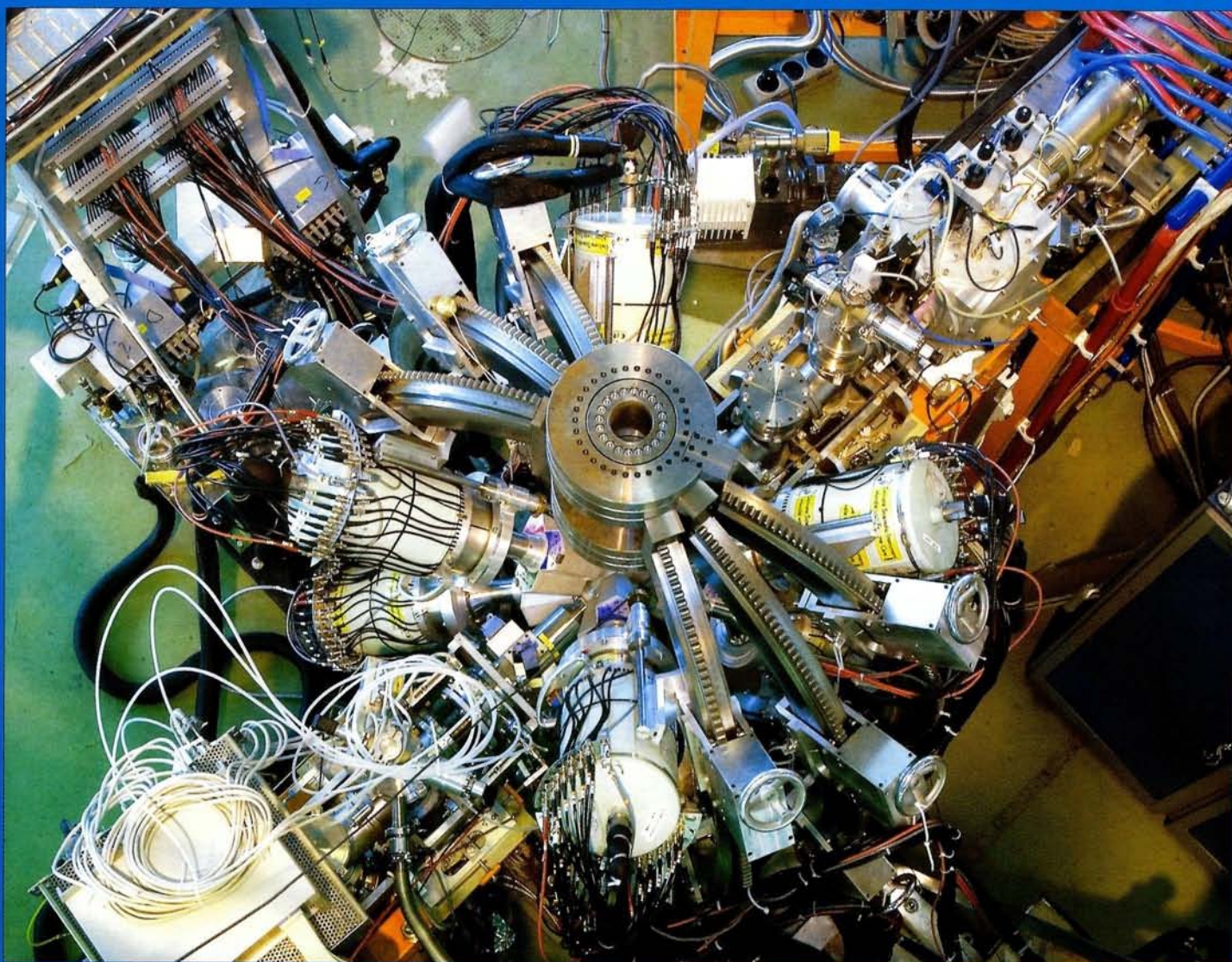


# CERN COURIER

VOLUME 45 NUMBER 10 DECEMBER 2005



## On the hunt for excited states

### **HOMESTAKE**

Future assured for  
underground lab p5

### **DARK MATTER**

Galactic gamma rays  
may hold the key p17

### **SNOWMASS**

US workshop gets  
ready for the ILC p24

# Opera

## Music to your ears

### 2D & 3D electromagnetic modelling

If you're aiming for design excellence, you'll be pleased to hear that OPERA, the industry standard for electromagnetic modelling, gives you the most powerful tools for engineering and scientific analysis.

Designed for parameterisation and customisation, OPERA is incredibly easy to use and has an extensive toolset, making it ideal for a wide range of applications. What's more, its high performance analysis modules work at exceptional levels of speed, accuracy and stability, even with the most

demanding models. As a result millions of elements can be solved in minutes, leaving you to focus on creating outstanding designs.

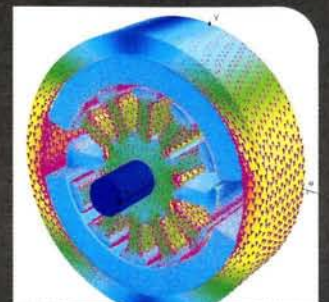
#### Fast, accurate model analysis

- Actuators and sensors – including position and NDT
- Magnets – ppm accuracy using TOSCA
- Electron devices – space charge analysis including emission models
- RF Cavities – eigen modes and single frequency response
- Motors – dynamic analysis including motion

Don't take our word for it – order your free trial and check out OPERA yourself.



Electron trajectories through a TEM focussing stack



B-field in a PMDC motor

Vector Fields Ltd Culham Science Centre, Abingdon, Oxon, OX14 3ED, U.K.  
Tel: +44 (0)1865 370151 Fax: +44 (0)1865 370277 Email: info@vectorfields.co.uk

Vector Fields Inc 1700 North Farnsworth Avenue, Aurora, IL, 60505. USA  
Tel: (630) 851 1734 Fax: (630) 851 2106 Email: info@vectorfields.com

A Cobham plc company



## 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.

**Editor** Christine Sutton  
CERN, 1211 Geneva 23, Switzerland  
E-mail: cern.courier@cern.ch  
Fax: +41 (0) 22 785 0247  
Web: cerncourier.com

**Advisory board** James Gillies, Rolf Landua and Maximilian Metzger

### Laboratory correspondents:

**Argonne National Laboratory** (US): D Ayres  
**Brookhaven National Laboratory** (US): P Yamin  
**Cornell University** (US): D G Cassel  
**DESY Laboratory** (Germany): Ilka Flegel, Petra Folkerts  
**Fermi National Accelerator Laboratory** (US): Judy Jackson  
**Forschungszentrum Jülich** (Germany): Markus Buescher  
**GSI Darmstadt** (Germany): G Siegert  
**INFN** (Italy): Barbara Gallavotti  
**IHEP, Beijing** (China): Tongzhou Xu  
**Jefferson Laboratory** (US): Steven Corneliussen  
**JINR Dubna** (Russia): B Starchenko  
**KEK National Laboratory** (Japan): Youhei Morita  
**Lawrence Berkeley Laboratory** (US): Spencer Klein  
**Los Alamos National Laboratory** (US): C Hoffmann  
**NIKHEF Laboratory** (Netherlands): Paul de Jong  
**Novosibirsk Institute** (Russia): S Eidelman  
**Orsay Laboratory** (France): Anne-Marie Lutz  
**PPARC** (UK): Peter Barratt  
**PSI Laboratory** (Switzerland): P-R Kettle  
**Rutherford Appleton Laboratory** (UK): Jacky Hutchinson  
**Saclay Laboratory** (France): Elisabeth Locci  
**IHEP, Serpukhov** (Russia): Yu Ryabov  
**Stanford Linear Accelerator Center** (US): Neil Calder  
**TRIUMF Laboratory** (Canada): Marcello Pavan

### Produced for CERN by Institute of Physics Publishing Ltd

Institute of Physics Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK  
Tel: +44 (0)117 929 7481; E-mail: jo.nicholas@iop.org; Web: iop.org

### Publishing director

Richard Roe

### Publisher

Jo Nicholas

### Art director

Andrew Giaquinto

### Production

Jonathan Cailles, Ruth Leopold

### Technical illustrator

Alison Tovey

### Display advertisement manager

Jonathan Baron

### Deputy advertisement manager

Ed Jost

### Display sales North America

John Lamb

### Recruitment and classified sales

Kathryn Zerboni, Moo Ali and Adam Hylands

### Advertisement production

Katie Graham

### Product manager

Claire Webber

### Advertising

Jonathan Baron, Ed Jost, John Lamb, Kathryn Zerboni, Moo Ali or Adam Hylands

Tel: +44 (0)117 930 1265 (for UK/Europe display advertising),

+1 215 627 0880 (for North American display advertising), or

+44 (0)117 930 1196 (for recruitment advertising);

E-mail: sales@cerncourier.com; Fax: +44 (0)117 930 1178

### General distribution

Jacques Dallemeagne, CERN, 1211 Geneva

23, Switzerland. E-mail: courier-adressage@cern.ch

In certain countries, to request copies or to make address

changes, contact:

**China** Keqing Ma, Library, Institute of High Energy Physics,

PO Box 918, Beijing 100049, People's Republic of China.

E-mail: keqingma@mail.ihep.ac.cn

**Germany** Veronika Werschner, DESY, Notkestr. 85, 22607

Hamburg, Germany. E-mail: desypr@desy.de

**Italy** Loredana Rum or Anna Pennacchietti, INFN, Casella Postale

56, 00044 Frascati, Rome, Italy. E-mail: loredana.rum@inf.infn.it

**UK** Barrie Bunning, Library and Information Services Group, R61

Library, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon

OX11 0QX, UK. E-mail: B.J.Bunning@rl.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: vosses@aol.com

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

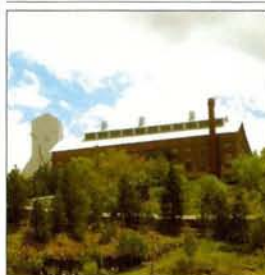
**Printed by** Warners (Midlands) plc, Bourne, Lincolnshire, UK

© 2005 CERN ISSN 0304-288X

**IoP** 

# CERN COURIER

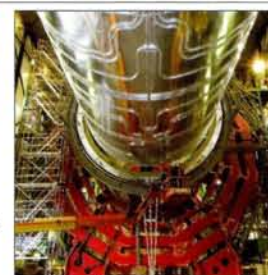
VOLUME 45 NUMBER 10 DECEMBER 2005



Research goes underground p5



Capturing gamma-ray bursts p20



The secrets of keeping cool p28

## News

5

*Homestake poised to become a goldmine for scientific research. NSRRC operates in top-up mode. SNS reaches major milestone on journey to completion next June. LEIR gets ions on course for the LHC.*

## Physicswatch

9

## Astrowatch

10

## CERN Courier Archive

11

## Features

A magnetic memorial to decades of experiments

12

*Chris Jones finds the magnet from CERN's first g-2 experiment.*

Setting the record straight

15

*Walter Oelert talks about fact and fiction in antimatter research.*

Do gamma rays reveal our galaxy's dark matter?

17

*Wim de Boer describes an analysis of the observed excess of diffuse gamma rays.*

Gamma-ray bursts: a look behind the headlines

20

*Arnon Dar asks whether a 35 year old mystery has really been solved.*

ILC comes to Snowmass

24

*A report on the workshops held this summer to advance plans for this next-generation machine.*

How CERN keeps its cool

28

*Giorgio Passardi and Laurent Taviani look at the lab's use of cryogenics.*

REX-ISOLDE accelerates the first isomeric beams

31

*Georgi Georgiev presents a new technique to study nuclei.*

## People

33

## Recruitment

42

## Bookshelf

51

**Cover:** The Miniball detector at CERN's REX-ISOLDE facility, with the REX post-accelerator just visible to the top right. Isomers – short-lived excited nuclear states – can now be post-accelerated in REX (p31).

## Look to the traditional ...

Saint-Gobain Crystals can provide you with many of your traditional radiation detection tools:

- > Inorganic scintillators and detectors
- > Plastic cast and fiber scintillators
- > Gas-filled radiation detectors



## and beyond ...

Introducing our BrillanCe™350 and BrillanCe™380 scintillators. Their light output is similar to NaI(Tl) but with much better energy resolution!



Compare:

Scintillator	Decay Time tau (ns)	PHR @662 keV
NaI(Tl)	250	6.5%
BrillanCe 350	28	<4%
BrillanCe 380	16	<3%

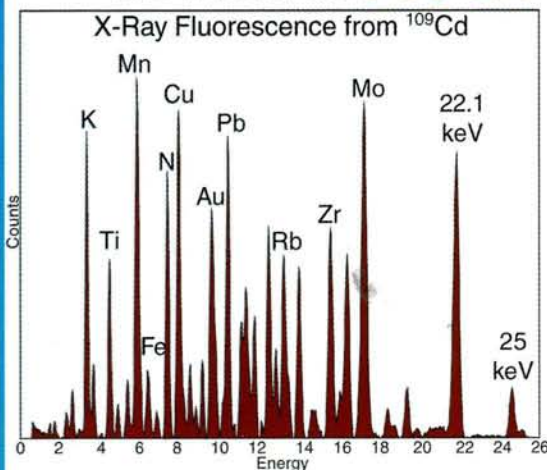
Web site: [www.detectors.saint-gobain.com](http://www.detectors.saint-gobain.com)  
E-mail: [scintillation@saint-gobain.com](mailto:scintillation@saint-gobain.com)

**SAINT-GOBAIN**  
CRYSTALS

Saint-Gobain Crystals manufactures Bicron® and Crismatec® brand scintillation detectors

## X-Ray Detector

XR-100CR at **149 eV FWHM** Resolution



**No Liquid Nitrogen**  
**Solid State Design**  
**Easy to Use**  
**Low Cost**

### APPLICATIONS

- Nuclear Physics
- Synchrotron Radiation
- High Energy Physics
- Neutron Experiments
- Astrophysics
- Research & Teaching
- Nuclear Medicine
- X-Ray Fluorescence



XR100CR X-Ray Detector with PX4 Digital Pulse Processor, Power Supply, Shaping Amplifier & MCA



XR100CR fitted for vacuum applications

Visit Us Now  
[www.amptek.com](http://www.amptek.com)

## Digital Pulse Processor

**NEW!!!**

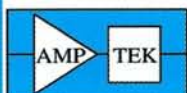


**PX4**

**Digital Pulse Processor**  
**Power Supply**  
**Shaping Amplifier**  
**MCA**

### Features

- Trapezoidal shaping to reduce ballistic deficit
- Wide range of shaping time settings
- High count rate capability
- High throughput
- MCA with 8 k channels
- High energy resolution
- Excellent pile-up rejection
- Enhanced stability
- USB interface
- Software instrument control, data acquisition and analysis
- Oscilloscope mode available
- Compatible with all Amptek XR100 detectors and detectors of other manufacturers



**AMPTEK Inc.** 14 De Angelo Drive, Bedford, MA 01730-2204 USA  
Tel: +1 (781) 275-2242 Fax: +1 (781) 275-3470  
E-mail: [sales@amptek.com](mailto:sales@amptek.com) [www.amptek.com](http://www.amptek.com)

## UNDERGROUND LABS

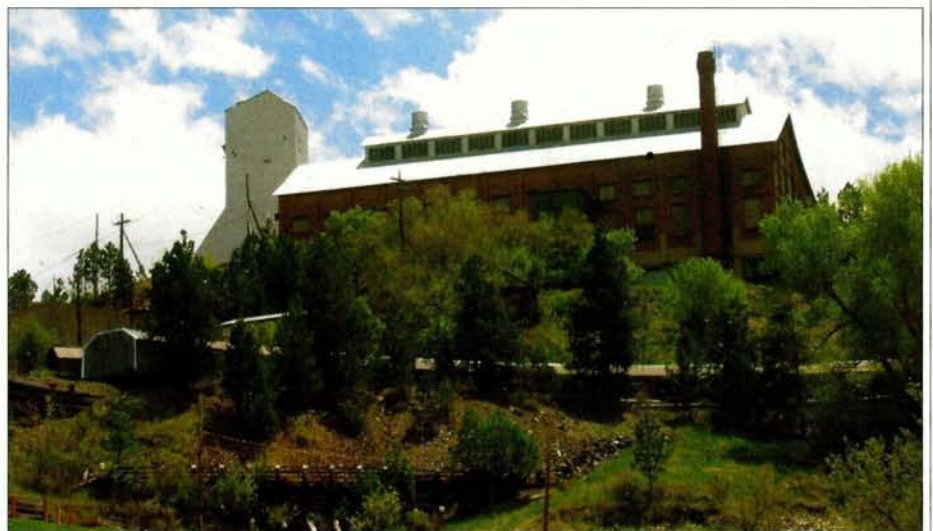
# Homestake poised to become a goldmine for scientific research

A new frontier in experimental science was crossed in October when the state of South Dakota committed \$20 million to pave the way for its acquisition and conversion of the Homestake Mine into a multidisciplinary underground laboratory, which it will operate until at least 2012. This boost from the state also aids longer-term planning, helping to position Homestake as a possible home for the proposed Deep Underground Science and Engineering Laboratory (DUSEL). The transfer of the property is scheduled to take place on 15 December.

The 125 year-old Homestake Mine, which was once the largest goldmine in the western hemisphere, is the deepest in North America, reaching 2500 m below ground. It became well known as the site of the first solar-neutrino experiment, which ran continuously from 1967 to 1994 and earned Raymond Davis the Nobel Prize in Physics in 2002 (*CERN Courier* December 2002 p15). In May 2004 the company that owned the mine announced that it would turn off the pumps that prevent the mine from flooding (*CERN Courier* July/August 2003 p15).

The state of South Dakota's funding will re-establish access into the mine, pump out the accumulated water and establish an operating laboratory at the 1500 m level, where Davis's experiment was located. The lower levels will be developed in later years. Experimental Letters of Interest for short- and long-term experiments are now being solicited from the international community. The first experiments are scheduled to begin in 2007.

These depths provide the low-background environment needed to conduct a spectrum of physics experiments including studies of



The Homestake Mine in South Dakota, where the shafts extend underground to 2500 m.

neutrinoless double beta decay and dark-matter searches. With more than 500 km of tunnels, the mine provides safe access to various depths, can accommodate large detectors, and offers expandable spaces to sustain evolving experiments over decades.

Homestake is one of two finalists selected by the National Science Foundation (NSF) for the location of a future DUSEL; the other site is Henderson Mine in Colorado. Both proposals have received grants of \$500 000 from the NSF to develop conceptual design reports. The site for DUSEL should be chosen in late 2006.

For the first time, a single site dedicated to science will house an array of experiments spanning the disciplines of particle and nuclear physics, geology, hydrology, engineering, geomicrobiology and biochemistry. Forty years after Davis installed

his solar-neutrino detector at Homestake, a new generation of experimentalists will avail themselves of the same site for this spectrum of modern-era experiments. As DUSEL is developed in the coming years these experiments will delve even deeper underground in a quest to answer some of the greatest scientific mysteries of our time – from dark matter, neutrinos and nucleosynthesis to probing the limits of life.

Physics, astrophysics and earth sciences are anticipated to be among the first disciplines to establish experiments. As well as experiments on neutrinoless double beta decay and searches for relic dark matter, large detectors will study proton decay and be used for long-baseline neutrino experiments, ultimately to probe neutrino mass, hierarchy and possible leptonic CP violations.

The diverse geology at Homestake, with

## Sommaire

Homestake deviendra une mine d'or scientifique	5	Le LEIR lance ses ions dans la course au LHC	7
Taiwan: le NSRRC fonctionne en remplissage continu	6	Des chercheurs découvrent l'eau qui ne mouille pas	9
Oak Ridge: la source SNS passe un jalon crucial	7	Spitzer observe la lueur des toutes premières étoiles	10

the existing deep drifts and boreholes, will be an equally big boon for earth scientists. For the first time, they will have access to more than  $34 \text{ km}^3$  of the Earth's crust to study the subterranean environment.

Geomicrobiologists will investigate the genome and the limits of life in extreme environments; hydrologists will study fluid flows through rocks; geochemists will explore

the formation of minerals; and at the intersection of physics and geology, scientists will measure geoneutrinos emanating from the Earth's crust.

The Homestake project is a partnership between the scientific community and the South Dakota Science and Technology Authority, which will oversee the conversion and manage the mine. The scientific team is

headed by Kevin Lesko of Lawrence Berkeley National Laboratory and the University of California at Berkeley. The early implementation plan will create an operational facility in advance of the NSF selection process and be the basis of Homestake's staged approach to creating DUSEL.

● For further information see <http://neutrino.lbl.gov/Homestake/LOI>.

## LIGHT SOURCES

# NSRRC operates in top-up mode

On 12 October the National Synchrotron Radiation Research Center (NSRRC), Taiwan, became the fourth synchrotron facility in the world to operate fully in top-up mode, joining the Swiss Light Source (SLS), the Advanced Photon Source (APS) in the US, and SPring-8 in Japan. While the SLS and APS were originally designed to operate in top-up mode, the NSRRC is an example of how a third-generation synchrotron accelerator that previously operated in decay mode can successfully advance to full top-up operation.

In top-up mode, the storage ring is kept full by frequent injections of beam, in contrast with decay mode, where the stored beam is allowed to decay to some level before refilling occurs. Top-up operation has the advantage for light-source users that the photon intensity produced is essentially stable. This provides valuable gains in usable beamtime for experiments, and significantly shortens the time for optical components in beamlines to achieve thermal equilibrium.

