the lifetime of long-lived $A_{2\pi}$ (with l≥1) on an applied electric field – the Stark-mixing effect – the DIRAC experiment is in a unique position to investigate the splitting of pionium energy levels. This will allow another combination of pion-scattering lengths to be extracted, so that a_0 and a_2 can finally be determined individually.

Further reading

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Résumé

DIRAC observe des atomes dimésoniques et mesure leur durée de vie

Les « atomes dimésoniques » tels que les atomes $\pi^+\pi^-$ et πK constituent un outil exceptionnel pour l'étude de la chromodynamique quantique (l'étude de l'interaction forte) à très basse énergie. Par exemple, l'interaction à basse énergie entre le pion et le kaon promet de nous en apprendre davantage sur la structure à trois saveurs (quarks u, d et s) des interactions hadroniques. L'expérience DIRAC auprès du Synchrotron à protons du CERN étudie les atomes $\pi\pi$ et πK formés dans les collisions de protons dans une feuille cible. Elle permet de mesurer la durée de vie des atomes afin de mettre à l'épreuve les prédictions de la chromodynamique quantique à basse énergie.

Jürg Schacher, University of Bern, on behalf of the DIRAC collaboration.

Micropattern detector conference goes east

MPGD2011, the first conference in the international series on micropattern gaseous detectors to be held in Asia, provided an international view of the state of the art in research in this field.

Micropattern gaseous detectors (MPGDs) have opened a new era in state-of-the-art technologies and are the benchmark for gas-detector developments beyond the LHC. They could eventually enable a plethora of new radiation-detector concepts in fundamental science, medical imaging, security inspection and industry. Given the ever-growing interest in this rapidly developing field, an international conference series on MPGD detectors was founded in 2009 to provide a scientific forum to review the current highlights, new results and concepts, applications and future trends, with the first conference organized in Crete (*CERN Courier* December 2009 p23). The second in the series, MPGD2011, took place in Kobe on 29 August – 1 September. With it being two years since the previous meeting, there were many new developments to discuss at MPGD2011.

The conference was held at the Maiko Villa Kobe hotel, which is located near the Akashi Strait Bridge. Connecting the Japanese mainland with Awaji island, this is the world's largest suspension bridge. It was clearly visible from the venue and symbolically emphasized the connection and synergy of the worldwide communities. Half of the 120 participants were from overseas, visiting from 16 countries. Attendance was clearly unaffected by the Great East Japan Earthquake on 11 March 2011, which was in contrast to many other international conferences and events in Japan in 2011 that were cancelled owing to low participation from foreign countries following the disaster.

Japan is the most advanced of any country in terms of having a successful partnership between academia and industry in the development of particle-physics detectors. MPGD developments have been an active field in the country since the early 1990s, shortly after the invention of the micro-strip gas chamber (MSGC). However, in the Asian region and especially in Japan, most MPGD R&D has been carried out independently from other countries. Elsewhere, worldwide interest in the technological development and the use of the novel MPGD technologies led to the establishment of the international research collaboration RD51 at CERN in 2008. By 2011, 80 institutes from 25 countries had joined the collaboration. Only one institute from Japan – Kobe University – has so far joined RD51, although there is an annual domestic MPGD workshop with some 80 participants and around 30 presentations. Holding the international MPGD conference in Japan, followed by a meeting of the RD51 collaboration on 2–3 September, was highly important from the perspective of improving communication and enhancing the synergy between the worldwide MPGD communities.

Fig. 1. The MPGD2011 participants pose in front of the Akashi Strait Bridge, Kobe. (Image credit: Tadaaki Isobe/RIKEN.)

MPGDs are a relatively novel kind of particle detector, based on gaseous multiplication using micro-pattern electrodes instead of thin wires in a multiwire proportional chamber (MWPC). By using a pitch size of a few hundred micrometres, which is an order-of-magnitude improvement in granularity over wire chambers, these detectors offer an intrinsic high rate-capability (> 10^6 Hz/mm), excellent spatial resolution (around 30–50 μm) and single-photoelectron time resolution in the nanosecond range. The MSGC, a concept invented by Anton Oed in 1988, was the first of the microstructure gas detectors. Further advances in photolithography techniques gave rise to more powerful devices, in particular, the gas-electron multiplier (GEM) of Fabio Sauli in 1997, and the micromesh gaseous structure (Micromegas) of Ioannis Giomataris and colleagues in 1996. Both of these devices exhibit improved operational stability and increased radiation hardness. During their evolution, many types of MPGDs have arisen from the initial ideas, such as the thick GEM (THGEM), the resistive thick GEM (RETGEM), the microhole and strip plate (MHSP) and the micropixel gas chamber (μ-PIC). ▷

Homage to Georges Charpak

Georges Charpak, well known as the inventor of the MWPC, and winner of the Nobel Prize in Physics in 1992, passed away on 29 September 2010. Charpak and his group made many achievements in the field of gaseous detectors including MPGDs (*CERN Courier* December 2010 p33). Special events were added to this conference in homage to him. One was a special session, Homage to Georges Charpak, in which Amos Breskin, Fabio Sauli and Ioannis Giomataris gave memorial talks. A specially prepared booklet *Seminal Papers by Georges Charpak* was handed to all participants.

Another special event was the award of the first young-scientist Charpak Award, sponsored by *Nuclear Instruments and Methods*. The award-selection committee, with Sauli as chair, judged presentations at the conference from the point of view of originality, scientific importance, contribution weight and presentation quality. From the various young presenters (under 36 years of age), it was Kiseki Nakamura of Kyoto University and Sverre Dørheim of the Technische Universität München who won the prize for their contributions on "Direction-sensitive dark matter search with MPGD" and "A prototype GEM-TPC for PANDA", respectively.

Fabio Sauli, left, presented the young scientist "Charpak Award" to Kiseki Nakamura of Kyoto University, centre, and Sverre Dørheim of Technische Universität München. (Image credit: Tadaaki Isobe/RIKEN.)

Today, a large number of groups worldwide are developing MPGDs for:

- future experiments at particle accelerators (upgrades of muon detectors at the LHC and novel MPGD-based devices for time-projection chambers (TPCs) and digital hadron calorimetry at a future linear collider);
- experiments in nuclear and hadron physics (KLOE2 at DAΦNE, the Panda and CMB experiments at the Facility for Antiproton and Ion Research, STAR at the Relativistic Heavy Ion Collider, SBS at Jefferson Lab and many others);
- experiments in astroparticle physics and neutrino physics;
- and industrial applications such as medical imaging, material science and security inspection.

This report cannot summarize all of the interesting developments in the MPGD field but it illustrates the richness with a few conference highlights and their implications.

During the three days of MPGD2011, results were presented in 39 plenary talks – including three review talks – and some 30 posters. Five industrial companies linked closely to MPGD technologies also exhibited their products.

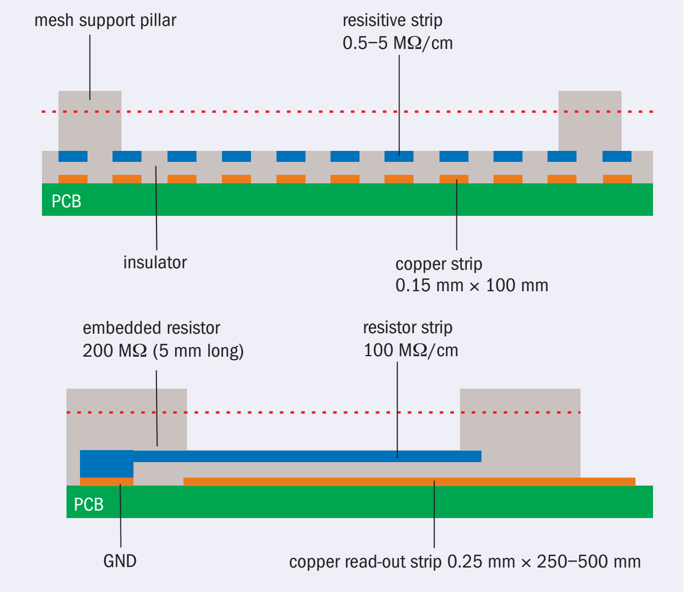

Fig. 2. Resistive "bulk Micromegas" structures.

Marcel Demarteau of Argonne National Laboratory discussed the paramount importance of the interplay between future physics challenges and the development of advanced detector concepts, with instrumentation being the enabler of science, both pure and applied. The greatest payoffs will come from fundamentally reinventing mainstream technologies under a new paradigm of integration of electronics and detectors, as well as integration of functionality. As an example, several conference talks discussed recent progress in the development of integrated Micromegas (InGrid) directly on top of a CMOS micropixel anode (the Timepix chip), which offers a novel and fully integrated read-out solution. These detectors will be used in searching for solar axions in the CAST experiment at CERN and are also are under study for a TPC at the International Linear Collider and for a pixellized tracker (the "gas on slimmed silicon pixels" or GOSSIP detector) for the upgrades of the LHC experiments.

