INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 50 NUMBER 6 JULY/AUGUST 2010

A universe of particles

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

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by IOP Publishing Ltd
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Tel +44 (0)117 929 7481

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General distribution Courrier Adressage, CERN, 1211 Geneva 23, Switzerland. E-mail: courrier-adressage@cern.ch
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UK Mark Wells, Science and Technology Facilities Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1SZ. E-mail: mark.wells@stfc.ac.uk
US/Canada Published by Cern Courier, 6N246 Willow Drive, St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US. Fax 630 377 1569. E-mail: creative_mailing@att.net
POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147, St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN, 1211 Geneva 23, Switzerland. Tel +41 (0) 22 767 61 11
Telefax +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

 ISSN 0304-288X

IOP Publishing

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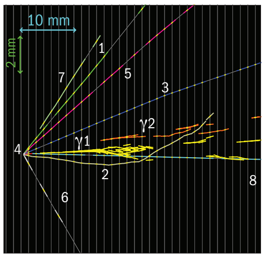


The pieces begin to fall together p5

A new chapter opens for CERN p28

One cool physics project for kids p29

Cover: A scene in the main show at CERN's new permanent exhibition "Universe of Particles" (p28). This colourful display describes the moment when stars explode and throw their debris – the elements of life – into space, later to become planets, Earth and ourselves.

NEWS

NEUTRINOS

OPERA catches its first tau-neutrino

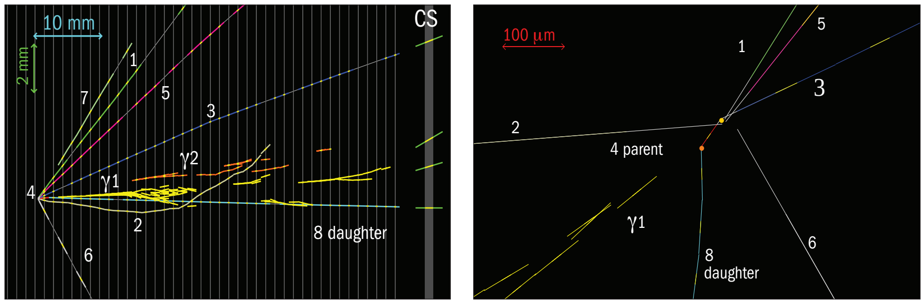
The OPERA collaboration has announced the observation of the first candidate tau-neutrino (ν_τ) in the muon-neutrino (ν_μ) beam sent through the Earth from CERN to the INFN's Gran Sasso Laboratory 730 km away. The result is an important final piece in a puzzle that has challenged science for almost half a century.

The puzzle surrounding neutrinos originated in the 1960s when the pioneering experiment by Ray Davis detected fewer neutrinos arriving at the Earth from the Sun than solar models predicted (*CERN Courier* December 2002 p15). A possible solution, proposed in 1969 by Bruno Pontecorvo and Vladimir Gribov, was that oscillatory changes between different types of neutrinos could be responsible for the apparent neutrino deficit. Conclusive evidence that electron-neutrinos, ν_e, from the Sun change type *en route* to the Earth came from the Sudbury Neutrino Observatory in 2002, a few years after the Super-Kamiokande experiment found the first evidence for oscillations in ν_μ created by cosmic rays in the atmosphere. Accelerator-based experiments have since observed the disappearance of ν_μ, confirming the oscillation hypothesis, but until now there have been no observations of the appearance of a ν_τ in a ν_μ beam.

OPERA's result follows seven years of preparation and more than three years of beam provided by CERN (*CERN Courier* November 2006 p24 and p27). The neutrinos are generated at CERN when a proton beam from the Super Proton Synchrotron strikes a target, producing pions and kaons. These quickly decay, giving rise mainly to ν_μ that pass unhindered through the Earth's crust towards Gran Sasso. The appearance and subsequent decay of a τ in the OPERA experiment would provide the telltale sign of ν_μ to ν_τ oscillation through a charged-current interaction.

Detecting the τ decay is a challenging task, demanding particle tracking at micrometre resolution to reconstruct the topology: either a kink – a sharp change (>20 mrad) in direction occurring after about 1 mm – as the original τ decays into a charged particle together with one or more neutrinos, or the vertex for the decay mode into three charged particles plus a neutrino.

The OPERA apparatus has two identical Super Modules, each containing a target section and a large-aperture muon spectrometer. The target consists of alternate walls of lead/emulsion bricks – 150 000 bricks in total – and modules of scintillator strips for the target tracker. The nuclear-emulsion technique allows the collaboration to measure the neutrino-interaction vertices with high precision. The scintillators provide an electronic trigger for neutrino interactions, localize the particular brick in which the neutrino has interacted, and perform a first tracking of muons within the target. The relevant bricks are then extracted from the walls so that the film can be developed and scanned using computer-controlled scanning microscopes.



OPERA's τ^- candidate event. The longitudinal view (left) shows the tracks of charged particles detected in the emulsion layers, together with the showers indicative of two photons (γ1 and γ2). A closer transverse view (right) reveals the kink characteristic of a decay with track 4 (the parent) leading to track 8 (the daughter product). Track 4 is about 1.3 mm long. Both the kink angle and the path length satisfy the selection criteria for the decay of a τ^-.

The collaboration has identified the first candidate ν_τ in a sample of events from data taken in 2008–2009, corresponding to 1.89×10^{19} protons on the target at CERN. The sample contains 1088 events, including 901 that appear to be charged-current interactions. The search through these has yielded one candidate with the characteristics expected for the decay of a τ^- into a charged hadron (h^-), neutral pions (π^0) and a ν_τ. Indeed, the kinematical analysis suggests the decay $\tau^- \rightarrow \rho^- \nu_\tau$. The event has a significance of 2.36 σ of not being a background fluctuation for the τ^- decay to $h^-(\pi^0)\nu_\tau$.

This candidate event is an important first step towards the observation of $\nu_\tau \rightarrow \nu_\mu$ oscillations through the direct appearance of the ν_τ. That claim will require the detection of a few more events, but so far the collaboration has analysed only 35% of the data taken in 2008 and 2009 and ultimately should have five times as much data than as at present.

Further reading

N Agafonova *et al.* OPERA collaboration 2010 arXiv:1006.1623v1, submitted *Phys. Letts. B.*

Sommaire

FERMILAB

DØ sees anomalous asymmetry in decays of B mesons

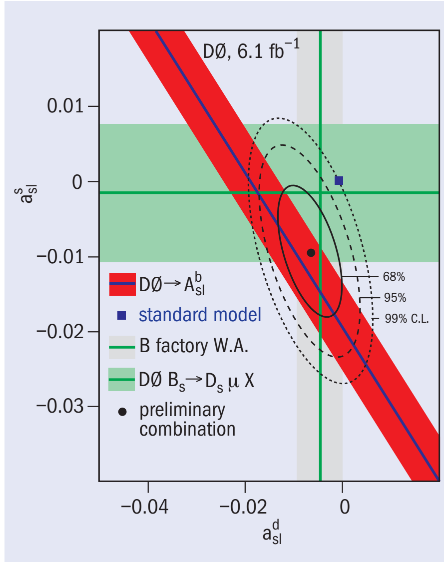
The DØ collaboration at Fermilab has reported evidence of a violation of matter–antimatter symmetry ("CP symmetry") in the behaviour of neutral mesons containing b quarks. Studying collisions where B mesons decay semi-leptonically into muons, the team finds about 1% more collisions when two negatively charged muons are produced than collisions with two positively charged muons. The collisions in the DØ detector occur through a symmetric proton–antiproton state and the expected CP asymmetry from the Standard Model is predicted to be much smaller than what has been observed. An asymmetry of 1% is therefore completely unexpected.

The properties of B mesons, created in collisions where a $b\bar{b}$ quark pair is produced, are assumed to be responsible for this asymmetry. Mesons containing b quarks are known to oscillate between their particle ($B=\bar{b}d$ or $\bar{b}s$) and anti-particle ($\bar{B}=b\bar{d}$ or $b\bar{s}$) state before they decay into a positively charged muon (for the B) or a negatively charged muon (for the $\bar{B}$). If a B meson oscillates before its decay, its decay muon has the "wrong sign", i.e. its charge is identical to the charge of the muon from the other b decay. Having 1% more negatively charged muon pairs therefore implies that the B meson decays slightly more often into its matter state than into its antimatter state.

The DØ detector has two magnets, a central solenoid and a muon-system toroid, which determine the curvature and charge of muons. By regularly reversing the polarities of these magnets the collaboration can eliminate most effects coming from asymmetries in the detection of positively and negatively charged muons. This feature is crucial for reducing systematic effects in this measurement.

Another known source of asymmetry arises in muons produced in the decays of charged kaons. Kaons contain strange quarks and the interaction cross-sections of positively and negatively charged kaons with the matter making up the DØ detector differ significantly: more interactions are open to the K^-, which contains strange quarks, than to the K^+, which contain strange antiquarks. In detailed studies the collaboration has derived the contribution of this effect almost entirely from the data, making the measurement of the asymmetry in B-meson decays largely independent of external assumptions and simulation.

The final result is 3.2 σ from the Standard Model expectation, corresponding to a probability of less than 0.1 per cent that this measurement is consistent with any known effect. The analysis was based on an integrated luminosity of 6.1 fb^{-1} and the plan is to increase the accuracy of this measurement by adding significantly more data and improving future analysis methods.



The semileptonic dimuon B meson charge asymmetry, A^b_{sl}, obtained by the DØ collaboration, compared with the Standard Model prediction and with the measured muon asymmetries a^s_{sl} and a^d_{sl} for B^0_s and B^0_d mesons.

Further reading

V M Abazov *et al.* 2010 DØ collaboration, arxiv:1005.2757, submitted to *Phys. Rev. D.*; www-D0.fnal.gov/Run2Physics/WWW/results/final/B/B10A/.

CERN

CERN Council opens the door to greater integration

At its 155th session, on 18 June, the CERN Council opened the door to greater integration in particle physics when it unanimously adopted the recommendations of a working group that was set up in 2008 to examine the role of the organization in the light of increasing globalization in particle physics.

"This is a milestone in CERN's history and a giant leap for particle physics," said Michel Spiro, president of the CERN Council. "It recognizes the increasing globalization of the field, and the important role played by CERN on the world stage."

The key points agreed at the meeting were:

- All states shall be eligible for membership, irrespective of their geographical location;
- A new associate membership status is to be introduced to allow non-member states to establish or strengthen their institutional links with the organization;
- Associate membership shall also serve as the obligatory pre-stage to full membership;
- The existing observer status will be phased out for states, but retained for international organizations;

International co-operation agreements and protocols will be retained. "Particle physics is becoming increasingly integrated at the global level," explained CERN's director-general Rolf Heuer. "The decision contributes towards creating the conditions that will enable CERN to play a full role in any future facility, wherever in the world it might be."

CERN currently has 20 member states: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the UK. India, Israel, Japan, the Russian Federation, the US, Turkey, the European Commission and UNESCO have observer status. Applications for membership from Cyprus, Israel, Serbia, Slovenia and Turkey have already been received by the CERN Council, and are currently undergoing technical verification. At future meetings, Council will determine how to apply the new arrangements to these states.

In other business, Council recognized that further work is necessary on the organization's medium-term plan, in order to maintain a vibrant research programme through a period of financial austerity, and endorsed CERN's new code of conduct.

Full details of the new membership arrangements can be found in Council document *CERN/2918*, which is available at http://indico.cern.ch/getFile.py/access?resId=1&materialId=0&contribId=35&sessionId=0&subContId=0&confId=96020.

LHC NEWS

Further commissioning improves luminosity

By the end of June the LHC was making good progress towards delivering the first 100 nb^{-1} of integrated luminosity at an energy of 3.5 TeV per beam. This followed some two weeks devoted to beam commissioning, with the goal of achieving stable collisions at 3.5 TeV with the design intensity of 8×10^{11} protons per bunch. The first days of July saw machine fills for physics with six bunches per beam at this nominal intensity, providing further boosts to the goal of reaching 1 fb^{-1} before the end of 2011.

The first collisions at 3.5 TeV between bunches at nominal intensity were achieved on 26 May, following earlier tests on ramping the energy with bunches at this intensity (*CERN Courier* June 2010 p5). However, to make progress towards further stable running, the accelerator team needed to perform a variety of commissioning studies to establish the appropriate baseline for operating the LHC in these conditions.

These studies involved establishing the optimal reference settings for both ramping the energy and for a "squeeze" to β^* of 3.5 m, prior to bringing the beams into collision. (The squeeze reduces the beam size at the interaction points and is described by the parameter β^*, which gives the distance from the interaction point to the place where the beam is twice the size.) The settings include the all-important collimator positions, a key part of the machine protection system, and this alone involved 108 setup operations.

The work also involved commissioning the transverse damper – basically, an electrostatic deflector – to subdue instabilities in the nominal bunches as they are ramped to 3.5 TeV.

By 26 June the teams were ready with a new sequence to ramp, squeeze and collapse the separation at the interaction points to bring three bunches per beam at nominal intensity into collision at 3.5 TeV. With a physics run at an instantaneous luminosity of $5 \times 10^{29}\ cm^{-2}\ s^{-1}$, the integrated luminosity in the experiments since 30 March already doubled, rising to more than 30 nb^{-1}. A few days later, on 7 July, the machine ran with seven bunches per beam at nominal intensity and achieved a new luminosity record of $10^{30}\ cm^{-2}\ s^{-1}$. This is one more step towards the goal for 2010 of $10^{32}\ cm^{-2}\ s^{-1}$, which will require 800 nominal bunches per beam.

● Sign up to follow CERN's Twitter feed for the latest LHC news. See http://twitter.com/cern/.

First LHC results aired in Hamburg

"Physics at the LHC 2010", which took place at DESY in Hamburg on 7–12 June, was the first large conference to discuss 7 TeV collision data from the LHC. Covering all fields of LHC physics, it attracted 270 participants, among them many young postdocs and students.

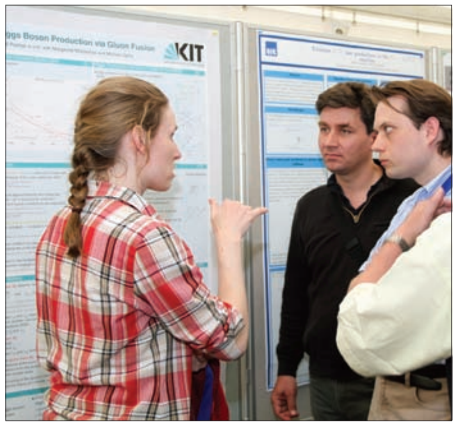
On the opening day, Steve Myers, CERN's director for accelerators and technology, gave an overview of the LHC's status and the steps required to increase the luminosity. The spokespersons of the four big experiments, Fabiola Gianotti (ATLAS), Guido Tonelli (CMS), Jurgen Schukraft (ALICE) and Andrzej Golutvin (LHCb) summarized the commissioning of their experiments and the progress in understanding the detectors, and also flashed up the first physics results.

The main message from these presentations was that the LHC is progressing well and that the experiments are well prepared. Data-taking is going smoothly, triggers and reconstruction are working well and detectors are rapidly being understood. Data processing on the LHC Computing Grid is also performing as expected.

There was special emphasis at the conference on the operation and performance of detectors and in the afternoon sessions young researchers reported on experiences in all of the experiments. The reports showed that many design performances have already been achieved or are within close reach. One by-product of understanding the detectors is a "detector tomography", which has been performed using mainly photon conversions; this has allowed several shortcomings of the detector simulations to be identified and removed.

The pay-off for the years of hard work that led to this excellent knowledge of the detectors has been a quick turnaround time for physics results. After only a few weeks of high-energy data-taking at 7 TeV

David Gross presents his theoretical outlook.



The poster session gives time for discussions.

in the centre-of-mass with an integrated luminosity of about 16 nb^{-1} delivered to each experiment, all four collaborations have rediscovered almost the full Standard Model particle spectrum – except for the top quark, which is just round the corner.

Among the first LHC physics highlights are the observations of W and Z bosons, and of high-p_T jets. In several presentations the audience was reminded of how long the community waited for single weak bosons to be produced in the early days of the $Sp\bar{p}S$. Now, dozens of W and Z bosons have already been reported by ATLAS and CMS in different decay channels. However, there is still a long way to go to match the excellent work done in the electroweak sector by the experiments at Fermilab's Tevatron.

The political support for the LHC in Germany was touched upon on the third day of the conference. In their messages, Georg Schütte, state secretary in the German Ministry for Education and Research, and Bernd Reinert, state secretary for science and research of the state of Hamburg, expressed the keen interest of the funding bodies for further support and exploitation of the LHC.

Looking at the prospects from the scientific point of view, Mike Lamont of CERN sketched the plans for the LHC and emphasized the goal of collecting 1 fb^{-1} proton-collision data per experiment at 7 TeV before the end of 2011 (plus two heavy-ion runs). With this integrated luminosity, the LHC will already compete with the Tevatron in a number of fields. It would be sensitive to W' and Z' bosons with masses up to 1.9 TeV and 1.5 TeV, respectively, and low-mass supersymmetry would also be in reach. However, the Higgs – if this is indeed nature's choice – will most likely take longer to be discovered.