The upgrade to top-up mode at the NSRRC, which started in 2003, included improvement to kickers, the addition of various diagnostic instruments, a redesign of radiation safety shielding, modification of control software, and a revised operation strategy for the injector and booster. In parallel a more powerful superconducting radio-frequency cavity was installed and commissioned in November 2004, as part of a five-year programme. This has prepared the NSRRC to serve its users in biology and genomic medicine.

The injection chain at the NSRRC consists of a 140 keV electron gun, a 50 MeV linac and a 1.5 GeV booster that sends the beam into the storage ring at a rate of 10 Hz. With the upgrade, the time interval between two



NSRRC's control room with top-up operation displayed on the monitor in the background.

injections is now set to 2 min, while previously, in decay mode, it was every 6 h. The stored beam current has initially been maintained at 200 mA with approximately 0.6 mA per current bin and photon stability in the range of  $10^{-3}$  to  $10^{-4}$ . As experience is gained, the current will gradually be increased up to the 400 mA maximum allowed by the new superconducting RF in the storage ring.

As a user-driven facility, NSRRC chose the fixed time interval injection mode rather than fixed current bin to reduce interference with data-acquisition processes. Since early 2005, the operational division has informed beamline managers of the new characteristics of the beam's time cycle, injection perturbations and top-up status. Users thus have access to enough information to conduct their experiments successfully.

During the transition period, special

attention was paid to finding a reproducible filling pattern through optimizing and fine-tuning a variety of parameters. Other tasks included mastering the timing jitters of injection components, launching position and angle, as well as understanding the horizontal acceptance of the ring. These are some of the key determinants of injection efficiency.

The overall programme, led by NSRRC director Chien-Te Chen, now allows students from more than 60 universities access to beamtime allocated on one of 27 beamlines. These include two at SPring-8 Japan that are owned by the NSRRC. The NSRRC itself supported more than 3000 user-runs in 2005, 20% more than in 2004.

### Further reading

G H Luo *et al.* The Status of Top-Up Injection at NSRRC APAC'04 Proceedings Gyeongju, Korea.

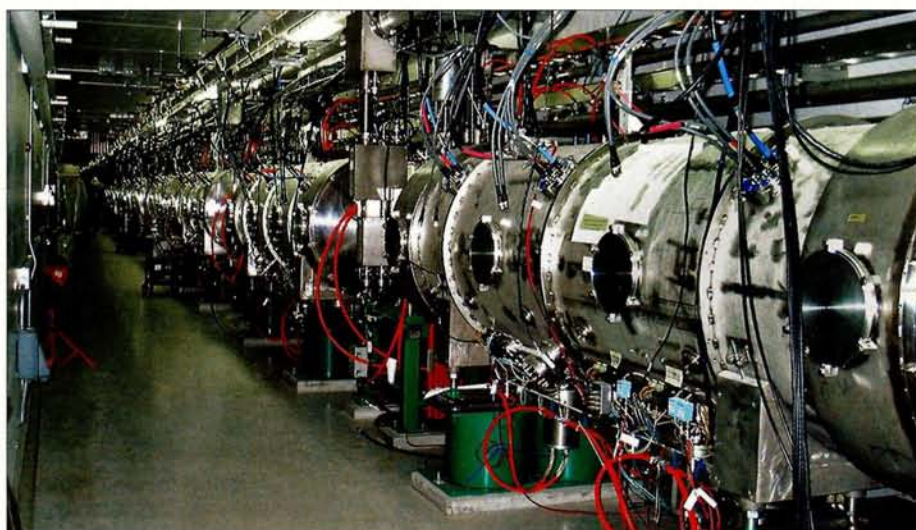
## ACCELERATORS

# SNS reaches major milestone on journey to completion next June

The Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory (ORNL) of the US Department of Energy (DOE) has met a crucial milestone on its way to completion in June 2006 – operation of the superconducting section of the linear accelerator. The SNS will produce neutrons by accelerating a pulsed beam of high-energy  $H^-$  ions down a 300 m linac, compressing each pulse to high intensity, and delivering them to a liquid mercury target where neutrons are produced in a process known as spallation.

The SNS linac is the world's first high-energy, high-power linac to apply superconducting technology to the acceleration of protons. It has two sections: a room-temperature section, for which beam commissioning was completed last January, and a superconducting section, which operates at 2 K (or recently as high as 4.2 K). The cold linac provides the bulk of the acceleration and has already achieved a beam energy of 912 MeV, or 91% of the linac's design energy of 1 GeV.

Although the superconducting cavities are designed to operate at 2 K, much of the beam commissioning was performed at 4.2 K, with minimal loss in cavity performance – an unexpected outcome. Compared with the design intensity of  $1.6 \times 10^{14}$   $H^-$  ions per pulse, beam pulses as high as  $8 \times 10^{13}$  ions per pulse were accelerated at repetition rates of up to 1 Hz (compared with the 60 Hz



ORNL's pioneering linac prepares for the Spallation Neutron Source. (Courtesy ORNL.)

design), limited by the power capability of the 7.5 kW commissioning beam dump. All basic beam parameters were verified without any major surprises and transverse beam profiles were measured using a newly developed laser-profile measurement system that is noninvasive and unique to this  $H^-$  ion linac.

Six DOE national laboratories are collaborating on this DOE Office of Science project. Thomas Jefferson National Accelerator Facility in Virginia was responsible for the superconducting linac and its refrigeration system while Los Alamos National Laboratory in New Mexico provided

the radio-frequency systems that drive the linac. The other laboratories are Argonne, Berkeley and Brookhaven.

During its first two years of operation, the SNS will increase the intensity of pulsed neutrons available to researchers nearly tenfold compared with existing facilities, providing higher-quality images of molecular structure and motion. Together, ORNL's High Flux Isotope Reactor and the SNS will represent the world's foremost facilities for neutron scattering, a technique the laboratory pioneered shortly after the Second World War.

## CERN

## LEIR gets ions on course for the LHC

On 10 October, at the very first attempt, a beam travelled round the Low Energy Ion Ring (LEIR) at CERN. LEIR is a central part of the injector chain to supply lead ions to the Large Hadron Collider (LHC) from 2008. It will transform long pulses from Linac 3 into short

and dense bunches for the LHC.

The following day, after only 1 h of tuning, the beam circulated for about 500 ms per injection. The RF cavities were not yet in operation, so the beam was lost at the end of the injection plateau. The beam used consisted of  $O^{4+}$  ions, which have a longer lifetime than lead ions; work with lead ions will begin at a later stage.

After the installation of a new ion source built by a team from the Low Temperatures Department of the French Atomic Energy

Commission (CEA/DRFMC/SBT) in Grenoble at the beginning of 2005, final work on installing LEIR took place in the summer. Now the aim is to improve understanding of the accelerator's behaviour and to optimize the ion beam. In addition, the new electron-cooling system, developed and manufactured in collaboration with the Budker Institute of Nuclear Physics in Novosibirsk, is to be commissioned. This should reduce the beam dimensions, making it possible to accumulate several pulses from Linac 3.

25 YEARS  
1980-2005

# Magnets and coils

SCANDITRONIX  
*Magnet*

[www.scanditronix-magnet.se](http://www.scanditronix-magnet.se)

## Photomultiplier Tubes



Sizes available: 13mm, 19mm, 29mm, 38mm,  
51mm, 76mm, 89mm, 133mm

Designer and Manufacturer  
of Photomultiplier Tubes

 **ADIT**

PO Box 870 / 300 Crane Street  
Sweetwater, Texas 79556 (USA)  
Ph: 915-235-1418 or 800-399-4557  
Fax: 915-235-2872  
e-mail: [adit@aditpmt.com](mailto:adit@aditpmt.com)

[www.aditpmt.com](http://www.aditpmt.com)

Visit our website or contact us for a brochure

## When your users demand a stable orbit

# Libera

**Bunch-by-Bunch**  
dumps coupled bunch instabilities



**All-In-One  
Customizable  
Connectivity**

 Instrumentation  
Technologies

[i-tech@i-tech.si](mailto:i-tech@i-tech.si)

Order Libera Bunch-by-Bunch  
documentation at [www.i-tech.si/  
products-libera-documentation.html](http://www.i-tech.si/products-libera-documentation.html)



## Researchers find water that doesn't get wet

Everyone knows that water likes to stick to water – we see it all the time in the form of surface tension and in the spherical shape of water droplets. Now, a rather surprising result from Greg Kimmel and colleagues at Pacific Northwest National Lab shows that sometimes water can be hydrophobic.

The team studied what happens when water molecules are added to create a monolayer on a platinum substrate at temperatures in the range 20 to 155 K. At temperatures above about 60 K small islands of two-dimensional ice form, with successive water molecules falling off these islands and sticking to the platinum until a solid monolayer is formed. The researchers found that at temperatures less than 120 K additional monolayers of water will stick as expected to this initial layer of crystalline ice films.

However, above 135 K the system ceases to behave in this way, and becomes more like a waxy leaf or polished table top, where water forms large drops rather than wetting the surface. It seems that of the four bonds that water could form with other water molecules, one is used up to stick to the platinum and the other three are used to stick to each other. The net result is a hydrophobic layer of ice. Only when up to 50 additional monolayers



At low temperatures, water on a platinum surface can form a hydrophobic layer, like the waxy surface of a leaf. (Copyright Tomasz Dobrowolski / Dreamstime.com.)

have been added are all the non-wetting portions of the first entirely covered.

Whether this sort of phenomenon ever happens in nature is not yet clear. However, it could be relevant in understanding how ice crystals form in clouds after seeding.

### Further reading

Greg Kimmel *et al.* 2005 *Phys. Rev. Lett.* **95** 166102.

## Dark matter or just general relativity?

Recently, Fred Cooperstock and Steven Tieu of the University of Victoria proposed that general relativity might be able to explain the observed galactic rotation curves without the need for any “exotic dark matter” (*CERN Courier* October 2005 p9). Since then, Mikolaj Korzynski of Warsaw University has argued that the gravitational field in the Cooperstock–Tieu solution is generated “not only by the galaxy matter, but by a thin, singular disc as well” and that their model should be considered unphysical. In simple terms, the model implicitly has some extra matter in it.

D Vogt and P S Letelier of the Universidade Estadual de Campinas in Brazil have now

analysed the presence of this singular disc, calculating the physical variables of the disc's energy-momentum tensor. They are led to the conclusion that “the disc is made of exotic matter, either cosmic strings or struts with negative energy density”. They also point out that even if the Cooperstock–Tieu model has problems, a proper general relativistic solution should be further investigated.

### Further reading

Mikolaj Korzynski 2005 [www.arxiv.org/abs/astro-ph/0508377](http://www.arxiv.org/abs/astro-ph/0508377).

D Vogt and P S Letelier 2005 [www.arxiv.org/abs/astro-ph/0510750](http://www.arxiv.org/abs/astro-ph/0510750).

## The mathematics of four-legged tables

Not all good physics involves expensive equipment or sophisticated mathematics. A case in point is the stability of four-legged tables – long a problem outside the cafeteria at CERN, where in summer people can often be seen rotating tables to find a position where the slightest touch does not spill their coffee. This has fascinated André Martin of CERN for some time, and now he has written a first proof to back up the empirical finding.

Martin has shown that a perfect four-legged square table, “posed on a continuous irregular ground with a local slope of at most 15 degrees can be put in equilibrium on the ground by a ‘rotation’ of less than 90 degrees.” In fact, the tables at CERN are circular, and do not have the perfect, infinitely narrow feet of Martin's proof, but he conjectures that equilibrium can also be found for tables that are not square, provided the four feet are on a circle.

### Further reading

André Martin 2005 [www.arxiv.org/abs/math-ph/0510065](http://www.arxiv.org/abs/math-ph/0510065).

## DNA makes noses out of nanotubes

A new approach to electronic noses is based on carbon nanotubes. A team from the University of Pennsylvania and the Monell Chemical Sensors Center in Philadelphia has taken single-strand DNA molecules that are tailored to bind to certain molecules and stuck them onto carbon nanotubes.

When the DNA molecules pick up molecules from the air, they either lose or gain electrons and this changes the charge on a nanotube and in turn affects how much current it can carry. The sensors are quite fast, “picking up a scent” in about 10 seconds and needing just 30 seconds to recover. Such devices could form the basis for a new generation of chemical sensors.

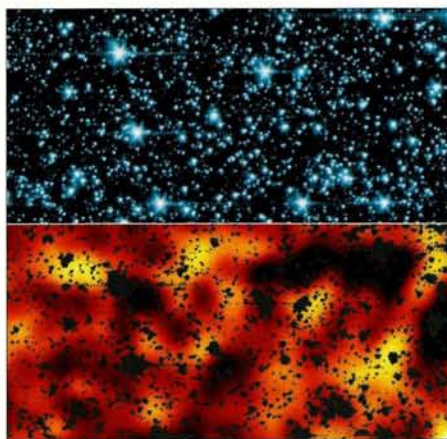
### Further reading

Cristian Staii *et al.* 2005 *Nano Letters* **5** (9) 1774.

## Spitzer sees light from the very first stars

Deep observations with NASA's Spitzer Space Telescope have revealed infrared background anisotropies that can be attributed to emission from the very first stars in the universe. The diffuse glow detected by Spitzer would have been emitted more than 13 billion years ago by the first generation of stars, which are believed to have been more than a hundred times more massive than the Sun and to have lived for only a few million years before exploding as the first supernovae.

Stars of the very first generation in the universe – made only of primordial hydrogen and helium – are called Population III stars. The absence of heavy chemical elements allows them to reach masses and sizes well beyond those of the metal-rich Population I stars – like our Sun – and the older Population II stars, which are poorer in metal. These early giant stars, with masses of several hundred solar masses, have so far never been seen in galaxies observable today. Even the Hubble Ultra Deep Field has only seen galaxies with stars already enriched in heavy elements such as carbon and oxygen; and there are now doubts on the true nature and distance of the candidate Population III galaxy, which was thought to be the farthest known galaxy at a redshift of 10 (*CERN Courier* May 2004 p13). It therefore seems that the detection of the very remote first stars and galaxies emerging from the “dark ages” at redshifts of about 10 to 30 will require next-generation facilities like the James Webb Space Telescope, which should replace the



Spitzer infrared (3.6  $\mu\text{m}$ ) image of stars and galaxies in the Draco constellation (top) and the resulting image showing the infrared background fluctuations (enhanced for clarity) after masking out all stars, galaxies and artefacts (bottom). The anisotropies have a typical size of 1–2 arcmin and could be due to the glow of the first stars in the universe. (NASA/JPL-Caltech/A Kashlinsky (GSFC).)

Hubble Space Telescope in 2013.

Now, rather unexpectedly, A Kashlinsky and collaborators claim they have already had a glimpse at those unknown territories with the modest 85 cm Spitzer Space Telescope. Removing the emission of all foreground stars and galaxies in deep infrared observations, they identified fluctuations of the background radiation on larger scales, which could be attributed to the diffuse light from the Population III era. In an article published in

*Nature*, they discuss all other possible sources of these infrared background fluctuations: from instrumental artefacts to distant unresolved galaxies or clusters, including solar-system zodiacal light and galactic emission from interstellar clouds. They conclude that the angular size of the anisotropies is significantly different from what is expected from sources in the solar system and in our galaxy, and that their amplitude is too large to be due to unresolved faint galaxies. The fluctuations are also rather independent of the parameters used to remove foreground objects.

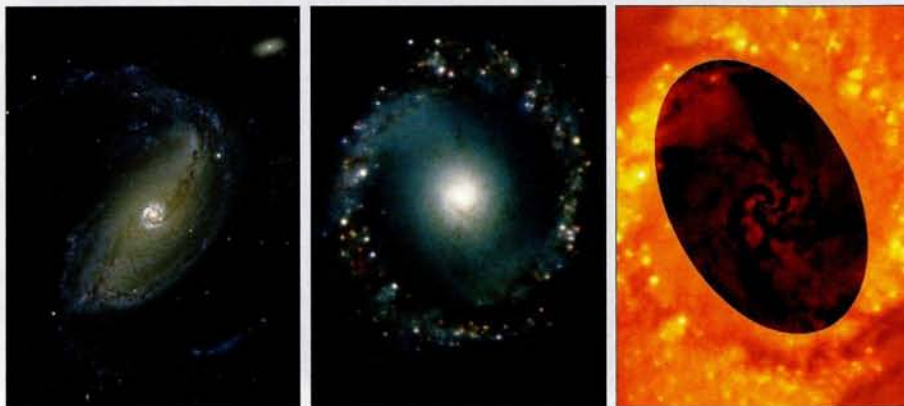
The relatively large amplitude (of the order of 10%) of the anisotropies could result from the fact that the era of Population III stars lasted only about 300 million years and that the very bright stars are forming at the peaks of the density field, which has been strongly amplified since the time of the cosmic microwave background emission by the gravitational pull of dark matter. A more detailed comparison of the results, with theoretical models predicting the level of fluctuations during the Population III era, will have to await forthcoming papers that are likely to be based on better results extracted from longer-exposure images. It is nevertheless exciting to think that an 85 cm telescope was able to detect the light emitted only a few hundred million years after the big bang by the very first stars lighting up the universe.

### Further reading

A Kashlinsky et al. 2005 *Nature* **438** 45.

## Pictures of the month

Images from ESO's Very Large Telescope reveal the surroundings of a super-massive black hole in the centre of NGC 1097, a spiral galaxy located about 45 million light-years away in the southern constellation Fornax (the furnace). The inner ring (enlarged in the middle image) is a region of intense star formation surrounding the active nucleus at the centre. A masking process was applied on the infrared image (right) to suppress the stellar light of the galaxy, thus revealing spiral arms channelling gas and dust to the super-massive black hole at the heart of the galaxy. (ESO.)



## ROBBINS LECTURE

# The practical value of science

We have been prone to think of science primarily as the birthplace of technology and the child of human need. It is not uncommon to find individuals and organizations justifying their scientific activities in terms of their applications, that is, its so-called "practical" or technological values. We find this kind of justification made on two quite different, but related, levels.

For example, the popular writer for the newspapers and magazines, in discussing with the scientific worker the nature of his discoveries, will invariably seek to find what he calls the "useful" application of this discovery, and by "useful" he means: how can it be utilized to increase the physical ease of the human environment? He is convinced that his readers, that is, the popular readers, have this uppermost in their minds and will read only those stories which contain some elements of material comfort in them. The other level, which is based on a similar conviction, is that our public legislators, from whom a very large fraction of the money to support scientific activities must now come, are moved only by the "practical" values that they might directly see as a result of their appropriations.

In both these conceptions, the protagonists have overlooked the fact that it has been the great new truths resulting from the activities of scientists as curious human beings that have

## EDITOR'S NOTE

The main extract here is by Melvin Calvin, who was professor of chemistry at the University of California, and had worked with Ernest Lawrence and others at what was then the Radiation Laboratory. Calvin used the 88 inch cyclotron there to produce radioactive tracers for research on photosynthesis, biodynamics and plant physiology, for which he received the Nobel Prize in Chemistry in 1961. The theme of the full article is that there can no longer be "pure" science – every branch of science reacts with others, and science affects and is affected by the humanities.

produced the great transformations which have taken place in the last half-dozen centuries in man's view of himself and his place in the universe. Kepler's concern to understand the motion of the heavenly bodies led him to follow Copernicus in putting the sun in the centre of our immediate region of space. The earth then became one of the smaller bodies rotating about it, and thus man's home was finally displaced from its central position in the heavens which it had long occupied. This contributed to a profound change in man's concept of his place. Darwin's

formulation of evolution in terms of natural selection again placed man in a new relation to life itself which has significantly affected all of his thinking and is still one of the central themes influencing not only the philosophers but the practical politicians as well, not to mention the scientists themselves!

Thus, it is apparent that for the welfare of mankind, scientists must understand the basic knowledge of other fields than their own, and, in addition, must understand the world about them in terms of the humanist as well. And, conversely, the student of the humanities must understand the interrelationships of his own specialty (for example, of urban planning, with the humanitarian, or aesthetic, provisions for peace of mind and of environment) as well as the relationship of his specialty to new knowledge advanced in the area of science.

Science must be returned to its proper place as one of the essential components of a liberal education. Its position should be alongside the humanistic, aesthetic and literary arts. In the final analysis science is one of the three or four principal ways that mankind has evolved, up till now, of taking a view of the world around him.

● Extracted from a six-page article, "The impurity of science", first presented in the Robbins Lectures at Pomona College, Claremont, California, on 27 February 1962.

## LAST MONTH AT CERN

# Beam-intensity records broken at the PS

Two "world records" were announced from the proton synchrotron at the beginning of November, both achieved with the new  $m_2$  beam, which utilizes two of CERN's 10 m electrostatic separators, in conjunction with focusing and bending magnets, to provide particular kinds of particles separated from all others. Kaons of momentum 3.5 GeV/c and antiprotons of 5 GeV/c were obtained, the highest values for either particle yet reached anywhere. This beam was also used to give

electrons of 600 MeV/c.

The accelerator itself was running well after its long shutdown, and during the first fortnight 215 hours were devoted to nuclear physics with only 4½% lost as a result of breakdowns of one kind or another. The average beam intensity during this time was  $4.2 \times 10^{11}$  protons per pulse. This was in fact about the same as that obtained before the shutdown. Investigations had shown that previous measurements of beam intensity had over-

estimated the values by about 15% and a new calibration is now in use. A similar recalibration has been carried out at the Brookhaven alternating-gradient synchrotron, and the two groups concerned have agreed on a new "international standard": one AGS proton equals one CPS proton.

Later in the month the average beam intensity at the PS was higher and a new peak intensity of over  $5.9 \times 10^{11}$  protons was registered in one pulse.