A key point that must be solved to advance with MPGDs is the industrialization of the production and manufacturing of large-size detectors. Rui de Oliveira of CERN discussed the current status of the new facility for large-size MPGD production at CERN, which will be able to produce 2 m × 0.6 m GEMs, 1.5 m × 0.6 m Micromegas and 0.8 m × 0.4 m THGEMs. He also presented recent developments and improvements of fabrication techniques – single-mask GEMs and resistive "bulk Micromegas". GEMs and Micromegas prototypes have been produced in the CERN workshop with a size of nearly 1 m^2 for the ATLAS and CMS muon upgrades for the future high-luminosity LHC (the HL-LHC project, p19). Large-area cylindrical GEMs are currently being manufactured for the KLOE2 inner tracker.

Moving away from applications in particle physics, large-area MPGDs are being developed for muon tomography to detect nuclear contraband and for tomographic densitometry of the Earth. Industry has also become interested in manufacturing MPGD structures; technology-transfer activities and collaboration have been actively pursued during the past year with several companies in Europe, Japan, Korea and the US.

One of the highlights of MPGD2011 was the recent trend in the development of MPGDs with resistive electrodes. This technique is an attractive way to quench discharges, thus improving the robustness of the detector against sparks. There were more than 10 presentations devoted to resistive MPGDs. The resistive bulk Micromegas for the ATLAS muon upgrade (MAMMA) employs a 2D read-out board utilizing resistive strips on top of the insulator, covering copper strips (figure 2). This industrial-assembly process allows regular production of large, robust and inexpensive detector modules. The design has achieved stable operation in the presence of heavily ionizing particles and neutron background, similar to the conditions expected in the ATLAS cavern in the HL-LHC upgrade. There were also other presentations describing basic developments of the GEM, THGEM and μ-PIC using resistive materials.

Alexey Buzulutskov of the Budker Institute of the Nuclear Physics, Novosibirsk, reviewed recent advances in cryogenic avalanche detectors, operated at low temperatures (from a few tens of degrees kelvin down to a few degrees). Recent progress in the operation of cascaded MPGDs at cryogenic temperatures could pave the road toward their potential application in: the next-generation neutrino physics and proton-decay experiments; liquid argon TPCs for direct dark-matter searches; positron-emission tomography (PET); and a noble-liquid Compton telescope combined with a micro-PET camera.

The MPGD2011 conference also featured a physics presentation announcing the observation of electron-neutrino appearance events using the beam from the Japan Proton Accelerator Research Complex to the Super-Kamiokande detector (*CERN Courier* September 2011 p6). The results were mainly based on the three large-volume TPCs, instrumented with bulk Micromegas detectors and read out via some 80 000 channels. This is a good example of the interplay between physics and technology. Last, but not least, interesting results of gaseous photomultipliers with caesium-iodide and bialkali photocathodes coupled to GEM, THGEM and Micromegas structures, were reported at the conference. A sealed prototype of an MPGD sensitive to visible light has been produced by Hamamatsu.

● For more information about the conference and for the presentations, see http://ppwww.phys.sci.kobe-u.ac.jp/~upic/mpgd2011. The contributions will be submitted for publication in the open-access journal *JINST*, http://jinst.sissa.it.

Résumé

Conférence sur les détecteurs gazeux microstructurés

Les détecteurs gazeux microstructurés ont ouvert une ère nouvelle dans la technologie des détecteurs et servent de référence pour le développement des détecteurs gazeux au-delà du LHC. Ils pourraient finalement permettre toute une série de nouveaux concepts de détecteurs de rayonnement, non seulement pour la science fondamentale mais aussi pour l'imagerie médicale, les inspections de sécurité et l'industrie. La deuxième édition de cette conférence, MPGD2011, s'est tenue à l'Université de Kobe. Elle a été l'occasion de faire un état des lieux de la recherche dans ce domaine très dynamique

Atsuhiko Ochi, Kobe University.

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Faces & Places

COLLABORATION

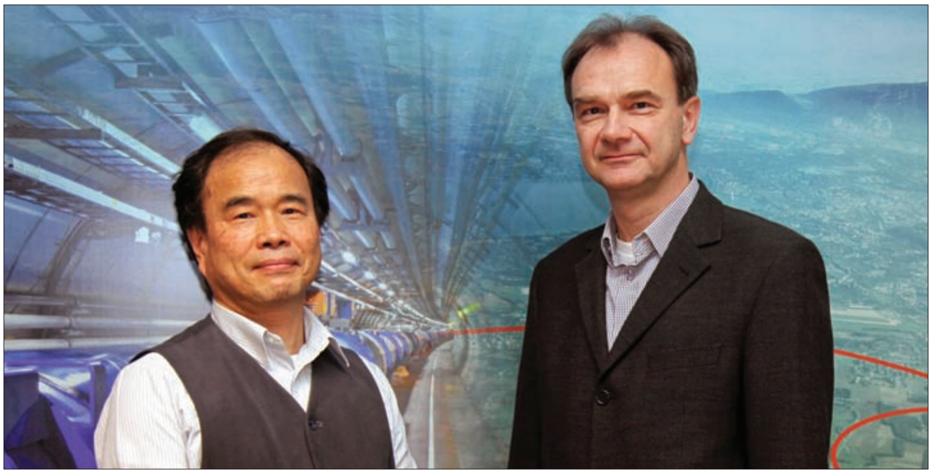
A new chair and new initiatives at ECFA

Manfred Krammer of the Institute of High-Energy Physics of the Austrian Academy of Sciences has become the chair of the European Committee for Future Accelerators (ECFA) and its "restricted' subcommittee RECFA as of 1 January. He takes over from Tatsuya Nakada of École polytechnique fédérale de Lausanne.

ECFA represents the interests of the high-energy particle-physics community from the CERN member states. It provides a unique forum for discussing developments, future projects and common interests in the field of high-energy physics. Information and views are exchanged between representatives from the various countries, as well as from the large laboratories. Biannual meetings allow the discussion of proposals and progress reports for new facilities, as well as reports from dedicated ECFA study groups and other items of importance for the community.

The RECFA subcommittee regularly visits the ECFA countries. These visits monitor the evolution of high-energy physics activities in the respective countries and – through contact with national policy-makers and funding agencies – promote the importance of high-energy physics in science and society.

A recent activity has been the study of the proposals and reports for future accelerator-based neutrino facilities. The review report of the relevant study group was presented at ECFA's latest plenary meeting in November. The *Conceptual Design Report of A Large Hadron Electron Collider at CERN (LHeC)* was also presented at the same meeting. This report will be the focus of another ECFA review panel under the chair of Thomas Müller of Karlsruhe Institute of Technology.



Manfred Krammer, right, takes over from Tatsuya Nakada as chair of ECFA.

During the meeting, a decision was also taken to create a European committee to review the R&D effort for future projects. High-energy physics relies heavily on detector R&D developments: every significant improvement in detection techniques opens a new area for fundamental-physics research. Considerable amounts of labour and financial resources are committed to this field across Europe and around the world. R&D programmes related to approved and well established scientific projects and collaborations, such as the LHC, are evaluated and followed up by existing committees run by the host laboratories. This is not the case, however, when an important, large-scale project is in its preliminary and preparatory phase but not yet approved and supported by a leading or host lab.

The new European committee will receive R&D proposals, make recommendations after evaluation and monitor progress. It will help to create coherence in the global R&D effort by encouraging synergies between different activities and advising funding agencies. It is primarily concerned with large R&D projects related to accelerator experiments, involving many laboratories and requiring significant resources. DESY will host this new committee, which will meet twice yearly, chaired by Yannis Karyotakis, director of the Laboratoire d'Annecy le Vieux de Physique des Particules. A first meeting is planned for 2–3 May at DESY.

The coming years will be exiting for particle physics, with spectacular results expected soon from the LHC experiments. These results will be the long-awaited input for the discussion on future projects in particle physics. The process to update the European Strategy for Particle Physics has just started with the aim to conclude in 2013 (*CERN Courier* January/February 2012 p5). ECFA will certainly play an active role in these discussions.

LABORATORIES

French labs form a cluster of excellence

On 11 January, the Laboratoire d'excellence (LABEX) P2IO (Physics of the 2 Infinities and Origins) was officially launched. LABEX is a recent initiative from the French government to promote clusters of excellence in various disciplines. P2IO is one of the largest such networks, regrouping the nine laboratories south of Paris that deal with particle physics, nuclear physics, astroparticle physics, cosmology, astrophysics and planetology, as well as three smaller teams.

Some 2000 people work in the P2IO teams, making it one of the strongest nodes in subatomic physic worldwide.

P2IO has three main objectives. It will explore the most pressing scientific and technological issues in the physics of the infinitely small and the infinitely large, and of the conditions for appearance of life. It will help to transform the way that these large laboratories – which represent a major fraction of the French national potential in these fields – work together by fostering greater synergy between them. It will also serve as a contact point and form a better structure for all of the new collaborations stemming from the future Paris-Saclay University.

P2IO has been granted an annual budget of €1.4 million for the next 10 years. This will be used mainly to recruit post-doctoral positions in the areas that are P2IO's scientific priorities and to launch innovative and significant R&D programmes in the P2IO technological areas of accelerators, sensors and computing. In addition, P2IO will also support related activities in health (radiotherapy and imaging) and energy (nuclear energy for the future).