The last day of the conference was dedicated to overview talks from other fields (astroparticle physics, dark-matter physics) and concluded with an excellent experimental summary by CERN's Peter Jenni and a visionary overview of theory by David Gross, the 2004 Nobel laureate in physics. Gross reflected on 20 predictions made in 1993 – a good fraction of which have already come true. There is reason to hope that at least a few others (among them the discoveries of the Higgs, supersymmetry and the origin of dark matter, and the transformation of string theory into a real predictive theory) will also come true. There are exciting times ahead.

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

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

ACCELERATORS

Two-orbit energy recovery linac operates at Novosibirsk free-electron laser facility

Over the past 30 years, the Budker Institute of Nuclear Physics in Novosibirsk has developed many free-electron lasers (FELs). The most recent one, which has been in operation since 2003, is a continuous-wave terahertz FEL based on a single-orbit energy-recovery linac (ERL), which is the world's most intense radiation source at terahertz wavelengths. The laboratory is now making progress in constructing a four-orbit 40 MeV electron ERL to generate radiation in the range 5–250 μm. Already operating with two orbits, this is the world's first multiturn ERL.

FELs provide coherent radiation in the wavelength range from 0.14 nm to 1 mm. They use the phenomenon of stimulated radiation from relativistic electrons moving in an undulator – a special magnet that creates a periodic alternating field such that the electron trajectory remains close to a straight line (the undulator axis). Travelling through an undulator, electrons amplify a collinear electromagnetic wave if the last one has wavelength $\lambda = d/(2\gamma^2)$, where d is the undulator period, and γ is the particle's total energy divided by its mass.

Unfortunately, the maximum electron efficiency of FELs is only about 1%, which makes energy recovery a desirable feature. The simplest realization of energy recovery for an FEL is to install it into a straight section of a storage ring. Such storage-ring FEL facilities exist now but the power of their radiation does not exceed a few watts. The intrinsic limitation of the power is caused by multiple interactions of the same electrons with light, which increases the energy spread of the beam. To achieve high light power, it is better to use a fresh beam, which is just what ERLs can do (*CERN Courier* June 2005 p26).

The Novosibirsk ERL has a rather complicated magnetic system, which makes use of a common accelerating structure (figure 1). This differs from other ERL-based FEL facilities in that it uses low-frequency (180 MHz) non-superconducting RF cavities, with continuous-wave operation. The existing terahertz FEL uses one orbit, which lies in the vertical plane. This FEL generates coherent radiation, tunable in the range 120–240 μm. It produces a continuous train of 40–100 ps pulses at a repetition rate of 5.6–22.5 MHz. The maximum average output power is 500 W, with a peak power of more than 1 MW. The minimum measured linewidth is 0.3%, which is close to the Fourier-transform limit. A beamline directs the radiation from the FEL in the accelerator hall to the user hall. It is filled with dry nitrogen and separated from the accelerator vacuum by a diamond window, and from the air by polyethylene windows. Radiation is delivered to six stations, two of which are used for the measurement of radiation parameters, and the other four by users, typically biologists, chemists and physicists.

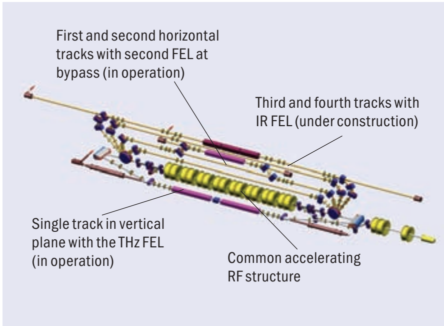
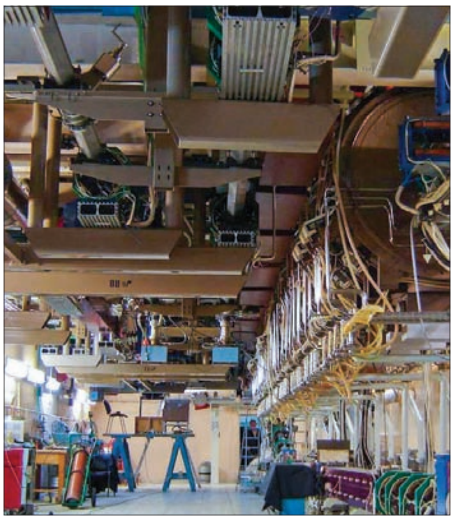


Fig. 1. The Novosibirsk ERL-based high power FEL facility. The terahertz FEL and the FEL at the bypass are both in operation; the third and fourth ERL tracks are under construction.



The location of two FELs in the accelerator hall. The original terahertz FEL is at the lower right, with the RF cavities of the ERL above it. Centre left is the new undulator for the bypass FEL.

The other four orbits of the final ERL lie in the horizontal plane. The beam is directed to these orbits by switching on two round magnets. The electrons will pass through the RF cavities four times, to reach 40 MeV. After the fourth orbit the beam will be used in an FEL, before being decelerated four times. A bypass with another FEL is installed at the second orbit (20 MeV). When the bypass magnets are switched on, the beam passes through this FEL. The length of the bypass has been chosen to provide the delay necessary in this case to give deceleration on the third pass through the accelerating cavities.

Two of the four horizontal orbits were assembled and commissioned in 2008. The electron beam was accelerated twice and then decelerated down to the low injection energy, thus successfully demonstrating the world's first multiorbit ERL operation. The first lasing of the FEL at the bypass was achieved in 2009, providing radiation in the wavelength range 40–80 μm. At first a significant (several per cent) increase in beam loss occurred during lasing. Sextupole correctors were therefore installed in some of quadrupoles to make the 180° bends achromatic to second order. This increased the energy acceptance for the reused electron beam. The output power is about 0.5 kW at an ERL average current of 9 mA. The output of this new FEL is near 70 μm, so the power obtained is also the world record for this wavelength range.

The beamline to deliver radiation from the new FEL to existing user stations has been assembled and commissioned. Thus, the world's first two-orbit ERL is now operating for a far infrared FEL. In the meantime, the assembly of the third and fourth ERL orbits is in progress.

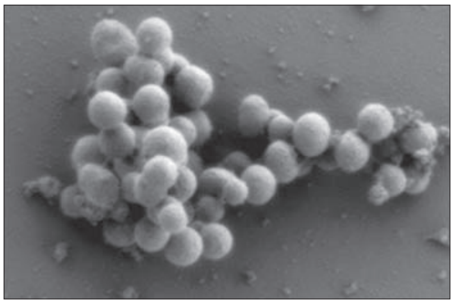
SCIENCEWATCH

Compiled by John Swain, Northeastern University

Artificial life makes its first appearance in the laboratory

Sometimes a paper has an abstract so clear that it just has to be quoted. Craig Venter and colleagues at the J Craig Venter Institutes in Maryland and San Diego have constructed a genome from scratch and inserted it into a mycoplasma cell so that it reproduces itself. Apart from using an existing mycoplasma cell as a sort of support structure for the DNA, this is as close to the creation of artificial life as anyone has ever come.

As the authors write: "We report the design, synthesis and assembly of the 1.08-Mbp *Mycoplasma mycoides* JCVI-syn1.0 genome starting from digitized genome sequence information and its transplantation into a *Mycoplasma capricolum* recipient cell to create new *Mycoplasma mycoides* cells that are controlled only by the synthetic chromosome. The only DNA in the cells is the designed synthetic DNA sequence, including 'watermark' sequences and other designed gene deletions and polymorphisms, and mutations acquired during the building process. The new cells have expected phenotypic properties and are capable of continuous self-replication."



Scanning electron micrograph of M Mycoides.

Clearly, a new age in biology has begun.

Further reading

D G Gibson *et al.* 2010 *Science* **329** 52.

Life in common

All life shares a common ancestor. This is a standard notion in biology, but one that has so far not really received a good test. After all, living things swap genetic material all of the time, so it might seem that life today must have come from more than one primordial organism.

To test the idea, Douglas Theobald of Brandeis University in Waltham, Massachusetts, selected 23 common proteins with structures that vary in details from species to species. Looking at them in 12 species – four each from the three "branches of life": archea, bacteria and eukaryotes – he found that a model with a single ancestor and single gene swapping was a remarkable 103 489 times more likely than the best multiancestor model considered.

Deep down, it looks as though all life does come from a common start.

Further reading

L D Theobald 2010 *Nature* **465** 219.

Atomic clock beats quantum limit

Atomic clocks are based on two-state systems and the uncertainty in their time measurements is constrained by the uncertainty relation between the phase and the rate at which that phase changes. This implies a quantum limit on how accurately time can be measured using conventionally accessible states. Now Ian Leroux and colleagues at Massachusetts Institute of Technology have found a way to get round this limit. The idea is to construct squeezed states that allow the uncertainty in one variable to be pushed into another, so time can be arbitrarily precisely measured without violating the uncertainty principle. The technique opens up the possibility of better GPS-like navigation and precision experiments than were previously thought possible.

Further reading

I D Leroux *et al.* 2010 *Phys. Rev. L.* **104** 250801.

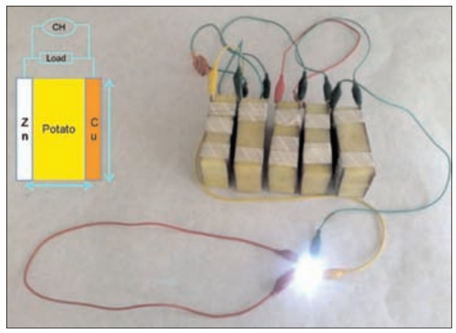
Boiled potato power

Most school children at some time made a battery by sticking copper and zinc strips into a potato. It does not work very well but now Alex Goldberg of Hebrew University in Jerusalem and colleagues have found a simple way to get 10 times the voltage: just boil the potatoes first.

Lest this sound frivolous, it turns out that energy production from potatoes can be 50 times cheaper than common batteries and could actually be useful for low-power appliances in developing countries. This is one to try at home with the kids!

Further reading

Alex Goldberg *et al.* 2010 *JRSEnergy* **2** 033103.



The basic potato battery powered two white LEDs.

Dark laser pulses

Traditional optical fibres carry information in the form of pulses of laser light, but now it could possibly be better to send information on pulses of darkness from a "dark laser". This is not quite John Cage's 4' 33", but it is almost as weird. Steven Cundiff of Colorado University and colleagues describe a mode-locked quantum-dot diode laser that is normally "on" but is "off" for well defined times; unlike the normal case where the source is normally off with well defined times when it's on. The dark pulses are 70% less intense than the background light. An advantage is that light pulses can smear as they go through a fibre, but dark pulses do not.

Further reading

Mingming Feng *et al.* 2010 *Optics Express* **18** 13385.

Compiled by Marc Türler, ISDC and Observatory of Geneva University

X-rays reveal missing matter in hot gas

X-ray observations suggest that about half of the ordinary, baryonic matter in the universe is in the form of hot, diffuse gas. The detection of absorption lines from the Sculptor Wall by the two leading European and American X-ray satellites is the strongest evidence yet that the "missing matter" in the nearby universe is in the form of diffuse gas, located in the web of large-scale structures.

The composition of the universe has been precisely determined in the past decade by cosmological studies, in particular by the analysis of the fluctuations in the map of the cosmic microwave background radiation (*CERN Courier* May 2008 p8). The matter-energy content of today's nearby universe is dominated by dark energy and dark matter, with less than 5% in the form of ordinary, baryonic matter. Observable matter in the form of stars and gas inside galaxies accounts for about only one half of the nucleons (protons and neutrons) expected from cosmology. The other half remains elusive.

The vast amount of hot, X-ray emitting gas that pervades clusters of galaxies often contains several times the mass of the actual galaxies (*CERN Courier* July 2003 p13). This suggests that the "missing matter" could be of similar nature, possibly slightly cooler (10^5–10^7 K) and less dense so that it remains almost undetectable. An alternative to a direct detection of such a warm–hot intergalactic medium (WHIM) is to search for the absorption of X-rays from a background source shining through this gas. A strong claim for the detection of absorption lines that could be attributed to the WHIM on the line of sight to the bright blazar Markarian 421 was published five years ago (*CERN Courier* March 2005 p13). However, as Taotao Fang – the lead author of the new study – points out, this earlier work was the subject of quite some debate. The main issue is that the location of the intervening gas was determined through a blind search. Therefore, the quite high significance of the X-ray absorption lines is reduced by the fact that the position of these lines was not known a priori and that they could appear at any redshift between the background source and the Earth.

An artist's illustration of gas and galaxies in the Sculptor Wall crossed by the beam of light from a background blazar. (Courtesy NASA/CXC/M Weiss.)

The new study by Fang of the University of California, Irvine, and colleagues is more robust because it searches for absorption at the position of a known foreground structure that is likely to have associated WHIM.

The team focused on a nearby filamentary structure – the Sculptor Wall – containing thousands of galaxies and chose a suitable background blazar called H2356-309 as the source of X-rays. Blazars are a type of active galaxy with a relativistic jet that points towards Earth and produces a featureless radiation spectrum. This makes it easier to detect feeble absorption lines from atoms along the line of sight. Long observations of H2356-309 with NASA's Chandra X-ray observatory and ESA's XMM-Newton satellite allowed Fang and collaborators to obtain a significant (4 σ) detection of an absorption line originating from highly ionized oxygen (O VII) at a redshift coinciding with the distance of the Sculptor Wall and consistent with the predicted temperature and density of the WHIM.

This detection by two independent satellites is the best evidence yet that the missing baryons are in the form of WHIM. The detection in the Sculptor Wall, stretching across tens of millions of light-years, suggests that the WHIM follows the filamentary, large-scale structure of the universe outlined by the distribution of galaxies and dark matter (*CERN Courier* September 2007 p11).

Further reading

T Fang *et al.* 2010 *ApJ* **714** 1715.

Picture of the month

This impressive view of the Whirlpool Galaxy (Messier 51) was taken by the 1.23-m telescope of the Calar Alto Observatory, in southern Spain. This famous galaxy in the constellation of the Hunting Dogs (*Canes Venatici*) was observed for 35 hours through red, blue and green filters, as well as a narrow-band filter for the Balmer H-α emission line at a wavelength of 656 nm. This pink emission from the recombination of ionized hydrogen was enhanced by a factor of four in the combined image to highlight the numerous star-formation regions along the spiral arms. The widespread star formation results from the compression of gas and dust in the spiral arms, which is amplified by the interaction with the smaller galaxy (NGC 5195) to the left. (Courtesy CAHA, Descubre, DSA, OAUV. Vicent Peris (OAUV/DSA/PixInsight), Jack Harvey (SSRO/DSA), Steven Mazlin (SSRO/DSA), Carlos Sonnenstein (Valkànik/DSA) and Juan Conejero (PixInsight/DSA).)

CERN COURIER ARCHIVE: 1967

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

CERN

Vacation students arrive for the summer months

Once again this year some 100 students have chosen to spend their summer vacation working at CERN. For periods varying from two to four months they will mingle with the CERN personnel, studying physics problems, take part in an experiment and follow a series of lectures, instead of sun-bathing on a beach at the seaside.

The students come from the 13 member states of CERN and were carefully chosen from over 350 who applied. They have all spent at least three years at University specializing in physics, electrical engineering, electronics or mathematics. During their stay they join one or other of the Divisions: proton synchrotron, synchrocyclotron, track chambers, nuclear physics apparatus, storage rings, data handling and health physics, where they will be involved in the everyday work. They can, in particular, take part in the development and make use of the experimental equipment, become familiar with the use of electronic computers and work on the new accelerator projects.

This annual invasion is not designed to step up the output of work from CERN but rather to give the young university students the opportunity to gain experience in the field of their studies, to learn to work in a team, to have some foretaste of their future careers in research laboratories and in industry.

In addition, the students have the chance to attend a series of lectures and special courses given by CERN specialists, including some of the Directors of Departments and Division Heads, on subjects such as computer programming, accelerator technology, theoretical physics, experiments in sub-nuclear physics, etc.

In this way, the 100 vacation students will take part in the life of a big laboratory such as CERN, and will be able to improve their theoretical grounding through the lectures and their practical experience though their work in the different Divisions which receive them.

● From the article on p128.

COMPILER'S NOTE

Summertime and the living is... crowded. Each year vacation students – now called summer students – arrive at CERN along with those migratory visitors who regularly appear about now. This summer, with so many people already on-site for LHC data-taking and the transformation of the Restaurant 1 area in full swing, the premium for ever-popular *al fresco* dining is at an all-time high.

Although better known for its research programme than for its advanced educational courses, CERN will this year welcome 149 students from the 20 member states and 49 from non-member states. There must be some 5000 ex-CERN summer students spread around the world by now. What are they all doing? Finding out could highlight important socioeconomic spin-offs from pure research. The new CERN Global Network is making use of the most notable example – the World Wide Web – to enable contact with the community of former "CERNois/es". So, past students, make yourselves known.