# A magnetic memorial to decades of experiments

**Chris Jones** looks back 45 years to when the arrival of a special magnet at CERN began a long dynasty of  $g-2$  experiments that continued at the laboratory for more than 20 years.



Fig. 1. The first  $g-2$  magnet arriving at CERN on 11 July 1960.

This is the simple story of a magnet, albeit a rather special one, which is celebrating its 45th birthday at CERN this year. It is somewhat surprising that it has survived! It lives out a peaceful retirement at the far end of the site, as befits a senior magnet that can claim to have fathered a family sharing the same aim.

The magnet came to CERN as the heart of the first  $g-2$  experiment, the aim of which was to measure accurately the anomalous magnetic moment, or  $g$ -factor, of the muon. This experiment was one of CERN's outstanding contributions to physics, and for many years was unique to the laboratory. Indeed, three generations of the experiment were performed at CERN during its first 25 years.

At present the best determined value of  $g$  for the muon is 2.0011659208 (Bennett *et al.* 2004). Clearly one is trying to measure to very high precision a number that is very close to two. The elegance of the experimental method, which uses physics to measure  $g-2$  directly through a determination of frequency (hence facilitating precision measurement), has attracted experimentalists for more than five decades. In addition this parameter has, with con-



Fig. 2. The 1960  $g-2$  team, photographed with the magnet. From left to right: Francis Farley, Johannes Sens, Georges Charpak, Theo Muller and Antonino Zichichi.

siderable reason, fascinated theorists over the same period and continues to be a rare target where experiment can test theory to the limit of its precision.

The purchase of this first 6 m-long  $g-2$  magnet was agreed by the CERN Finance Committee on 14 November 1959, and the magnet was delivered by Oerlikon of Switzerland on 11 July 1960 (figure 1). But was this really the first  $g-2$  magnet, and why was it of this form?

Before 1960 there were a number of experiments, and a list of outstanding names, each of which contributed their piece of the puzzle. If one piece is to be singled out, it must be the establishment of parity non-conservation in the pion-muon-electron decay sequence by the experiments of Richard Garwin, Leon Lederman and Marcel Weinrich, and by Jerome Friedman and Valentine Telegdi (Garwin *et al.* 1957; Friedman and Telegdi 1957). In this way, two fundamental, enabling "gifts of nature" became known: the muons are born 100% polarized in the pion rest frame, and the asymmetry of the angular distribution of the electrons emitted in their subsequent decay enables the polarization of the muon sample to be

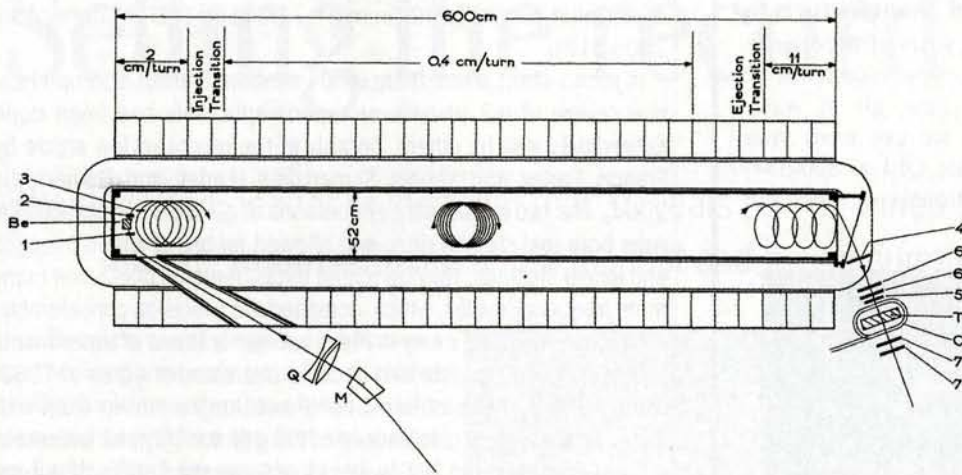


Fig. 3. The storage of muons in the first CERN g-2 magnet, as pictured in the paper in *Phys. Rev. Lett.* in 1961. The muons entered from the lower left, and the field gradient made their orbits move to the right, where they were ejected to stop in the polarization analyser.



Fig. 4. Farley (left) and Zichichi pictured working on magnetic measurements and shimming.



Fig. 5. The first g-2 magnet now retired at CERN; disassembled but still on site and, perhaps, ready to become an historical exhibit.

traced as a function of time (Combley *et al.* 1981).

The stage was thus set for a direct attack on the magnetic-moment anomaly for muons. The team that assembled was more than noteworthy with, in alphabetic order, Georges Charpak, Francis Farley, Richard Garwin, Theo Muller, Johannes Sens and Antonino Zichichi (figure 2, p12). The design of their experiment fully exploited the initial muon polarization and final decay electron asymmetry through the idea that it should be possible to store muons in a conventional bending magnet that provided an approximately uniform vertical field.

The magnet was installed in a longitudinally polarized beam of positive muons, arising from the decay of pions produced by CERN's 600 MeV synchrocyclotron (SC). The magnetic field was arranged in such a way that the muons, introduced at one end of the magnet,

were stored in circular orbits that moved along the magnet until they exited at the far end into the analyser; there they decayed, emitting an electron as a sign of polarization. Figure 3 shows how these orbits were suitably spaced (2 cm/turn) for capture upon entry to the magnet; then bunched closely together (0.4 cm/turn) in the centre for maximum storage times; and lastly spread out (11 cm/turn) at the end to eject the muons into the analyser. Some clever work was needed to add carefully calculated shims in order to create the very special magnetic field. Figure 4 illustrates the work of shimming the magnet and preparation in the halls of the SC.

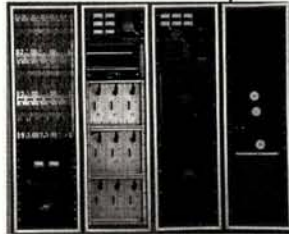
In the subsequent experiment much thought and care went into reducing systematic errors, with a result of  $g = 2.001165 \pm 5$  sent for publication only six months after the magnet was delivered ▽

## RF Amplifiers

QEI Corporation will design and manufacture to your RF Amplifier needs. Our 30 years of experience allows us to work with you to complete your requirements. Whether you require solid state or tube, air or water cooling, CW or pulse, LF to UHF, we can meet your needs. To discuss your project, contact QEI at 800-334-9154 (USA), 1-856-728-2020 (International), or via e-mail at [qeisales@qei-broadcast.com](mailto:qeisales@qei-broadcast.com).



8KW, 200MHz, CW, Water Cooled, Solid State RF Amp



65KW, 200MHz, CW, Single Tetrode RF Amp



QEI Corporation • One Airport Dr • PO Box 805 • Williamstown, NJ 08094 USA • 800-334-9154 (USA)  
1-856-728-2020 (International) • [qeisales@qei-broadcast.com](mailto:qeisales@qei-broadcast.com) (e-mail) • <http://www.qei-broadcast.com>

## G-2

(Charpak *et al.* 1961). The result agreed rather well with the theoretical value current at the time,  $g = 2.001165$  (*CERN Courier* April 2005 p12).

In such a short article there is no intention to make a comprehensive review of g-2 physics or experiments. This has been done exceedingly well by others, notably in the recent review article by Francis Farley and Yannis Semertzidis (Farley and Semertzidis 2004). The two subsequent generations of g-2 experiments at CERN were both real storage rings and allowed for higher muon energies and longer lifetimes. They permitted measurements of g-2 over many more frequency cycles, which increased the precision considerably.

One name among many in these two generations of experiments is that of Emilio Picasso, who became interested in g-2 as of 1963, when he was at Bristol and Cecil Powell urged him to work with Farley on theoretical calculations of the g-factor. (My own interest in g-2 was also triggered by Powell.) Picasso went on to lead the third-generation experiment and later the construction of a much bigger storage ring, the Large Electron-Positron Collider. The g-2 experiments moved to the US as of 1983 and have continued the battle at Brookhaven (*CERN Courier* January/February 2004 p6). Of the original pioneers at CERN, Farley still continues to be involved.

The first g-2 magnet at CERN – the focus of this article – can still be found at the far end of the Meyrin site (figure 5). It is partially disassembled, a little battered and those clever shims have disappeared, but fundamentally it still looks the same as in the pictures of 1960. Luckily no over-enthusiastic administrator has seen fit to scrap this monument to CERN history; perhaps there was a wise guardian angel who knew the magnet's value. The physics principles of the g-2 experiments are of a rare elegance and the essential parts could be explained to visitors on one panel. Is it not time to give a new lease of life to this 45-year-old magnet as the focus of a new historical exhibit at CERN?

### Further reading

- G W Bennett *et al.* 2004 *Phys. Rev. Lett.* **92** 161802.  
G Charpak, F J M Farley, R L Garwin, T Muller, J C Sens, V L Telegdi and A Zichichi 1961 *Phys. Rev. Lett.* **6** 128.  
Frederick Combley, Francis J M Farley and Emilio Picasso 1981 *Phys. Rep.* **68** 93.  
F J M Farley and Y K Semertzidis 2004 *Progress in Particle and Nuclear Physics* **52** issue 1.  
J I Friedman and V L Telegdi 1957 *Phys. Rev.* **105** 1681.  
R L Garwin, L M Lederman and M Weinrich 1957 *Phys. Rev.* **105** 1415.

### Résumé

*L'histoire d'un aimant*

*Il y a de cela 45 ans, un aimant arrivait au CERN qui allait fonder une dynastie d'expériences de mesure de l'anomalie du moment magnétique du muon, le facteur g. C'était un aimant de courbure classique, mais soigneusement conçu pour stocker les muons sur des orbites circulaires et permettre la détermination de leur polarisation par l'intermédiaire de leur désintégration. Curieusement, l'aimant a survécu et connaît une retraite paisible au CERN.*

Chris Jones, CERN.

**METROLAB**  
Instruments SA

World leader for  
advanced high-precision  
magnetic measurement



Photos courtesy of FOMAR Corporation and CERN

- NMR Teslameter
- Magnetic Field Camera
- Portable 3D Hall
- Digital Fluxmeter
- Quality
- Support
- Innovation

**www.metrolab.ch**

e-mail : [contacts@metrolab.ch](mailto:contacts@metrolab.ch) tel : +41 22 884 33 11 fax : +41 22 884 33 10

# Setting the record straight

Walter Oelert, leader of the team that 10 years ago obtained the first antimatter atoms, talks to **Tomasz Rozek** about the fact and fiction surrounding the discovery.

**Dan Brown's novel *Angels and Demons* has been enormously popular. A secret brotherhood murders a physicist who managed to produce the first antimatter on Earth. You have surely heard about the book?**

I have even read it. Indeed the author has me killed at the very beginning.

**Correct. You die and the antimatter stolen from CERN is used to blackmail the Vatican. CERN does produce antimatter, and the contact of antimatter with ordinary matter results in annihilation where large quantities of energy appear. Aren't you scared that one day Brown's scenario may become real?**

No, since there is no way to produce and store a large quantity of antimatter.

**What does "a large quantity" mean? Are we talking about kilograms?**

No, not even about nanograms. I am talking about single atoms. We are not able to produce and store amounts of antimatter that would cause damage of any kind, e.g. that could be used as an explosive, as in the book.

**You mean we are not able to now – or ever? Is that a problem of technology or perhaps a result of the laws of physics?**

Both. Let us start with technological reasons, which are probably less convincing. Even if somebody could produce lots of antimatter, their main headache would be how to store it. First, they must place it in a vacuum – any other "container" would immediately annihilate, that is disappear! So antimatter must be kept in the very middle of a vacuum by a magnetic field. This is possible, we hope to do it at CERN, but for a few or a few tens of atoms only.

The vacuum must be of the best quality. What we call a vacuum in daily life is far from the ideal. An electric light bulb is not empty but contains a very, very diluted gas. In the CERN "antimatter trap" the gas pressure is  $10^{-17}$  mbar. This means that on average there are a few tens of thousands of atoms per cubic metre. So even here we have annihilation with "stray" atoms. While it is possible to guard a few hundred antimatter atoms, protecting, say, 1 mg of antimatter from annihilation is practically impossible. And every act of annihilation results in the freeing of a certain amount of



Walter Oelert, holding a photomultiplier from the ATRAP antihydrogen experiment. (Courtesy Forschungszentrum Jülich.)

energy and degrading of the vacuum. This is a chain reaction.

**The technical limit is not a real one. What is impossible today may very well be possible tomorrow. Surely we will learn how to get a better and better vacuum?**

I agree that technical arguments may not be convincing. However, in one day CERN produces about  $10^{12}$  antiprotons. Renovations, equipment maintenance and upgrading, holidays and other interruptions limit the antiproton production to about 200 days a year. In 50 years of operation at CERN about  $10^{16}$  antiprotons would be produced. Even if all of them made anti-atoms, we would arrive at about one millionth of a milligram of antihydrogen – I repeat, in 50 years!

I must add that in the process of antihydrogen production only a tiny percentage of antiprotons make anti-atoms. Once, I calculated that even if all the natural energy resources of our planet – coal, petrol, gas – were used to produce antimatter, it would be enough to drive about 15 000 km by car. This is physics. It does not depend on our technological development.

nological development.

**So we can forget about antimatter as a future energy source?**

Of course! Until we find "natural resources" of antimatter (and I would not count on that), the production of antimatter on Earth for energy or, as in the book, for terrorism will never pay off. Much more energy would be used for its production than we could ever get back from annihilation.

**Would you agree that more people learned about CERN from *Angels and Demons* than from reading scientific information? Is CERN correctly described in Brown's book?**

This question is a trap so my answer will be diplomatic. In my opinion antimatter, and thus CERN as the only place where we are able to produce it, came into the book by accident. They were just a background. An atomic bomb at the Vatican would have done as well. I do not want to speak on behalf of the author but I have the impression that he wanted to touch on the conflict between science and faith. History shows that sometimes such a conflict has indeed been seen by the church and the scientific community. ▷

**And what about CERN? Is CERN really working on a proof that God does not exist – that scientific knowledge is the real god?**

A difficult question. For sure there are many people working at CERN who believe in God and their work actually confirms their convictions. There are also those who do not believe in God but believe in science. For them every discovery may be proof that God does not exist, but it is not true that we are working to prove that.

**“Soon all gods will be proven to be false idols. Science has now provided answers to almost every question man can ask.” This statement is made in the book by Maximilian Kohler, the [fictional] director-general of CERN. Do you agree?**

No, I do not agree. I am sure that science does not contradict faith. One person may say that he studies the laws of nature, another one that he wishes to understand how God initiated or created our world. In my opinion it is the same. Both are doing the same even if they believe in different things. The point of view represented by the head of CERN in the book was very popular in the 1950s and 60s. Not for the first time people believed then that science was close to completion; that technology would save the world. It seemed that building a sufficiently large number of nuclear reactors would solve the energy problem on Earth and so all other problems would disappear. However, people have not become happier and the old problems are still here. We continue to be dependent on nature, which dictates the conditions. I believe that despite more and more knowledge, ultimately it is nature that wins.

**Production of the first antimatter atom on Earth brought you great recognition...**

Antihydrogen production indeed led to extraordinary publicity. That is probably the reason that this work is considered to be one of 16 very important discoveries made at CERN. In my opinion, and from the scientific point of view, producing the first antihydrogen atom does not deserve such honour; the very production of antihydrogen is not a revolution in physics. It did not bring anything new and we do not care about the production itself but about studies of the antihydrogen atom. This is not at all simple. The first atoms produced moved with almost the speed of light. Indeed, one has to be fast to study such an object. Antihydrogen thus has to be cooled down and locked in a bottle; the slower it is, the better we can watch it. So the real goal is not the production of, but studies of, antimatter. I am sure that at some time physicists will manage to measure its gravitational interactions. That would really be something.

**Why are antimatter studies so interesting to the public? Usually it is difficult to sell what physicists do in their large laboratories.**

This is not completely true. There are at least a few problems that may be sold easily and in an interesting way even when drinking a good wine at a garden party. One example is relativistic physics – everybody is interested in the fact that the faster you move the younger you are. Another subject is astrophysics or the surrounding universe. It is fascinating to many, probably because we can make certain observations ourselves on a cloudless night. Besides, the astrophysical photographs are so impressive they are printed on the front pages of the daily papers. The curvature of time and space

is also an extremely interesting problem. The shortest path between two points is not at all a straight line.

**And what about antimatter?**

When it comes to particle physics, the problem is complicated. People do not know what we really do. Antimatter is an exception, which is surely due to science-fiction films, where antimatter is very often a subject. Serials gather an audience. If every Monday evening we watch the adventures of the same heroes who conquer the universe in space vessels powered by antimatter, then television characters are quickly treated as one's own family. In this way antimatter has become a family member.

**Is your interest in antimatter also a result of those films?**

No. I must admit that I have not seen many of them. Discussions on antimatter began much earlier than when the first episode of *Star Trek* was produced. The ancient Greeks had already discussed it – albeit under different names. One can read about it in the writings of Aristotle or Plato – writings that are rather philosophical according to our modern views. But 19th-century physicists also wrote about it, not yet knowing about the existence of its components.

I was always fascinated by the idea of symmetry, especially between the world and the antiworld. Does it exist at all? I think that studies of antimatter are so interesting because even in our everyday life we like asymmetry. Just have a look at an ancient Greek temple or a medieval church. But not only buildings – look at a Persian carpet. Only those that are factory-made display a full symmetry; the really expensive ones are handmade. Most appreciated are the very small breaks in symmetry, the subtle “faults” of the carpet weaver.

**It is said that as a young man you considered being an actor. Would you accept the role of Leonard Vetra, the creator of antimatter at CERN, if a film based on *Angels and Demons* was produced?**

Yes, but only on the condition that they do not take my eye or burn “Illuminati” across my chest with a hot iron. I think that from the acting point of view I would manage – after all Vetra is murdered on the first page of the novel. Does he say anything at all?

**Oh yes, but only a little. Exactly four sentences.**

Then I am sure I would manage.

**Résumé**

*Mise au point sur l'antimatière*

*Walter Oelert, un physicien du Forschungszentrum de Jülich, dirigeait au CERN le groupe qui avait produit, il y a 10 ans de cela, les premiers atomes d'antihydrogène. Dans cet entretien il sépare le réel de l'imaginaire concernant ses recherches, en particulier dans le contexte du succès de librairie de Dan Brown, *Anges et Démons*.*

**Tomasz Rozek**, Forschungszentrum Jülich, interviewed Walter Oelert from the Institut für Kernphysik at Jülich, for *wiedza i życie* (“Science and Life”), a popular Polish science magazine. This translation is published with their kind permission.



# Do gamma rays reveal our galaxy's dark matter?

An observed excess of diffuse gamma rays traces the distribution of dark matter in our galaxy through its annihilations. **Wim de Boer** describes a recent analysis of the data.

It is well known that visible matter in the form of stars and galaxies makes up only a small fraction of the total energy in our universe. The latest evidence is that 5% is made from particles we know about, while 95% is in a form we know nothing about. The large non-visible, "dark" fraction is known to exist from its gravitational effects and comes in two forms: dark matter, constituting 23% of the total energy, provides the familiar gravitational pull, thus slowing down the expansion of the universe; the remainder, the dominant 72% of the total energy, causes antigravity, i.e. it accelerates the expansion of the universe.

Dark matter was so named by the Swiss scientist Fritz Zwicky. In studying the movements of the galaxies in the Coma cluster in the 1930s, he discovered that there must be much more matter than is visible. Later, the rotation speeds of gases and stars in spiral galaxies revealed that practically every galaxy has a halo of dark matter surrounding it. This dark matter must be much more widely distributed than the visible matter, since the rotation speeds do not fall off like  $1/\sqrt{r}$ , as expected from the visible matter in the centre, but stay more or less constant.

## Annihilations

The fact that the dark matter is distributed over large distances implies that it undergoes little energy loss, so any interactions it has must be weak. Therefore, dark-matter particles are generically called WIMPs, for weakly interacting massive particles. These WIMPs must, however, be able to annihilate if they were produced in thermal equilibrium with all other particles in the early universe. At that time the number densities of different particles were all of the same order of magnitude and just as the baryon/photon ratio was reduced by 10 orders of magnitude by baryon annihilation, the WIMP number density, which is of the same order of magnitude as the baryon number density, can only have been reduced by annihilation, assuming the WIMPs are stable. (If they are not stable they must have a lifetime of the order of the lifetime of the universe, otherwise they would no longer exist.)