The launch ceremony, attended by 300 people, provided the occasion to present details of the various programmes and actions lines within P2IO. In the formal session, Jacques Martino, in the name of all the P2IO funding agencies (CNRS, CEA, Paris Sud University, École Polytechnique), expressed his satisfaction with P2IO's rapid start-up (the 2012 budget has already been fully allocated), the attractiveness of the programme it supports, the strategic importance of such a network for all of the partners and the key role that it will play in the future Paris-Saclay University. He wished good luck to Guy Wormser, co-ordinator of the P2IO steering committee, and to all of the labs and teams involved.

Key players at P2IO attended the official launch in January. (Image credit: B Mazoyer/LAL.)

● For more information on P2IO, see www.labex-p2io.fr.

COLLABORATION

New protocol links CERN, Georgia and JINR

A new tripartite protocol on Scientific and Technical Co-operation in High Energy Physics and Information Technologies was signed between CERN, the government of Georgia and the Joint Institute of Nuclear Research (JINR) in Dubna on 20 December. The minister of education and science, Dimitri Shashkini, visited CERN to sign on behalf of Georgia. The signature by the minister reflects both Georgia's interest in expanding its co-operation with CERN and the new responsibility of the ministry of education and science for funding scientific activities. The agreement will provide enhanced participation of Georgian scientists in CERN's projects, either directly or through Georgia's membership in JINR.

Georgian physicists began participating in CERN's activities in the early 1960s. Some of them played leading roles in the Boson Spectrometer experiment, which was approved at CERN in 1969 and carried out at Serpukhov. In the 1980s, individual Georgian physicists made contributions to the DELPHI and ALEPH experiments. Now, two Georgian teams – essentially supported by JINR – are involved in the ATLAS experiment; indeed, young Georgian physicists took part in detector construction, specifically for the muon chambers and the tile calorimeter, in JINR. Other groups from the Georgian Academy of Science and Tbilisi State University participate in the CMS experiment.

Beyond participation in the LHC experiments, the protocol also provides enhanced collaboration in theoretical physics, accelerator science and technology, engineering, and educational programmes, in which Georgia takes a great interest. In recent years, 16 teachers have participated in CERN's High-School Teachers Programme, and a number of students have attended various programmes organized by CERN.

Georgia's minister of education and science, Dimitri Shashkini (left), shakes hands with Richard Lednický, vice-director of JINR, while Rolf Heuer looks on.

*On 10 January, the President of the Republic of Serbia, Boris Tadić (left), and CERN's director-general, Rolf Heuer, signed the agreement concerning the granting to Serbia of the status of associate membership as the pre-stage to membership of CERN (*CERN Courier *January/February 2012 p5).*

AWARDS

Honours for Richter, Higgs and Altarelli

US President Obama has named SLAC director emeritus and Nobel laureate Burton Richter as one of two winners of the Enrico Fermi Award, one of the US government's oldest and most prestigious awards for scientific achievement. The other winner is Mildred Dresselhaus, a professor of physics and engineering at MIT.

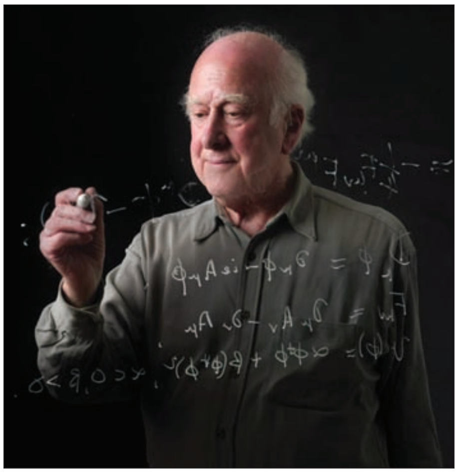
Richter is honoured "for the breadth of his influence in the multiple disciplines of accelerator physics and particle physics, his profound scientific discoveries, his visionary leadership as director of SLAC (1984–1999), his leadership of science and his notable contributions in energy and public policy." The Enrico Fermi Award honours the memory of Nobel laureate Enrico Fermi. It is a presidential award and is one of the oldest and most prestigious science and technology honours bestowed by the US government.

Peter Higgs, emeritus professor at the University of Edinburgh, is the winner of the 2011 Edinburgh Award for his work in theoretical physics that has brought international recognition to the city. At the award ceremony he will have a mould of his handprints taken, which will then be engraved on a flagstone in the City Chambers quadrangle. First launched in 2007, the award is a way for the citizens of Edinburgh to pay a lasting tribute to individuals who have made an outstanding contribution to the city through their work or achievements. Past winners include the author J K Rowling and the Olympic cyclist Chris Hoy.


Burt Richter. (Image credit: D Rogers/SLAC.)

On 16 January, Guido Altarelli, of CERN and Universita di Roma, was at the Karlsruhe Institute of Technology (KIT) to receive the 2011 Julius Wess award of the KIT Center Elementary Particle and Astroparticle Physics. He received the award "for his work on theoretical concepts in quantum field theory and their connection to experiment, in particular his research on the consequences of supersymmetric models on physics at high energies". The award was established in 2008 in memory of Julius Wess, who for more than two decades devoted himself to the advancement of theoretical and experimental physics at Karlsruhe.


Guido Altarelli, left, with Detlef Löhe of KIT. (Image credit: KIT.)


Peter Higgs during a visit to CERN in 2008. (Image credit: Claudia Marcelloni/ATLAS.)

HONOURS

Sergei Denisov becomes academician

Sergei Denisov of the Institute for High Energy Physics (IHEP), Protvino, has been elected a full member (academician) of the Russian Academy of Sciences. This is Russia's highest scientific honour, in recognition of outstanding scientific achievement and it provides important opportunities to shape the country's scientific policies.

Denisov's contributions to particle physics go back to the 1960s, when he participated in the first experiments at the high-energy frontier with Serpukhov's 70 GeV accelerator, discovering anti-helium and the unexpected rise of total cross-sections with increasing beam energy. In the 1970s he led one of the first modern, multipurpose electronic experiments, Sigma, which studied production properties of the J/ψ particle in great detail. He went on to lead the IHEP tagged neutrino programme in the 1980s, with what was then the world's largest liquid-argon detectors for neutrinos.

He is still active in experiments at CERN (DELPHI and now ATLAS) and Fermilab (E-672 and now D0), where large components have been constructed under his leadership, for the D0 muon system and for the ATLAS calorimetry, and where many exciting results have been obtained. Denisov is also professor at Moscow State University and many scientists have received an excellent education from him and begun their own research under his leadership.


Sergei Denisov. (Image credit: courtesy Denisov family.)

FACILITIES

Fermilab to build Illinois Accelerator Research Center

Work has begun on a new accelerator-research facility at Fermilab. The Illinois Accelerator Research Center (IARC) will provide a state-of-the-art facility for research, development and industrialization of accelerator technology. The aim behind the new centre is to foster breakthroughs in accelerator technology and encourage the application of accelerator technology to solve global problems in energy, environment, medicine, industry, national security and fundamental science. IARC will also offer advanced educational opportunities to a new generation of accelerator engineers and scientists.

Located in the heart of the industrial area of the Fermilab campus, IARC will house 3900 m^2 of technical, office and educational space for scientists and engineers from Fermilab, Argonne National Laboratory, Illinois universities and industrial partners. A major focus will be to develop partnerships with private industry for the commercial and industrial applications of accelerator technology.

Officials broke ground for the Illinois Accelerator Research Center at Fermilab on 16 December, with Pier Oddone, Fermilab director, centre right. (Image credit: Fermilab Visual Media Services.)

The project is jointly funded by the US Department of Energy (DOE) and the State of Illinois. The Illinois Jobs Now! capital bill provided $20 million to the Illinois Department of Commerce and Economic Opportunity to fund a grant for the design and construction of a new building that will form part of the IARC complex. The DOE is also providing $13 million to Fermilab to refurbish an existing heavy-industrial building that will add 3300 m^2 of specialized workspace.

CELEBRATION

Happy birthday, particle hunter

Hans Volker Klapdor-Kleingrothaus, well known for his contributions to neutrino physics, and in particular double beta decay, turned 70 on 25 January.

Having started his research career in heavy-ion physics, he began in 1976 to investigate the beta decay of isotopes far from the line of stability. This led to his interest in the weak interaction in nuclei and its consequences for astrophysics, cosmology and particle physics, especially in the context of the neutrino and its properties. His evaluations of nuclear matrix elements for double beta decay have been a milestone in the field for decades.

In 1987, together with scientists from the Moscow Kurchatov Institute, he proposed and set up the Heidelberg-Moscow experiment to search for neutrinoless double beta decay. Based on enriched ^{76}Ge, this ran in the Gran Sasso National Laboratory from 1990 to 2003, and is still the most sensitive in this field (*CERN Courier* March 2002 p5). In 2001, the experiment claimed the first evidence of neutrinoless double beta decay and, from 2004, a signal at the level of 6 σ giving an effective neutrino mass of 0.22 ± 0.02 eV.