ERICE

International physics school in Sicily

The fifth Course of the International School of Physics "Ettore Majorana" took place between 1 and 14 July at Erice (Trapani) Sicily. Some 127 participants came from 62 laboratories in 30 countries. There were 34 hours of lectures, 15 seminars and 30 discussion sessions.

Lecturers at the school, left to right, B Zumino, S Coleman, A Zichichi, N Cabibbo, S Glashow, M Gell-Mann. (Courtesy Foto Piacentino).

The lectures covered: weak and electromagnetic currents (N Cabibbo, CERN); the theory of soft pions (S Coleman, Harvard University, US); the relativistic quark model of baryons and mesons (M Gell-Mann, California Institute of Technology, Pasadena, US); chiral symmetry and strong interactions (S Glashow, Harvard University, Cambridge, Massachusetts, US); meson resonances (I Hughes, University of Glasgow, UK); the administration of radiative corrections (B Touschek, Laboratori Nazionali di Frascati, Italy); the method of the algebra of fields and that of phenomenological Lagrangians (B Zumino, New York University, US).

Fifteen seminars followed the lectures and gave B Gregory, CERN, W Jentschke, DESY, RFA, and G H Stafford, of Rutherford High Energy Laboratory, UK, the opportunity of reporting various experiments carried out in their respective laboratories.

The "Provincia di Catania" where Ettore Majorana was born [a renowned theorist who in 1938, at the age of 31, mysteriously disappeared for ever], has established an annual prize called Premio Internazionale di Fisica "Ettore Majorana" to honour his memory. This prize was given, on this first occasion, to Murray Gell-Mann for his "extraordinary contribution of original and fundamental ideas which have remarkably extended our understanding of the fundamental properties of matter ... the following deserve special mention: 1) the law of strangeness conservation; 2) the theoretical prediction of the existence of the K_2^0 meson; 3) the eight-fold way theory of approximate symmetry; 4) the algebra of currents; 5) the notion of quarks. All of these ideas concern the symmetry properties of elementary particles, a subject which Ettore Majorana investigated with such brilliancy and enthusiasm."

● From the article on pp148–150.

Workshop looks deep into the proton and QCD

The DIS 2010 meeting in Florence covered a variety of collider results, despite the travel disruptions caused by ash from the Icelandic volcano. First measurements from the LHC at 7 TeV were one of the highlights.

The International workshop on Deep Inelastic Scattering and Related Subjects began as a forum for discussing results on deep inelastic scattering (DIS) from the electron–proton collider, HERA. However, it has quickly become successful at bringing together theorists and experimentalists to discuss results from all collider experiments, both in terms of the latest developments in measurements of the proton structure and in QCD dynamics in general. This year the brand-new measurements of inclusive properties of proton–proton interactions at the LHC found a natural niche for discussion in the 18th workshop, DIS 2010, held in Florence on 19–23 April.

The DIS 2010 logo was in some ways prophetic: many participants had to find new modes of transport to the workshop as a result of the travel disruptions across Europe caused by the volcanic ash cloud.

Volcanic disruptions

The cloud of volcanic ash present over most of Europe on the weekend before the workshop caused many flight cancellations and around 140 participants were unable to reach Florence in person; notably there were almost no participants from the UK or the US. On the other hand, more than 200 participants from mainland Europe embarked on long and often adventurous journeys to reach the conference site, a 16th-century cloister in the old part of the city. Owing to the late arrivals, the first day of plenary talks started a little later than planned – immediately with a coffee break, followed by an introduction from the director of INFN Florence, Pier Andrea Mandò.

The programme continued with a full agenda of plenary talks that set the scene and introduced a wealth of experimental results and recent developments in theory. Monica Turcato of Hamburg University and Katja Krueger of Heidelberg University presented the highlights from the ZEUS and H1 experiments at HERA. Horst Fischer of Albert-Ludwigs-Universität Freiburg reviewed the results on spin from all experiments. Thomas Gehrmann of Universität Zürich and Stefano Forte of Università di Milano reported on the recent progress in perturbative QCD. The session ended with the highlights from the ATLAS and CMS experiments at the LHC, with Thorsten Wengler of Manchester University and Ferenc Sikler of KFKI RMKI, Budapest, having the honour of showing the first published results on charged-particle spectra at 900 GeV and 2.36 TeV, as well as the first preliminary distributions at 7 TeV.

The opening day ended with a welcome cocktail, during which the conveners of the seven parallel sessions set a plan for installing EVO videoconferencing facilities to allow remote participation for those unable to get there, and reshuffled their programmes. Paul Laycock of Liverpool University was appointed convener of the Future of DIS working group "on the fly", so relieving the organizers of a difficult situation.

The following two and a half days were dedicated to parallel sessions, which were held in the cloister's painted rooms and library. The working groups covered a broad programme: parton densities; small-x, diffraction and vector mesons; QCD and final states; heavy flavours; electroweak physics and searches; spin physics; and the future of DIS.

The final two days of the conference began early, at 8.00 a.m., with plenary talks by US speakers over EVO. These included reports on: the rich physics of the CDF and DØ experiments at the Tevatron, by Massimo Casarsa and Qizhong Li of Fermilab; heavy-ion physics at RHIC, by Bill Christie of Brookhaven; and DIS results at Jefferson Lab, by Dave Gaskell. The plenary session on Friday had CERN's Mike Lamont as a special guest, who reported on the status of the LHC accelerator and its performance. The conveners of the seven working groups summarized their sessions, splitting their reports ▷

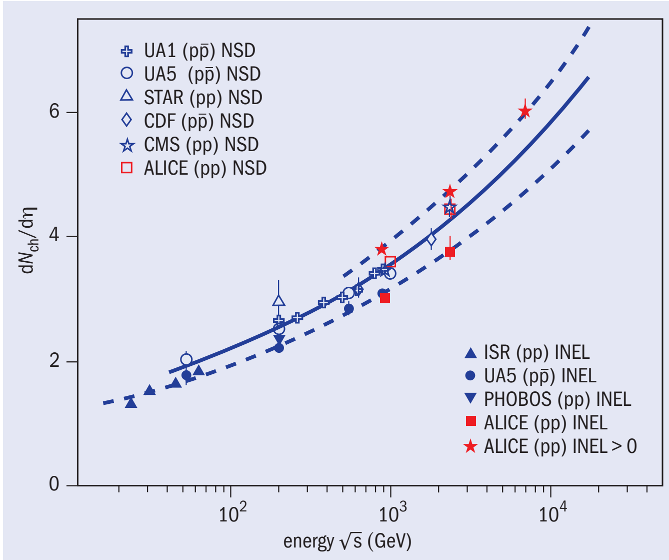


Fig. 1. Charged multiplicities from different experiments as a function of centre-of-mass energy, including first results at 7 TeV from the ALICE experiment. NSD stands for "inelastic – single diffractive" and INEL indicates inelastic events, INEL>0 having at least one track.

into theoretical and experimental parts. Halina Abramowicz of Tel Aviv University concluded the workshop, pointing out how the different topics such as parton densities, low-x, diffraction, jets, heavy flavours and spin physics are all tools for improving understanding of the structure of the proton and its implications for the LHC.

Bright horizons

The combined results of ZEUS and H1 in neutral-current and charged-current cross-sections, used as input to fits of the parton distributions in the proton, have led to an incredible accuracy (1–2%), which allows a 5% uncertainty in the prediction of W and Z production at central rapidities at the LHC. The recent inclusion in the fits of combined data on charm reveals that the QCD evolution is sensitive to the treatment of heavy flavours and that the choice of the charm mass plays an important role in the predictions for the LHC. H1 and ZEUS are now focusing on the extension of the precision inclusive measurements to high/low photon virtualities, Q^2, and high $x_{Bjorken}$. Also on the way is the completion of jet and heavy-flavour measurements based on all of the HERA statistics (0.5 fb^{-1} per experiment). Together, these will provide stringent tests of QCD at all Q^2 and will further constrain the proton parton distributions.

Meanwhile, CDF and DØ now have 7 fb^{-1} each on tape and are sensitive to processes with cross-sections below 1 pb. Such a harvest provides a number of outstanding electroweak and QCD results: running α_s has been measured at the highest p_t ever, and the combined W mass measurement from the Tevatron is more precise than the direct measurements at LEP. The combined limit on the Standard Model Higgs lies in the range $163 < M_{Higgs} < 166$ GeV at 95% confidence level. More results are on the horizon, with the 10 fb^{-1} expected by the end of 2011.

The newborn LHC experiments are performing well and are taking their first look at the particle spectra provided by nature at previously unexplored centre-of-mass energies. A few weeks after the first collisions, distributions at 7 TeV were already available. Figure 1

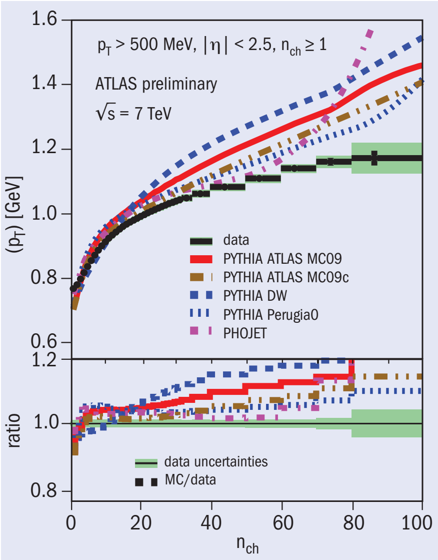


Fig. 2. Preliminary charged-particle transverse momentum (p_T) spectra at 7 TeV from the ATLAS experiment, compared with various Monte Carlo (MC) predictions.

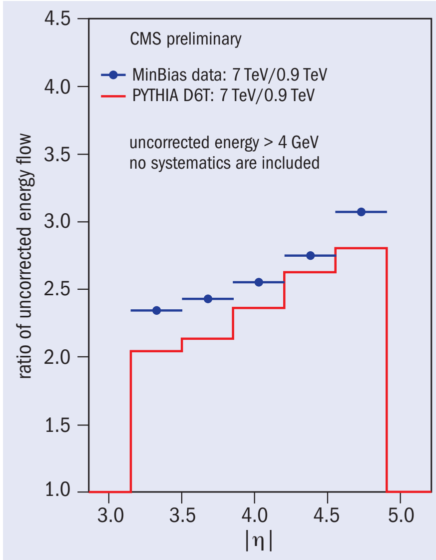


Fig. 3. Preliminary results from the CMS experiment on the ratio between the energy flow at 7 TeV and 0.9 TeV, as a function of rapidity, |η|, compared with the Pythia Monte Carlo.

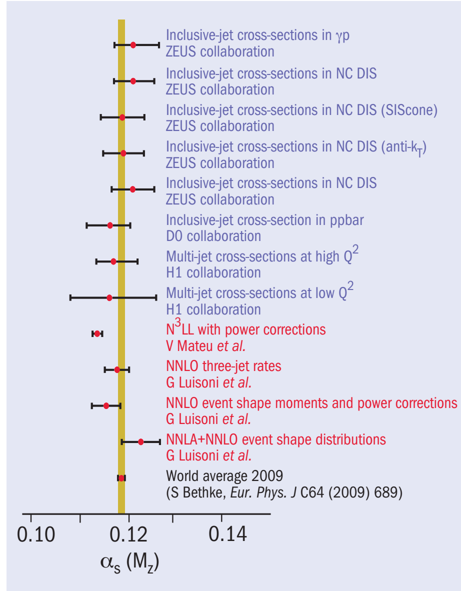


Fig. 4. A compilation of results on α_s together with some calculations presented at DIS 2010. (Courtesy of Claudia Glasman.)

shows the multiplicity of charged particles as a function of the centre-of-mass energy from different measurements, including from ALICE at 7 TeV. Figure 2, where the average transverse momentum as a function of the charged-particle multiplicity of ATLAS data at 7 TeV is compared with various Monte Carlos (MCs), seems to point to the inadequacy of the models at this energy.

With increasing centre-of-mass energy, the momentum fraction of the partons can be small and the probability of multiparton interactions increases. Looking in detail at the event topology with the available LHC data is already informative: comparing the forward energy flow from minimum-bias events at different √s provides a new, independent constraint on the underlying event models. For example, figure 3 shows the ratio of energy flow measured by CMS at 7 TeV and 0.9 TeV as a function of the rapidity, compared with the Pythia MC.

Exclusive reactions – mainly at HERMES, Jefferson Lab and RHIC – allow the extraction of the generalized parton distributions. This was defined at the workshop as "a major new direction in hadron physics", aimed at the 3D mapping of the proton and, more generally, of the nucleon.

In all, with results from Belle at KEK, BaBar at SLAC, COMPASS at CERN – as well as from Jefferson Lab, RHIC, the Tevatron, HERA and LHC experiments – QCD was seen at work over a range of studies from e^+e^- to muon scattering and DIS to heavy ions and up to the energy frontier of LHC. In this stimulating contest, theory is preparing for present and future challenges with the first next-to-next-to-leading order (NNLO) calculations of precision observables and NNLO parton distributions. An example of the interplay between the precision of the available data and the theoretical predictions is given in figure 4, which shows a compilation of all of the α_s measurements presented in the QCD session of the workshop.

The two main future projects, the LHeC electron–proton collider and the EIC electron–ion collider, were discussed extensively in the session on the future of DIS. The interest manifested by 350 or so registrations for the workshop promises a bright future for the field as well as for the DIS workshop series. The next workshop will be held at Jefferson Lab in April 2011 – a site in the US will be the ideal place to discuss future facilities.

● The workshop was organized by the University and INFN Florence, and by the University of Piemonte Orientale. We would like to thank the sponsors: INFN, DESY, CERN, Jefferson Laboratory, Brookhaven National Laboratory and CAEN Viareggio. Special thanks go to our co-organizers Giuseppe Barbagli, Dimitri Colferai and Massimiliano Grazzini, to all of the students and postdocs of our universities who helped out, and to the founder of the workshop series, Aharon Levy.

Further reading

For more about the programme and presentations at DIS 2010, see http://indico.cern.ch/conferenceTimeTable.py?confId=86184.

Résumé

Un atelier passe au crible les protons et la QCD

L'Atelier international sur la diffusion profondément inélastique et les sujets connexes était à l'origine un forum destiné à la discussion des résultats concernant la diffusion profondément inélastique en provenance du collisionneur électron–proton HERA. Il a cependant bien vite démontré sa capacité de réunir des théoriciens et des expérimentateurs pour discuter ensemble les résultats de toutes les expériences en collisionneur, s'agissant des dernières avancées des mesures de la structure du proton et de la dynamique QCD en général. Cette année, les toutes récentes mesures des propriétés inclusives des interactions proton–proton au LHC ont trouvé naturellement leur place dans la discussion lors du 18e atelier (DIS 2010), qui s'est tenu à Florence du 19 au 23 avril

Elisabetta Gallo, *INFN Firenze, and* **Marta Ruspa**, *Università del Piemonte Orientale and INFN Torino.*

PAX promotes beams of polarized antiprotons

The goal of a proton–antiproton collider with both beams polarized is coming a step nearer with the PAX collaboration's proposal to test polarization by spin filtering at CERN's Antiproton Decelerator.

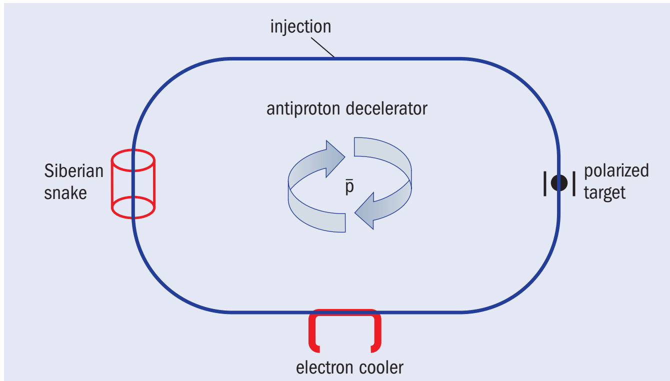


Fig. 1. Antiprotons injected into the AD are decelerated to energies of around 50–500 MeV. The beam polarization is generated by spin-dependent attenuation in the polarized target. The Siberian snake is required to study the longitudinal spin dependence of the proton–antiproton interaction.

The physics potential for QCD experiments with high-energy polarized antiprotons is enormous but until now many experiments have been impossible owing to the lack of a high-luminosity beam. This situation could change with the advent of a stored beam of polarized antiprotons and the realization of a double-polarized, high-luminosity antiproton–proton collider. The collaboration for Polarized Antiproton Experiments (PAX) has already formulated the physics programme that would be possible with such a facility (PAX collaboration 2006). Following studies with proton beams, it is now planning to make the first measurements with polarized beams at CERN's Antiproton Decelerator (AD), which is currently the world's only stand-alone antiproton storage facility.

The experimental approach adopted by the PAX collaboration to produce a beam of polarized antiprotons is based on spin filtering, a technique that exploits the spin dependence of the strong interaction (Oellers *et al.* 2009 and *CERN Courier* April 2009 p8). The total cross-section, σ, depends on the relative orientation of the spins of the colliding particles, i.e. $\sigma(\uparrow\uparrow)\neq\sigma(\uparrow\downarrow)$. The method was shown to work in the 1990s with protons in a 23 MeV beam stored in the Heidelberg Test Storage Ring, which passed through a polarized hydrogen gas target (Rathmann *et al.* 1993).