If WIMPs in our galaxy collide and annihilate into quark pairs, these in turn will produce stable particles including gamma rays. The gamma rays play a very special role as they point straight back to the source, in contrast to charged particles, which change their direction in galactic magnetic fields; moreover, as they hardly inter-

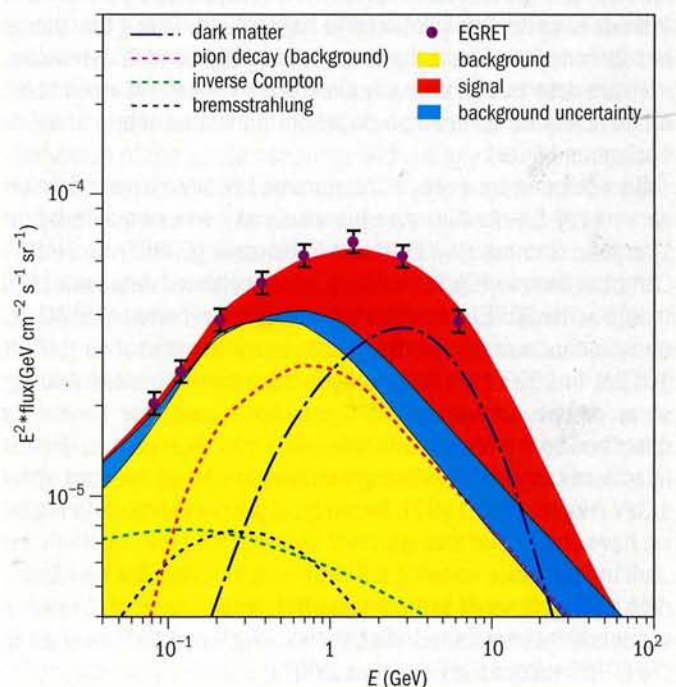


Fig. 1. The Energetic Gamma Ray Emission Telescope (EGRET) spectrum of diffuse gamma rays towards the galactic centre. The yellow area represents the contribution from the conventional background, whilst the blue area is the estimated uncertainty in the background shape from solar modulation and the cross-section uncertainties. The red area is the contribution of the gammas from the  $\pi^0$  decays produced by the annihilation of a pair of 60 GeV WIMPs into mono-energetic quark pairs, each having an energy equal to the WIMP mass. Dashed lines indicate individual contributions.

act they can be easily observed from across the galaxy. Gamma rays therefore offer a perfect means for reconstructing the distribution or halo profile of dark matter through observations in different sky directions.

Of course this assumes that gamma rays from dark-matter annihilation can be differentiated from the background, but this is indeed  $\triangleright$

possible, since the spectral shapes are very different, as can be understood as follows. WIMPs have almost no kinetic energy, so after their annihilation into quark pairs the WIMP mass is converted into the energy of the quarks. The gamma rays produced in the fragmentation of such mono-energetic quarks have been well studied at CERN's Large Electron Positron collider; they originate mainly from the decay of the copiously produced  $\pi^0$  mesons. The background, on the other hand, originates predominantly from the decay of  $\pi^0$  mesons produced by cosmic rays (mainly protons) scattering inelastically on the gas of the galactic disc, and so corresponds to the spectrum of gamma rays produced in fixed-target experiments with proton-proton collisions. In this case the gamma-ray spectrum can be calculated from the known cosmic-ray spectrum.

Clearly the steep power-law spectrum of cosmic rays will yield a spectrum of gamma rays that differs from that of the mono-energetic quarks produced in dark-matter annihilation. These different shapes can therefore be fitted to the data with free normalization factors, which then determine the relative contributions from dark-matter annihilation and background. Fitting the shapes has the advantage that the amount of background is determined from the data itself in each sky direction, so there is no need to rely on complicated galactic propagation models to obtain absolute background fluxes.

So what can be seen in the gamma-ray sky? A very detailed gamma-ray distribution over the whole sky was obtained by the Energetic Gamma Ray Emission Telescope (EGRET) on NASA's Compton Gamma Ray Observatory, which collected data from 1991 to 2000. The EGRET telescope was carefully calibrated at SLAC in a quasi-monochromatic photon beam in the energy range 0.02 to 10 GeV. In 1997 the EGRET collaboration published their findings on a diffuse component of the gamma rays that cannot be described by the background: they observed an excess as large as a factor of two above the background for gamma-ray energies above 1 GeV (Hunter *et al.* 1997). Recently, at the University of Karlsruhe, we have shown that this apparent excess traces the distribution of dark matter, since knowing the distribution of both the visible and dark matter allows us to reconstruct the rotation curve of our galaxy, especially its peculiar non-flat shape, which can be explained by the EGRET excess (de Boer *et al.* 2005).

**Mapping the flux**

Figure 1 (p17) shows the excess for the flux from the galactic centre. The curve through the data points corresponds to the two-parameter fit, where the parameters are the normalization factors for the two known spectral shapes of signal and background, as discussed above; the red and yellow areas indicate the contributions from the dark-matter annihilation signal and the background, respectively. The WIMP mass was taken to be 60 GeV, which gives an excellent fit, although WIMP masses between 50 and 100 GeV are allowed, if extremes of the background shapes are allowed. The fit was repeated for 180 independent sky directions. In every direction the excess was observed and in every direction an excellent fit could be obtained for a WIMP mass of 60 GeV, if the contribution from the extragalactic background was also taken into account towards the galactic poles.

Such a detailed mapping of the flux of dark-matter annihilation in the sky allows a reconstruction of the distribution of dark matter in

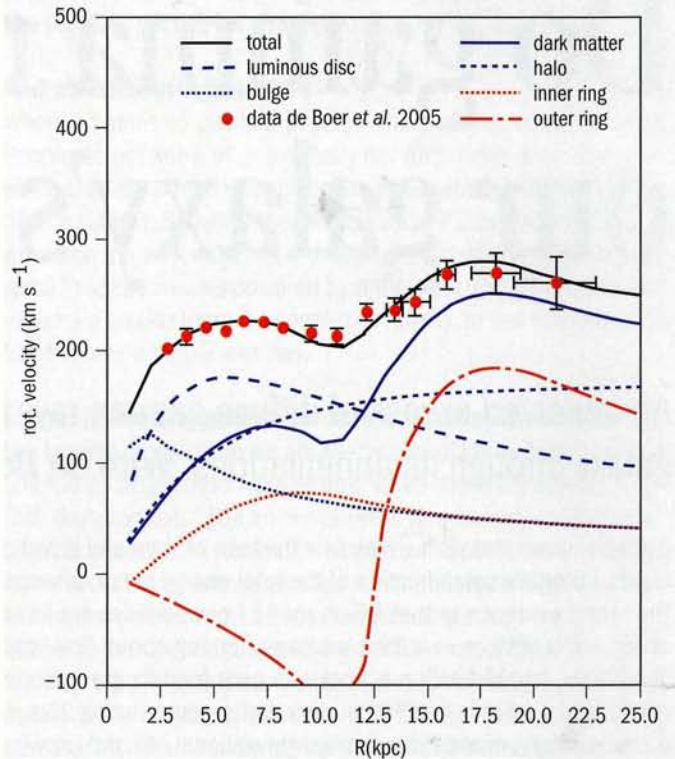


Fig. 2. The rotation curve from our galaxy with the dark-matter contribution, given by the sum of the triaxial pseudo-isothermal halo profile plus the two rings, which is determined from the EGRET excess of diffuse gamma rays (red data points).

our galaxy. The result is surprising: it yields a pseudo-isothermal profile, as observed from the rotation curves in many galaxies, but with a substructure in the galactic plane in the form of doughnut-shaped rings at radii of 4 and 14 kpc. The position of our solar system at a distance of 8 kpc from the centre is located between this inner and outer ring. The enhanced gamma radiation at 14 kpc was also discussed in the original paper by Hunter *et al.* in 1997 and called the "cosmic enhancement factor".

The ring structures in the dark-matter halo are expected to have a significant influence. A star inside the outer ring will feel an inward gravitational force from the galactic centre and an outward force from the outer ring, so the total gravitational force is reduced. This means that fast stars will go out of orbit inside the outer ring, thus causing a minimum in the rotation curve for radii within the outer ring. Outside the ring the gravitational forces from the centre and the ring add together, thus providing a maximum in the rotation curve. These effects are indeed observed, as shown in figure 2, indicating that the EGRET excess really does trace the dark matter in our galaxy.

The origin of these substructures in the dark-matter distribution is thought to be the hierarchical clustering of dark matter into galaxies: small clumps of dark matter grow from the quantum fluctuations appearing after inflation in the early universe and these clumps combine to form galaxies. That the outer ring originates from the infall of a dwarf galaxy is supported by the fact that hundreds of millions of old, mostly burned-out stars have recently been discovered in this region (Newberg *et al.* 2002, Ibata *et al.* 2003 and

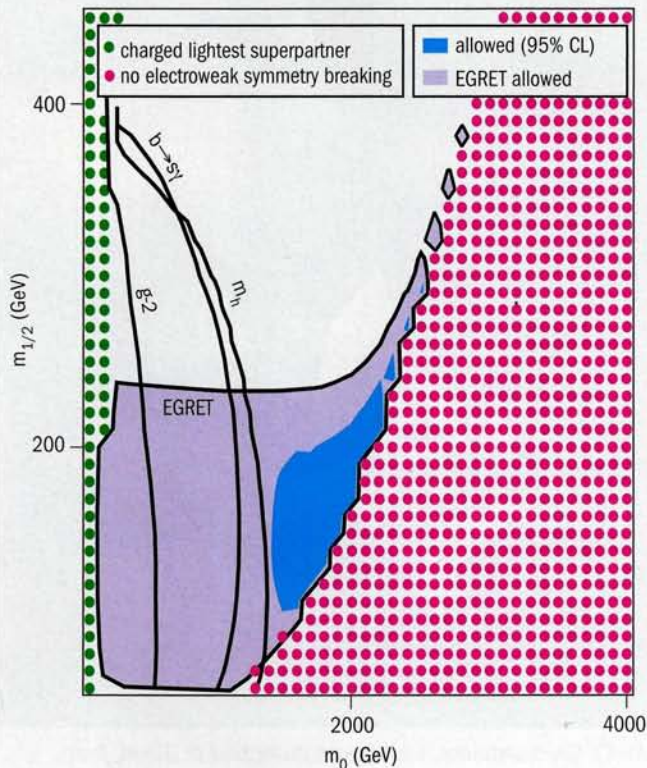


Fig. 3. The allowed region of the masses of supersymmetric particles is indicated by the blue area in the  $m_0, m_{1/2}$  plane, where  $m_0(m_{1/2})$  are the grand unification scale masses of the spin-0 (1/2) SUSY particles. The EGRET data require low  $m_{1/2}$  values, which implies values of  $m_0$  in the tera-electron-volt range, if all constraints from the Higgs limit ( $m_h$ ),  $g-2$  and the  $b \rightarrow s\gamma$  branching ratio are considered (limits exclude regions to the left). The correct relic density prefers large values of  $\tan \beta$  (the ratio of vacuum expectation values of the two Higgs fields) for these mass parameters, typically above 50.

Crane *et al.* 2003). The small velocity dispersion and large-scale height perpendicular to the galactic disc of these stars proves that they cannot be part of the disc.

The position and shape of the inner ring coincides with a ring of molecular hydrogen. Molecules form from atomic hydrogen in the presence of dust or heavy nuclei, so a ring of neutral hydrogen suggests an attractive gravitational potential well in which the dust can settle. The significant contribution of the inner ring to the rotation curve is also indicated in figure 2.

### The perfect WIMP

The conclusion that the EGRET excess traces dark matter makes no assumption about the nature of the dark matter, except that its annihilation produces hard gamma rays consistent with the fragmentation of mono-energetic quarks between 50 and 100 GeV. Supersymmetry, which presupposes a symmetry between particles with even spin (bosons) and odd spin (fermions), provides a good WIMP candidate. This symmetry requires a doubling of the particle species in the Standard Model: each boson obtains a fermion as superpartner and vice versa. These superpartners are still to be found, but the lightest is expected to be stable, neutral, massive

and barely interacting with normal matter, i.e. it is the perfect WIMP.

Although the present data cannot prove the supersymmetric nature of dark matter, it is intriguing that the WIMP mass and WIMP annihilation cross-section (which can be calculated from the present WIMP density) are perfectly compatible with supersymmetry, including all constraints from electroweak precision experiments and limits from direct searches for Higgs bosons and supersymmetric particles, at least if the spin-0 superpartners are in the tera-electron-volt range. Figure 3 shows the allowed range of masses for spin-0 and spin-1/2 superpartners, assuming mass unification at the grand unification scale, i.e. common masses  $m_0$  ( $m_{1/2}$ ) for the spin-0 (1/2) supersymmetric particles.

The allowed region in figure 3 is within reach of the Large Hadron Collider, so finding the predicted spectrum of light spin-1/2 and heavy spin-0 superpartners would prove the supersymmetric nature of the WIMP, especially if the lightest superpartner is stable and has the same mass as the WIMP mass deduced from the EGRET data. The lightest superpartner has properties akin to a spin-1/2 photon for the allowed region of figure 3, in which case the dark matter could be considered the supersymmetric partner of the cosmic microwave background, if supersymmetry is discovered. It is interesting to note that this region of parameter space yields perfect unification of the gauge couplings without any free parameters. In our first analysis in 1991, the scale of the supersymmetric masses had to be treated as a free parameter (Amaldi *et al.* 1991).

The statistical significance of the EGRET excess is at least  $10\sigma$  and alternative models without dark matter do not yield good fits if all sky directions are considered. Furthermore, alternative models do not explain the peculiar shape of the rotation curve, or the occurrence of the hydrogen rings at 4 and 14 kpc and the high density of old stars at 14 kpc. Therefore, we conclude that the EGRET excess provides an intriguing hint that dark matter is not so dark, but is visible by flashes of typically 30–40 gamma rays for each annihilation.

### Further reading

- U Amaldi, W de Boer and H Fürstenau 1991 *Phys. Lett.* **260** 447.
- W de Boer, C Sander, V Zhukov, A V Gladyshev and D I Kazakov 2005 *Astron. Astrophys.* (in press) <http://arxiv.org/abs/astro-ph/0508617>.
- J D Crane *et al.* 2003 *ApJ* **594** L119.
- S D Hunter *et al.* 1997 *ApJ* **481** 205.
- R A Ibata *et al.* 2003 *Mon. Not. Roy. Astron. Soc.* **340** L21.
- H J Newberg *et al.* 2002 *ApJ* **569** 245.

### Résumé

*Les rayons gamma révèlent-ils la matière noire galactique?*

*En 1997, le télescope EGRET de l'Observatoire Compton des rayons gamma (CGRO) avait observé un excès de rayons gamma diffus dans notre galaxie. Une analyse récente par une équipe de l'Université de Karlsruhe, appuyée sur les mesures des expériences de physique des hautes énergies, montre que cet excès pourrait provenir de l'annihilation des particules de matière noire.*

Wim de Boer, IEKP, Karlsruhe University.

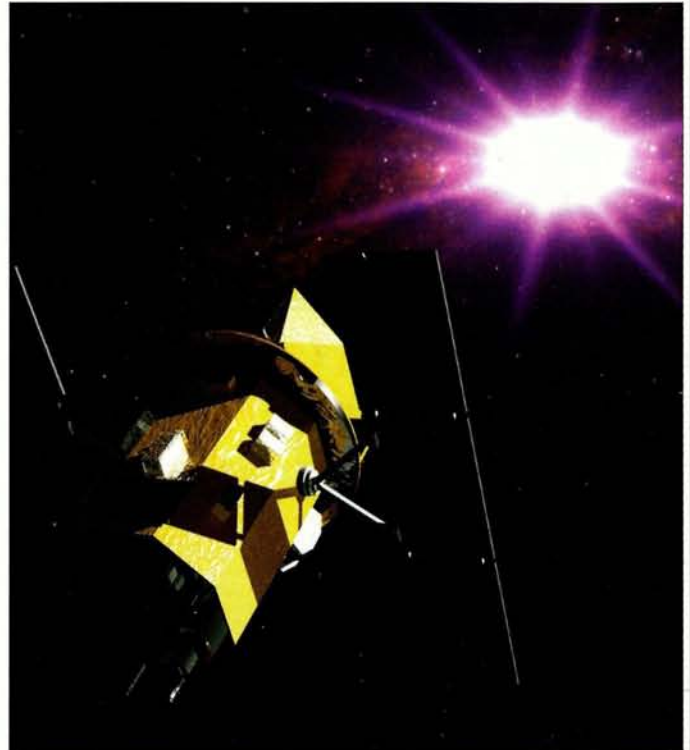
# Gamma-ray bursts: a look behind the headlines

Has the 35 year old mystery regarding gamma-ray bursts really been solved, and are recent observations really a complete surprise? **Arnon Dar** thinks not.

Gamma-ray bursts (GRBs) – intense but brief flashes of gamma rays – were first discovered accidentally by US military satellites in 1967, and have since become a major puzzle for astrophysics. By 1992, however, observations mainly with the Burst and Transient Source Experiment (BATSE) on-board NASA's Compton Gamma Ray Observatory, had provided compelling evidence that GRBs originate mostly at large cosmological distances and, moreover, divide into two distinct classes: short hard-spectrum bursts (SHBs) with a typical duration of less than one second, and long soft bursts that typically last longer than two seconds. However, the nature of the GRBs remained a mystery.

A significant breakthrough came when the Italian and Dutch space agencies put BeppoSAX into orbit in 1996. This X-ray satellite localized GRBs in its field of view with arcminute precision and led to the discovery of X-ray, optical and radio afterglows for long-duration GRBs. These afterglows faded relatively slowly and enabled subarcsecond localization of the long GRBs, as well as measurement of their cosmological redshifts and absolute brightness, identification of their star-forming galaxies and finally their progenitors – ultrarelativistic jets ejected from supernova explosions due to the core collapse of massive stars (*CERN Courier* June 2003 p5 and p12). Yet despite this impressive progress, many important questions regarding long GRBs remained unanswered. What type of core-collapse supernova produces them? What sort of remnant is left over? What is the true production mechanism? Moreover, despite extensive searches no afterglow was detected for the SHBs, and their redshifts, intrinsic brightness, host galaxies and progenitors remained unknown.

This situation has changed dramatically in the past few months



NASA's Swift satellite, which was launched in 2004, has proved a great success in its mission to detect and localize gamma-ray bursts quickly and precisely so that their afterglows can be promptly studied from both space and Earth.

after the successful launch in November 2004 of Swift, NASA's multi-wavelength observatory dedicated to the study of GRBs. Its main missions are to detect GRBs, measure their properties, localize their sky positions with sufficient precision shortly after detection, and communicate these positions automatically to other space- and ground-based telescopes in order to discover and follow up the afterglows in a broad range of wavelengths, soon after the beginning of the bursts. By the end of September 2005, Swift had detected and localized 70 GRBs. Three of these – 050509B, 050724 and 050813 – were SHBs and follow-up observations have discovered elliptical host galaxies at redshifts 0.225, 0.258 and 0.722, respectively. Shortly after Swift's detection and localization of SHB 050509B, NASA's High Energy Transient Explorer satellite, HETE-2, which had been launched in 2000, detected and localized another SHB, 050709, on 9 July 2005 (Gehrels *et al.* 2005 and Villasenor *et al.* 2005). Follow-up measurements have found and measured its X-ray and optical afterglows, which led in turn to the discovery of its host – a star-forming young galaxy at redshift 0.16 (Hjorth *et al.* 2005 and Fox *et al.* 2005).

The observed brightness and energy fluence, and the measured redshifts of the SHBs imply that their intrinsic brightness is smaller than that of typical long GRBs by two to three orders of magnitude. Moreover, their inferred total emitted radiation, assuming isotropic emission, is smaller by four to five orders of magnitude. So it is quite possible that SHBs are seen at relatively small redshifts because they are intrinsically faint and cannot be seen from large cosmological distances. However, it is not clear why around 20% of the bursts observed by BATSE are SHBs, but only 5% of those seen by Swift.

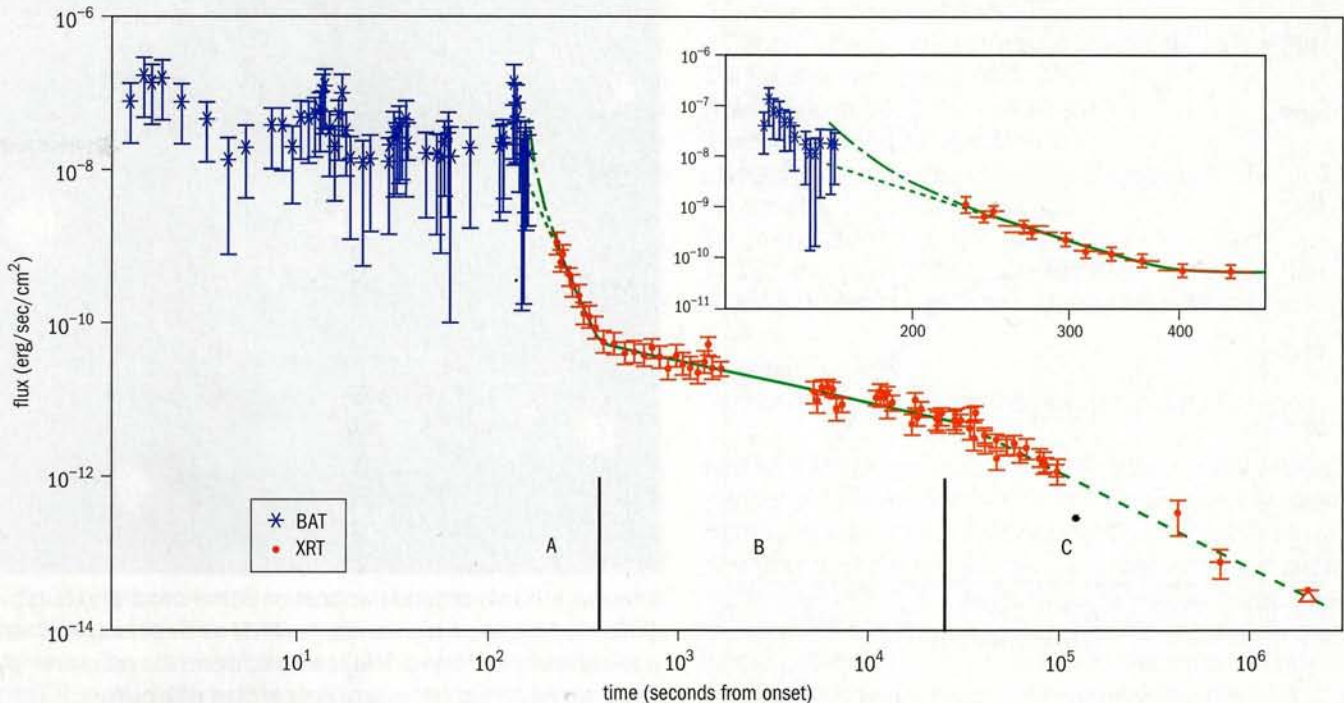


Fig. 1. The gamma-ray (15–150 keV) light curve of GRB 050319 and its X-ray afterglow (0.2–10 keV) as measured by the Burst Alert Telescope (BAT) and the X-ray Telescope (XRT) on-board Swift (G Cusumano et al. 2005 <http://arxiv.org/abs/astro-ph/0509689>).