(Image credit: H V Klapdor-Kleingrothaus.)

The highly accurate and radio-pure germanium detectors used in the Heidelberg-Moscow experiment are well suited to direct searches for dark matter. In 1997 Klapdor-Kleingrothaus proposed a next-generation, large-scale experiment, GENIUS, that would search simultaneously for neutrinoless double beta decay, dark matter and low-energy solar neutrinos. GENIUS-TF, a small prototype with six naked germanium detectors in liquid nitrogen, started operating in 2003 at Gran Sasso (*CERN Courier* July/August 2003 p9). Another small-scale experiment at Gran Sasso, the Heidelberg Dark-Matter Search, operated in 2000–2005. This used two germanium isotopes to reduce backgrounds and for a long time had the best sensitivity in the world for the WIMP-neutron spin coupling.

Professionalism, interpersonal skills and fluency in foreign languages have underlined Klapdor-Kleingrothaus' success in international co-operation, particularly with Russia starting from 1970 with his first six-month visit to the Institute of Nuclear Physics at the University of Leningrad. He has organized international conferences and symposia on hot topics of modern particle and nuclear physics, successfully initiating two series of meetings: the International Conference "Dark Matter in Astro- and Particle Physics", most recently in Christchurch, New Zealand (*CERN Courier* March 2009 p17) and the International Conference on Physics Beyond the Standard Model, most recently in Cape Town, South Africa (*CERN Courier* October 2010 p15).

A professor at the University of Heidelberg since 1980, Klapdor-Kleingrothaus has supervised almost 100 PhD and diploma students and is the author of several textbooks on neutrino physics and related problems, which have been translated into many languages. He is also a yachtsman, hunter and mountain-climber. He plans this year to climb the Matterhorn for a second time.

WORKSHOP

Cool discussions in Alushta

Participants in Alushta. (Image credit: Sergei Yakovenko/JINR.)

Beam cooling played a vital role in experiments with colliding proton–antiproton beams at CERN and Fermilab, but this recently came to an end when the Tevatron ceased operation last year. However, many successful programmes that rely on both stochastic and electron cooling continue at smaller accelerators and new projects are under way or proposed. Other cooling methods, such as laser cooling or ionization cooling of muons, are also being considered in new concepts for accelerators.

The recent advances in beam cooling provided the main focus at COOL'11, the latest in a series of biennial workshops. Hosted by the Joint Institute for Nuclear Research (JINR) at its scenic "Pansionat" located on the shore of the Crimean Peninsula in Alushta, Ukraine, the workshop took place on 12–16 September. It attracted some 50 experts from around the world to discuss the latest achievements in the field. The scientific programme was complemented by a half-day excursion to the city of Yalta, which provided an opportunity to enjoy the local landscape, historic places and the comfortable weather.

Stochastic and electron cooling were the main cooling techniques discussed. Two major projects will rely heavily on these methods – the Facility for Antiproton and Ion Research (FAIR), which was recently launched in Darmstadt, and the Nuclotron-based Ion Collider Facility (NICA), which will be a major extension of the accelerator facility of JINR Dubna (*CERN Courier* April 2011 p10).

At FAIR, stochastic cooling will be used to reduce the phase space of secondary beams of antiprotons and rare isotopes. It will also be applied for the accumulation of antiprotons and to provide the best beam quality in experiments with stored antiprotons. Electron cooling is under consideration for further extensions to the facility.

In the NICA project, a booster injector and a collider consisting of two heavy-ion storage rings will be added to the existing Nuclotron. The aim is to provide ion collisions in the energy range 1–4.5 GeV/u. Beam cooling will be indispensable to achieve the highest luminosity in gold–gold collisions. In the booster, electron cooling will support dense beam formation. For the collider, both stochastic and electron cooling will be used.

The benefits of electron cooling for ion energies in the range of several giga-electron-volts/atomic mass unit was amply verified by the success of the 4.3 MeV electron-cooling system in the Recycler ring at Fermilab, which resulted in the luminosity records achieved in the final phase of Tevatron operation (*CERN Courier* November 2011 p28). This progress encouraged proposals to build new electron-cooling systems with electron energies of millions of electron-volts, such as the 2 MeV electron cooler, which is currently in the final manufacturing stage at Novosibirsk for the Cooler Synchrotron (COSY) storage ring at the Forschungszentrum Jülich.

Extensions of electron cooling to higher energies are considering the use of electrons accelerated in RF linacs for cooling at the highest energies. Another option is the proposed method of coherent electron cooling, which employs electrons from a linac and a free-electron laser stage for high-bandwidth amplification of the cooling signal. This approach is being investigated in computer simulations and a demonstration experiment is planned at Brookhaven National Laboratory.

A different technique proposed for future high-energy accelerators is the use of ionization cooling for the cooling of muons, either for high luminosity in a muon collider or for application in a future neutrino factory. As a precursor, the Muon Ionization Cooling Experiment (MICE) is being prepared at the Rutherford Appleton Laboratory, where the cooling effect of a sequence of hydrogen-absorber sections and high-field RF cavities is being investigated with a secondary muon beam.

For low-energy storage rings, various applications of beam cooling were reported at the workshop. Stochastic and electron cooling for experiments with stored protons and heavy ions are routinely in use at COSY and at the heavy-ion Experimental Storage Ring at GSI. Laser cooling of singly charged magnesium ions and electron cooling of protons in the Laser-equipped Storage Ring at Kyoto University are aiming at low beam-temperature and the study of beam crystallization. At even lower energies, electron cooling is foreseen in electrostatic storage rings, for example, at the Max-Planck-Institute Heidelberg for experiments with ions and molecules.

Another new project, approved last June, is the Extra Low-ENergy Antiproton ring (ELENA), which will be constructed at CERN in the coming years (*CERN Courier* September 2011 p9). It will further decelerate (from 5 MeV to 100 keV) and cool the beam from the Antiproton Decelerator before the transfer to experiments, significantly improving beam quality at low energy. Various cooling techniques are involved in taking antiprotons from the high energies at which they are produced to capture in a trap nearly at rest: stochastic and electron cooling in the storage rings, evaporation cooling in the trap. Fittingly, CERN is to host the next workshop in this series, in 2013.

● Contributions to COOL'11 are available at http://cool11.jinr.ru/presentations.html and the proceedings are published by *JACoW* at www.jacow.org.

MEETING

A conference, **Progress on Statistical Issues in Searches**, will take place at SLAC, Stanford, California, on 4–6 June 2012. It will deal with statistical issues that arise in experiments searching for new phenomena. The participation of practitioners of particle physics, astrophysics, cosmology, photon science (research using high-intensity X-ray beams for structural studies) and statistics is intended to foster mutual exchanges of ideas and experience, identify open problems, and promote collaborative research. Further details can be found at www-conf.slac.stanford.edu/statisticalissues2012/.

PUBLICATIONS

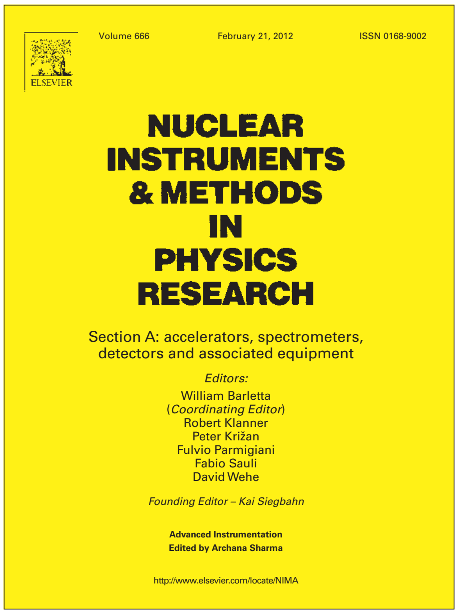
NIM-A announces topical issue on detector technologies

As high-energy particle physics pushes exploration at frontiers in both energy and luminosity, experiments are becoming increasingly complex – and this, in turn, drives the need for developments in particle detectors and their associated technologies.

Experiments now depend on high-performance silicon and gaseous tracking detectors, electromagnetic and hadron calorimetry, transition radiation detectors and novel techniques for particle identification. Magnet systems have evolved with superconducting magnets featuring in present and future experiments. The alignment system, which is critical in optimizing the overall performance of detectors, has become one of the essential design aspects of large experiments. Electronic developments are also important in enabling the exploitation of these detectors that are nowadays designed to operate in the hostile conditions of radiation and high luminosity.

These subjects are the focus of a recently published topical issue of *Nuclear Instruments and Methods*, Section A (NIM-A) on Advanced Instrumentation, edited by Archana Sharma of CERN. The freely available publication provides a panorama of the state of the art in radiation detection and instrumentation for large experiments at present and future particle accelerators.

The issue is freely available at Sciverse ScienceDirect, www.sciencedirect.com/science/journal/01689002/666.