In contrast to the proton–proton system, the experimental basis for predicting the build-up of polarization in a stored antiproton beam by spin filtering is practically nonexistent. It is therefore a high priority to perform a series of dedicated spin-filtering experiments using stored antiprotons together with a polarized target, which the PAX collaboration is aiming to undertake at the AD ring at CERN (PAX collaboration 2009b). Figure 1 illustrates schematically the proposed experimental set-up.

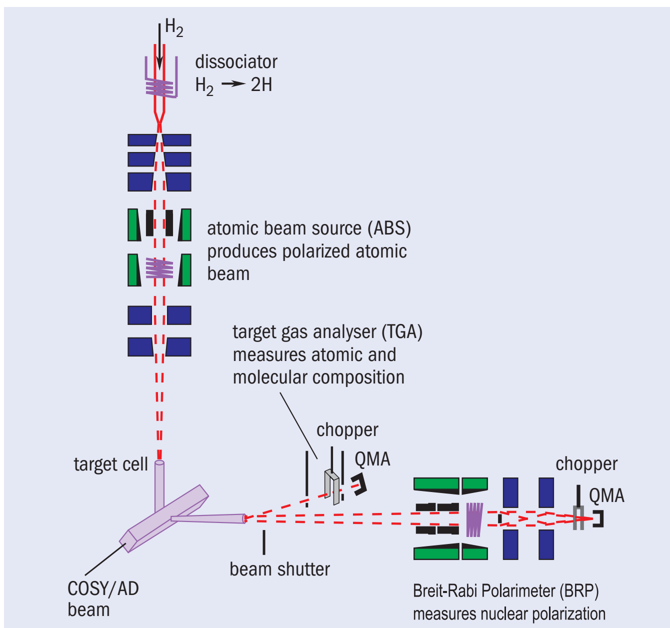


Fig. 2. The internal polarized target used in the studies at COSY. Polarized hydrogen atoms produced in the atomic beam source are injected into the target cell and the nuclear polarization of atoms extracted from the storage cell is determined with the Breit-Rabi polarimeter. The Target Gas Analyser provides information about the atomic and molecular composition of the target gas.

Expected build-up

The AD is a unique facility at which stored antiprotons in the appropriate energy range are available with characteristics that meet the requirements for the first antiproton polarization build-up studies. In 2009, the European Research Council awarded an Advanced ▷

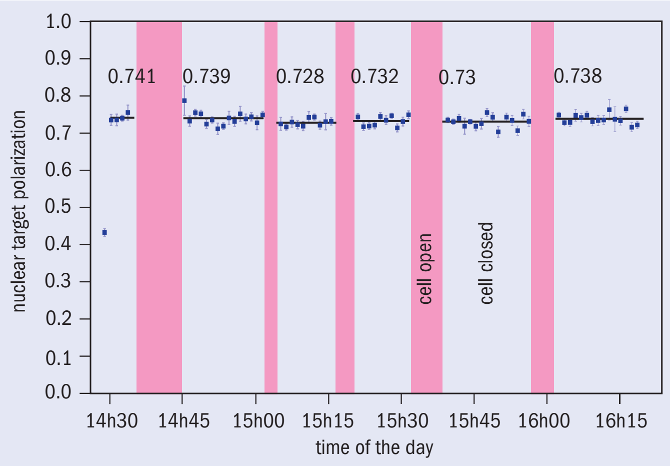


Fig. 3. Results of nuclear polarization of the hydrogen target determined with the Breit-Rabi polarimeter after opening and closing the storage cell a few times. The polarization clearly remains unaffected.

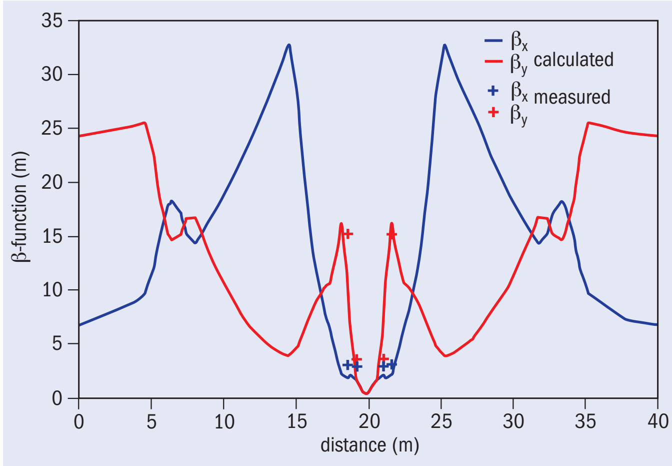


Fig. 4. COSY lattice model calculation (solid lines) for the settings with electron cooler, normal polarity and non-zero dispersion in the COSY straight sections. The measured β-functions are denoted by crosses.

Grant to the Jülich group to pursue these studies at the AD. Once an experimental proton–antiproton data base is available, work can begin to design a dedicated polarized antiproton ring.

The Jülich group has made predictions for the spin-dependent cross-sections for the expected build-up of polarization in an antiproton beam (PAX collaboration 2009). In addition, a group from the Budker Institute for Nuclear Physics, Novosibirsk, has recently generated estimates on the basis of a Nijmegen proton–antiproton potential. These indicate that antiproton beam polarizations of 0.15–0.20 (spin filtering with transverse target orientation) and 0.35–0.40 (longitudinal) might be expected (Dmitriev *et al.* 2010).

For efficient commissioning of the equipment required for measurements at the AD, the PAX collaboration is preparing polarization build-up studies using stored protons at the Cooler Synchrotron (COSY) at Jülich (PAX collaboration 2009a). Because the spin-dependence of the proton–proton interaction is well known at energies where electron cooling is available at COSY (up to 130 MeV), details of the polarization build-up process can also be studied.

Beautiful techniques

The polarized internal target (figure 2, p21), consisting of an atomic beam source and a Breit-Rabi type target polarimeter, has been successfully operated with an openable storage cell. Such an openable cell constitutes an important development for the investigations with stored antiprotons at the AD: when the beam is injected into the AD with a momentum of around 3.5 GeV/*c*, any restriction of the machine acceptance reduces the number of stored antiprotons during the spin-filtering studies. Only after cooling and deceleration to the experimental energies of interest, around 50–500 MeV, would the storage cell be closed.

The storage-cell technique works beautifully, as figure 3 shows, with the target polarization unaffected by the opening and closing of the storage cell (Barschel 2010). This constitutes a major milestone because for the first time, both high polarization and density have been achieved with an openable storage cell. While this is crucial for investigations of the spin-dependence of the proton–antiproton interaction at the AD, many other experiments employing internal storage-cell targets can also benefit from this development.

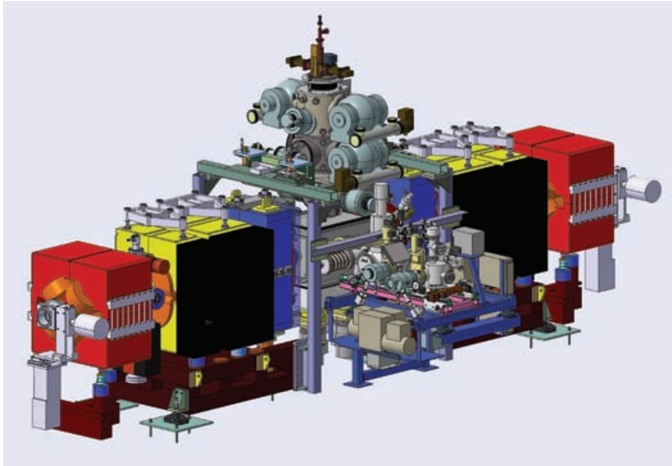


Fig. 5. Proposed PAX installation for the AD straight section between injection and electron cooling. The beam moves to the left. The AD quadrupole magnets (red) define the upstream and downstream boundaries of the low-β insertion, which consists of two long straight sections, two short arc-quadrupole magnets from COSY (yellow) and two quadrupole magnets from CELSIUS (blue). The atomic beam source is mounted above the target chamber. Helmholtz coils provide magnetic holding fields in the x, y and z directions. The Breit-Rabi polarimeter and Target Gas Analyser are mounted outwards of the ring.

The quadrupole magnets for the low-β insertion of PAX at COSY were installed during the summer shutdown in 2009. During beam-time in early 2010, the β-functions at the location of the PAX quadrupoles were measured for the non-zero dispersion setting, by varying the magnet currents. The calculated and measured values at the location of the quadrupoles match nicely, as figure 4 shows. The model calculations suggest that β-functions of β_x around 0.38 m and β_y around 0.36 m were reached. The measured beam lifetimes at COSY did not depend on whether the low-β section was powered on or not. More accurate values of β_x and β_y at the centre of the storage cell will be determined once the target chamber has been installed later this year.

In the second half of 2010, the PAX collaboration would like to perform machine studies at COSY to obtain a better insight into the actual limitations of the beam lifetime. The plan is then to carry out the first spin-filtering measurements at COSY with transversely polarized protons early in 2011.

The installation at the AD will consist of a set of additional quadrupole magnets, the internal target and a detection system surrounding the openable storage cell (figure 5). The PAX proposal for the AD is currently awaiting approval (PAX collaboration 2009b). It would be advantageous if the six additional quadrupole magnets could be installed without modification of the current AD lattice (i.e. while the central AD quadrupole magnet in that section remains in place). Subsequent machine studies to commission the low-beta section would ensure that the proposed experimental set-up for the spin-filtering studies is compatible with the other physics pursued at the AD. Once satisfactory operation of the equipment has been achieved, the first measurements of the polarization build-up in proton–antiproton scattering will be possible. A Siberian snake needs to be installed at a later stage, as figure 1 indicates, and the AD electron cooler upgraded to provide cooled antiproton beams with an energy of up to 500 MeV.

Further reading

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V F Dmitriev, A I Milstein and S G Salnikov 2010 http://xxx.lanl.gov/abs/1004.4716.

D Oellers *et al.* 2009 *Phys. Lett. B* **674** 269.

PAX collaboration 2006 *Technical Proposal for Antiproton–Proton Scattering Experiments with Polarization*, update www.fz-juelich.de/ikp/pax/proposals/files/techproposal20060125.pdf.

PAX collaboration 2009a *Proposal for Spin Filtering Studies at COSY*, www.fz-juelich.de/ikp/pax/proposals/files/proposal20090723.pdf.

PAX collaboration 2009b *Proposal Measurement of the Spin-Dependence of the ppbar Interaction at the AD-Ring*, http://arxiv.org/abs/0904.2325.

F Rathmann *et al.* 1993 *Phys. Rev. Lett.* **71** 1379.

Résumé

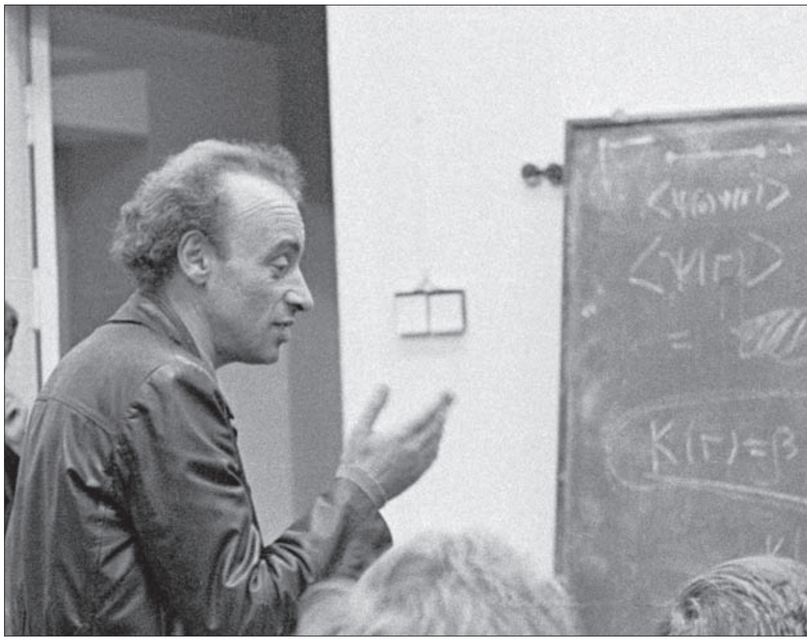
PAX milite en faveur des faisceaux d'antiprotons polarisés

Alors que le potentiel pour la physique des expériences avec antiprotons polarisés de haute énergie est immense, un grand nombre d'expériences étaient jusqu'ici impossibles en l'absence d'un faisceau à haute luminosité. L'avènement d'un faisceau stocké d'antiprotons polarisés et la construction d'un collisionneur antiproton-proton double polarité à haute luminosité pourraient toutefois changer les choses. La collaboration PAX a déjà élaboré le programme de physique qu'une telle installation rendrait possible. La collaboration, qui vient de mener des études sur des faisceaux de protons, s'apprête maintenant à effectuer les premières mesures avec faisceaux polarisés au décélérateur d'antiprotons du CERN (AD).

Paolo Lenisa, *Universitá di Ferrara and INFN, and* **Frank Rathmann**, *Institut für Kernphysik, Forschungszentrum Jülich, spokespersons of the PAX collaboration.*

QCD scattering: fro

Dmitri Diakonov looks at some of the work behind two equations that play a vital role in calculating QCD scattering processes at today's high-energy particle colliders.



Vladimir Gribov (seen here in 1979) led the group in Leningrad, now St Petersburg, that work on high-energy scattering in the 1960s. (Courtesy D Diakonov.)

Most particle physicists will be familiar with two famous abbreviations, DGLAP and BFKL, which are synonymous with calculations of high-energy, strong-interaction scattering processes, in particular nowadays at HERA, the Tevatron and most recently, the LHC. The Dokshitzer-Gribov-Lipatov-Alterelli-Parisi (DGLAP) equation and the Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation together form the basis of current understanding of high-energy scattering in quantum chromodynamics (QCD), the theory of strong interactions. The celebration this year of the 70th birthday of Lev Lipatov (p33), whose name appears as the common factor, provides a good occasion to look back at some of the work that led to the two equations and its roots in the theoretical particle physics of the 1960s.

Quantum field theory (QFT) lies at the heart of QCD. Fifty years ago, however, theoreticians were generally disappointed in their attempts to apply QFT to strong interactions. They began to develop methods to circumvent traditional QFT by studying the unitarity and analyticity constraints on scattering amplitudes, and extending Tullio Regge's ideas on complex angular momenta to relativistic theory. It was around this time that the group in Leningrad led by Vladimir Gribov, which included Lipatov, began to take a lead in these studies.

Quantum electrodynamics (QED) provided the theoretical laboratory to check the new ideas of particle "reggeization". In several pioneering papers Gribov, Lipatov and co-authors developed the leading-logarithm approximation to processes at high-energies; this later played a key role in perturbative QCD for strong interactions (Gorshkov *et al.* 1966). Using QED as an example, they demonstrated that QFT leads to a total cross-section that does not decrease with energy – the first example of what is known as Pomeron exchange. Moreover, they checked and confirmed the main features of Reggeon field theory in the particular case of QED.

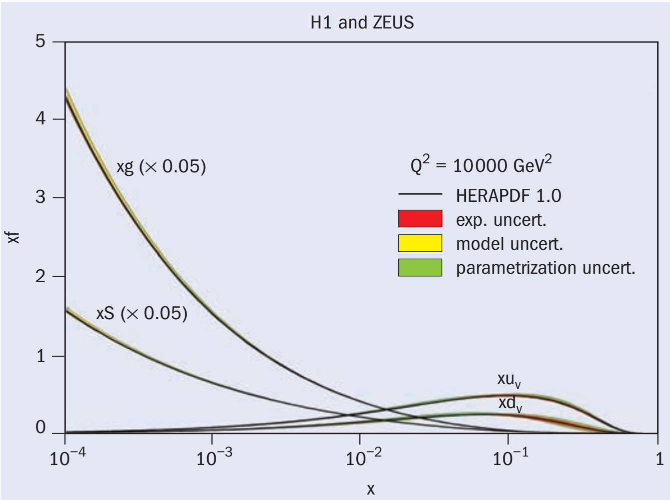
By the end of the 1960s, experiments at SLAC had revealed Bjorken scaling in deep inelastic lepton-hadron scattering. This led Richard Feynman and James Bjorken to introduce nucleon constituents – partons – that later turned out to be nothing other than quarks, antiquarks and gluons. Gribov became interested in finding out if Bjorken scaling could be reproduced in QFT. As examples he studied both a fermion theory with a pseudoscalar coupling and QED, in the kinematic conditions where there is a large momentum-transfer, Q^2, to the fermion. The task was to select and sum all leading Feynman diagrams that give rise to the logarithmically enhanced $(\alpha \log Q^2)^n$ contributions to the cross section, at fixed values of the Bjorken variable $x=Q^2/(s+Q^2)$ between zero and unity, where s is the invariant energy of the reaction.