### Has the mystery been solved?

These observations have led to recent press releases by NASA and some prestigious universities, and the publication of articles in astrophysical journals and in *Nature*, *Science* and *Scientific American*, which claim that “the 35 year old mystery of GRBs” has finally been solved and that SHBs have been proven to be produced by the merger of neutron stars or of a neutron star and a stellar black hole in close binary systems. But is this so?

The relatively small redshifts of SHBs and their association with both star-forming spiral galaxies and elliptical galaxies containing mainly old stars appears consistent with their origin in the merger of neutron stars in binary systems, as the merger usually takes place a long time after the formation of the neutron stars. The idea is that a large number of the neutrinos and antineutrinos that are emitted in the merger collide with each other outside the merging stars and annihilate into electron–positron pairs, which form a fast expanding fireball that produces the GRB (Goodman *et al.* 1987). Later, it was suggested that instead of spherical fireballs, mergers produce highly relativistic jets along the rotation axis, which can produce shorter and brighter GRBs through, for example, inverse Compton scattering of ambient light around the merging stars.

At first sight the merger scenario seems consistent with the observations, but a more careful examination raises serious doubts. The cosmic rate of such mergers as a function of redshift can be calculated from general relativity using the observed properties of galactic neutron-star binaries and their production rate, which must be proportional to the measured star formation rate. Despite the small statistics the redshift distribution of the SHBs detected by Swift and HETE-2 appears inconsistent with the theoretical expectations from the merger model.

A second problem concerns an X-ray flare observed by the Chandra X-ray Observatory in the afterglow of SHB 050709 on day 16 after the burst. In the fireball models of GRBs, X-ray flares in the afterglow are interpreted as due to “re-energization” of the afterglow by the central engine (Zhang and Meszaros 2004). The final merger in a neutron-star binary due to gravitational wave emission, however, takes place in less than a millisecond and produces a black hole. It is hard to imagine that the remnant can “re-energize” the X-ray afterglow after 16 days, a time scale one billion times larger than a millisecond. On the other hand, in the alternative “cannonball” model of GRBs, X-ray flares are produced when the highly relativistic jets from the central engine (in this case mass accretion on a compact object) encounter density changes in the interstellar medium (Dado *et al.* 2002). Indeed, SHB 050709 took place not far from the centre of a galaxy where star formation produces strong winds and density irregularities.

Other scenarios for SHB production have been dismissed as unfavoured by the observations, but this may have been premature. Accretion-induced collapse of neutron stars in compact neutron-star/white-dwarf binaries is consistent with all the observations. Origin in a supernova collapse was ruled out for 050509B and 050709 by follow-up measurements with powerful optical telescopes, but only for these SHBs; much larger statistics are needed to conclude that SHB production in a type Ia supernova is unlikely. Origin in soft gamma-ray repeaters (SGRs), which are anomalous pulsars that occasionally produce GRBs, was ruled out by the claim that they are too faint to be observed at the measured redshifts of SHBs. Consider, however, the burst emitted on 27 December 2004 by the galactic SGR 1806-20. It was the brightest GRB ever recorded from any astronomical object, beginning with a short ▷

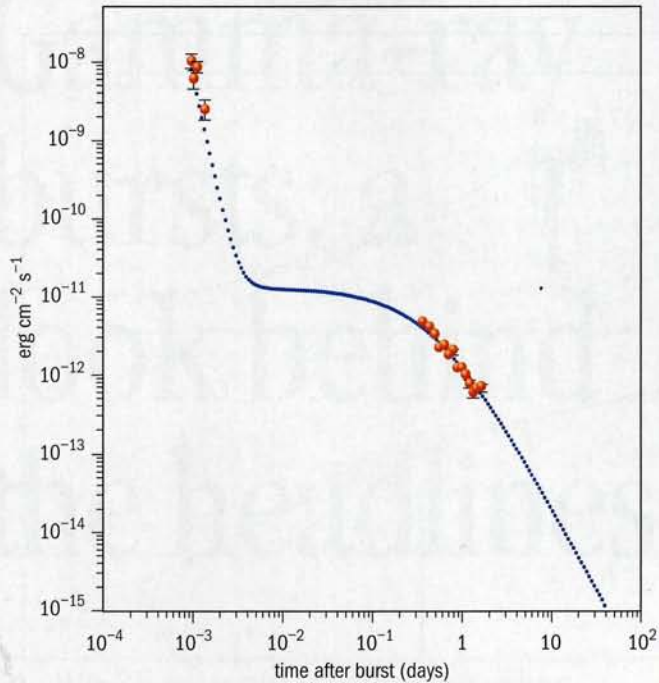


Fig. 2. The universal shape of the X-ray afterglow of GRBs as predicted by the cannonball model in 2001, compared with the early and late-time X-ray afterglow (2–10 keV) of GRB 990510, as measured by BeppoSAX (figure from Dado et al. 2002).

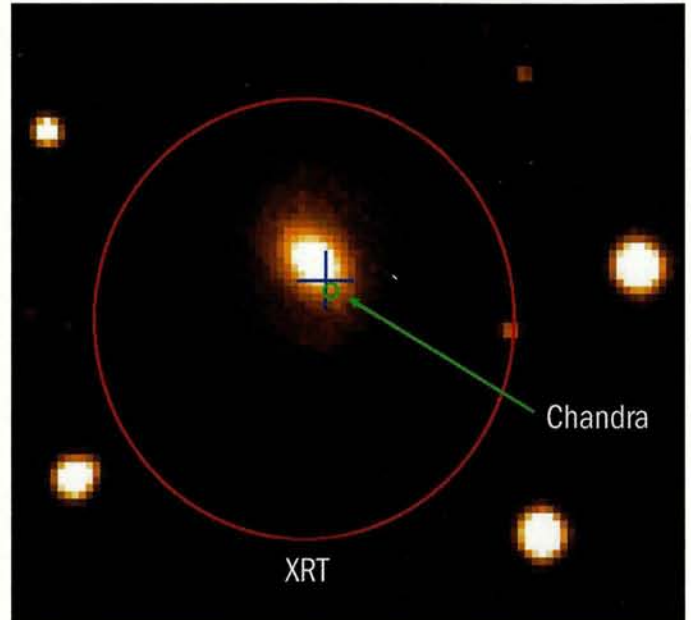
0.2 second spike that was followed by a much longer and dimmer tail modulated by the 7.55 second period of the pulsar. Had it taken place in a distant galaxy, the spike, if detected, would have been classified as an SHB.

The maximum distance from which such a spike could be detected depends on the uncertain distance of SGR 1806-20 and, if it was relativistically beamed into a small solid angle like ordinary long GRBs, on its viewing angle. A viewing angle three to four times smaller than that for the spike presumably beamed from the superburst of SGR 1806-20 would be sufficient to make it look like a normal SHB at a redshift of  $z \sim 0.25$  (Dar 2005). Moreover, SGRs may be born not only in core collapse supernova explosions but, for example, in the accretion-induced collapse of white dwarfs, as suggested by the fact that, despite their young age, only one of the four known SGRs is located inside a supernova remnant. This may explain why SHBs are produced both in elliptical galaxies with old stellar populations and in star-forming spiral galaxies with young stellar populations.

**Unsurprising behaviour**

Because of its higher sensitivity, Swift can see deeper into space than any previous gamma-ray satellite. Indeed, the 14 long GRBs localized by Swift for which a redshift has been reported have a mean redshift of  $\langle z \rangle = 2.8$ . This is twice the mean of  $\langle z \rangle = 1.4$  for the 43 GRBs with a known redshift that have been localized by BeppoSAX, HETE-2 and the interplanetary network over the past seven years.

Swift’s record redshift so far is  $z = 6.29$ , for GRB 050904, which looks like an ordinary burst with an ordinary afterglow (Haislip et al. 2005). This redshift is comparable to that of the most distant quasar measured to date, and in the standard cosmological model it corresponds to a look-back time of nearly 14 billion years, to



Images of the sky around the location of the short-hard burst GRB 050724. The X-ray Telescope (XRT) on Swift has localized it to within the red circle. The small circle and the cross are precision locations within an elliptical host galaxy from subsequent observations with X-ray (Chandra), optical (Swope) and radio (VLA) telescopes. (Credit: Gianpiero Tagliaferri/Osservatorio Astronomico di Brera.)

when the universe was only one billion years old. Thus this single GRB already indicates that star formation and core-collapse supernova explosions took place at this early cosmic time, and together with previous measurements shows that the rate of star formation has not declined between  $z = 1.4$  and  $z = 6.29$ . It also demonstrates that long GRBs and their optical afterglows, which are more luminous than any known astronomical object by many orders of magnitude, can be used as excellent tools for studying the history of star formation, galaxies, and intergalactic space since the time of the early universe.

The X-ray telescope on-board Swift also recorded, in fine detail, the evolution of X-ray afterglows of a dozen or so GRBs, from right after the burst until they became undetectable. Most of these X-ray afterglows demonstrate a universal behaviour: an initial fast fall-off within the first few minutes followed by a shallow decline over the next few hours, which afterwards steepens gradually into a much faster power-law decline (see figure 1, p21). In some cases Swift has also detected X-ray flares superimposed on this universal behaviour. These observations were presented in *Nature* and *Science* as complete surprises that cannot easily be explained by current theoretical models of GRBs (*CERN Courier* October 2005 p11). This may be true for the popular fireball models of GRBs, but it is not true for the cannonball model, which correctly predicted these effects long ago.

The fast initial fall-off and the gradual roll over of the shallow decline to a later power-law decline were in fact already indicated by observations in 1998. Figure 2 shows the comparison with these observations of the universal behaviour predicted from the cannonball model in 2001. Moreover, an X-ray flare had also already been seen in 1997 by BeppoSAX in the afterglow of GRB 970508 (Pian et

*al.* 2001) and can also be explained in the cannonball model.

In the cannonball model, the early X-ray afterglow originates in thin bremsstrahlung from a rapidly expanding plasmoid – the cannonball – which stops expanding within a few observer minutes after ejection. Synchrotron emission from the ionized interstellar electrons, which are swept into the decelerating cannonball, then takes over. The shallow decline followed by the roll-over into a power-law decline is a simple effect of off-axis viewing of decelerating jets in the interstellar medium, which has been observed in many optical afterglows but misinterpreted by fireball models. The flares are caused by collisions of the jet with density jumps in the interstellar medium produced by stellar winds and supernova explosions.

In conclusion, it seems that the localization of SHBs by Swift and HETE-2, which led to the discovery of their afterglows, the identification of their host galaxies and the measurements of their redshifts, have been over-interpreted. While these are undoubtedly observational breakthroughs, the origin of SHBs is still an unsolved mystery. Nevertheless, the small redshifts of SHBs are good news for gravitational wave detectors such as LIGO and LISA, in particular, if SHBs are produced mainly by mergers of neutron stars or a neutron star and a black hole in binaries, as first suggested in 1987. Moreover, the observed behaviour of the early X-ray afterglows of long GRBs and the X-ray flares – both claimed to be a complete surprise and unexpected in the fireball models – were predicted correctly long ago, like many other features of long gamma-ray bursts, by the cannonball model.

#### Further reading

- S Dado *et al.* 2002 *A&A* **388** 1079.  
 A Dar 2005 <http://arxiv.org/abs/astro-ph/0509257>.  
 D B Fox *et al.* *Nature* 2005 **437** 845.  
 N Gehrels *et al.* 2005 *Nature* **437** 851.  
 J Goodman *et al.* 1987 *ApJ* **314** L7.  
 J Haislip *et al.* 2005 <http://arxiv.org/abs/astro-ph/0509660>.  
 J Hjorth *et al.* 2005 *Nature* **437** 859.  
 E Pian *et al.* 2001 *A&A* **372** 456.  
 J S Villaseñor *et al.* 2005 *Nature* **437** 855.  
 B Zhang and P Meszaros 2004 *J. Mod. Phys. A* **19** 2385.

#### Résumé

*Sursauts gamma: les gros titres ne disent pas tout*

*La découverte des sursauts gamma date de la fin des années 60, mais leur origine est longtemps restée mystérieuse. Les récentes observations du satellite Swift de la NASA ont donné lieu à de gros titres dans de prestigieuses publications, affirmant que le mystère vieux de 35 ans des sursauts gamma avait finalement été résolu dans le cas des sursauts brefs; les sursauts longs, par contre, présenteraient un comportement inattendu. Mais ce comportement est-il vraiment inattendu et le mystère est-il réellement dissipé?*

**Arnon Dar**, Technion, Haifa, Israel.

## SUPPLIER INFORMATION



### Janis Research Company Inc

#### Microscopy Cryostats

The ST-500 and ST-500-LN cryostats are optimized for microscopy, imaging and high spatial resolution photoluminescence in both transmission and reflection. Temperature ranges are 3.5K to 450K for the LHe model, and 10K to 450K for the ultra-low profile LN2/LHe model. Both models offer extremely low vibrations, large optical apertures and short working distances.

Janis Research Company, Inc. 2 Jewel Drive,  
 PO Box 696, Wilmington, MA 01887-0696, USA  
 Tel: +1 978 657 8750  
 Fax: +1 978 658 0349  
 E-mail: sales@janis.com  
 Web: www.janis.com

## SUPPLIER INFORMATION

- Do you want to promote your latest catalogue?
- Have you recently upgraded your company website/  
or do you just want to increase the traffic?
- Have you had a new product launch that you want  
to continue to promote?

If you have answered YES to one or more of these questions, you should reserve your space in the Supplier Information section.

FOR ONLY £625, 50 WORDS OF TEXT AND AN IMAGE OF YOUR HOMEPAGE, LATEST CATALOGUE OR NEW PRODUCT CAN APPEAR IN THE NEXT SUPPLIER INFORMATION SECTION.

Call Jonathan Baron or Edward Jost on +44 (0)117 930 1265 or +44 (0)117 930 1026, respectively, to be included.



## new ultra-low temperature photomultiplier

Our range of photomultipliers for ultra-low temperature applications has been extended, and now includes a 130mm hemispherical tube that can operate down to -200°C and has an ultra-low background quartz envelope to enable detection down to 160 nm.

This new photomultiplier is suitable for

- High energy physics studies
- Liquid argon and xenon detectors
- UV light detection

Please contact us for full details

#### Electron Tubes Limited

Bury Street, Ruislip,  
 Middx, HA4 7TA, UK  
 tel: +44 (0) 1895 630771  
 fax: +44 (0) 1895 635953  
 e-mail: info@electron-tubes.co.uk

#### Electron Tubes Inc.

100 Forge Way, Unit F  
 Rockaway, NJ 07866, USA  
 tel: (973) 586 9594  
 toll free: (800) 521 8382  
 fax: (973) 586 9771  
 e-mail: sales@electron-tubes.com



visit our all-new website at  
[www.electrontubes.com](http://www.electrontubes.com)

# ILC comes to Snowmass

In August nearly 700 scientists and engineers from North America, Asia and Europe got together at Snowmass in the US to advance the design of the International Linear Collider and its detectors, and to refine the physics case for this next-generation machine.



Workshop co-chairs Uriel Nauenberg (left) and Ed Berger (centre) with HEPAP chair Fred Gilman. (All photos courtesy of Fermilab.)



Barry Barish (left), director of the Global Design Effort, engages participants in one of the Snowmass working groups.

In August 2004 the Executive Committee of the American Linear Collider Physics Group (ALCPG), galvanized by the technology choice for the future International Linear Collider (ILC), decided to host an extended international summer workshop to further the detector designs and advance the physics arguments. Subsequently, the International Linear Collider Steering Committee (ILCSC) elected to hold their Second ILC Accelerator Workshop in conjunction with the Physics and Detector Workshop. Ed Berger of Argonne and Uriel Nauenberg of Colorado were selected to co-chair the organizing committee for this joint workshop, which was held at Snowmass, Colorado, US, for two weeks in August. ALCPG co-chairs Jim Brau of Oregon and Mark Oreglia of Chicago, along with accelerator community representatives Shekhar Mishra from Fermilab and Nan Phinney from SLAC, rounded out the committee. While hosted by the North American community, the workshops were planned with worldwide participation in all the advisory committees and in the scientific programme committees for the accelerator, detector, physics and outreach activities.

As Berger described in the opening address, the primary accelerator goals at Snowmass were to define an ILC Baseline Configuration Document – to be completed by the end of 2005 – and to identify critical R&D topics and timelines. On the detector front, the goal was to develop detector design studies with a firm understanding of the technical details and physics performance of the three major detector concepts, the required future R&D, test-beam plans, machine-detector interface issues, beamline instrumentation and cost estimates. The physics goals were to advance and sharpen ILC physics studies, including precise higher-order calculations, synergy with the physics programme of CERN's Large Hadron Collider (LHC),

connections to cosmology, and, very importantly, relationships to the detector designs. A crucial fourth goal was to facilitate and strengthen the broad participation of the scientific and engineering communities in ILC physics, detectors and accelerators, and to engage the greater public in this exciting work.

## A rich new world

Over the past few years, prestigious panels in Europe (the European Committee for Future Accelerators – ECFA), Asia (the Asian Committee for Future Accelerators – ACFA) and the US (the High Energy Physics Advisory Panel – HEPAP) have reached an unprecedented consensus that the next major accelerator for world particle physics should be a 500 GeV electron-positron linear collider with the capability of extension to higher energies. This machine would be ideal for exploiting the anticipated discoveries at the LHC and would also have its own unique discovery capabilities. The ability to control the collision energy, polarize one or both beams, and measure cleanly the particles produced will allow the linear collider to zero in on the crucial features of a rich new world that Peter Zerwas of DESY described on the first day of the workshop, which might include Higgs bosons, supersymmetric particles and evidence of extra spatial dimensions.

This physics programme dictates specific requirements for the detectors and for the accelerator design. As the ILC community turns increasingly to design and engineering, there was considerable activity in the physics groups to formulate these requirements concretely. Early in the workshop, an international panel set up this spring presented a proposed list of benchmark processes to be used in optimizing the ILC detector designs. This brought a new



flavour to the physics discussions – one that will continue in future work on physics at the ILC.

This influence was felt most strongly in the working groups on Higgs physics and supersymmetry. Precision electroweak data predict that the neutral Higgs boson will be observed within the initial energy reach of the ILC, which will provide a microscope to study the whole range of possible Higgs boson decays and measure coupling strengths to the percent level. To accomplish this goal, the ILC detectors must have significantly better performance in several respects than those at CERN's Large Electron-Positron



CERN theorist Gudrid Moortgat-Pick speaks out.

collider (LEP). In contrast with the quite specific implications of Higgs boson physics, the idea of supersymmetry encompasses various models with diverse implications. Some of the signatures of supersymmetry will be studied at the LHC, but the problem of understanding the exact nature of any new physics will be a difficult one. Through the study of a diverse set of specific parameter sets for supersymmetry, work done at Snowmass showed that the ILC experiments could address this problem robustly, and the necessary detector performances were specified.

### Precision is crucial

The precision of the ILC experiments should be supported by equally precise theoretical calculations. Among those discussed at the workshop were Standard Model analyses, including higher-order contributions in quantum chromodynamics, calculations of radiative corrections to the key Higgs boson production processes, and precision calculations within models of new physics. The Supersymmetry Parameter Analysis project, presented at Snowmass, proposes a convention for the parameters for supersymmetry models from which observables can be computed to the part-per-mille level for unambiguous comparison of theory and experiment. The fourth in the series of LoopFest conferences on higher-order calculations took place during the Snowmass workshop, the highlight this year being a presentation of new twistor space methods for computing amplitudes for emission of very large numbers of gluons and other massless particles. New calculations of the process  $e^+e^- \rightarrow \bar{t}t$  showed that higher-order corrections enhance this process by a factor of two near threshold, making it possible for the 500 GeV ILC to obtain a precise measurement of the top quark Yukawa coupling.

The capabilities of the ILC will make it possible to explore new models, which include Higgs sectors with CP violation (for which the ILC offers specific probes of quantum numbers), and models with a "warped" extra dimension, which predict anomalies in the top quark couplings that can be seen in  $\bar{t}t$  production just above threshold.

Many of the discussions of new physics highlighted the connections to current problems of cosmology. Supersymmetry and many other models of new physics contain particles that could make up (at least part of) the cosmic dark matter. If these models are correct, dark-matter candidates will be produced in the laboratory at the LHC. Studies at Snowmass showed how precise measurements at the ILC could be used to verify whether these particles have the

properties required to account for the densities and cross-sections of astrophysical dark matter. Here all the strands of ILC physics – exotic models, precision calculations and incisive experimental capabilities – could combine to provide physical insight that can be obtained in no other way.