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ELSEVIER

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH

Section A: accelerators, spectrometers, detectors and associated equipment

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Advanced Instrumentation
Edited by Archana Sharma

http://www.elsevier.com/locate/NIMA

NEW PRODUCTS

FLIR Systems has announced the new SC8400/SC6500 series of thermal-imaging cameras. Equipped with a cooled InSb detector that produces crisp 1280 × 1024-pixel thermal images, both measure temperatures up to 3000°C with an accuracy of ± 1°C or ± 1 %. They come with a full range of connectivity options. For further details, tel +33 160 370 100, e-mail research@flir.com or visit www.flir.com.

Goodfellow Cambridge Ltd has introduced copper foam that combines the thermal conductivity of copper with the structural benefits of a metal foam. The foam matrix is completely repeatable, regular and uniform throughout the material, yielding a rigid, highly porous and permeable structure with a controlled density of metal per unit volume. It is available in standard pore sizes of 2, 4, 8, and 16 pores per cm, with densities of 3–12%. For more information, tel +44 1480 424 800, e-mail info@goodfellow.com or see www.goodfellow.com.

Optical Surfaces Ltd has announced mounts designed to support mirrors in applications where stability is important, such as off-axis parabola, spheres and flats. Constructed in black, anodized aluminium, four models provide a stable platform for mirror diameters from 100 mm to 254 mm. Angular alignment can be made about two axes by means of dual-action adjusters with fine screw and ultrafine differential micrometer action. For further details, tel +44 208 668 6126, e-mail sales@optisurf.com or visit www.optisurf.com.

Resolve Optics Ltd has introduced a new 15 mm focal-length *f*2 lens that delivers high image resolution and minimal geometric distortion from 400–750 nm. Manufactured to the highest quality standards from cerium-doped glass or synthetic silica, it can withstand exposure of up to 53 kGy and temperatures of up to 55°C without discolouration. Available in 6 mm, 9 mm, 15 mm and 25 mm fixed-focus formats for use with 1/2", 2/3" and 1" CCTV cameras. For more information, tel +44 1494 777 100, e-mail sales@resolveoptics.com or visit www.resolveoptics.com.

Telonic Instruments has introduced the TOS5300 range of Hipot (Flash) withstanding-voltage and insulation-resistance testers manufactured by Kikusui in Japan. The three models are designed for use in tests to help ensure the safety of electrical equipment. They offer control over the rise and fall time for the test voltage and a stable output unaffected by mains voltage variations. Upper and lower current limits can be set within the range of 0.01–110 mA in AC mode and 0.01–11 mA in DC mode. For further details, tel +44 118 978 6911, or e-mail doug@telonic.co.uk.

Wavelength Electronics has announced the PTC series PCB-mount temperature controllers, which operate from a single power supply between 5 V and 30 V. Two models drive ±5 A or ±10 A to a Peltier thermoelectric cooler or a resistive heater, and mount directly onto a circuit board. They interface with a variety of temperature sensors and the bias current is adjustable. For more details, contact Lisa Mueller, tel +1 406 587 4910, e-mail lisa@teamwavelength.com or visit www.teamwavelength.com.

CORRECTION

A mistake occurred in the item "The shape of trees" in Sciencewatch last month (*CERN Courier* January/February p12). It was Leonardo da Vinci who observed that that "all the branches of a tree at every stage of its height when put together are equal in thickness to the trunk," as Christophe Eloy correctly observes in his paper *Phys. Rev. Lett.* **107** 258101.

GREECE

Auditorium named in honour of Themis Kanellopoulos

On the occasion of the its 50th anniversary, the Greek National Center for Scientific Research "Demokritos" has named its main auditorium after its first scientific director, Themis Kanellopoulos (1916–1995), in honour of his pioneering scientific achievements and his essential contributions to the development of research in Greece. At a ceremony in November, Kanellopoulos was especially cited for his role in the centre's foundation and establishment as a multidisciplinary research centre.

Kanellopoulos had an unusual career. After graduating with honours from the School of Mathematics at the University of Athens in 1937, he served his country during the Second World War and its aftermath. However, at the age of 37 he went to the UK with great determination to pursue PhD studies in physics under the supervision of Rudolph Peierls and Gerald E Brown. He then worked at the Nordita Institute in Copenhagen and from 1957 onwards in the Theory Division at CERN. In 1960 he decided to suspend his scientific career to follow his vision and lay the foundations for co-ordinated research in Greece. He was the scientific director of "Demokritos" until 1966.

The auditorium during the naming ceremony in November. (Image credit: Demokritos.)

The new plate bearing the name Themis Kanellopoulos. (Image credit: Nikos Gangas.) Right: Kanellopoulos, left, during a meeting at the International Atomic Energy Agency. (Image credit: IAEA.)

The centre was established in 1959, as an independent public organization dedicated to the promotion of nuclear research and technology. Today it is active in several fields of the natural sciences and engineering and hosts important laboratory facilities. One traditional priority is the support of educational activities. "Demokritos" runs various Master's and PhD programmes – an activity that goes back to one of Kanellopoulos' most significant achievements: the establishment in Greece of organized post-graduate studies for the first time.

VISITS

Polish deputy-minister of the ministry of the economy, **Hanna Trojanowska**, came to CERN on 15 December. She visited the CMS detector, toured the CMS control room and met many of the Polish scientists working at CERN.

A day later, the Polish deputy prime minister and minister of the economy, **Waldemar Pawlak**, centre, was welcomed to CERN by **Sergio Bertolucci**, director of research and computing, left, and **Felicitas Pauss**, head of international relations. The minister toured the ATLAS underground experimental area and the CERN computer centre and had a rare opportunity to view the LHC tunnel.

During a visit on 16 December, Israeli minister of industry, trade and labour, **Shalom Simhon**, was welcomed in the ATLAS visitor centre before he toured the ATLAS underground experimental area, where he could see the ATLAS detector. He also had a chance to see the LHC tunnel and the CERN Control Centre.

OBITUARY

Milla Baldo Ceolin 1924–2011

At the end of November the particle-physics community lost one of its most inquisitive, enthusiastic and active members, when Milla Baldo Ceolin, emeritus professor at the University of Padua, passed away after several months of disabling illness.

After graduating in Padua in 1952, Milla began her scientific career in research with balloon-borne nuclear emulsions exposed to cosmic rays in the high atmosphere. She then took part in a systematic study of the K^0–$\overline{K}^0$ system produced by the new generation of accelerators in collaboration with W F Fry of the University of Wisconsin, also measuring the K_1–K_2 mass difference. In a subsequent exposure of nuclear emulsion to a pion beam from the Bevatron at Berkeley, in 1958 Milla and D J Prowse discovered the first antihyperon: the antilambda.

At the beginning of the 1960s she decided to change detection technique and began experiments with bubble chambers at Argonne, CERN and the Institute for Theoretical and Experimental Physics (ITEP) in Moscow to investigate selection rules and conservation laws in the kaon system, with higher statistics. In the meantime her group in Padua grew steadily, working in international collaborations.

The main field of her investigations changed to neutrino physics after the discovery of neutral currents in 1973. The NUE experiment at CERN, carried out with Helmut Faissner's group at Aachen, used a set of large spark chambers to measure, for the first time, both neutrino and antineutrino elastic-scattering cross-sections off electrons and provided a value for the Weinberg angle, $\sin^2\theta_W$ They also obtained new results in other neutral-current reactions and

Milla Baldo Ceolin. (Image credit: Baldo-Ceolin family.)

coherent processes on aluminium nuclei. Returning to the bubble-chamber technique, but this time with liquid deuterium, in a large collaboration (Italy, France, the Netherlands and Norway) at CERN's Super Proton Synchrotron, Milla and colleagues performed systematic investigations on neutrino neutral- and charged-currents on (quasi) free protons and neutrons.

In 1976 Milla proposed an experiment on $\nu_\mu \rightarrow \nu_e$ oscillations with a long baseline and a low-energy neutrino beam at CERN. Carried out a few years later, it found no evidence for oscillations but set important limits on the oscillation parameters. Her curiosity for quantum mixings then turned to the search for neutron–antineutron oscillations with cold neutrons with a novel technique at the Institut Laue Langevin in Grenoble, and for $\nu_\mu \rightarrow \nu_\tau$ oscillation with a huge detector in a large collaboration (NOMAD) at CERN, where she led the Italian contingent. In both cases, the experiments obtained important upper limits. Having supported from the start the ICARUS detector for the study of solar neutrinos and of nucleon stability, in recent years she invested much effort to have the detector working in the Gran Sasso Laboratory: the experiment is now a reality.

Milla became full professor in 1964 and a few years later was appointed director of the Padua Section of INFN and then became director of the Department of Physics. She was a member of several academies and was awarded the Feltrinelli Prize by the Accademia dei Lincei, as well as the Gold Medal for Education and Arts, the Gold Medal for Science and the Enrico Fermi Prize from the Italian Physical Society.

In 1988 she started the world-renowned series of Workshops on Neutrino Telescopes at the Instituto Veneto di Scienze, Lettere ed Arti in Venice. These gathered hundreds of scientists to discuss neutrino properties, astrophysics and cosmology; her quest for perfection was manifest both in the scientific programmes and in the cultural and social events.