At some point Lipatov joined Gribov in the project and together they studied not only deep inelastic scattering but also the inclusive annihilation of e^+e^- to a particle, h, in two field-theoretical models, one of which was QED. They showed that in a renormalizable QFT, the structure functions must violate Bjorken scaling (Gribov and Lipatov 1971). They obtained relations between structure functions that describe deep inelastic scattering and those that describe jet fragmentation in e^+e^- annihilation – the Gribov-Lipatov reciprocity relations. It is interesting to note that this work appeared at a time before experiments had either detected any violation in Bjorken scaling or observed any rise with momentum transfer of the transverse momenta in "hard" hadronic reactions, as would follow from a renormalizable field theory. This paradox led to continuous and sometimes heated discussions in the new Theory Division of the Leningrad (now Petersburg) Nuclear Physics Institute (PNPI) in Gatchina.

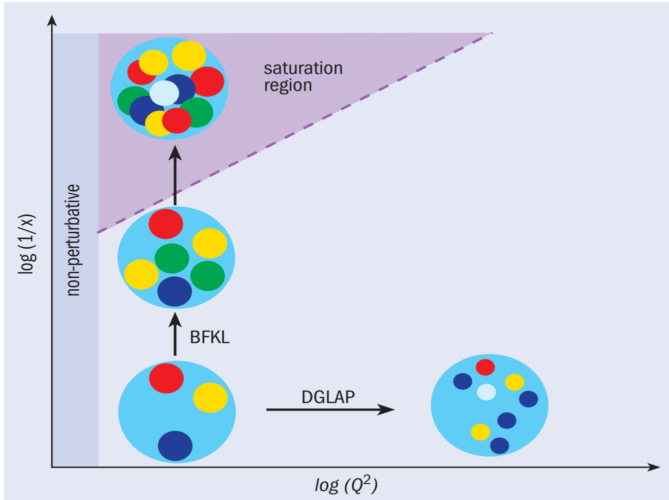
Somewhat later, Lipatov reformulated the Gribov-Lipatov results for QED in the form of the evolution equations for parton densities (Lipatov 1974). This differed from the real thing, QCD, only by colour factors and by the absence of the gluon-to-gluon-splitting kernel, which was later provided independently by Yuri Dokshitzer at PNPI, and by Guido Altarelli and Giorgio Parisi, then at Ecole Normale Superieure and IHES, Bures-sur-Yvette, respectively (Dokshitzer 1977, Altarelli and Parisi 1977). Today the Gribov-Lipatov-Dokshitzer-Altarelli-Parisi (DGLAP) evolution equations are the basis for all of the phenomenological approaches that are used to describe

om DGLAP to BFKL

hat began



*The DGLAP equations form the basis for extracting parton distribution functions from data at the electron–proton collider HERA. This figure shows the proton–parton densities extracted from the combined H1 and ZEUS measurements, for virtuality, Q^2=10 000 GeV^2, corresponding to W production at the LHC. The gluon (xg) dominates the proton content at low Bjorken-x (*CERN Courier *January/February 2010 p21).*



As a proton is probed at increasing Q^2, the number of partons rises but their size decreases, as described by the DGLAP equations. By contrast, when the fraction of momentum carried by a parton, x, becomes smaller, the number of partons increases, but their size stays the same; this is where the BFKL evolution applies. Eventually the partons should start to overlap – a region that the LHC should explore.

hadron interactions at short distances.

The more general evolution equation for quasi-partonic operators that Lipatov and his co-authors obtained allowed them to consider more complicated reactions, including high-twist operators and polarization phenomena in hard hadronic processes.

Lipatov went on to show that the gauge vector boson in Yang-Mills theory is "reggeized": with radiative corrections included, the vector boson becomes a moving pole in the complex angular momentum plane near j=1. In QCD, however, this pole is not directly observable by itself because it corresponds to colour exchange. More meaningful is an exchange of two or more reggeized gluons, which leads to "colourless" exchange in the t-channel, either with vacuum quantum numbers (when it is called a Pomeron) or non-vacuum ones (when it is called an "odderon"). Lipatov and his collaborators showed that the Pomeron corresponds not to a pole, but to a cut in the plane of complex angular momentum.

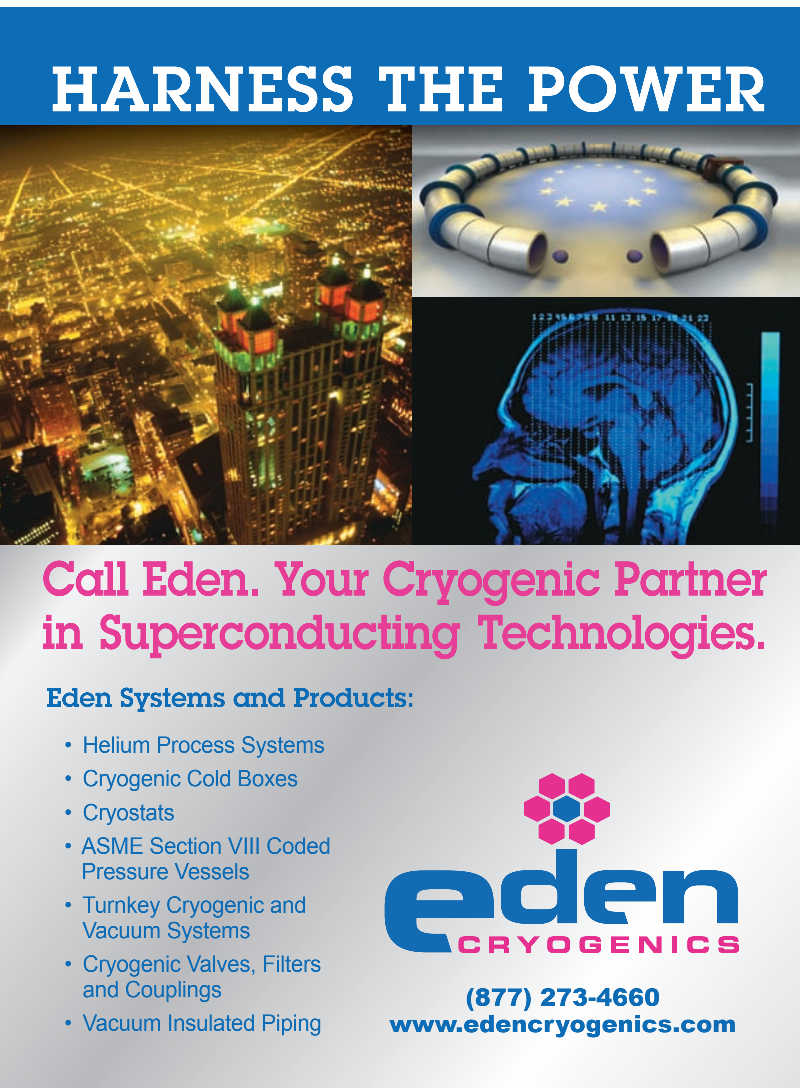
A different approach

The case of high-energy scattering required a different approach. In this case, in contrast to the DGLAP approach – which sums up higher-order α_s contributions enhanced by the logarithm of virtuality, ln Q^2 – contributions enhanced by the logarithm of energy, ln s, or by the logarithm of a small momentum fraction, x, carried by gluons, become important. The leading-log contributions of the type $(\alpha_s \ln(1/x))^n$ are summed up by the famous Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation (Kuraev *et al.* 1977, Balitsky and Lipatov 1978). Compared with DGLAP, this is a more complicated problem because the BFKL equation actually includes contributions from operators of higher twists.

In its general form the BFKL equation describes not only the high-energy behaviour of cross-sections but also the amplitudes at non-zero momentum transfer. Lipatov discovered beautiful symmetries in this equation, which enabled him to find solutions in terms of the conformal-symmetric eigenfunctions. This completed the construction of the "bare Pomeron in QCD", a fundamental entity of high-energy physics (Lipatov 1986). An interesting new property of this bare Pomeron (which was not known in the old reggeon field theory) is the diffusion of the emitted particles in ln k_t space.

Later, in the 1990s, Lipatov together with Victor Fadin calculated the next-to-leading-order corrections to the BFKL equation, obtaining the "BFKL Pomeron in the next-to-leading approximation" (Fadin and Lipatov 1998). Independently, this was also done by Marcello Ciafaloni and Gianni Camici in Florence (Ciafaloni and Camici 1998). Lipatov also studied higher-order amplitudes with an arbitrary number of gluons exchanged in the t-channel and, in particular, described odderon exchange in perturbative QCD. The significance of this work was, however, much greater. It led to the discovery of the connection between high-energy scattering and the exactly solvable two-dimensional field-theoretical models (Lipatov 1994).

More recently Lipatov has taken these ideas into the hot, new field in theoretical physics: the anti-de Sitter/conformal-field theory correspondence (ADS/CFT) – a hypothesis put forward by Juan ▷



Maldacena in 1997. This states that there is a correspondence – a duality – in the description of the maximally supersymmetric N=4 modification of QCD from the standard field-theory side and, from the "gravity" side, in the spectrum of a string moving in a peculiar curved anti-de Sitter background – a seemingly unrelated problem. However, Lipatov's experience and deep understanding of re-summed perturbation theory has enabled him to move quickly into this new territory where he has developed and tested new ideas, considering first the BFKL and DGLAP equations in the N=4 theory and computing the anomalous dimensions of various operators. The high symmetry of this theory, in contrast to standard QCD, allows calculations to be made at unprecedented high orders and the results then compared with the "dual" predictions of string theory. It also facilitates finding the integrable structures in the theory (Lipatov 2009).

In this work, Lipatov has collaborated with many people, including Vitaly Velizhanin, Alexander Kotikov, Jochen Bartels, Matthias Staudacher and others. Their work is establishing the duality hypothesis almost beyond doubt. This opens a new horizon in studying QFT at strong couplings – something that no one would have dreamt of 50 years ago.

● The author thanks Victor Fadin and Mikhail Ryskin for helpful comments.

Further reading

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Résumé
De l'équation de DGLAP à l'équation de BFKL

Les célèbres équations de DGLAP et de BFKL sont familières aux physiciens des particules. L'équation de Dokshitzer-Gribov-Alterelli-Parisi (DGLAP) et celle de Balitsky-Fadin-Kuraev-Lipatov (BFKL) fondent notre compréhension actuelle de la diffusion à haute énergie en chromodynamique quantique (QCD), la théorie des interactions fortes. Elles jouent un rôle important dans l'analyse des données, et notamment des données provenant des collisionneurs de particules : HERA, le Tevatron, et, tout récemment, le Grand collisionneur de hadrons (LHC). Dans cet article, Dmitri Diakonov retrace une partie des travaux ayant conduit à la découverte des deux équations, montrant comment ils s'enracinent dans la physique théorique des particules des années 1960.

Dmitri Diakonov, *Petersburg Nuclear Physics Institute.*

FACES AND PLACES

ANNIVERSARY

A grand finale for DESY's 50th anniversary

On 19 May the DESY laboratory brought the celebrations for its 50th-anniversary year to a close with a major event in Hamburg, which saw an impressive 2500 guests in attendance from all around the world.

The guest list read like the *crème de la crème* of particle physics and photon science, including current and former directors of fellow laboratories, such as CERN, KEK and SPring8 and SLAC. There were also numerous representatives from other laboratories, institutions and committees connected with DESY, including Argonne National Laboratory, the Budker Institute of Nuclear Physics, Jefferson Laboratory and the Laboratoire de l'Accélérateur Linéaire to name but a few.

The celebrations featured various speeches, a round-table discussion and different tours of DESY, as well as a banquet, stage shows and a much acclaimed band. The evening's – indeed, the year's – festivities came to an end way after midnight, with frenetic applause from DESY staff and guests alike.

Helmut Dosch, director of DESY, speaking at the lab's anniversary celebration. (Courtesy DESY.)

EXHIBITION

CERN shows particle physics in a new light

"Universe of particles" – CERN's new permanent exhibition in the Globe of Science and Technology – provides a hi-tech experience to intrigue the general public about some of the world's most sophisticated physics tools and experiments.

Among the first attractions to catch the eye are large projections that fill the walls and a 6 m diameter circular screen in the middle of the ground that swirls with stars, planets and particle collisions from the LHC experiments. Visitors are invited to explore spherical, interactive consoles spread around the exhibit focusing on four main themes: Why does CERN collide particles?; How do we accelerate particles?; How do we detect particles?; and The diversity of CERN. Touch-screen balls allow visitors to explore ALICE, ATLAS, CMS and LHCb through virtual tours that give a sense of scale for each and explain how they work. Object balls contain exhibits related to each theme, such as a hydrogen bottle – the proton source for all of the particle accelerators at CERN.

Following the formal inauguration on 28 June, CERN staff and users had the chance to experience the new exhibition on 29–30 June before it was officially opened to the general public on 1 July. Entry is free and opening hours are between 10.00 a.m. and 5.00 p.m., from Monday to Saturday.

The exhibition was made possible thanks to the generous support of Rolex SA. Atelier Brueckner provided the inspiration for the futuristic, hi-tech design, with programming for the interactive features supplied by IART. Bernard Pellequer, manager of the Globe, and Rolf Landua, head of CERN's Education, Visits and Exhibitions Group, have co-ordinated the project.

Inauguration of the exhibition, left to right: Shirin Brückner, from Atelier Brückner, Dante Martinelli, Swiss Ambassador at the office of the UN and other international organizations, Bruno Meier, director-general of Rolex, Rolf Heuer, director-general of CERN, and Charles Beer, Conseiller d'Etat de la Republique et Canton de Genève.

The exhibition focuses on four central themes: collisions, acceleration, detectors and diversity.

INDUSTRY

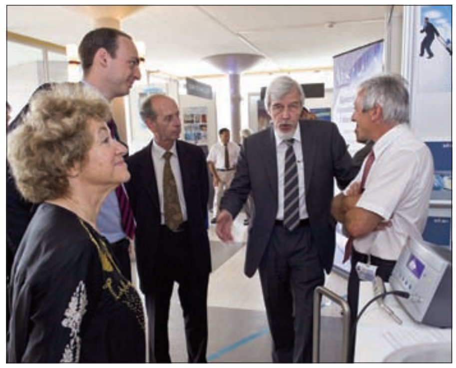
French firms display their technical know-how at CERN

Thirty-six French companies presented their latest technological advances to the CERN community during the industrial exhibition “La France au CERN”, held on 7–9 June.

The exhibition displayed products and technologies specifically related to activities at CERN and also featured several seminars. UBIFRANCE, the French Agency for International Business Development, which is responsible for promoting French technologies and know-how abroad, organized the event, and PSA Peugeot/Citroen sponsored the event.

The inauguration took place in the presence of Rolf Heuer, director-general of CERN, together with Catherine Cesarsky, the French high-commissioner for atomic energy, Michel Spiro, president of CERN Council, and Jean Baptiste Mattei from the French permanent mission at the UN in Geneva.

The next such exhibition, “Netherlands at CERN”, will be held in November.



CERN’s director-general, Rolf Heuer (centre-right), toured the exhibition with, left to right, Catherine Cesarsky, the French high-commissioner for atomic energy, François Bouillon of UBIFRANCE in Switzerland, and Michel Spiro, president of CERN Council.

OUTREACH

School children are inspired by project to ‘Draw me a physicist’

In a child’s imagination, scientists are colourful, slightly eccentric figures with unusual powers. This is what emerged from *Dessine-moi un physicien* (Draw me a physicist), an exhibition that brought together 160 drawings and definitions by children in the region close to CERN. The exhibition was the result of a 6-month-long project by CERN and 20 primary school classes from the Pays de Gex in France and the communes of Meyrin, Satigny and Vernier in Switzerland

Some 400 schoolchildren aged 9 to 11 were asked to make drawings and come up with definitions of a physicist. Subsequently they came to CERN to see things for themselves and talk to some real physicists. They used the information garnered during the visit to make a second drawing and write a second definition. Each class or school then selected eight pairs of drawings for the exhibition in CERN’s Globe of Science and Innovation. The exhibition was inaugurated by CERN’s director-general, Rolf Heuer, on 14 June and lasted until 23 June. Members of CERN Council also had a chance to visit the exhibition on 17 June.

● To view all of the drawings, visit the website http://dessine-moi-un-physicien.web.cern.ch/dessine-moi-un-physicien/.

Some children had quite “cool” ideas about physicists, even before coming to CERN.

Children at one of the schools enthusiastically show their “before” and “after” drawings.

AWARDS

Indian string theorist wins 2010 ICTP Prize

The Abdus Salam International Centre for Theoretical Physics (ICTP) has awarded its 2010 ICTP Prize to Shiraz Minwalla, a string theorist at the Tata Institute of Fundamental Research (TIFR) in Mumbai. The ICTP Prize, created in 1982, recognizes young scientists (under 40) from developing countries who work and live in those countries and who have made outstanding and original contributions in physics or mathematics.

As a researcher and faculty member at Harvard University, the Indian Institute of Technology and, most recently, TIFR, Minwalla has won many fellowships and awards. His papers have generated numerous citations and the ICTP Prize recognizes his influential work in string theory.