### The accelerator design effort

In August 2004 the International Technology Recommendation Panel concluded that the ILC should be based on superconducting radio-frequency accelerating structures. This recommendation has been universally adopted as the

basis for the ILC project, now being coordinated via the Global Design Effort (GDE), led by Barry Barish from Caltech. At Snowmass, the accelerator experts carried the baton from the successful launch of the ILC design effort at the first ILC workshop at KEK in Japan in November 2004. Snowmass also provided the forum for the first official meeting of the GDE. The working groups established for the first ILC workshop at KEK formed the basis of the organizing units through Snowmass. In addition, six global groups were formed to work towards a realistic reference design: Parameters, Controls & Instrumentation, Operations & Availability, Civil & Siting, Cost & Engineering, and Options.

Sources of electrons and positrons are the starting points of the accelerator chain. The successful production of intense beams of polarized electrons at the SLAC Linear Collider (SLC) between 1992 and 1998 demonstrated the best mechanism for producing electrons. When polarized laser light is fired at special cathode materials, electrons are produced with their spin vectors aligned, with polarization of up to 90% achieved in the laboratory. The ability to select the "handedness" of the beam is an incisive capability that will allow probes of the left- or right-handed nature of the couplings of new particles, such as those in supersymmetric models.

As well as the positron production systems used previously, other approaches are being studied to achieve polarized beams. One involves passing the high-energy electron beam through the periodic magnetic field provided by an "undulator", similar to those used at synchrotron light sources. The intense photon beams radiated by the undulating electrons can be converted in a thin target into electron-positron pairs. A second method involves boosting the energies of photons produced in laser beams by Compton back-scattering them from electrons, and then similarly converting the boosted photons to yield positrons. If the intermediate photons are polarized, both of these methods allow polarized positron production.

The electron and positron beams produced must be "cooled" in so-called damping rings, in which their transverse size is reduced via synchrotron radiation during several hundred circuits. A few different designs are being studied for these rings. Challenges include precise component alignment and the high degree of stability required for low emittance, while minimizing collective effects that can blow up the beams.

Most of the length of the linear collider, some 20 km or so, will be devoted to accelerating the electron and positron beams in two ▷

opposing linacs. The debate at Snowmass centred on critical issues, such as the operating choice for the accelerating voltage gradient in the superconducting niobium cavities and the choice of advanced technologies that must be used to power the cavities. The details of the shape and surface preparation of the cavities are among the issues that affect the gradient that can be supported. Larger radii of curvature of the cavity lobes are desirable to reduce peak surface electric fields that can induce breakdown. Also, advanced surface preparation techniques such as electropolishing are being refined, and cavities are being produced and tested by strong international teams at regional test facilities. Based on experience to date, a draft recommendation was reached for a mean initial operating gradient of around 31 MV per metre. Each linac would then need to be just over 10 km long to reach the initial target centre-of-mass energy of 500 GeV.

Similar expert attention was devoted to the modulators, klystrons and distribution systems that convert "wall-plug" power into the high-power (10 MW) millisecond-long pulses applied to the cavities. Industrial companies in Europe, Asia and the US have developed prototype klystrons for this purpose. These are in use at the TESLA Test Facility at DESY, which provides a working prototype linac system. Several innovative ideas for solid-state modulators or more compact klystrons are also being explored with industry.

Once at their final energy, the beams must be carefully focused and steered into collision. The collision point lies at the ends of the two linacs and encompasses the interaction region, including the detector(s). The working recommendation, defined at the workshop at KEK, is to consider two interaction regions, each with one detector. Many important ramifications were discussed at Snowmass. For example, the current plan calls for the beams to be brought into the interaction region with a small horizontal crossing angle of either 2 or 20 mrad. In either case the final-focus magnets must be carefully designed to be compact and stable with respect to vibrations that could be transferred to beam motion. A detailed engineering design is being prepared, which will also include beam-steering feedback systems to maintain the beams in collision and optimize the luminosity. Intermediate values for the crossing angle, such as 14 mrad, are also under study.

Of no less importance is the need to remove the spent beams safely from the interaction region and transport them to the beam dumps. As each beam carries an equivalent of several megawatts of power, the design must allow the necessary clearances, and be capable of being aborted safely in the event of equipment failure. The "machine protection" system and beam dumps remain subjects for active R&D. Many crucial diagnostic systems for measuring the beam energy, polarization and luminosity will be based in the extraction lines, and excellent progress was made in defining the loca-



*The cosmic-ray-shower study in Aspen Mall drew in the public for discussions with physicist Greg Snow of Nebraska (centre) and Cheryl Brooks (right), a teacher with the QuarkNet programme.*

tions and configurations of the necessary instrumentation.

The GDE will build on the consensus reached at Snowmass and produce an accelerator Baseline Configuration Document (BCD) by the end of 2005. As Nick Walker from DESY summarized at the end of the workshop, the BCD will define the most important layout and technology choices for the accelerator. For each subsystem a baseline technology will be specified, along with possible alternatives which, with further R&D, will offer the promise to reduce the cost, minimize the risk or further optimize the performance of the ILC. The

engineering details of the baseline design will then be refined and costed. A Reference Design Report will follow at the end of 2006. This will represent a first "blueprint" for the ILC, paving the way for a subsequent effort to achieve a fully engineered technical design.

### Detector concepts

The Snowmass workshop was an important opportunity for proponents of the three major detector-concept studies to work together on their detector designs. They are planning to draft detector outline documents before the next Linear Collider Workshop (LCWS06) in Bangalore in March 2006. Detector capabilities are challenged by the precision physics planned at the ILC. The environment is relatively clean, but the detector performance must be two to ten times better than at LEP and the SLAC Linear Collider. Details of tracking, vertexing, calorimetry, software algorithms and other aspects of the detectors were discussed vigorously.

The three major international detector concepts rely on a "particle flow" approach in which the energy of jets is measured by reconstructing individual particles. This technique can be much more precise than the purely calorimetric approach employed at hadron colliders like the LHC. In a typical jet, 70% of the energy consists of hadrons, which are measured with only moderate resolution in the hadron calorimeter, while 30% consists of photons, which are measured with much better precision in the electromagnetic calorimeter. Of the hadronic energy typically 60% is carried by charged particles, which can be measured precisely with the tracking system. The hadron calorimeter is thus relied on only for the 10% carried by neutral hadrons. For the particle-flow approach, it is necessary to separate the charged and neutral particles in the calorimeters, where the showers overlap or are often very close to each other. Separation of the showers is accomplished differently in each of the detector concepts, trading off detector radius, magnetic-field strength and granularity of the calorimeter.

A specialized group worked on the development of the particle-flow algorithms. A conventional shower-reconstruction algorithm tends to combine the showers of different hadrons, but more sophisticated software should be able to separate them based on the sub-structure of the showers. At present the energy resolution of jets is

still limited by confusion in the reconstruction, but significant progress was achieved at Snowmass, with optimism that a resolution of  $30\%/ \sqrt{E}$  can be reached.

In the Silicon Detector Concept (SiD) the goal is a calorimeter with the best possible granularity, consisting of a tungsten absorber and silicon detectors. To make this detector affordable, a relatively small inner calorimeter radius of 1.3 m is chosen. Shower separation and good momentum resolution are achieved with a 5 T magnetic field and very precise silicon detectors for charged particle tracking. The fast timing of the silicon tracker makes SiD a robust detector with respect to backgrounds.

The Large Detector Concept (LDC), derived from the detector described in the technical design report for TESLA, uses a somewhat larger radius of 1.7 m. It also plans a silicon-tungsten calorimeter, possibly with a somewhat coarser granularity. For charged particle tracking, a large time-projection chamber (TPC) is planned to allow efficient and redundant particle reconstruction. The larger radius is needed to achieve the required momentum resolution.

The GLD concept chooses a larger radius of 2.1 m to take advantage of a separation of showers just by distance. It uses a calorimeter with even coarser segmentation and gaseous tracking similar to the LDC. Progress at Snowmass on the GLD, LDC and SiD concepts was summarized at the end of the workshop by Yasuhiro Sugimoto of KEK, Henri Videau of Ecole Polytechnique and Harry Weerts of Argonne, respectively. A fourth concept was introduced at Snowmass, one not relying on the particle-flow approach.

A common challenge for all detector concepts is the microvertex detector. Physical processes to be studied at the ILC require tagging of bottom and charm quarks with unprecedented efficiency and purity, as well as of tau leptons. This task is complicated by backgrounds from the interacting beams and the long bunch trains during which readout is difficult. The detectors must be extremely precise, and also extremely thin, to avoid deflection of low-momentum particles and deterioration of interesting information. Several technologies are under discussion, all employing a "pixel" structure based on the excellent experience of the SLD vertex detector at SLAC, ranging from charge-coupled devices (CCDs) and complementary metal-oxide semiconductor (CMOS) sensors used in digital cameras, to technologies that improve on the ones already used for the LHC.

In the gaseous tracking groups much discussion centred on methods to increase the number of points in the TPC, compared with LEP experiments. A possibility is to use gas electron-multiplier foils, a technology that was developed at CERN for the LHC detectors. Micromesh gaseous structure detectors, or "micromegas", are another option, pursued mainly in France. The availability of test beams is crucial for advancing detector designs. TPC tests have been performed at KEK, and a prototype of the electromagnetic calorimeter has been tested at DESY. Further tests are also planned at the test-beam facilities at CERN and Fermilab.

As befitting a workshop with both detector and accelerator experts present in force, discussion of the machine-detector interface issues played a big role. The layout of the accelerator influences detectors in many ways – for example, beam parameters determine the backgrounds, the possible crossing angle of the beams affects the layout of the forward detectors, and the position of the final focus magnets dictates the position of important detector elements. All of these parameters have to be optimized by accelerator and detector experts

working in concert. At a well attended plenary "town meeting" one afternoon, several speakers debated "The Case for Two Detectors". Issues included complementary physics capabilities, cross-checking of results, total project cost and two interaction regions versus one.

### Outreach, communication and education

A special evening forum on 23 August addressed "Challenges for Realizing the ILC: Funding, Regionalism and International Collaboration". Eight distinguished speakers, representing committees and funding agencies with direct responsibility for the ILC, shared their wisdom and perspectives: Jonathan Dorfan (chairman of the International Committee for Future Accelerators, ICFA), Fred Gilman (HEPAP), Pat Looney (formerly of the US Office of Science and Technology Policy), Robin Staffin (US Department of Energy), Michael Turner (US National Science Foundation), Shin-ichi Kurokawa (ACFA chair and incoming ILCSC chair), Roberto Petronzio (Funding Agencies for the Linear Collider) and Albrecht Wagner (incoming ICFA chair). The brief presentations were followed by animated questions and comments from many in the audience.

Educational activities played a prominent role in the Snowmass workshop. Reaching out to particle experimenters and theorists, the accelerator community ran a series of eight lunchtime accelerator tutorials. Of broader interest to the general public were a dark-matter café and quantum-universe exhibit in the Snowmass Mall, a Workshop on Dark Matter and Cosmic-Ray Showers for high-school teachers, and a cosmic-ray-shower study in the Aspen Mall. Two evening public lectures attracted many residents and tourists, with Young-Keek Kim talking on " $E = mc^2$ ", and Hitoshi Murayama on "Seeing the Invisibles". A physics fiesta took place one Sunday in a secondary school in Carbondale, where physicists and teachers from the workshop engaged children in hands-on activities.

Communication was also on the Snowmass agenda, and the communications working group defined a strategic communication plan. During the workshop a new website, [www.linearcollider.org](http://www.linearcollider.org), was launched together with *ILC NewsLine*, a new weekly online newsletter open to all subscribers (*CERN Courier* November 2005 p47).  
 ● Proceedings of the Snowmass Workshop will appear on the SLAC Electronic Conference Proceedings Archive, eConf. Links to all presentations can be found at the workshop website at <http://alcp2005.colorado.edu>.

### Résumé

*Snowmass accueille l'ILC*

*Au cours de ces dernières années, la communauté de la physique des particules est parvenue à un consensus quant à son prochain grand accélérateur d'envergure mondiale, lequel devrait donc être un collisionneur rectiligne électron-positon de 500 GeV, énergie susceptible d'être augmentée. En août, près de 700 physiciens et ingénieurs d'Amérique du Nord, d'Asie et d'Europe se sont rassemblés pendant deux semaines à Snowmass, Colorado, pour avancer la conception du Collisionneur linéaire international ILC et de ses détecteurs et préciser le programme d'expérimentation.*

**Edmond Berger**, Argonne, with **Phil Burrows**, Queen Mary London, **Klaus Moenig**, LAL/DESY, **Michael Peskin**, SLAC, and **Perrine Royole-Degieux**, IN2P3/Orsay.



Fig. 1. One of the polarized targets that was developed for the S134 experiment in the 1970s.

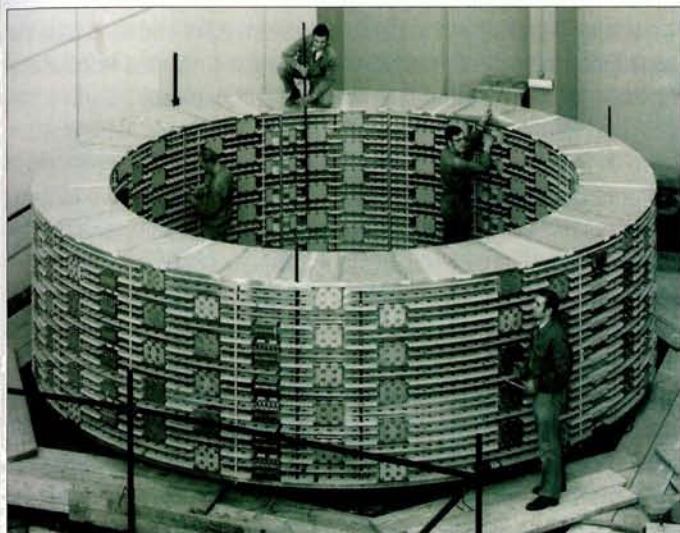


Fig. 2. A superconducting coil of the Big European Bubble Chamber, BEBC, which was constructed in the 1970s.



Fig. 3. Installing the eighth coil in the ATLAS barrel toroid magnet.

# How CERN k

Research at CERN centres on very high application of very low temperature techniques a look at the evolution of the

Cryogenics at CERN has now reached an unprecedented scale. When the Large Hadron Collider (LHC) starts up it will operate the largest 1.8 K helium refrigeration and distribution systems in the world, and the two biggest experiments, ATLAS and CMS, will deploy an impressive range of cryogenic techniques. However, the use of cryogenics at CERN, first in detection techniques and later in applications for accelerators, dates back to some of the earliest experiments.

The need for cryogenics at CERN began in the 1960s with the demand for track-sensitive targets – bubble chambers – that contained up to 35 m<sup>3</sup> of liquid hydrogen, deuterium or neon/hydrogen mixtures. These devices required cryogenic systems on an industrial scale to cool down to a temperature of 20 K. For more than a decade they were a major part of CERN's experimental physics programme (*CERN Courier* July/August 2004 p26). At the same time, cryogenic non-sensitive targets were used in other experiments. Over the past 30 years some 120 such targets have been constructed, ranging in size from a few cubic centimetres to about 30 m<sup>3</sup> and usually filled with liquid hydrogen or deuterium, again requiring cooling to 20 K.

## Cool targets, cool detectors

At the smallest scale, the demand from the fixed-target programme for polarized targets at very low temperatures led to the development of dilution refrigerators at CERN in the 1970s (figure 1). Going below the range of helium-3 evaporating systems, these require small-scale but highly sophisticated cryogenic techniques.

Polarized targets remain very much part of the current physics programme at CERN, where the COMPASS experiment uses solid targets made of ammonia or lithium deuteride. The basic method for obtaining a high polarization of the nuclear spins in the targets is the dynamic nuclear polarization process. This uses microwave irradiation to transfer to the nuclei the almost complete polarization of electrons that occurs at low temperatures (less than 1 K) and in a high magnetic field (2.5 T), generated by a superconducting solenoid.

On a larger scale, in detector technology the development in the 1970s of sampling ionization chambers – calorimeters – broadened the demand for low temperatures at CERN. Using liquid argon to measure the energy of ionizing particles, these detectors required cryogenic systems to cool down to 80 K. Several calorimeters, with typical volumes of 2–4 m<sup>3</sup>, were built in this period, both for fixed-target experiments and use at CERN's first collider, the Intersecting Storage Rings (ISR) – which was also the world's first proton collider.

Two decades later, in 1997, the NA48 experiment extended the technique from argon to krypton. With its very high density, liquid krypton not only provides the "read out" through the ionization of the

# keeps its cool

particle energies, but it also involves the  
**Giorgio Passardi** and **Laurent Tavian** take  
 laboratory's use of cryogenics.

liquid by charged particles, but also acts as a passive particle absorber, so avoiding the use of a material such as lead or uranium. The cooling fluid for this detector is saturated with liquid nitrogen and the heat is extracted by re-condensing the evaporated krypton via an intermediate bath of liquid argon, which in turn feeds the  $10\text{ m}^3$  liquid-krypton cryostat by gravity.

Around the same time as the development of the first liquid-argon calorimeters, experiments began to require helium cryogenics, mainly at 4.5 K, for superconducting magnets. These were used to analyse particle momenta in magnetic spectrometers. The largest built for the fixed-target programme at CERN was the superconducting solenoid constructed for the Big European Bubble Chamber (BEBC) in the 1970s (figure 2). This had an internal diameter of 4.7 m and produced a field of 3.5 T. The associated combined He/H<sub>2</sub> refrigeration system had a cooling capacity of 6.7 kW at 4.5 K.

With the advent of the Large Electron-Positron (LEP) collider at the end of the 1980s, collider experiments took on a much greater role at CERN. Two of the LEP experiments, ALEPH and DELPHI, opted for large superconducting solenoids for momentum analysis – the choice between superconducting and normal (resistive) magnets depending on considerations related to “transparency” (to particles) and/or economy. Each of these solenoids required a helium cooling system of 800 W at 4.5 K.

A current novel application for a superconducting magnet occurs in the CAST experiment located on the surface above the cavern where the DELPHI experiment for LEP was installed. This uses a 10 m, 9.5 T prototype LHC superconducting dipole and also makes use of the DELPHI refrigerator to cool the superfluid helium cryogenic system for the magnet. The aim of the experiment is to detect axions, a possible candidate particle for dark matter that could be emitted by the Sun, through their production of photons in the dipole's magnetic field (CERN Courier March 2005 p7).

Now, however, the major effort at CERN is focused on the LHC, with four big experiments: ALICE, ATLAS, CMS and LHCb. Basic design criteria led the two largest experiments, ATLAS and CMS, to construct superconducting spectrometers of unprecedented size, while ALICE and LHCb opted for resistive magnets.

ATLAS has several components for its magnetic spectrometry. A “slim” central solenoid (with a length of 5.3 m, a 2.4 m inner diameter and a 2 T field) is surrounded by a toroid consisting of three separate parts – a barrel and two end-caps. The overall length of the toroid is 26 m, with an external diameter of 20 m (figure 3). It is powered up to 20 kA and has a stored energy of 1.7 GJ. CMS, by contrast, is built around a single large solenoid, 13 m long, with an inner diameter of ▷



Fig. 4. Inserting the inner wall of the vacuum tank and heat shield into the 13 m-long CMS solenoid.



Fig. 5. One of the first of the 288 superconducting radio-frequency modules, which was installed to eventually double the energy of the Large Electron-Positron collider.



Fig. 6. The warm compressor for one of the 1.8 K refrigerator units for the Large Hadron Collider.



Fig. 7. A 1.8 K cold box being delivered to its underground site close to the Large Hadron Collider.

5.9 m and a uniform field of 4 T (figure 4). When powered up to 20 kA it has a stored energy of 2.6 GJ (*CERN Courier* March 2004 p6).

ATLAS also has a cryogenic electromagnetic calorimeter, with the largest liquid-argon ionization detector in the world to measure the energy of electrons and photons (*CERN Courier* September 2005 cover and p7). This consists of a cylindrical structure made of a barrel and two end-caps, with a length of 13 m and an external diameter of 9 m. Altogether, the cryostats for the three sections contain 83 m<sup>3</sup> of liquid argon and operate at 87 K.

Both ATLAS and CMS have refrigerating plants that are independent from the system required to cool the LHC to 1.8 K (see below). ATLAS will use two helium refrigerators and one nitrogen refrigerator, while CMS will have a single helium refrigerator. These will provide cooling for current leads and thermal shields, as well as for the refrigeration at 4.5 K for the spectrometer magnets, and in the case of ATLAS also at 84 K for the electromagnetic calorimeter.

### Cool accelerators

The use of helium cryogenics was extended to accelerator technology at CERN during the 1970s, when superconducting radiofrequency beam separators were constructed for the Super Proton Synchrotron, and superconducting high-luminosity insertion quadrupoles were built for use at the ISR. These required cooling of 300 W at 1.8 K and 1.2 kW at 4.5 K, respectively. The 1990s saw the larger scale use of cryogenics for accelerators with the upgrade of LEP to higher energies.

LEP was built initially with conventional copper accelerating cavities, but with the successful development of 350 MHz superconducting cavities in 1980s, its energy could be doubled. As many as 288 superconducting cavities were eventually installed, increasing the energy from 45 to 104 GeV per beam (figure 5). This involved the installation of the first very large capacity helium refrigerating plant at CERN, with four units each of a capacity of 12 kW at 4.5 K, later upgraded to 18 kW, supplying helium to eight 250 m long strings of superconducting cavities, and a total helium inventory of 9.6 tonnes.

LEP was closed down at the end of 2000 to make way for the construction of the LHC in the same tunnel. This liberated most of the existing cryogenic infrastructure from LEP for further use and upgrading for the LHC, which will require the largest 1.8 K refrigeration and distribution system in the world to cool some 1800 superconducting magnet systems distributed around the 27 km long tunnel (*CERN Courier* January/February 2004 p27). A total of 37 500 tonnes has

to be cooled to 1.9 K, requiring about 96 tonnes of helium, two-thirds of which is used for filling the magnets.