Milla's students and colleagues have always been stimulated by her nonconventional approach to scientific, academic and cultural issues. We are grateful to her and will miss her.

● *Her friends and colleagues in Padua.*

CINEMA

The Muppets go to CERN

Anyone who has been to the cinema to see *The Muppets* – which was recently released in most European countries having being screened first in the US last November – will have seen the arrival of this almost legendary gang of puppets at the word's largest particle-physics laboratory.

In the movie, Kermit the Frog sets to reunite his gang of Muppets, and his journey takes him all of the way to CERN, where he finds Bunsen Honeydew (the absent-minded but extremely intelligent Muppet) and Bunsen's long-suffering assistant, Beaker. After their rise to fame on *The Muppet Show*, Bunsen and Beaker have taken up posts at CERN and – by the looks of the scene in question – they've been working for the ATLAS experiment at the LHC.

● From the article in the online publication *International Science Grid This Week*, http://www.isgtw.org/spotlight/muppets-go-cern. For more and a short clip, see also the online publication *symmetrybreaking*: http://www.symmetrymagazine.org/breaking/2011/11/23/muppet-scientists-at-the-lhc/.

The Muppets visit the ATLAS detector at CERN, where they meet Bunsen Honeydew (second from left) and his assistant Beaker (far left). (Image credit: Walt Disney Studios.)

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6BE, UK.
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We are seeking qualified applicants for teaching and research in the area of theoretical particle physics. The starting date is as soon as possible. The research should be focused on relativistic quantum field theory and phenomenology of high energy particle physics. Additional activities in the fields of astroparticle physics and/or cosmology are welcome. We expect significant contributions to the teaching program of the physics department.

A Ph.D. degree is required; additionally, Habilitation (post-doctoral lecturing qualification), an exemplary record of research achievement as an assistant / an associate / a junior professor or university researcher and/or an outstanding career outside academia are highly desirable. Ability in and commitment to teaching are essential. German is not necessary to begin but will be expected as a teaching language within the first 5 years.

The application should include supporting documents regarding success in teaching.

Please send a cover letter stating research aims and a CV to:
An den Dekan der Fakultät 1 der RWTH Aachen, Prof. Dr. G. Hiß, 52056 Aachen, Germany. The deadline for applications is March 31, 2012.

This position is also available as part-time employment per request.

RWTH Aachen University is certified as a family-friendly university and offers a dual career program for partner hiring. We particularly welcome and encourage applications from women, disabled people and ethnic minority groups, recognizing they are underrepresented across RWTH Aachen University. The principles of fair and open competition apply and appointments will be made on merit.

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- Participation in experiments like ALPS, Belle II and OLYMPUS

Requirements
- Ph.D. completed within the last 4 years
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DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department. Please arrange for three letters of reference to be sent before the application deadline to the DESY human resource department.

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

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Human Resources Department | Code: EM001/2012
Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-1589 |
E-Mail: personal.abteilung@desy.de
Deadline for applications: 31 March 2012
www.desy.de

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YOUR PROFILE

You have received an excellent master/Diplom degree (or equivalent) in particle physics, astroparticle physics or cosmology. We expect strong commitment to teamwork, excellent communication skills, and high flexibility.
Please apply with a curriculum vitae, a one-page summary of your thesis, two letters of reference, and a one-page description of your research interests within the framework of the graduate school. Selection will be based on competitive evaluation. Preference will be given to those candidates whose research interests combine two of the aforementioned scientific areas.

YOUR DUTIES AND RESPONSIBILITIES

You will work in close collaboration with your advisor(s) on the scientific goals of this graduate school. You will participate in the school’s training programs (e.g., seminars, special lectures, etc.), and present your work at our annual workshop.

OUR OFFER

The candidate will be employed as a regular employee. The position is to be filled as soon as possible and is for a fixed term of two years. with a possible prolongation of 12 months. This is a part-time vacancy (75 % of the standard weekly hours for full time employees). The successful candidate has the opportunity to pursue a doctoral degree.
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RWTH is committed to promoting the careers of women and therefore looks forward to receiving applications by female candidates. For positions in organisational units where women are underrepresented, in cases of equal qualification, ability and professional achievement, preference will be given to female applicants unless reasons specific to an individual candidate tilt the balance in his favour. The University positively welcomes applications from suitably qualified disabled people.

YOUR CONTACT PERSON

For further information, please contact

Prof. Dr. Stefan Schael
Tel. +49 (0) 241-80-27158
Fax. +49 (0) 241-80-22661
Stefan.Schael@physik.rwth-aachen.de

Please send your application by 31 March 2012 to:

Prof. Dr. Stefan Schael
I. Physikalisches Institut B
RWTH Aachen
D-52056 Aachen, Germany

You can also obtain further information from our websites: www1b.physik.rwth-aachen.de/~schael/GK-LHC

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International Centre for Theoretical Physics

Post title	**Research Scientist**
Organisational unit	**The Abdus Salam International Centre for Theoretical Physics (ICTP) - *www.ictp.it***
Duty station	**Trieste, Italy**
Grade	**P-3**
Post number	**EU/TP/ITA/SC/0824**
Closing date	**30 April 2012**
Purpose of post	To initiate, develop and coordinate competitive research and training programmes in the field of High energy physics related to experiments at the LHC and future accelerators. To work on theoretical aspects of LHC physics.

Main responsibilities

Research:

To undertake front-line research in "Physics at LHC and Future High Energy Colliders".

- to suggest, develop and realize scientific projects related to interpretation of results from the LHC and other accelerator experiments; to study discovery potential of future colliders; to lead a research team composed of post-doctoral fellows and visitors, with particular emphasis on visitors from developing countries
- to establish and maintain scientific contacts with CERN and other accelerator centers, to participate in working group and committees related to collider experiments; to act as a liaison between the High Energy group and other groups around the world, where front-line research is conducted in his/her areas of expertise
- to establish wide cooperation with scientists from developing countries; to identify the scientific needs of developing countries in his/her field of expertise, and to formulate the appropriate recommendations for incorporation within ICTP's programmes
- to report on results of the research at major international meetings

Management:

- to assist the Supervisor in the organization of ICTP scientific meetings as well as training programmes in the field of his/her competence
- to assist the Supervisor in reviewing applications and make selection of post-doctoral fellows, visitors and associates; to assist visitors during their stay in the Centre
- whenever needed and requested to take part in various committees set up by the Director to ensure the smooth functioning of ICTP

Teaching:

- to lecture in the High Energy Diploma and other programmes
- to supervise the Diploma thesis
- to participate in joint PhD programmes with Italian institutions

Profile:

- Ph.D. or equivalent doctoral level in physics, with speciality in High Energy.
- 4 to 7 years of post-doctoral research experience, of which preferably 2 years acquired at the international level.
- Excellent knowledge of written and spoken English.
- An appropriate attitude towards the international and multicultural characteristics involved in the assignment.

Conditions of employment:

ICTP is a world-class institution focused on research in basic sciences with the responsibility for the promotion, dissemination and support of science, especially in developing countries. It operates under the aegis of UNESCO and IAEA. This is an extra-budgetary position of a continuing nature but the duration of the appointment will be subject to the availability of funds. UNESCO's salaries are calculated in US Dollars. They consist of a basic salary and a post adjustment, which reflects the cost of living changes in a particular duty station and exchange rates. For this post, the annual remuneration will start at US$85,482 if there are no dependants and at US$91,578 if there are dependants, and is exempt from income tax. There is an attractive benefits package, which includes 30 days of annual vacation, home travel, education grant for dependent children, pension plan and medical insurance. The initial appointment, which is for 2 years, includes a probationary period of 12 months, and is renewable, subject to satisfactory service.

How to apply:

Candidates should use ICTP's online application system which is accessible via ICTP's intranet site at **http://www.ictp.it/about-ictp/job-opportunities.aspx**. They should include a curriculum vitae, list of publications and names of three referees. Candidates without access to the Internet may send a paper application by completing the official UNESCO CV form available at the Personnel Office, Abdus Salam International Centre for Theoretical Physics, Strada Costiera, 11, 34151 Trieste, Italy. E-mail: **personnel_office@ictp.it, phone: +39-040-2240-595/596/695, fax: +39-040-2240-7593**.

Department of Physics

Research Assistant in Accelerator Science

Salary is in the range £32,256 to £36,018 per annum inclusive of London Allowance

A postdoctoral Research Assistant position is available from April 2012 to work within the John Adams Institute (JAI) for accelerator science at Royal Holloway. The duration of the post is three years in the first instance, with possibility of renewal subject to funding.

The post will involve working on the LHC High Luminosity upgrade design study in the area of the collimation system, involving beam dynamics and background simulations, and will require significant collaboration with accelerator physicists at CERN.

There may be some opportunity to teach at undergraduate or postgraduate level. Further details about JAI and the work of the Royal Holloway Particle Physics Group can be found on our web site at http://www.pp.rhul.ac.uk Royal Holloway is one of the larger colleges of the University of London, situated in Egham in Surrey, on a pleasant campus about 25km west of central London, close to the town of Windsor and to Heathrow Airport.