Each year, the ICTP Prize is awarded in honour of a scientist who has made outstanding contributions to the field in which the prize is given. This year it honours Nicola Cabibbo, the eminent theoretical high-energy physicist, who has also been a key player in ICTP since its early days and is currently chair of the ICTP Scientific Council.

Shiraz Minwalla: influential work in string theory. (Courtesy Academia Mexicana de Ciencias.)

2010 Markov Prize goes to Veniamin Berezinsky

The Institute for Nuclear Research (INR) of the Russian Academy of Sciences in Moscow has awarded the 2010 M A Markov Prize to Veniamin Berezinsky of INFN, Laboratori Nazionali del Gran Sasso and INR. He is recognized for his "outstanding contribution to the physics of cosmic rays and development of the theory of cosmogenic neutrinos at ultra-high energies". He received the award at the 8th Markov Readings in Moscow on 13 May.

Berezinsky's best known papers include the first proposal of cosmogenic neutrinos and calculations of their fluxes, written with George Zatsepin in 1968, and the proposal of the pair-production dip-model for ultra-high-energy cosmic rays, with S I Grigorieva in 1988, and with A Z Gazizov and S I Grigorieva in 2006.

The M A Markov Prize was established by INR in memory of Moisey Alexandrovich Markov (1908–1994), who was one of the founders of the institute. Markov was a leading Russian scientist, theoretical physicist and promoter of science who made pioneering contributions to research in neutrino physics, as well as in studies of fundamental problems in elementary particle physics, quantum gravity and at the boundary between particle physics and cosmology. The Markov Readings are held each year on 13 May to commemorate his birthday.

From left to right : Victor Matveev, director of the Institute for Nuclear Research of the Russian Academy of Sciences; Olga Ryazhskaya, an INR laboratory head; Veniamin Berezinsky, Laboratory Nazionali del Gran Sasso and INR; and Mikhail Panasyuk, director of the Skobeltsyn Institute of Moscow State University. (Courtesy INR.)

HONOURS

Lyn Evans elected to the Royal Society

Lyn Evans has become a fellow of the Royal Society, the world's oldest scientific academy in continuous existence, which was founded in 1660. The announcement of newly elected fellows, on 20 May, cites Evans' role as LHC project leader and as an outstanding expert in accelerator physics. "His elucidation of performance limitations allowed the CERN SPS to exceed its design performance by more than an order of magnitude, and was essential for the success of the antiproton collider that discovered the W and Z bosons ... Under his leadership, the critical components of the LHC, including the most challenging superconducting magnet system ever built, were produced, installed and commissioned."

Elected by peer review for life, the fellows provide the backbone of the Royal Society. There are currently more than 60 Nobel Laureates among the approximately 1400 fellows and foreign members. The membership has included Isaac Newton, Charles Darwin, Ernest Rutherford, Albert Einstein and, currently, Stephen Hawking.

Lyn Evans, right, with Paul Collier in the central control room as they wait for the first LHC collisions at 7 TeV in the centre of mass on 30 March 2010.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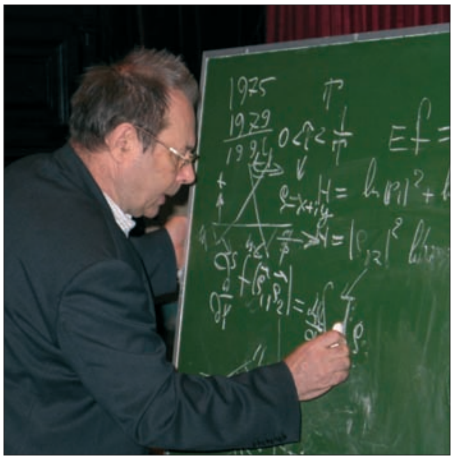
APPRECIATION

Lev Lipatov celebrates his 70th birthday

Lev Lipatov, whose name enters the abbreviations DGLAP and BFKL, which are familiar to every high-energy physicist, turned 70 in May.

Lev graduated from the University of Leningrad (now St Petersburg) in 1962 and soon joined the group of Vladimir Gribov at Ioffe Physical-Technical Institute, one of the best in the former Soviet Union. Apart from numerous visiting positions abroad, Lev was a staff member at the Petersburg Nuclear Physics Institute (PNPI). (For the first few years, before the institutes separated, the PNPI was part of the Ioffe Physical-Technical Institute in Leningrad.) In 1980 he became head of the Quantum Field Theory Department and he was elected head of the Theory Division at PNPI as well as Corresponding Member of the Russian Academy of Sciences in 1997.

Apart from his pioneering and influential work on the theory of high-energy scattering in QCD (p24), Lev is famous for his finding of the deep relation between the behaviour of perturbation series in quantum field theory, with classical solutions.



Pioneering physicist Lev Lipatov during a lecture on the BFKL theory. (Courtesy PNPI.)

Lev's research earned him the Alexander von Humboldt prize in 1995 and the prestigious Marie Curie Fellowship in 2006. In 2001 he received the International Pomeranchuk prize, simultaneously with Tullio Regge.

SPIRES database lists more than 200 papers by Lev (as of April 2010), with more than 16 000 citations. Among them are 10 papers listed as "renowned", having more than 500 citations each; three of these have around 2000 citations. A recently published Festschrift, entitled *Subtleties in Quantum Field Theory*, is a collection of papers by Lev's friends, colleagues and collaborators, which pays tribute to his pioneering contributions to various topics in modern theoretical physics.

The word "subtlety" probably best characterizes Lev's work. He typically becomes interested in certain fine details of a theory (some would call them "technical") and he then elaborates on them. He builds a new formalism based on subtleties and ultimately it becomes overwhelming and commands our understanding, rather like a beautiful game of chess (and Lev is a fine chess-player). Methods are of primary importance – the results will follow.

NEW PRODUCTS

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XP Power has announced its ECP40 series of ultra-low-profile compact open-frame 40 W AC/DC power supplies. A total of 14 models are available, comprising single, dual and triple output models. The single output models provide output voltages that range from +5 to +48 VDC; dual-output models have output-voltage combinations of +5, +12, +15 or +24 VDC; and triple outputs include +12, –12 or –15 VDC options. For more details, contact Steve Head, tel +44 118 984 5515; or e-mail shead@xppower.com.

VISITS

Clotilde Fonseca, minister of science and technology of Costa Rica, centre left, visited CERN on 18 May. She was welcomed by **Feliticas Pauss**, CERN co-ordinator for external relations, left, and **Peter Jenni**, former spokesperson for the ATLAS experiment, right. She toured the ATLAS visitor centre and had an introduction to CERN's activities by **José Salicio Diez**, centre, CERN's adviser for Latin America, before attending a UNOSAT meeting.

Gennadiy Mesyats, right, vice president of the Russian Academy of Sciences (RAS) and director of the Lebedev Physical Institute (LPI) and **Vladimir Ritus**, seated left, chief research officer at LPI and co-ordinator of the RAS Presidium Programme "CERN Accelerator Complex-related Experimental and Theoretical Research into Fundamental Interactions" came to CERN on 26–30 April. They visited experiments in which Russian institutes are involved and toured many of CERN's facilities, including the silicon facility with **Vladimir Eremin**, standing left, of the Ioffe Physical Technical Institute, and **Michael Moll** of CERN. They also met Russian physicists working at CERN and had discussions with the director-general, Rolf Heuer, and Tadeusz Kurtyka, adviser for non-member states.

The deputy minister for science, technology, and innovation in Malaysia, **Haji Fadillah bin Haji Yusof**, centre, came to CERN on 20 May. Accompanied by CERN's adviser for non-member states, **John Ellis**, right, and CERN's adviser for Malaysia, **Emmanuel Tsesmelis**, he visited the LHC superconducting magnet test hall, where he saw a model of the ATLAS detector on display. His visit also included a tour of the ATLAS visitor centre.

LETTER

Owen Lock remembered

We were saddened to read about the death of Owen Lock (*CERN Courier* June 2010 p31).

In the early 1950s, both of us took Owen's course on "High-energy nuclear physics", as it was then called. The lectures were later published in a small monograph – virtually the first in the field – providing one of the few surveys of the properties of the mu- and pi-mesons then available.

The lectures were simple and clear, and delivered with an infectious enthusiasm that was quite rare for British universities at that time. He was one of our heroes, so it was with some disappointment that we learnt of his subsequent switch to the more administrative side of CERN. We have no doubt, however, that the clarity of his thinking was a major asset in his later career.

Both Owen and his attractive and vivacious wife Eleanor were prominent at physics department parties, providing a counterpoint to some of the more conservative faculty. Owen was also an accomplished cricketer with both bat and ball. His enthusiastic participation in the annual departmental cricket match – staff versus students – will be remembered by his Birmingham colleagues.

Malcolm Derrick and Brian Musgrave, Argonne National Laboratory.

RECRUITMENT

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The international Facility for Antiproton and Ion Research (FAIR) is a large novel accelerator and experimental complex for forefront research. It will be realized in Darmstadt, Germany, with the goal of opening up new horizons for our understanding of the structure of matter, especially for hadron, nuclear, atomic and plasma physics, and related applied disciplines. Construction of the new facility with a total investment of € 1 billion will start in 2010 and is planned to start operation by 2017/2018.

FAIR will be realized through international co-operation of (so far) fifteen states which will be represented in a limited liability company under German law, the international FAIR GmbH located in Darmstadt. FAIR GmbH is to be founded this year. It will be responsible for the successful design, construction, commissioning and operation of the facility. FAIR will collaborate closely with the GSI Helmholtz Centre for Heavy Ion Research, where FAIR will be located. FAIR will actually use the present GSI infrastructure; GSI's accelerators will serve as injectors for FAIR.

At present, FAIR is represented by the FAIR International Steering Committee (ISC) with delegates from the participating states. In this capacity, the FAIR ISC is inviting applications for the appointment of the position of

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The Research Director will be a member of the Board of Directors of the FAIR GmbH. Within this function, she/he will be responsible for coordinating and supervising the construction and realization of the experiment facilities for the four FAIR communities: APPA, CBM, NuSTAR and PANDA. A major effort will be dedicated to assist the FAIR collaborations in securing the funding for the experimental setups. The Research Director represents the FAIR GmbH in the FAIR collaborations.

Candidates are expected to have outstanding experience in leading positions in international projects of research in the above-mentioned fields, as well as in science and laboratory management.

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- display skill and sensitivity in representing a scientific institution to national and international bodies and authorities;
- have a record of building strong liaisons with international and national companies and laboratories, and of negotiating with a focus on impact and result;
- have shown the ability to manage complex matters in a competitive multinational scientific environment.

The successful candidate will be appointed initially for a five-year term of office starting on 1st of October 2010.

The application should include a letter of motivation, a detailed curriculum vitae, and a publication list. It should be addressed to the **Chairman of the Scientific-Technical Committee of FAIR, Prof. Dr. A.C. Mueller, c/o Dr. B. Vierkorn-Rudolph, Federal Ministry of Education and Research (BMBF), Heinemannstr. 2, 53175 Bonn, Germany,** or by email to Beatrix.Vierkorn-Rudolph@bmbf.bund.de, who may be contacted with any questions or requests for further information.

We appreciate a simultaneous electronic application to **Beatrix.Vierkorn-Rudolph@bmbf.bund.de.**

The deadline for the receipt of applications will be **August 31st, 2010.**

Qualified women are particularly encouraged to apply.

GSI

European XFEL

Scientist for a magnetic measurement lab (f/m)
Controls engineer for a magnetic measurement lab (f/m)

The European XFEL will make available X-rays of unique quality for studies in physics, chemistry, the life sciences, materials research and others. Located in the Hamburg area, Germany, it will comprise scientific instruments for a wide range of experimental techniques. Construction of the European XFEL is underway, its commissioning is scheduled for 2014. The European XFEL GmbH is a non-profit company with DESY as the main shareholder.

This facility will generate photon beams in the hard X-ray energy range. This radiation is produced in undulator systems (magneto-mechanic devices) with lengths of 200 m and more, which use forefront technology. A central role will be given to the construction of a magnetic laboratory, which is needed to tune the magnetic properties of the undulator systems to their design values. For this lab we are looking for a:

Scientist for a magnetic measurement lab (f/m) Reference number: S-029 (CP)

The position

- extension of the existing magnetic lab to XFEL size and needs
- setup of two new magnetic benches including purchasing and commissioning
- adoption and, if needed, new implementations and developments of: magnetic sensors, measurement techniques, measurement procedures and strategies, magnetic tuning techniques, data evaluation software
- development and provision of validated measurement procedures for the XFEL undulator systems
- documentation and reporting

Requirements

- degree in experimental physics, physics engineering or equivalent
- experimental, hands-on skills
- relevant and proven hands-on experience adequate to the above mentioned responsibilities
- proven control software programming skills for the control of measurement hardware: LabWindows/C, LabView
- team orientation: willingness to collaborate with others
- background in the physics of accelerators, synchrotron radiation as well as insertion devices technology is an advantage
- communicative and collaborative personality

Controls engineer for a magnetic measurement lab (f/m) Reference number: E-013 (CP)

The position

- general hardware and software support for the construction and operation of the new magnetic lab
- configuration, design and implementation of measurement electronics
- design, construction, test, validation and maintenance of measurement setups, including participation in measurement campaigns
- software development for new measurement and data evaluation tools as required
- documentation and reporting
- general maintenance of the magnetic lab

Requirements

- degree in engineering, electronics engineering or equivalent
- proven record of projects on hard- and software control of experimental setups under LabWindows/C, LabView
- experience in electronics, motion control systems, magnetic measurements and techniques
- background in accelerator and/or synchrotron radiation labs is welcome
- organizational skills
- manual hands-on experience and skills

For additional information on either position please contact Joachim Pflüger (joachim.pflueger@xfel.eu).

Application: Please apply via e-mail to recruitment@xfel.eu and provide a motivation letter and a CV in English, as well as your work certificates and/or references.

Duration: These appointments are initially limited to 3 years.

Salary and benefits are similar to those of public service organizations in Germany. Handicapped applicants will be given preference over other, equally qualified applicants. The European XFEL GmbH is an equal opportunity, affirmative action employer and encourages applications from women. English is the working language. Knowledge of German will be considered an asset.

The European XFEL GmbH intends to achieve a widely international staff. Non-German candidates hired from abroad receive an international allowance.

Deadline for application: 15 August 2010

European XFEL GmbH | Albert-Einstein-Ring 19 | 22761 Hamburg | Germany
Mailing address: Notkestr. 85 | 22607 Hamburg | Germany

www.xfel.eu

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS IN THE FOLLOWING RESEARCH AREAS

THEORETICAL PHYSICS (N. 15)
EXPERIMENTAL PHYSICS (N. 20)

The INFN Fellowship Programme 2010/2011 offers 35 (thirtyfive) positions for non Italian citizens for research activity in theoretical (n. 15) or experimental physics (n. 20).

Fellowships are intended for young post-graduates who are under 35 years of age by November 15, 2010.

Each fellowship, initially, is granted for one year and then, may be extended for a second year.

The annual gross salary is EURO 28.000,00.

Round trip travel expenses from home country to the INFN Section or Laboratory will be reimbursed, also lunch tickets will be provided for working days.

Candidates should choose at least two of the following INFN sites, indicating their order of preference.

- INFN Laboratories:
Laboratori Nazionali di Frascati (Roma), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Sud (Catania);

- INFN Sections in the universities of:
Bari, Bologna, Cagliari, Catania, Ferrara, Firenze, Genova, Lecce, Milano, Milano Bicocca, Napoli, Padova, Pavia, Perugia, Pisa, Roma La Sapienza, Roma Tor Vergata, Roma Tre, Torino, Trieste.

The research programs, must be focused on the research fields of the Section or Laboratory selected (**http://www.infn.it**).

Applications, in electronic form, must be sent to INFN no later than November 15, 2010.

To register, candidates must use the website **http://www.ac.infn.it/personale/fellowships/**

The application form requires:

- statement of research interests;
- curriculum vitae;
- three reference letters (specifying name, surname and e-mail of each referee).

Theoretical fellowships must start from september to december 2011. Requests for starting earlier accepted.

Experimental fellowships must start no later than april 2011. Requests to posticipate accepted.

ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
(Prof. Roberto Petronzio)

Experimental Particle Physics LHCb Team Leader Position

"Horia Hulubei" National Institute of Physics and Nuclear Engineering

The 'Horia Hulubei' National Institute of Physics and Nuclear Engineering (**http://www.ifin.ro/**) at Bucharest seeks applications for a research leadership position as Team Leader of the IFIN-H partnership with the 'LHCb - A Large Hadron Collider beauty experiment' Collaboration (**http://lhcb.web.cern.ch/lhcb/**) at CERN-Geneva.

The successful candidate will have a PhD in particle physics and a minimum of fifteen years of progressive research practice, with at least 20 particle-physics papers published within ISI journals. Former experience in the LHCb area and, preferably, in research and personnel management as well as international research projects would be advantageous.

Curriculum vitae, list of publications, a statement of the research interest, and three letters of recommendations from experts in the field should be sent via e-mail to: **ralucas@nipne.ro**.
Applications will be accepted until July 31st, 2010.