Although normal liquid helium at 4.5 K would be able to cool the magnets so that they become superconducting, the LHC will use superfluid helium at the lower temperature of 1.8 K to improve the performance of the magnets. The magnets are cooled by making use of the very efficient heat-transfer properties of superfluid helium, and kilowatts of refrigeration power are transported over more than 3 km with a temperature difference of less than 0.1 K.

The LHC is divided into eight sectors, and each will be cooled by a two-stage cryoplant consisting of a 4.5 K refrigerator coupled to a 1.8 K refrigeration unit. The transport of the refrigeration capacity along each sector is made by a cryogenic distribution line, which feeds the machine every 107 m. A cryogenic interconnection box will link the 4.5 K and 1.8 K refrigerators and the distribution line. Together the refrigerators will provide a total cooling power of 144 kW at 4.5 K and 20 kW at 1.8 K. The 4.5 K refrigerators are equipped with a 600 kW liquid-nitrogen precooler, which will be used to cool down the corresponding LHC sector to 80 K in less than 10 days.

Four new 4.5 K refrigerators built by two industrial companies have been in place since the end of 2003 (*CERN Courier* May 2004 p15), and four 4.5 K refrigerators recovered from LEP are being upgraded for use at the LHC. In addition, eight 1.8 K refrigerator units procured from industry provide the final stage of cooling (figures 6 and 7). Four 1.8 K units built by one company have already been installed; the other four units, made by the other company, are currently being installed and will be tested in 2006.

For the next 15 years or so, CERN will need to continue to provide strong support in cryogenics for its unique accelerator facilities, including the final consolidation and operation of the LHC. Further long-term perspectives will depend a great deal on the next generation of accelerators. Detectors, on the other hand, have proved quantitatively less demanding for cryogenics in comparison with the accelerators; however, over the years their cryogenic needs have generated a variety of different applications, with a temperature range from 130 K (liquid-krypton calorimeters) down to a few tenths of a millikelvin for polarized targets. Innovation in detector technology has often in the past led to the application of cryogenics – a trend that will no doubt continue into the future.

● This article is based on: G Passardi and L Taviani 2002 *Cryogenics at CERN* Proceedings of the 19th International Cryogenic Engineering Conference (ICEC 19); L Taviani 2005 *Latest developments in cryogenics at CERN* Proceedings of the 20th National Symposium on Cryogenics, Mumbai (TNSC 20).

### Résumé

*Le sang froid du CERN*

*Quand le CERN lancera l'exploitation du LHC, il s'appuiera sur les plus grands systèmes mondiaux de réfrigération et de distribution d'hélium à 1,8 K, tandis que les collaborations ATLAS et CMS feront appel à une palette impressionnante de techniques cryogéniques. Cependant, l'utilisation de la cryogénie au CERN remonte à l'époque de certaines des premières expériences, d'abord dans les détecteurs et ensuite autour des accélérateurs.*

**Giorgio Passardi and Laurent Taviani, CERN.**

# REX-ISOLDE accelerates the first isomeric beams

CERN's REX-ISOLDE facility has opened up a new avenue for nuclear investigations by accelerating isomeric beams for the first time, as **Georgi Georgiev** explains.

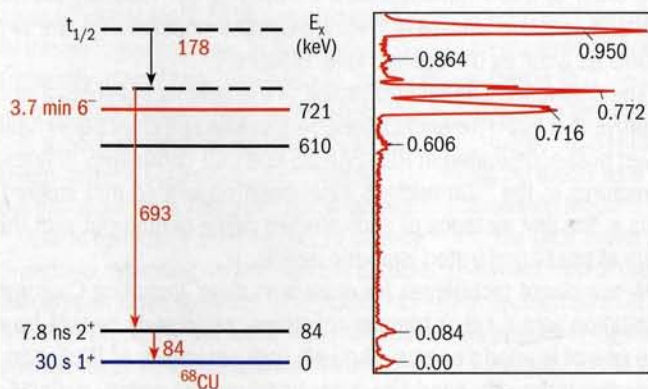
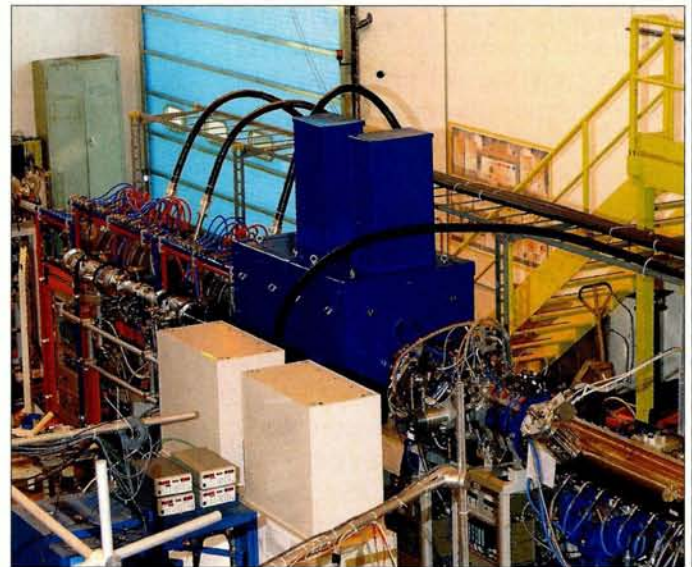


Fig. 1. Energy-level scheme of  $^{68}\text{Cu}$  as known from beta-decay (left side) and transfer reaction studies (right side). The two states marked with dashed lines were populated via the Coulomb excitation of the  $6^-$  state.

Since 2001, the combination of the Isotope-Separator On-Line (ISOLDE) and the Radioactive Beam Experiment (REX) has provided accelerated beams of radioactive ions. Now, with the aid of a laser-separation technique, specific metastable excited states – isomers – can be selected and “post-accelerated” in REX. This allows not only nuclear-decay experiments, but also the production of short-lived excited states.

Purity is an important parameter of any radioactive beam. At ISOLDE, the Resonant Ionisation Laser Ion Source (RILIS) allows the selection of a single chemical element. Combined with the mass selection of the ISOLDE separators, this results in a high-purity beam composed of essentially a single isotope. In a further step, narrow-bandwidth lasers can select different long-lived isomers from the same isotope (Köster *et al.* 2000a and 2000b). This has already allowed the separation of two different beta-decaying states in  $^{68}\text{Cu}$  as well as the unambiguous identification of three isomeric states in  $^{70}\text{Cu}$  (Van Roosbroeck *et al.* 2004). (These are both neutron-rich radioactive isotopes of copper, which occurs naturally as the stable isotopes  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$ .)

Now, in experiment IS435, isomeric beams of  $^{68}\text{Cu}$  and  $^{70}\text{Cu}$  have been post-accelerated in REX-ISOLDE to 2.8 MeV per nucleon. The beams were then directed onto a target in the centre of the Miniball set-up, which was used to detect emitted gamma rays, and hence



The REX post-accelerator for radioactive ion beams at ISOLDE.

the existence of excited states in the different nuclei. The experiments are showing that the technique can produce isomeric beams of sufficient purity to study individual excited states in a radioactive nucleus, as the preliminary results for  $^{68}\text{Cu}$  indicate.

The radioactive nucleus  $^{68}\text{Cu}$  has two beta-decaying states, the ground state with spin 1 and positive parity ( $I^\pi = 1^+$ ) and a metastable (isomeric) one with  $I^\pi = 6^-$ . Both states are well known and decay to the stable  $^{68}\text{Zn}$  nucleus. In nuclei, protons and neutrons tend to fill energy levels in pairs, with the angular momentum of the pairs coupling to zero. So in  $^{68}\text{Cu}$ , with an odd number of protons (29) and an odd number of neutrons (39), the multiplet structure of the low-lying energy states is largely determined by the coupling of the two odd nucleons, which occupy different orbitals outside the full core of pairs. The structures containing the ground state and the beta-decaying isomeric state are expected to be significantly different, as in these states, although the odd proton is in the same orbital ( $2p_{3/2}$ ), the odd neutron is in very different orbitals ( $2p_{1/2}$  and  $1g_{9/2}$ ). Previous investigations using transfer reactions (Sherman *et al.* 1977) and beta-decay and lifetime measurements (Hou *et al.* 2003) have indicated the existence of different multiplet structures (figure 1), but not much is known about the composition of the states.

The aim of experiment IS435 was to study these two multiplet

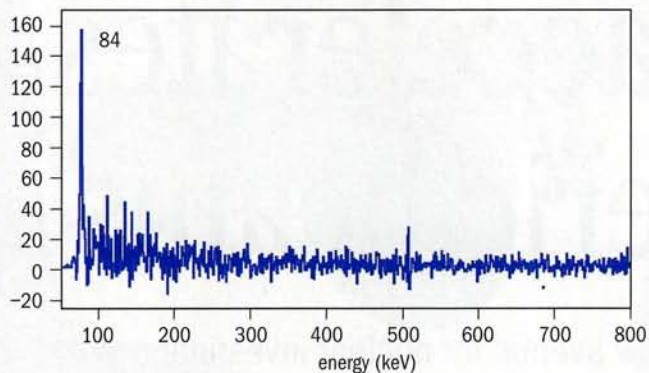


Fig. 2. Energy spectrum of the gamma rays observed in the Coulomb excitation of the  $1^+$  state of  $^{68}\text{Cu}$ . No Doppler corrections have been applied.

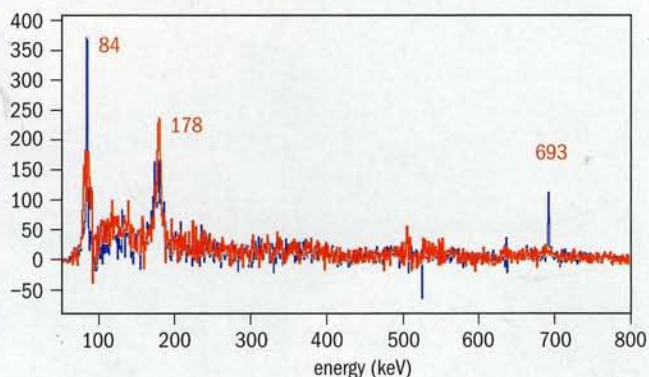


Fig. 3. Energy spectrum of the gamma rays observed in the Coulomb excitation of the  $6^-$  state of  $^{68}\text{Cu}$ . The blue line is without Doppler corrections. The red one is the result after the Doppler corrections have been applied.



The Miniball set-up at the REX-ISOLDE facility for studying the spectra of exotic short-lived nuclei.

structures. In one case, an almost pure ( $\sim 90\%$ ) beam of the ground state of  $^{68}\text{Cu}$  ( $1^+$ ) was accelerated and underwent Coulomb excitation in order to investigate the coupling between the proton  $p_{3/2}$  and neutron  $p_{1/2}$  orbitals. Figure 2 shows the gamma-ray energy spectrum from the Miniball detector. It clearly reveals a gamma transition of 84 keV indicating that the  $I^\pi = 2^+$  state of the ground-state multiplet is excited with quite a high probability. This hints at a sig-

nificant electric quadrupole (E2) component in the transition connecting these two states, contradicting the conclusions of some previous studies (Hou *et al.* 2003).

Figure 3 shows the gamma-ray energy spectrum from the excitation of the isomeric  $6^-$  state of  $^{68}\text{Cu}$ . Here a Doppler-broadened line is clearly visible at 178 keV together with lines at 84 keV and 693 keV that are not Doppler-broadened. Applying the Doppler correction to the spectrum (the red line in the figure) leads to a narrowing of the 178 keV line and a broadening or complete disappearing of the 84 keV and 693 keV lines respectively. This indicates that the gamma rays from these two transitions were not emitted in flight but from nuclei at rest – in other words from states that have relatively long half-lives compared with the other states excited, and that therefore come to rest before they decay. Taking into account the energy of the beam leads to an estimate of the half-lives of these two transitions of the order of a few nanoseconds. Comparing the results from the transfer reaction and beta decay indicates positions for the two states as given by the dashed lines in figure 1.

The distinctively different patterns of the spectra in figures 2 and 3 prove that two different isomeric beams with sufficient purity have been post-accelerated at REX-ISOLDE and that completely different structures in the  $^{68}\text{Cu}$  nucleus have been populated and studied. This is the first instance of such studies being carried out with the help of post-accelerated isomeric beams.

A number of techniques for nuclear studies, including Coulomb excitation and nuclear transfer reactions, will clearly benefit from the use of isomeric beams. The very high selectivity of RILIS combined with the very good beam spot and precise energy definition after the REX linac make REX-ISOLDE a unique place for this type of measurement during the coming years.

• IS435 was performed by CERN; IKS KU Leuven; INRNE, Bulgarian Academy of Sciences, University of Sofia; Università di Camerino; LMU, Munich; MPI, Heidelberg; University of Köln; TU Darmstadt; TU Munich; Warsaw University; IPN Orsay; Lund University; INP, NCSR “Demokritos”; University of Gent; Miniball and the REX collaboration.

**Further reading**

- L Hou *et al.* 2003 *Phys. Rev.* **C68** 54306.
- U Köster *et al.* 2000a *Nucl. Instr. and Meth.* **B160** 528.
- U Köster *et al.* 2000b *Hyperfine Interactions* **127** 417.
- J D Sherman *et al.* 1977 *Phys. Lett.* **B67** 275.
- J Van Roosbroeck *et al.* 2004 *Phys. Rev. Lett.* **92** 112501.

**Résumé**

REX-ISOLDE accélère les premiers faisceaux d'isomères

Depuis 2001, la combinaison d'ISOLDE, le séparateur d'isotopes en ligne, et de REX, l'expérience à faisceaux radioactifs, fournit des faisceaux d'ions radioactifs. Maintenant, une technique laser de séparation permet de sélectionner puis de post-acceleré dans REX des ions excités métastables – ou isomères – spécifiques. Cela permet d'étudier certaines désintégrations nucléaires et la production d'états excités éphémères, comme le décrit l'article dans le cas d'isomères du cuivre.

Georgi Georgiev, CERN.



# PEOPLE

## AWARDS

# APS announces prize-winners for 2006...

The American Physical Society has announced many of its awards for 2006, naming recipients who work in particle physics and related fields, from supergravity to accelerator techniques.

The 2006 Dannie Heineman Prize for mathematical physics goes to Sergio Ferrara of CERN, Daniel Freedman of the Massachusetts Institute of Technology and Peter van Nieuwenhuizen of the State University of New York, Stony Brook. They win an award for "constructing supergravity, the first supersymmetric extension of Einstein's theory of general relativity, and for their central role in its subsequent development".

Also in theoretical physics, the J J Sakurai Prize for outstanding achievement in particle theory is awarded to Savvas Dimopoulos of Stanford University. He is rewarded for "his creative ideas on dynamical symmetry breaking, supersymmetry and extra spatial dimensions, which have shaped theoretical

research on TeV-scale physics, thereby inspiring a wide range of experiments".

Research in electroweak physics is recognized in the award of the Tom W Bonner Prize, for outstanding experimental research in nuclear physics, to John Hardy of Texas A&M University and Ian Towner of Queen's University, Kingston, Ontario. They receive the award for "their ultra-high precision measurements and extraordinarily detailed analyses of  $0^+ \rightarrow 0^+$  nuclear beta decay rates to explore the unitarity of the Cabibbo-Kobayashi-Maskawa [CKM] quark mixing matrix as a test of the electroweak Standard Model".

The CKM matrix is also cited in the award to William Ford of the University of Colorado, John Jaros of SLAC, and Nigel Lockyer of the University of Pennsylvania of the W K H Panofsky Prize in experimental particle physics. They are recognized for "their leading contributions to the discovery of the long b-

quark lifetime with the MAC and Mark II experiments at SLAC. The unexpectedly large value of the b-quark lifetime revealed the hierarchy of the CKM quark mixing matrix."

The Robert R Wilson Prize is awarded for achievement in the physics of particle accelerators. For 2006 this goes to Glen Lambertson of the Lawrence Berkeley National Laboratory for "fundamental contributions to accelerator science and technology, particularly in the area of beam electrodynamics including the development of beam instrumentation for the feedback systems that are essential for the operation of high luminosity electron and hadron colliders".

Particle physics also features in the Apker Award for outstanding achievements in physics by undergraduate students. David Miller of the University of Chicago receives the award for his work on the search for high-energy axions with the calorimeter of the CERN Axion Solar Telescope (CAST).

# ...while IOP gives awards for UK physics

High-energy physics, cosmology, and research involving present and future developments in particle accelerators are among the areas of physics recognized by the 2006 awards of the UK's Institute of Physics.

Ken Peach receives the Rutherford Medal and Prize for "his contributions to high-energy physics as leader of key experiments at CERN investigating CP violation and as director of particle physics at CCLRC's Rutherford Appleton Laboratory [RAL], where he has played a key role in reviving accelerator science for particle physics applications in the UK". Peach is now director of the newly created John Adams Institute for Accelerator Science based at Oxford University and Royal Holloway, University of London.

Research at RAL is also recognized in the award of the Glazebrook Medal and Prize to Andrew Taylor for "his contributions to neutron scattering physics, through his leadership as director of the ISIS facility at the Rutherford Appleton Laboratory, and to the realization of



Ken Peach: winner of the 2006 Rutherford Medal and Prize, for work at CERN and RAL.

the second target station at ISIS". ISIS is currently the world's leading pulsed neutron and muon source.

The Boys Medal and Prize, awarded for distinguished research in experimental physics (in particular to recognize physicists early in their careers) goes to Karl Krushelnick of Imperial College London. He is recognized for "his contribution to plasma physics through his wide-ranging investigations on the interaction of ultra-intense lasers with matter", which includes research at RAL's Central Laser Facility on the laser-driven plasma acceleration of electrons.

Cosmology meets particle physics in the research of Ruth Gregory, from the University of Durham, who receives the Maxwell Medal and Prize for outstanding contributions to theoretical physics during the past 10 years. She is rewarded for "her contributions to physics at the interface of general relativity and string theory, in particular for her work on the physics of cosmic strings and black holes".

## AWARDS

# JINR researchers win “Brightness Award”

Evgeny D Donets, Denis E Donets, Vladimir V Salnikov and Evgeny E Donets from the Joint Institute for Nuclear Research (JINR) have been awarded the Ion Source Prize, or “Brightness Award”, which recognizes innovative and significant achievements in the fields of ion-source physics and technology. The team has been rewarded for their development of the electron-string source of highly charged ions.

Evgeny D Donets, the team’s scientific leader, received the award at the 11th International Conference on Ion Sources, held in September in Caen, France. Donated by Bergoz Instrumentation of Saint Genis Pouilly, France, the prize includes \$6000, to be shared by the four winners.

The team discovered the electron-string phenomenon – a stationary state of a hot, pure electron plasma – which they used to



Left to right: award-winners Evgeny D Donets, Denis E Donets, Vladimir V Salnikov and Evgeny E Donets, all staff at the Veksler and Baldin Laboratory of High Energies, JINR.

create a new kind of ion source that has been successfully realized at an accelerator at JINR. Use of the phenomenon allows beams of highly charged ions to be produced with high pulse intensity, while maintaining an

extremely low power consumption. This provides excellent source reliability. JINR’s ion source is used for the injection of  $\text{Ar}^{16+}$  and  $\text{Fe}^{24+}$  ions into the Nuclotron, the laboratory’s superconducting synchrotron.

## Brasília honours Roberto Salmeron

Roberto Salmeron, one of the first 10 experimental physicists to join CERN when the laboratory was founded, was honoured with the title of doctor honoris causa on 19 October by the University of Brasília. Salmeron came to CERN after completing his PhD under Patrick Blackett at the University of Manchester on work on the production of strange particles in cosmic rays. After a period of eight-and-a-half years as a staff member, he left CERN to work on the foundation of the University of Brasília, where he started the Physics Institute and was its first director and the first dean of science.

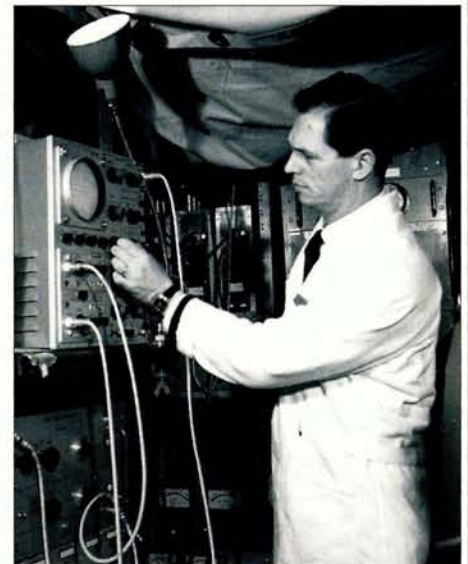
Brazilian universities suffered persecution after the military *coup d’etat* of March 1964, and by the end of 1965 the situation at the University of Brasília had become intolerable. As many as 223 professors resigned, including Salmeron, who was invited to return to his position at CERN by Victor Weisskopf, then director-general.

Salmeron worked at CERN for another year and a half, and at the end of 1967 was invited by Louis Leprince-Ringuet to join the Laboratoire de Physique Nucléaire des Hautes



Roberto Salmeron, left, receiving the award of doctor honoris causa from Lauro Morhy, rector of the University of Brasília.

Energies de l’Ecole Polytechnique in Paris. There he continued to do experiments at CERN for another 25 years, until he retired with the position of director of research emeritus at CNRS. During this time he worked on several committees at CERN: the Track Chamber Committee, the Super Proton Synchrotron Committee and the Academic Training Committee.