Applicants should have a PhD (or be about to submit a thesis) in particle physics, accelerator physics or a related field.

Informal enquiries about the posts can be made to g.blair@rhul.ac.uk

For further details of this post and to apply online at https://rhul.engageats.co.uk or contacting the Recruitment Team by email: recruitment@rhul.ac.uk or tel: 01784 414241.

Please quote the reference: X0112/6820.

Closing date: 29 March 2012 in the first instance, but the post will remain open until filled.

The College is committed to equality and diversity, and encourages applications from all sections of the community.

John Adams Institute J.A.I. for Accelerator Science

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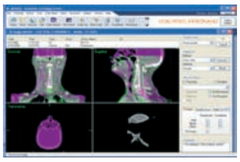
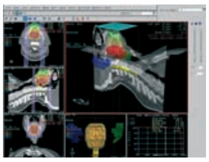




Bookshelf

Radioactivity: A History of a Mysterious Science

By Marjorie C Malley

Oxford University Press

Hardback: £14.99 $21.95

Between 1899 and 1902, Polish physicist Marie Curie processed 100 kg of radioactive pitchblende ore – in 20 kg batches – by hand, in the courtyard of a leaky shed in Paris. The feat provided her with the atomic weight of radium and earned her a Nobel prize. But the research also left her with lifelong medical complications from exposure to radioactivity.

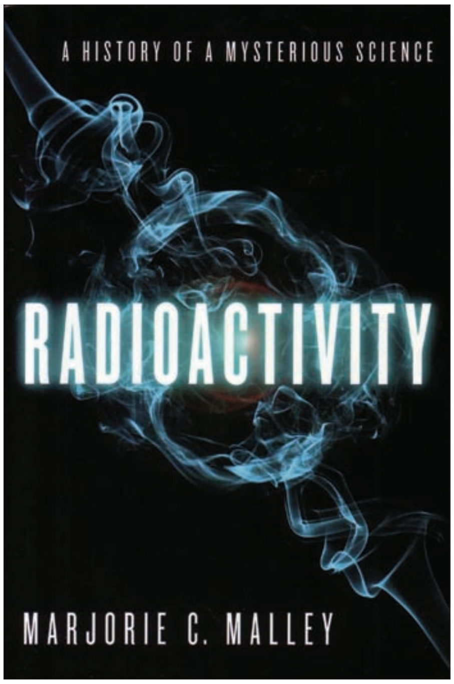
Marjorie C Malley's comprehensive history of radioactivity captures the excitement, promise and tragedy of the "mysterious" field from its inception in the late 19th century to the present day. The narrative spans two continents and two world wars, taking in decorative uranium glassware, radium spas and atom bombs along the way. Avoiding technical detail, Malley explores the cultural, technological and scientific forces that shaped research in radioactivity, and relates the important personalities and discoveries that drove the field forward.

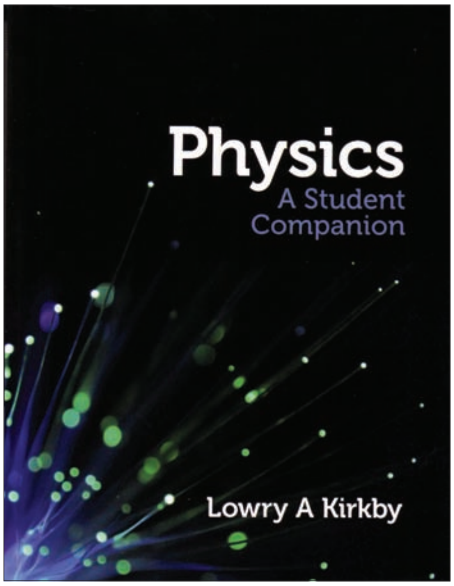
Malley's cast spreads across France, Germany, the UK and Canada. We are introduced to Wilhelm Röntgen, discoverer of X-rays; Henri Becquerel, who noticed that invisible rays from uranium registered on photographic plates, even in the dark; and Marie Curie, who first applied electrical techniques to understanding radioactive substances and who discovered the elements radium and polonium in the process.

In Canada, Ernest Rutherford and Frederick Soddy investigated further the radioactivity of both uranium and thorium and found that in the course of emitting radiation they change into different elements. The shock of atomic transmutation – with its undertones of alchemy – was almost heresy to chemists at the time. When they returned to the UK, Rutherford went on to discover the atomic nucleus, while Soddy was the first to form the concept of isotopes.

Two aspects of Malley's narrative stand out for me: the "reasonable" hypotheses that scientists put forward for the origins of radioactivity, which seem so outlandish now; and the shocking ignorance of the true medical dangers of radiation that prevailed until relatively late in the 20th century.

In fluorescent paint factories of the 1920s, workers wetted the tips of their brushes with their lips, swallowing radioactive radium in the process. Alpha radiation from the paint often led to the death of jaw tissue and mysterious cancers. Researchers regularly mixed radioactive solutions with their fingers: physicist Stefan Meyer had to give up playing the bass viol because of radiation damage to his fingers.





Malley's clearly written text captures the intellectual excitement of early research into radioactivity, though I found her section on the cultural forces shaping radioactivity rather weak. Although she notes that individuals, scientific ideals, culture and nationalism (among others) triggered the spurt of research interest in radioactivity, I was unconvinced that research into radioactivity deserves a special place among the countless other scientific advances of the 20th century. Was its development really that unique? I also felt that in a history of radioactivity, the implications of using nuclear power – for good or evil – were rather glossed over in deference to scientific papers and super scientists.

In *Radioactivity*, Malley weaves disparate historical threads into an accessible and engaging narrative for the nonexpert. I would recommend this book, describing it as a well written and useful overview of the topic for students and teachers. Those seeking in-depth analysis of the implications of the technology – or biographies of the scientists involved – should look elsewhere.

● *Cian O'Luanaigh, CERN.*

Physics: A Student Companion

By Lowry Kirkby

Scion Publishing Ltd

Paperback: £27.99 $50

Lowry Kirkby once turned down an offer to study physics at Manchester University and instead went to Oxford. This was Manchester's loss; she was clearly a model student, assiduous in producing, collating and annotating her lecture notes and using them to help her graduate with a top first-class degree in 2007. She has now turned these notes into a "student companion".

As companions go, this is an excellent one and it should become a best friend to all physics undergraduates, particularly in those important, lonely weeks of study in the run-up to examinations. I encourage all lecturers to recommend this book to their students.

Lowry covers the bulk of the core physics required in degree programmes accredited by the Institute of Physics in the UK and most of the syllabus for the Graduate Record Examination in the US. This includes Newtonian mechanics and special relativity; electromagnetism; waves and optics; quantum physics; and thermal physics. These are taken to about the end of the second year of university study for a student majoring in physics. So, for example, the material goes as far as Fraunhofer diffraction in wave-optics, time-independent perturbation theory in quantum mechanics and the grand canonical partition function in statistical mechanics.

Clearly a single, relatively slim volume such as this (400 pages) cannot serve as a

Bookshelf

textbook for all these topics. But that is not its intention; it is meant as a supplement to the textbooks, a digest for students who have already studied and understood the details.

There are five aspects to the presentation of the material, which can be described as: commentary, summaries, boxed equations, derivations and worked examples. It all sits together very well indeed as a single-volume study aid. In a book with so much detail and so many equations, I found remarkably few errors or misprints. The author, proofreaders and editor are to be commended on the high standards of the production.

Do physics students still have bookshelves? If they do, then this book should have a place on all of them. But smart phones, tablets and e-readers now seem to be the preferred media. While the book is reasonably portable, an e-version would be just the sort of thing that today's physics students would always want to have to hand.

● *George Lafferty, Manchester University.*

Books received

Advanced Statistical Mechanics

By Barry M McCoy

Oxford University Press

Hardback: £57.70 $99

Statistical mechanics is the study of systems where the number of interacting particles becomes infinite. Tremendous advances have been made over the past 50 years that have required the invention of entirely new fields of mathematics, such as quantum groups and affine Lie algebras. These have provided profound insights into both condensed matter physics and quantum field theory, but none of these advances are taught in graduate courses in statistical mechanics. This book is an attempt to correct this, beginning with theorems on the existence (and lack) of order for crystals and magnets and with the theory of critical phenomena, it continues by presenting the methods and results of 50 years of analytic and computer computations of phase transitions.

Strong Coupling Gauge Theories in LHC Era: Proceedings of the Workshop in Honor of Toshihide Maskawa's 70th Birthday and 35th Anniversary of Dynamical Symmetry Breaking in SCGT

By H Fukaya et al. (ed.)

World Scientific

Hardback: £93 $150

E-book: $195

This workshop was the sixth Nagoya strong-coupling gauge theory (SCGT) workshop and the first after Yoichiro Nambu, Makato Kobayashi and Toshihide Maskawa shared the 2008 Nobel Prize in Physics for their work in dynamical symmetry breaking. The purpose of the workshop was to discuss both theoretical and phenomenological aspects of SCGTs, with emphasis on the models to be tested in the LHC experiments.