SAHA INSTITUTE OF NUCLEAR PHYSICS
KOLKATA, INDIA
www.saha.ac.in

Faculty Positions

SINP invites applications for faculty positions at different levels from scientists having outstanding academic records and research achievements. At present, major research activities of the Institute are in the following broad areas: Atomic, Nuclear and Plasma Physics, Condensed Matter & Surface Physics, High Energy Physics, Theoretical & Mathematical Physics and Biophysical Sciences. SINP is an autonomous organization funded by the Department of Atomic Energy of Government of India to carry out basic research in the above broad areas. SINP has excellent state-of-the-art in-house facilities and also has collaborative access to various high-energy accelerators and synchrotron facilities across the world. We seek applicants, who will complement and extend our current research activities. Prospective applicants should also have interest in graduate teaching. Applications may be submitted anytime of the year in plain papers/e-mails with details like cover letter, resume giving entire list of publications, a statement of research plan and contact details of 5 referees. Salary and rank will be commensurate with qualifications and research experience.

Director, Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata 700064, INDIA; director.sinp@saha.ac.in

IPB

Argonne NATIONAL LABORATORY

Principal RF Engineer

The Accelerator Systems Division at Argonne National Laboratory is seeking a candidate with a strong background in low-level rf (LLRF) systems to fill a full-time position at the Advanced Photon Source (APS). As the lead engineer, the successful candidate will be responsible for the design, development, commissioning, and operation of an advanced, state- of-the-art, FPGA- and DSP-based LLRF system for the APS Short Pulse X-ray (SPX) system comprised of S-band superconducting rf deflecting cavities. The successful candidate may also work on future R&D programs including an SRF cw accelerator for an x-ray free-electron laser oscillator (XFEL-O).

Requirements:

- Ph.D. and 10+years experience/equivalent, Master Degree and 12+ years experience/equivalent, Bachelor's Degree and 15+ years experience/equivalent.
- Comprehensive knowledge in modern control systems theory and applications.
- Experience in analog and digital LLRF techniques, feedback systems, and signal processing.
- Experience in high-power rf amplifiers, cavity tuning, and beam loading compensation techniques for superconducting cavities.
- Experience in rf amplitude and phase noise measurement techniques; ADCs and DACs, FPGAs, DSPs for LLRF applications.
- Practical experience with superconducting rf technology is a plus.
- Good verbal and written communication skills.

Candidates should submit a resume through the Argonne job website at http://www.anl.gov/jobs for Requisition 315981.

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC. Argonne is an equal opportunity employer, and we value diversity in our workplace.

Argonne is an equal opportunity employer, and we value diversity in our workforce.

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Work in a stimulating international environment with the prospect of publishing in high-impact journals

Gross salary **27 k€**, tax paid net salary **>1550 €/month**
47-50 days of annual and compensatory leave

Thesis subjects cover frontline research in:

- physics
- chemistry
- biology

All new positions on www.synchrotronjobs.com or go to www.esrf.eu/jobs

Academic position in theoretical high-energy physics

A full-time tenured academic position is available at the Department of Physics and Astronomy of the University of Leuven, Belgium starting October 1, 2011 in the field of theoretical high-energy physics.
More information can be found on the web:

http://www.kuleuven.be/personeel/jobsite/vacatures/science.html

Closing date: September 30, 2010

The full-time position can be offered in one of the academic levels (full professor, professor, associate professor, assistant professor), depending on the qualifications of the candidate. The level of assistant professor will be offered for a period of five years. A positive evaluation at the end of the five-year appointment will result in a tenured appointment as associate professor.
The K.U.Leuven is an equal opportunity employer. Non-Dutch speaking candidates should be able to teach in Dutch within three years.

KATHOLIEKE UNIVERSITEIT LEUVEN

Department of Physics and Astronomy
K.U.Leuven, Belgium
http://fys.kuleuven.be/index_en.php

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MAX-PLANCK-GESELLSCHAFT

Research project leader (W2) in experimental particle physics at the Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The Max-Planck-Institut für Kernphysik (MPIK, Max Planck Institute for nuclear physics) in Heidelberg, Germany, invites applications for an experimental **research project leader position (W2)** within the division of particle and astro-particle physics.

The division conducts experimental and theoretical research in neutrino physics, in Dark Matter searches and in physics beyond the Standard Model. It is currently a strong or leading partner in the neutrino experiments Gerda, Double Chooz and Borexino as well as in the Xenon100 and Xenon1T Dark Matter search experiments. The division has furthermore strong theoretical support connecting the on-going experimental projects with other relevant projects in the field. The successful candidate is expected to play an important role in the experimental program of the division. He/she will have the opportunity to contribute to the full set of activities involving the full spectrum from R&D activities to detector planning, simulations and data analysis.

Candidates must have a Ph.D. in experimental particle or nuclear physics and should have a ‚Habilitation' or equivalent teaching qualifications. We require expertise and international reputation which fits to the experimental program of the division. We provide excellent working conditions, an inspiring surrounding within the division as well as opportunities for interactions with other groups at MPIK. In addition there exist good contacts to groups at Heidelberg University and participation in teaching activities is possible and highly welcome.

The position is permanent and the starting date is as soon as possible. The Max Planck Society wishes to increase the participation of women in its research activities. Applications by women are therefore particularly welcome. The Max Planck Society is also committed to employing more handicapped individuals and especially encourages them to apply.

Applications **under reference number 09/2010** with a full CV, a statement of research interests, a publication list and names and addresses of three referees should be sent until **September 24, 2010** to

Prof. Dr. Manfred Lindner
Max-Planck-Institut für Kernphysik
Saupfercheckweg 1, 69117 Heidelberg, Germany
Tel.: +49-6221-516-800, Sec. -801, Fax -802
Email: lindner@mpi-hd.mpg.de
http://www.mpi-hd.mpg.de/lin/

COFUNDED BY MARIE CURIE ACTIONS

EMBL

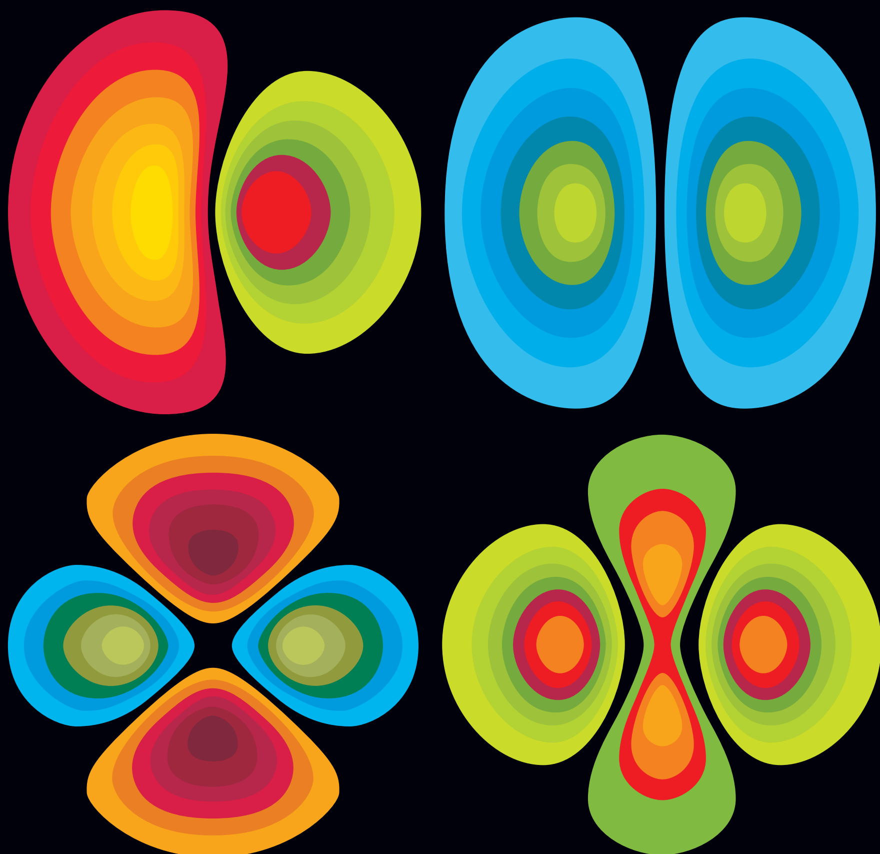
The 2010 EMBL Interdisciplinary Postdocs Call For Applications

The 2010 call for applications for the EMBL Interdisciplinary Postdocs (EIPOD) fellowships opened on June 15th. The fellowships are funded by EMBL and a Marie Curie Action Cofund Grant from the EU and provide young scientists with three years of secured funding. Complementary funding can be used to extend postdoctoral training up to a total duration of five years. Applicants are invited to propose an interdisciplinary project according to their scientific interest or may select from a set of predefined research projects.

Successful candidates will pursue interdisciplinary projects, transferring techniques to a new context or connecting scientific fields that are usually separate, across at least two labs at the five EMBL sites.

For more information and to apply online please visit:

http://www.embl.de/training/postdocs/eipod/index.html



BOOKSHELF

The Edge of Physics: A Journey to Earth's Extremes to Unlock the Secrets of the Universe by Anil Ananthaswamy, Houghton Mifflin Harcourt. Hardback ISBN 9780547394527, $25. Paperback ISBN 9780547394527 $15.95.

In his recent book *The Edge of Physics*, Anil Ananthaswamy, a science writer for *New Scientist*, covers the most extreme physics and astronomy experiments that are set to uncover the secrets of neutrinos, dark matter and dark energy, galaxy formation, supersymmetry and extra dimensions. The author takes us on an extraordinary journey over five continents to tour the best telescopes and particle detectors, from the summits of the Andes to deep down in the Soudan mine, stopping by the South Pole and paying a visit to CERN. Following him on this trip is already exciting, but reading his account of discussions with physicists, astronomers and engineers along the way is simply fascinating. He tells us about each experiment as he discovered them through discussions with the scientists involved. For example, he writes about the ATLAS experiment through the eyes of Peter Jenni, Fabiola Gianotti and François Butin, with added insight from a meeting with Peter Higgs.

This makes for lively reading about all of these experiments. He not only tells us the most striking details about how each one was built, but he also includes accurate information about the science and technology behind them, avoiding clichés in his efforts to make it understandable to all. You read about his stay at Lake Baikal, discussing neutrino physics with enthusiastic and dedicated physicists such as Igor Belolaptikov and Ralf Wischnewski, sharing stories and vodka with them on the shores of Lake Baikal in the midst of winter – the only time that the photomultiplier tubes of the underwater neutrino experiment can be serviced from the frozen surface of the lake. The reader learns about the scientific research at all of these places through personal accounts from the scientists involved. At times, it felt as if I was meeting old friends at a conference and hearing their best stories about their experiments, sharing their enthusiasm and discovering unknown details about their research.

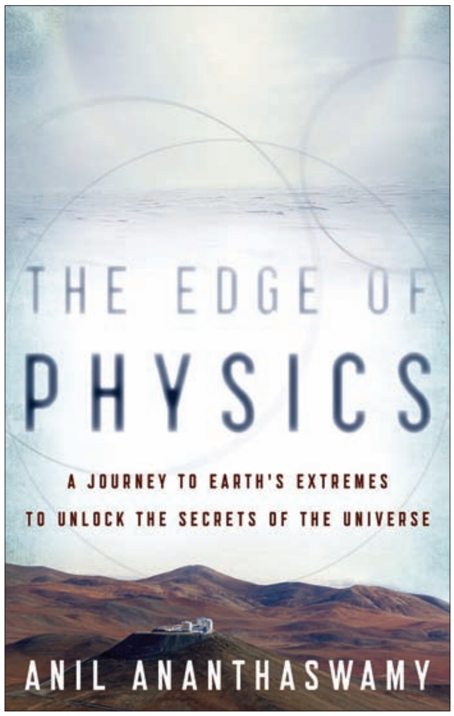
The Edge of Physics also allowed me to learn more about the best astronomy instruments, some located in idyllic places such as Hawaii, while others are under construction in the least life-sustaining places, such as in the Karoo desert in South Africa or the Hanle Valley in India. Ananthaswamy's book is as much a tribute to the science as it is to the dedicated scientists pushing the limits of knowledge. His clear explanations and entertaining style will appeal to scientists and non-scientists alike. A book not to be missed.

Pauline Gagnon, Indiana University and ATLAS.

Summer Bookshelf

Summer for physicists is the season of conferences as well as (or instead of!) well earned holidays, although this year many particle physicists will no doubt be hoping for profitable shifts on the LHC, taking up the nights as well as days.

For those who find some time for reading something other than drafts of their latest papers and preprints with new results, this Bookshelf reviews a selection of less technical books for more relaxed reading, whether on holiday or on those long plane journeys – or between shifts on the LHC!



Lake Views: This World and the Universe by Steven Weinberg, Belknap Press/ Harvard University Press. Hardback ISBN 9780674035157, $25.95.

This book collects some essays and book reviews written by Steve Weinberg between the years 2000 and 2008. They were written in his study at home, from where the author can see Lake Austin. In 25 chapters he covers an impressive number of subjects ranging from military history to his review of Richard Dawkins' book *The God Delusion*, passing through fundamental physics, missile defence, the boycott of Israeli academics and even offering some advice to young students and postdoctoral fellows.

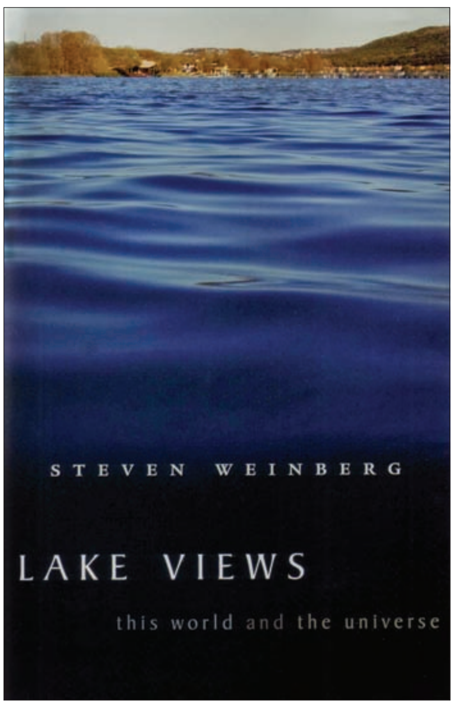
As with previous books, one is captivated by the depth and breadth of his knowledge, the elegance of his prose and his intellectual honesty. In each chapter there is a preamble where he explains the origin of the article, whether it was asked for by different journals or as an exposition to a learned society; an afterword reveals some of the reactions his views have elicited.

An important part of the book is dedicated to the current theory of multiverses and string landscapes. To a certain extent all of these developments were inspired by his remarkable work in the late 1980s (explained in the book) where he used anthropic reasoning to understand (if not explain) the possible value of the cosmological constant, also known as the dark energy of the universe. It is quite remarkable that the value derived from the observations carried out by groups studying galactic redshifts, as well as from the Wilkinson Microwave Anisotropy Probe satellite, are in good agreement with the values favoured by his analysis. The sections of the book describing this work, dealing with Einstein's famous blunder, are a masterpiece of insight and deep mastery of physics.

In other chapters, covering the humanities or religion, he takes his usual "rationalist, reductionist, realist and devoutly secular" viewpoint. Unlike Dawkins, his discourse is not the one of a "born-again atheist" (my quotes), but rather he explains his point of view in a relaxed form not devoid of humour. The effect of the relevant chapters is probably much stronger in US society, where religion plays a much bigger role than in Europe, where a large number of scientists, humanists, politicians and ordinary citizens would easily agree with his discourse. He raises provocation to the level of an art.

Another theme addressed in these essays is the ongoing discussion with philosophers or theologians on the notion of whether science explains only the "how" and not the "why" of things. He makes it very clear that the laws of nature have no purpose, and that the only legitimate purpose of science is to understand the basic laws that rule the universe. Finality is not the aim of science, but that does not make it a lesser element in the human endeavour to understand the universe that we live in.

Weinberg has not lost his punch. Far from that. This book is thought provoking, informative, challenging and fun to read. A single fault: it is too short.
Luis Álvarez-Gaumé, CERN.

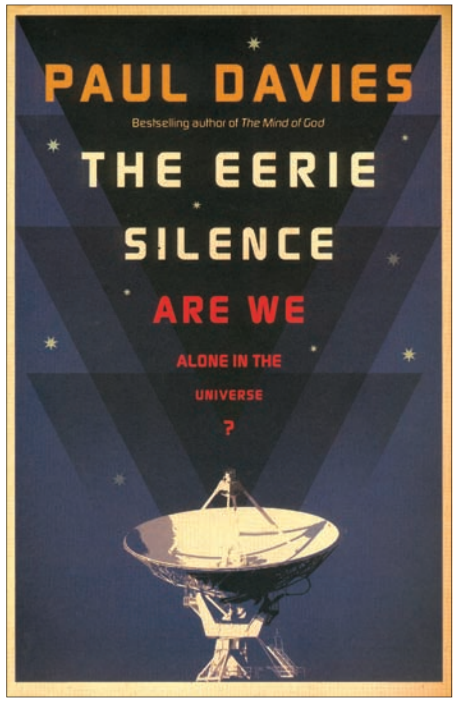


The Eerie Silence: Are We Alone in the Universe? by Paul Davies, Allen Lane. Hardback ISBN 9781846141423, £20. (US edition, **The Eerie Silence: Renewing Our Search for Alien Intelligence**, Houghton Mifflin Harcourt. Hardback ISBN 9780547133249 $27.)