Exclusive Reactions at High Momentum Transfer IV: Proceedings of the 4th Workshop

By Anatoly Radyushkin

World Scientific

Hardback: £109 $175

E-book: $223

These proceedings include talks given at the 4th Workshop on Exclusive Reactions at High Momentum Transfer at Jefferson Lab. The workshop focused on the application of a variety of exclusive reactions at high momentum-transfer, utilizing unpolarized and polarized beams and targets, to obtain information about nucleon ground-state and excited-state structure at short distances. This subject is central to the programmes of current accelerators and especially for planned future facilities.

Physics Beyond the Standard Models of Particles, Cosmology and Astrophysics

By H V Klapdor-Kleingrothaus, I V Krivosheina and R Viollier

World Scientific

Hardback: £136 $220

This book contains the proceedings of the Fifth International Conference on Physics Beyond the Standard Models of Particle Physics, Cosmology and Astrophysics. It reviews the status and future potential and trends in experimental and theoretical particle physics, cosmology and astrophysics, in the complementary sectors of accelerator, nonaccelerator and space physics.

Theory of High-Temperature Superconductivity: A Conventional Approach

By Todor M Mishonov and Evgeni S Penev

World Scientific

Hardback: £57 $88

E-book: $114

Drawing from the broad spectrum of phenomena, described in more than 100 000 articles on high-T_c superconductivity, the authors analyse the basic properties that can be understood within the framework of traditional methods of theoretical physics, e.g. for the overdoped cuprates. The book gives a pedagogical derivation of formulae describing the electron band-structure, penetration depth, specific heat, fluctuation conductivity, etc. Prediction of plasmons and their application for a new type of terahertz generators is also considered.

The World According to Quantum Mechanics: Why the Laws of Physics Make Perfect Sense After All

By Ulrich Mohrhoff

World Scientific

Hardback: £56 $81

E-book: $105

As a supplement to standard textbooks on quantum mechanics, this introduction to the general theoretical framework of contemporary physics focuses on conceptual, epistemological and ontological issues. The theory is developed by pursuing the question: what does it take to have material objects that neither collapse nor explode as soon as they are formed? The stability of matter thus emerges as the chief reason the laws of physics have the particular form that they do. The first of three parts familiarizes the reader with the basics; the second looks closer; and the final part aims to make epistemological and ontological sense of the theory.

Gribov-80 Memorial Volume: Quantum Chromodynamics and Beyond: Proceedings of the Memorial Workshop Devoted to the 80th Birthday of V N Gribov

By Yu L Dokshitzer, P Lévai and J Nyíri

World Scientific

Hardback: £117 $180

Theoretical physicist Vladimir Gribov was a key figure in the development of modern elementary particle physics. His insights into the physics of quantum anomalies and the origin of classical solutions (instantons), the notion of parton systems and their evolution in soft and hard hadron interactions, the first theory of neutrino oscillations and conceptual problems of quantization of non-Abelian fields have left a lasting impact on modern theoretical physics. Gribov-80 brought colleagues, younger researchers and leading experts together to discuss the new angles of the Gribov heritage in the LHC era.

Quips, Quotes and Quanta: An Anecdotal History of Physics, 2nd Edition

By Anton Z Capri

World Scientific

Paperback: £25 $38

When a ship's surgeon noticed during a routine episode of bloodletting that the sailors' blood was brighter in the tropics than in the north, he hypothesized that heat was a form of energy. This is just one of the stories covered in this entertaining book that deals with the history of physics from the end of the 19th century to about 1930. This second edition has been revised to include a prologue, epilogue, glossary, chronology and photographs, as well as additional quotes and anecdotes.

Inside Story

Interactions with Georges Charpak

Vladimir Peskov recalls his first encounters with the influential scientist.

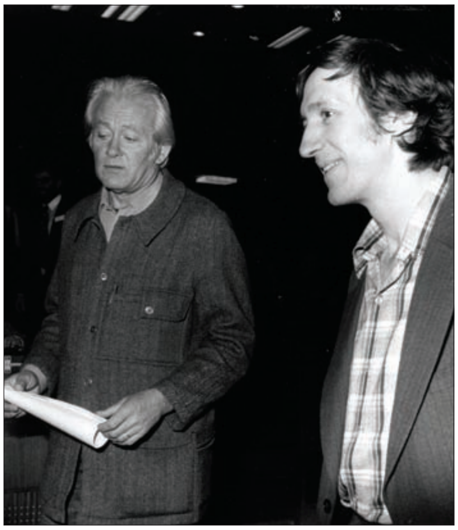
Georges Charpak (1924–2010), well known for his remarkable work on detector techniques that led to the 1992 Nobel Prize in Physics, would have been 88 this month. Here I would like to recall his warm personality, sense of humour and willingness to help people.

Having been born in the USSR in the Republic of Kazakhstan close to the labour camps (the "Gulag"), I never dreamt of becoming a researcher lucky enough to collaborate with as great a scientist as Georges. However, despite a hard childhood, I succeeded in joining the Institute for Physical Problems in Moscow, where I became a researcher in Piotr Kapitza's plasma laboratory.

Kapitza was investigating stationary high-power, high-frequency discharges in H_2 and D_2, but the plasma diagnostics was difficult: strong emission in the visible region masked the short-term instabilities developing inside the plasma column. After many attempts we realized that the best way to visualize the instabilities was to use the multiwire proportional counter (MWPC) invented by Georges. Among several modifications, we developed a photosensitive MWPC capable of detecting single photoelectrons created by the absorption of ultraviolet photons in a special, low-ionization gas mixture – and we succeeded in visualizing the hidden plasma instabilities.

Invitation to Vienna

One day (in 1981, I believe) I wrote to Georges describing our success in the application of his MWPC in plasma diagnostics. I had no hope of receiving a reply: not all letters were allowed to leave the USSR and Georges was so famous, would he reply to an unknown person in Moscow? How surprised I was when, two months later, I received a short, hand-written reply. He said that he would be very interested to learn more about our work and invited me to attend the Vienna Wire Chamber Conference in February 1982. I later received a formal invitation from the organizing committee, offering full coverage of the trip. It was extremely difficult to get permission from the Soviet authorities to go, despite Kapitza's support, but I was able to meet Georges for the first time in Vienna.


Georges, left, with the author in Vienna, 1982. (Image credit: V Peskov.)

Following a brief encounter at registration, he invited me for lunch on the first day of the conference. "I am very interested by your work and applications of the MWPC in plasma studies," he told me. "But you are not the first to develop a photosensitive MWPC." He gave me a paper, the authors of which were unknown to me, Tom Ypsilantis and Jacques Seguinot. I gave him my paper printed in Russian and translated into English. Georges briefly looked through it. "This is interesting! So your group developed almost the same detector, but independently ... and you use another photosensitive gas."

Suddenly, he asked: "What do Soviet physicists think about [Andrei] Sakharov? Do they protest that he is in exile in Gorki? I heard that there was even an attempt to expel him from the Academy of Sciences." This was a provocative question. In Brezhnev's time, to be involved in such discussion was a dangerous exercise. After a pause, I related how Kapitza had managed to defuse the situation so that Sakharov was saved. "Saved?" asked Georges ironically. "But he is in Gorki."

"But even this was a heroic act", I explained. "Do you know that Kapitza saved several lives during Stalin's Terror? Landay, Fock were liberated from prisons because of Kapitza's letters sent directly to Stalin, which was real heroism!" Georges looked at me and I began to feel some mutual sympathy.

During the conference I stayed in a small hotel close to the famous Vienna Opera and the temptation was great to go to the ballet. There were no tickets available but a person whose companion could not go sold me one, and I spent all of the money that I had received from the organizing committee. During the break I suddenly met Georges with members of his group and for the first time, I met Amos Breskin, Stan Majewski and others. When the ballet was over, Majewski asked Georges: "Why don't you invite Vladimir to CERN?"

"Good idea!" he replied. "But first I want to go to Moscow to see his institute and to be introduced to Kapitza!" The next morning, the young woman from the organizing committee who had introduced me to Georges was waiting for me.

"Professor Charpak told us that you spent all of the money at yesterday's ballet," she said. "The organizing committee decided to compensate you! You will receive extra money from us at lunchtime."

Return to Moscow

Seven months later, I was at Moscow airport to greet Georges, who had arrived thanks to Kapitza's efforts, but on the morning they were to meet, we learnt the sad news that Kapitza had been taken to hospital. Indeed, Georges's dream of meeting Kapitza never materialized. After some time in hospital, Kapitza became weak and passed away in 1984. Plasma research was stopped in our institute and I could no longer continue the work that I so much enjoyed.

Georges later sent a letter inviting me to join his lab at CERN for a year. I decided to use this opportunity to begin a new chapter in my own life, with many more interactions with Georges – but that is another story.

● *Vladimir Peskov, National Autonomous University of Mexico.*

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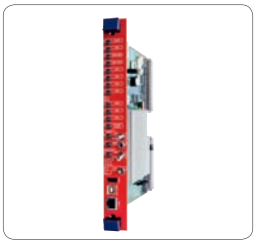

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