Besides being a theoretical physicist, cosmologist and astrobiologist, Paul Davies is a prolific bestselling author of books about science that are aimed at a general readership and address such "big questions" as the beginning, evolution and "the last three minutes" of the universe, the origin of life and the nature of time, etc. His latest book commemorates the 50th anniversary of the SETI project – the Search for Extra-Terrestrial Intelligence.

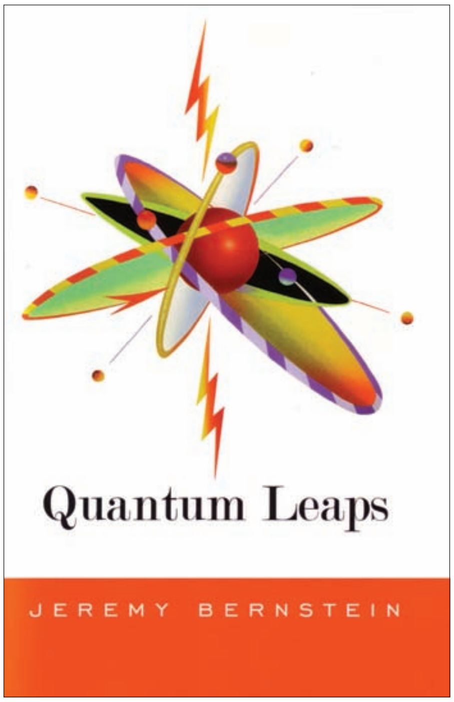
I became acquainted with this exceptionally bold enterprise, aimed at searching for (and, hopefully, finding) signals of extraterrestrial intelligence through Carl Sagan's highly successful and somewhat poetic TV series *Cosmos* and his book *Contact*, which was turned into a fascinating film starring Jodie Foster. Davies' new book represents a much more down-to-Earth perspective, so to speak, that tries as much as possible to remain within the boundaries set by a scientific appraisal of the topic. But even staying away from science-fiction fantasy and speculation, the currently accepted general laws of physics provide enough room for all sorts of mind-bending scenarios relating to the existence of alien civilizations or their mysterious and seemingly unexpected silence. Furthermore, "at any given time scientists can only state the laws of physics to the best of their current understanding. In science, the last word is never said; there is always room for revision in the light of new evidence".

Nevertheless, discussions around SETI require a good dose of "healthy scepticism" and the scientist in Davies answers Enrico Fermi's provocative question, "Where is everybody?", by freely admitting that "we are probably the only intelligent beings in the observable universe". In parallel, his human nature prefers the romantic moments when he dreams of a more meaningful universe, teeming with intelligent life.



This book is certainly a nice option for "summer reading". I particularly enjoyed reading about the searches for "weird life" on Earth – life based on a different set of amino acids, or using only two of the four standard nucleotides, for example. While known life selects right-handed sugars and left-handed amino acids, the laws of chemistry are mirror-symmetric and do not forbid the existence of life with the opposite chirality. Experiments have already been made, using chirality and many other signatures, to search for a "shadow biosphere" in our planet, whose biodiversity in the microbial domain remains mostly uncharted territory.

The book's main question – Are we alone in the universe? – must rank very highly in the list of the most profound questions that humans can ask and has a very curious feature: whether the answer is "yes" or "no", the consequences are "quite staggering" (as Arthur C Clarke would say). Davies answers, after more than 200 pages packed with information, with the concluding words: "We just don't know". However, I enjoy *Contact*'s conclusion much more, when Jodie Foster's



character says to a group of children: "The universe is a pretty big place. It's bigger than anything anyone has ever dreamed of before. So, if it's just us... it seems like an awful waste of space."
Carlos Lourenço, CERN.

Quantum Leaps by Jeremy Bernstein, Harvard University Press. Hardback ISBN 9780674035416, £14.95 (€17.10, $18.95).

At Bonn I often ask incoming students what persuaded them to study physics. It is a very personal question, which students in Germany already face before they enter university. However, it helps to break the ice and gets the students talking. I also ask because, after all of these years, my own answer is still not clear to me.

In this popular book Jeremy Bernstein describes how, as an American liberal-arts undergraduate, he got sucked into physics when faced with the peculiarities of quantum mechanics. His curiosity took hold of him. Even though he had no previous interest in science whatsoever, he couldn't resist. Here he has extended his personal voyage to explore how the wider world has reacted to quantum mechanics. Bernstein is well known for his profiles in *The New Yorker* magazine. To exemplify his point, he has here chosen an unusual selection of people who have publicly reacted to quantum mechanics in their lives and work: the Bishop of Birmingham, the Dalai Lama, W H Auden, Tom Stoppard, the physicist and communist Léon Rosenfeld, to name a few. Bernstein would not be Bernstein if he hadn't actually met and discussed with quite a few of these people. Some, like Tom Lehrer, seem to be tossed in for just this effect, but otherwise it is very charming.

Just when you think this is it, the book takes an unexpected twist. After having laid out *en passant* the basics of quantum mechanics in the previous portraits, Bernstein arrives at David Bohm and John Bell. He proceeds to give the best popular account of the quantum measurement problem that I know of. No mysticism, no philosophy: just put it on the table. Wonderful. A slight criticism, which is irrelevant for the argument presented and is not widely known: an electron beam sent through a Stern-Gerlach apparatus in fact only gives one spot and not two, as a result of two extra effects from the electric charge.

Through all of this Bernstein even manages to throw in two more novelists who were influenced by quantum mechanics in their work: Rebecca Goldstein and Michel Houellebecq. It all holds nicely together to give a fabulous account of the fascination of quantum mechanics, especially for the outsider.

This brought me back to my original question: why physics? In school, I had access to back issues of *Scientific American* and read everything that there was on the measurement problem, including the beautiful experiments by Alain Aspect. I was also fortunate to have a good friend, Thomas Burwick, to discuss all of this with. It was discussing with friends such profound questions that really drew me into physics. So, as an alternative title and a follow-up to Bernstein's earlier autobiographical book *The Life it Brings*, I'd like to propose *The People You Meet: Discussing Quantum Mechanics*. Enjoy.
Herbert Dreiner, University of Bonn.

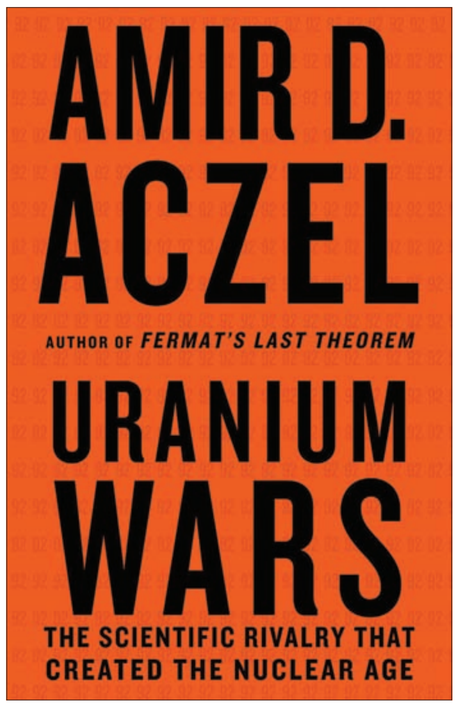
Uranium Wars: The Scientific Rivalry that Created the Nuclear Age by Amir D Aczel, Palgrave Macmillan. Hardback ISBN 9780230613744, £18.99 ($27). Paperback ISBN 9780230103351, £10.99. Digital Audio ISBN 9781427209320, $20.99. Online version ISBN 9780230100992, $12.99.

The discovery of nuclear fission and the race to develop the atomic bomb brought a new age both of history and of science. It is not surprising that it has produced, and continues to produce, its own copious literature. The classic is Richard Rhodes' 900-page *The Making of the Atomic Bomb*, "an epic worthy of Milton", according to 1944 Nobel laureate Isidor Rabi.

The many nuclear threads, whether scientific, political or anecdotal, are closely interwoven by Rhodes, making it indeed a Miltonesque epic. It is a wonderful book, but at the same time a difficult one to consult, with its various themes fragmented and scattered. In addition, new material has been revealed since Rhodes' book first appeared, but which now forms an integral part of Aczel's more succinct story.

One such ingredient was the publication in 1992 of the Farm Hall transcripts, from when German nuclear scientists were secretly brought together in the UK in 1945 and their conversations bugged. This disclosure produced its own ripple of literature.

Another new ingredient was the explosion of speculation surrounding what could have been said at the meeting in 1941 between Niels Bohr and Werner Heisenberg, highlighted by the unexpected success of Michael Frayn's play *Copenhagen* (*CERN Courier* June 2007 p25). This created a controversy out of all proportion to the

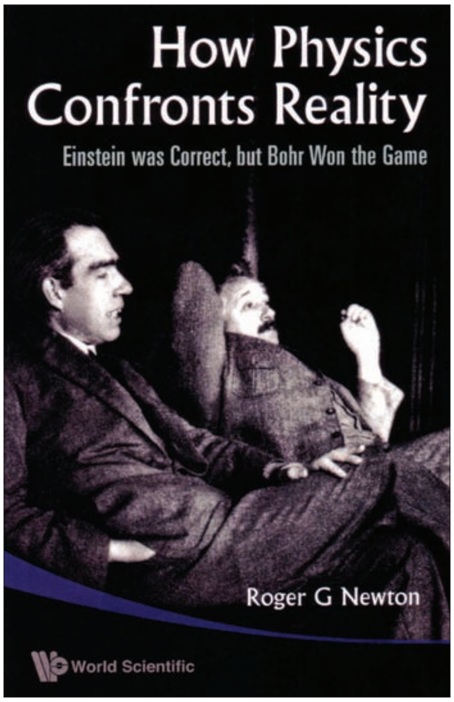


importance of this meeting for history. Other nuclear events and turning points – the Frisch-Peierls memorandum, which showed that a uranium-235 bomb would be easily transportable; whether to use uranium-235 or plutonium; gun-barrel versus implosion techniques; and above all the decision to use the bomb, twice – all affected history far more. The inconsequential Bohr-Heisenberg meeting became grossly inflated.

Bohr's private papers in Copenhagen were supposed to remain closed for 50 years after his death in 1962 but the controversy resulting from Frayn's play made the authorities change their mind in 2002. Aczel has drawn on this material, which includes a number of letters to Heisenberg drafted by Bohr, but never sent. Aczel reports "[Bohr's] damning words contradict everything that Heisenberg had said about his meetings with Bohr, the interpretations of the events in Copenhagen as portrayed in books..., as well as the Frayn play".

Other recently released material used by Aczel includes wartime papers that reveal the extent to which Japanese diplomatic communications were monitored by the Allies. The book is a useful survey of the history of nuclear physics and nuclear weapons, with the advantage of being succinct and up to date, from Einstein to Iran. Its revelations from the Bohr papers are important.

Gordon Fraser is editor of The New Physics for the 21st Century, *recently reissued by Cambridge University Press in paperback.*



How Physics Confronts Reality: Einstein was Correct but Bohr Won the Game
by Roger G Newton, World Scientific. Hardback ISBN 9789814277020, £41 ($54). Paperback ISBN 9789814277037, £22 ($29.95). Online version ISBN 9789814277044, $70.

In the mid-1960s, when the study of elastic scattering looked promising as a means to understand nuclear forces, I became acquainted with Roger Newton's textbook *Scattering Theory of Waves and Particles* (McGraw-Hill 1966). I found it to be of great help, even if life and physics turned out to be more complex than elastic scattering.

More recently, he addressed a wider, non-specialized audience, about the making of modern physics. The aim was to help "thinking about physics rather than simply doing it" (*Thinking about Physics*, Princeton University Press 2000). He achieves that in this latest book within nine chapters embedded in an introduction (plus preface) and an epilogue, followed by a list of references and further reading, in a total of 150 pages. Physics and reality in a terse mode!

The reader finds an account of particles and fields with Faraday and Maxwell and J J Thomson's electron; the origin of quantum theory and wave-particle duality; the uncertainty principle and new mathematical tools. But what is the significance of all of these? Bohr talked of the measurement problem and Schrödinger of entanglement. The whole of chapter 3 takes over these points to describe Einstein's "defection" from quantum theory – but typical of this book's style we also find an aside on Bose-Einstein statistics and Bose-Einstein condensation, just to show that Einstein was not getting out of touch at the time of the Einstein-Podolsky-Rosen paper.

The book then develops along twin threads: how, from the ancient intuition, the reality of atoms was visibly established without doubt (chapter 4); and how in the description of the laws of motion the distance increased between the foundations of the theory and everyday experience thanks to Einstein (chapter 5). A few pages about fields lead to new particles and their quantum origin, and then to the need for accelerators, from Lawrence's cyclotron to CERN's LHC. This is followed by an attempt to explain how the particles go together to form different kinds of matter.

The last chapter casts light on "methods and underpinnings" to bring order to the crowd of particles discovered from the 1950s onwards. The experimental methods are reduced to two examples, without reference to current experiments in particle physics. The theoretical methods cover symmetries, the Standard Model, Higgs particles, strings and superstrings.

The epilogue stresses that while nowadays we visualize the ultimate constituents of matter at an unprecedented level, the laws of dynamics have become awkward and distant from our intuition. This is indeed the leitmotif of the whole book, but the melody becomes inaudible. Where it emerges it does not help the flow of the text.

The tale is pleasant, intertwined by anecdotes, but it proceeds by alighting on topics, which are not always in a logical sequence. What is assessed is accurate and well thought out, but I am not sure that without some previous in-depth knowledge the reader will get to the point. Unfortunately, half of the further reading is out of print, and some I suppose is also out of date.

Maria Fidecaro, CERN.

Reflections on a Masterclass

High-school student **Slávka Marcinová** attended the Hands On Particle Physics Masterclasses 2010 at her local university in the Slovak Republic and was pleasantly surprised. In this essay she describes in English her experience.

It was on an ordinary March day when I did something that was way out of character. A friend of mine, who is admittedly a physics geek, told me about something called a Masterclass and suggestively handed me a leaflet with big, friendly "Hands On Particle Physics" on it. Now, I must say that I am the kind of student who would normally like to get her hands OFF particle physics – but then I noticed something that sparked my interest. "A videoconference", the leaflet read, "a chance to analyse real experiment results with foreign universities and the CERN scientists". I said, yes, that sure was something. Then I said that I would come.

My entire preparation consisted of revising what I knew about particle physics (note, that it really wasn't much...) and repeatedly assuring myself that I won't be meeting a roomful of Einstein-like geniuses and therefore look quite stupid; that they will be ordinary high-school students with an interest in physics, looking forward to learning new things... just like me. At least, I hoped so.

We were welcomed at the P J Šafárik University in Košice early in the morning and made our way to the lecture room just after we had been given some leaflets about things that I didn't quite have an idea of. Yes, "a hadron collider" sounded nice, but I sincerely hoped that the first lecture would provide a somewhat more basic overview of nuclear physics...

And that was precisely what it did.

The 2010 Masterclass under way in Košice. The annual masterclasses introduce high-school students to particle physics and now attract more than 5000 participants. (Courtesy P J Šafárik University.)

A (whole) New World

The lecture was not what I would call "Nuclear Physics for Dummies". However, at the same time it managed to elegantly explain what we needed in order to grasp the basics of what the micro-universe is made of. We were introduced to some new theories while we repeated what we already knew from physics classes and wrote down notes. The second, a lot more technical lecture, offered us a look into modern physics, something that we definitely didn't know from physics classes, something that got me genuinely interested, as did the still unanswered questions of today's physics. We were presented a task in the end, which, I must admit, sounded way too complicated. And with an atmosphere of, "What is this they want from us?", we moved to the practical part of the Masterclass.

Don't worry, it's a two-jet

A friendly looking nuclear-physics student (yes, there are ones like that) and a PowerPoint presentation was all that it took for us to understand what we were going to do and we spent the next hour observing what Z-bosons can turn into (such as electrons, taus, muons...) and writing the results down with the help of some other kind students. They assured us that nuclear physics can be fun... and you know, it is not as far from the truth as I would have thought. And that speaks for itself.

International dialogue

After lunch it was time for the videoconference to begin. Without any technical problems, we connected with universities in Debrecen, Budapest, London and with the scientists in CERN. We exchanged the results, and what I liked was that we got plenty of space to ask questions. The scientists were eager to help us, the atmosphere was informal and overall enjoyable. A short quiz followed and then we all got certificates of having attended the Masterclass. If one of the quiz's questions were, if I regretted taking part in this project, I would have said a clear "no".

In my opinion, the purpose of the 2010 Hands On Physics Masterclass was more than fulfilled because, apart from "getting the work done", the Masterclass got us interested in modern physics, its open questions and challenges – and that is, sadly, something the classes in school often fail to achieve.

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