Salmeron checks the electronics for a neutrino experiment at CERN in 1963.

During his time in Europe, Salmeron has always kept in contact with Brazilian colleagues and Brazilian science, working on local research plans and on establishing international collaborations on research and teaching with institutions and universities in several countries, including CERN and Fermilab. He continues to maintain these activities today.

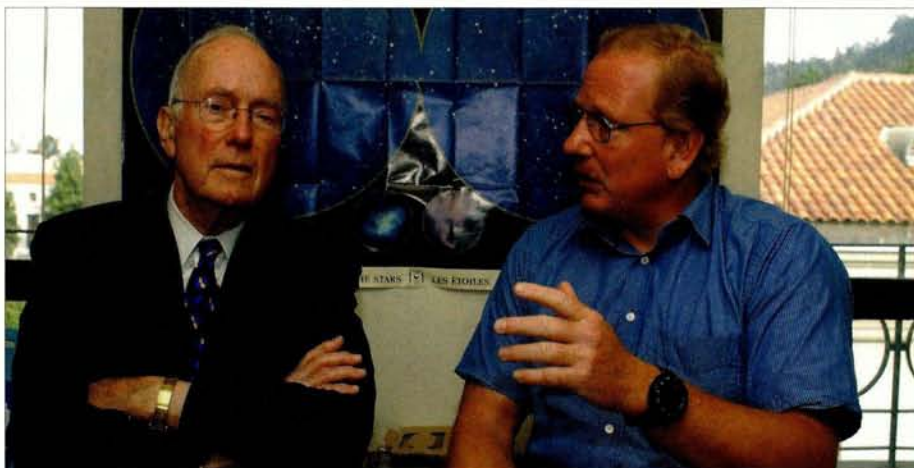
## ANNIVERSARIES

## Researchers mark laser pioneer's 90th

Amazing Light: Visions for Discovery, a three-day international symposium in celebration of the 90th birthday of Charles Townes, took place at the University of California, Berkeley, on 6–8 October. Townes, who won the 1964 Nobel Prize for his part in the invention of the maser and laser, is professor emeritus at Berkeley.

The three-day event, sponsored by the Templeton Foundation in association with other philanthropic partners, featured an outstanding array of speakers, with 20 Nobel laureates, including two of this year's winners of the Nobel Prize in Physics, Roy Glauber and Ted Hänsch.

Each day of the symposium was devoted to a different theme: The Ocean of Truth –



Charles Townes, left, with colleague and former student Reinhard Genzel of the University of California, Berkeley and director at the Max-Planck Institut für Extraterrestrische Physik in Munich. Genzel took part in a public forum during the symposium.

Exploring the Great Unknowns in Physics and Cosmology; New Windows to Discovery – Exploring Possibilities for Innovative Technologies; and The “Big Picture” –

Exploring Questions on the Boundaries of Science. The event also included a “young scholars” competition and concluded with a gala dinner to honour Townes

## Fermilab honours Bill Bardeen

On 23–24 September some 80 theoretical physicists gathered at Fermilab to celebrate the 64th birthday of Bill Bardeen. A member of the Fermilab staff for 30 years, Bardeen has made major contributions to the theory of anomalies in gauge theories, to perturbative quantum chromodynamics (QCD) and to the theory of dynamical symmetry breaking. He served as head of the Theory Department from 1986–1993 and throughout his tenure at Fermilab has been the ultimate authority on field theoretical issues. During 1993–1994 he was also head of theoretical physics at the Superconducting Super Collider Laboratory.

Friends, colleagues and former collaborators came from many parts of the world to laud Bardeen for his intellectual generosity, constant friendship and thoughtful criticism. Among the distinguished speakers were Steve Adler, Tom Appelquist, Sally Dawson, Dan Freedman, Mary K Gaillard, Harald Fritzsch, Roberto Peccei, Henry Tye and Bruno Zumino. Also present were Andrzej Buras, Dennis Duke and Taizo Muta, who were co-authors with Bardeen of a famous paper on perturbative QCD, and Steve Gasiorowicz, Bardeen's thesis advisor at the University of Minnesota.



Fermilab theorist Bill Bardeen (right) celebrated his 64th birthday with wife Marge and brother Jim at the Bardeen symposium.

Bardeen was awarded the 1996 J J Sakurai Prize of the American Physical Society for his work on anomalies and perturbative QCD. He is a member of the National Academy of Sciences and has been elected a fellow in the American Academy of Arts and Sciences and the American Physical Society.

Bardeen is a member of an important American scientific family. Joining in the celebration were brother Jim (University of Washington), brother-in-law Tom Greytak (MIT) and Bill's wife Marge (Fermilab education office), as well as his two children Chuck and Karen.

• The symposium programme and many photos of the event may be found at <http://theory.fnal.gov/bardeensymposium.html>.

## Yerevan's Karo Ispirian celebrates his 70th birthday



Karo Ispirian, who was 70 last month.

Karo Asatour Ispirian of Yerevan Physics Institute celebrated his 70th birthday on 7 November. Born in Alexandria, Egypt, Ispirian is well known for his pioneering theoretical and experimental works. These have been devoted to X-ray and optical transition radiation and corresponding detectors, Monte Carlo calculations of energy losses in thin layers, photon–photon and photon–relativistic ion interactions, and the high-energy application of single crystals, laser beams and carbon nanotubes. He has also contributed to the popularization of problems in physics.

## SCHOOLS

# Opportunities for new talents at Erice school of subnuclear physics

A large group of distinguished lecturers and young physicists from countries around the world met in Erice, Italy, from 29 August to 7 September at the Ettore Majorana Foundation and Centre for Scientific Culture for the latest International School of Subnuclear Physics, "Towards new milestones in our quest to go beyond the Standard Model". A particular feature of the school was to promote the "new talents" among the young generation of physicists.

Organized and directed by Nobel laureate Gerardus 't Hooft and Antonino Zichichi, director of the Ettore Majorana Centre, the school consisted of morning lectures on the most up-to-date topics in subnuclear physics, followed in the afternoon by special sessions dedicated to new talents and Enrico Fermi junior grants. During these special sessions selected students at the school had the opportunity to make open presentations of their research work. Each special session was followed by a discussion on the lectures held during the morning, making a major contribution to the lively intellectual atmosphere of the school.

The course this year concerned supersymmetric theories of strings and branes, as well as the most recent results from current experiments and perspectives for future colliding facilities. The lectures by CERN's Ignatios Antoniadis on experimental signatures of strings and branes, with updates on the status of local supersymmetry and its spontaneous breaking by Sergio Ferrara, also of CERN, exhaustively covered the most recent theoretical advances in this field. In



On the lookout for new talent: the participants of the International School of Subnuclear Physics, which was held in Erice, Italy, in August and September.

addition, Thomas Appellequist of Yale illustrated some particular problems beyond the Standard Model.

On the experimental side, a comprehensive review on the status of the LHC collider at CERN was given by Lucio Rossi, while the most relevant aspects in the design and construction of future linear colliders, with emphasis on Compact Linear Collider technology, were covered in the lectures of Franck Tecker from CERN. Highlights from Brookhaven were presented by Peter Steinberg, from SLAC by Marcello Giorgi, from Fermilab by Dmitri Denisov and from Frascati by Rinaldo Baldini. Three special topics, namely gamma-ray bursts, glueballs and gravitomagnetism, were also covered by CERN's Alvaro De Rújula, Sam Lindenbaum of City College New York and Ignazio Ciufolini of INFN/Lecce, respectively. Lectures by the school's directors completed the programme, with Zichichi talking on the main challenges in subnuclear physics and

't Hooft on quantum black holes.

As one of the aims of the school is to encourage and promote young physicists to achieve recognition at an international level, the best new talents were given a special diploma and the opportunity to publish their presentation at the school in the *European Physics Journal C-Direct* (young scientists section) and in the school's proceedings (to be published by *World Scientific*). Moreover, on the occasion of the World Year of Physics 2005, 10 junior grants (of which seven are reserved for non-G7, non-Schengen countries), which have been established by the Enrico Fermi Centre in Rome to honour the memory of the great physicist, were awarded to students at the school who distinguished themselves through the excellence of their research.

• For the "new talent" presentations and lectures given at the school, see <http://emsc.ccsem.infn.it/subnuclear2005/>.

**fug**  
F.u.G. Elektronik GmbH

DC Voltage and DC Current

high end power supplies for science and research

[www.fug-elektronik.de](http://www.fug-elektronik.de)

## SCHOOLS

# Italo-Hellenic school prepares young researchers for LHC physics

After the success last year of the first Italo-Hellenic School of Physics, "The Physics of LHC: Theoretical Tools and Experimental Challenges", a second school was held again this summer, continuing the mission to provide young researchers with an opportunity to acquire the techniques that are indispensable for physics at the Large Hadron Collider (LHC). Held from June 9–14, once again at Palazzo Palmieri, Martignano, just outside Lecce in the south of Italy, this year's "LHC school" attracted an audience of more than 40 young researchers, mainly Italian but with a number of Greek and other European students.

As implied by its title, the role of the school is to gather together young researchers who are engaged (or interested) in LHC studies and to help them discover and appreciate the tools necessary for the new collider, which is currently under construction. As before, the school had a format of six days with around 30 hours of lectures, which were divided evenly between theory and experiment, while the attendees themselves were made up of roughly one-third theorists and two-thirds experimentalists. Although addressed primarily to Italian and Greek PhD students and post-docs, this year saw an increase in participants from other countries.

The school's programme was rich and varied, encompassing not only topics that will be approached directly for the first time at the LHC, such as Higgs physics, but also past experience gained at other machines. The theory lectures ranged from calculational tools in quantum chromodynamics (Massimiliano Grazzini) and MonteCarlo techniques (Gennaro Corcella) to Standard Model physics, including electroweak physics (Andrea Romanino), Higgs physics (Dieter Zeppenfeld), B physics (Gino Isidori) and beyond (Kyriakos Tamvakis), and also included the quark–gluon plasma (Antonello Polosa). The experimental courses covered triggers and data acquisition (Chris Schwick), tracking (Lucia Silvestris), calorimetry (Chiara



Some of the speakers at this year's Italo-Hellenic school, together with the organizing committee, during a visit to the underground olive press attached to Palazzo Palmieri.

Roda), muon identification (Margherita Primavera), accelerator physics (Walter Scandale), top analysis at the Collider Detector at Fermilab (Sandra Leone), and the ALICE (Massimo Masera) and LHCb (Walter Bonivento) experiments at CERN. There was also a special guest lecture entitled "From Particles to Strings", given by John Iliopoulos, who was later honoured with the presentation of a painting by a well known local artist.

Although this second school followed soon after the inaugural course last year (*CERN Courier* September 2004 p45), the intention of the organizing and scientific committees is that, after a third school next year, it should become biennial, with the possibility of topical workshops in intervening years. Judging by the very positive feedback received from students both this year and last, the school as a whole is well targeted and serves a very useful purpose.

The organizers gratefully acknowledge the various bodies whose financial aid made the school not only possible but also a success: the universities of Lecce, Piemonte Orientale and Insubria, the Istituto Nazionale di Fisica Nucleare, the Union of Municipalities of the Grecia Salentina, the Province of Lecce and the Banca Nazionale del Lavoro.

The enthusiasm of the local authorities and institutes and the interest shown by the national funding agency, not to mention the satisfaction of the students themselves, set the scene for the school to be established as a regular fixture for young researchers in their quest toward a career in high-energy physics.

• The school was arranged by the local organizing committee, Claudio Corianò (chair), Vincenzo Barone and Philip G Ratcliffe. For further details of the 2005 school (including transparencies), see [www.le.infn.it/lhcschool](http://www.le.infn.it/lhcschool).

## WORKSHOPS

# Fermilab hosts neutrino beams workshop

On 7–11 July, Fermilab, the Universities Research Association and the University of Texas at Austin hosted the 5th International Workshop on Neutrino Beams and Instrumentation (NBI2005). Nearly 70 accelerator physicists, particle physicists and engineers from Brookhaven National Laboratory, CERN, Fermilab, Protvino, KEK, JPARC and the Rutherford Appleton Laboratory, as well as collaborating university groups, were in attendance.

Neutrino physics continues to offer exciting opportunities for experiments to shed light on the masses, mixing probabilities and CP-violating amplitudes of these elusive particles. With a wealth of new data from solar, cosmic ray and reactor neutrino experiments, an array of precision measurements are foreseen using controlled, accelerator-based neutrino beams. Many of the present and forthcoming experiments are “long baseline” experiments, which attempt to observe the properties of the neutrino particles before and after neutrino beams travel over many hundreds of kilometres. The tremendous physical distances of the



*Kazuhiro Tanaka of KEK, who opened the first NBI workshop in 1999, inspects a NuMI horn during a tour of the Fermilab workshop.*

detectors from the accelerator sources of neutrinos will require ever more intense neutrino beams to produce enough neutrinos to be detected at the remote detectors.

Inaugurated in 1999 by Kazuhiro Tanaka of the KEK laboratory, the NBI workshop series has permitted the exchange of progress and techniques in the design of so-called “conventional” neutrino beams, pioneered in the 1960s by Brookhaven and CERN, in which

beams from a proton accelerator strike a target and secondary particles from the target are collected by horn-shaped magnets into a drift tunnel where they decay to neutrinos. The challenge for current and future neutrino beams is to cope with the ever-larger proton accelerator power of 400–2000 kW.

The presentations and round-table discussions at NBI2005 centered on high-intensity proton-beam transport lines, target design, neutrino horns, instrumentation capable of withstanding the intense particle beams, and personnel protection and shielding. This year participants were also treated to a tour of the newly commissioned Neutrinos at the Main Injector (NuMI) facility, as well as the Fermilab workshop for the fabrication of horns and targets for the NuMI and MiniBooNE beam lines.

The next NBI workshop will be held in autumn 2006 and should be at CERN. With ever more potential for exciting discoveries, many challenges and opportunities lie ahead in this field.

● For more information about NBI2005, see [www.hep.utexas.edu/nbi2005/](http://www.hep.utexas.edu/nbi2005/).

## Flavour physics comes to the Alps

An international workshop on flavour dynamics took place in Chamonix, in the French Alps, on 8–15 October. Organized by Gerhard Buchalla of LMU Munich, Robert Fleischer of CERN and Harald Fritzsch of LMU Munich, with the assistance of Jeanne Rostant from CERN, it was attended by 58 physicists from Europe and a number of other countries including China, Israel, Japan and the US.

The talks addressed a variety of topics, including new theoretical developments in the analyses of K- and B-meson decays, the possible impact of physics beyond the Standard Model on the observables provided by these transitions, and aspects related to neutrino physics. These theoretical presentations were complemented by overviews on recent experimental results both



*The participants of the flavour-dynamics workshop enjoy the sunshine in the French Alps.*

from the B factories at SLAC and KEK, and from Fermilab’s Tevatron. There were also talks discussing the perspectives for B-decay studies at the LHCb experiment at CERN and for the exploration of rare kaon decays at future dedicated experiments, including a new

proposal at CERN.

The participants enjoyed the informal atmosphere of the workshop, which allowed the many graduate students to meet with researchers at the forefront of flavour physics and CP violation.

## INDUSTRY

# France shows its wares at CERN exhibition



Danièle Hulin (right) learns about an exhibit, together with Robert Aymar (second from left), CERN's director-general, and Monique Arribet from the French Embassy in Switzerland.

On 4–6 October French industry exhibited at CERN, showing products and technologies related to research in particle physics. Thirty-three French companies presented their latest developments in the fields of electrical engineering, information technology, vacuum

and low-temperature technologies, and civil engineering. The exhibition was inaugurated by Danièle Hulin, Directrice adjointe Secteur Physique, Chimie, Sciences pour l'Ingénieur (PCSI), Ministère délégué à l'Enseignement supérieur et à la recherche.

## PRODUCTS

**Kaleido Technology ApS** produces ultra-precision free-form mirrors for demanding applications. Mirrors up to 600 mm in diameter can be in glass, plastic and metal, with a surface roughness of less than 10 nm rms and a slope accuracy of better than 70  $\mu$ rad. High-precision moulded glass aspheric lenses are also available in diameters from 3–50 mm. These offer a single-element solution for collimating and focusing light to a diffraction-limited spot without aberrations. For more information, tel: +45 44 34 7040, e-mail: [contact@kaleido-technology.com](mailto:contact@kaleido-technology.com) or see [www.kaleido-technology.com](http://www.kaleido-technology.com).

**Lake Shore Cryotronics** has introduced the Model 455 gaussmeter to their family of digital signal processing gaussmeters.

Available for shipment in January 2006, features of the Model 455 include DC to 20 kHz AC frequency response, peak field detection to 50  $\mu$ s pulse widths, DC accuracy of 0.075% and temperature compensation. The display exhibits the probe temperature as well as frequency when operating in rms mode. The Model 455 also includes a standard Lake Shore Hall probe. For more information, tel: +1 614 891 2243, fax: +1 614 818 1600, e-mail: [info@lakeshore.com](mailto:info@lakeshore.com) or see [www.lakeshore.com](http://www.lakeshore.com).

**Resolve Optics Ltd** has announced a new high-performance 12–72 mm non-browning zoom lens that incorporates a range of features to assist operation in radiation environments. The 192-000 is a compact x6 optical tracking zoom using glass that can withstand a total dose of up to 108 rads and temperature of

## MEETINGS

**The 2nd International Workshop on Recent Progress in Induction Accelerators (RPIA2006)** will be held at KEK on 7–10 March 2006. The workshop will focus on all aspects related to induction acceleration: novel induction acceleration concepts; high-intensity electron, proton and ion facilities and projects; linear and circular accelerators; magnetic materials and high-power solid-state switching elements; beam dynamics experiments and stimulation. For further information, see: <http://confereqce.kek.jp/RPIA2006/>, or contact Ken Takayama, Organization Committee, KEK, e-mail: [takayama@post.kek.jp](mailto:takayama@post.kek.jp) or [RPIA2006@mil.k.kek.jp](mailto:RPIA2006@mil.k.kek.jp).

## CORRECTION

In the article "ITEP gives scintillation counters new START" (*CERN Courier* October 2005 p6) describing the development of scintillation detectors using photodiodes at the Institute for Theoretical and Experimental Physics (ITEP) in Moscow, the beginning of the second paragraph was edited to begin "Pioneering this technique, physicists from ITEP...". The team at ITEP would like to point out that they have not pioneered the technique, which has been under study by a number of groups for several years. Rather they have made the first successful implementation of the technique. Apologies to all concerned.

55 °C without dislocation. It is designed for use with single chip 1/2" and 2/3" CCTV cameras as well as Newvicon and Chalcon tubes. For more details, tel: +44 1491 777100, e-mail: [sales@resolveoptics.com](mailto:sales@resolveoptics.com) or see [www.resolveoptics.com](http://www.resolveoptics.com).

**Rubis-Precis** has developed a new range of high-precision ceramic components in alumina and zirconia to customers' specifications, providing solutions to the problems of wear, corrosion, high temperatures and electrical isolation. Pieces are machined to micron tolerance for a variety of applications in difficult environments, for example pistons mounted on stainless steel for medical pumps. For further information, tel: +33 3 81 68 27 27, fax: +33 3 81 68 68 34, e-mail: [chapolis@rubis-precis.com](mailto:chapolis@rubis-precis.com) or [feuvrier@rubis-precis.com](mailto:feuvrier@rubis-precis.com) or see [www.rubis-precis.com](http://www.rubis-precis.com).

## OBITUARIES

# Sir Joseph Rotblat 1908–2005

With the death of Joseph Rotblat on 31 August 2005 the world has lost one of its most engaged and capable advocates of nuclear disarmament and world peace.

Rotblat was born into a Polish Jewish family. His father was a prosperous paper merchant until the business collapsed during the First World War. After the war, Rotblat, penniless, worked as an electrician during the day and in the evenings studied for a physics degree at Warsaw University. He graduated in 1932, and while studying for his doctorate worked in the Radiation Laboratory in Warsaw. Early in 1939, after completion of his doctorate, Rotblat went to Liverpool on the invitation of James Chadwick to work on the study of uranium fission, which had just been discovered. He could not afford to bring his wife, Tola, so was delighted when Chadwick was able to offer him a fellowship in the summer of the same year. He went to Poland to collect her, but had to return to England on his own, because Tola, recuperating from an appendicitis operation, was not well enough to travel. Two days after he left Poland, the Germans invaded, and Tola did not survive the Nazi barbarism. Rotblat never remarried.

At the beginning of 1944, Chadwick and Rotblat went to Los Alamos to collaborate on the development of the atomic bomb, given the fear that the Germans might have a similar project. Later that year, on the occasion of a dinner at the Chadwicks', Rotblat was shocked by the statement of General Leslie Groves that the real purpose of the bomb was to subdue the Soviets. At the time the Soviets were allies in a fierce war, making huge sacrifices to vanquish the common enemy.

Later in 1944, it became clear that, in Rotblat's words, "the war in Europe would be over before the bomb project was completed", making his "participation in it pointless" ("Leaving the Bomb Project", *Bulletin of the Atomic Scientists*, August 1985). He therefore "asked for permission to leave it and return to Britain".

Given the German defeat, Rotblat considered the continuation of the bomb project to be immoral, and therefore did not want to continue to collaborate. In this he was



Sir Joseph Rotblat. (Courtesy AIP Meggers, Gallery of Nobel Laureates.)

unique among the many scientists working on the bomb project.

Back in British academia, Rotblat felt that it would be best to work for the application of scientific advances to human and social problems, and switched his work towards medical applications of radioactivity. In 1950 he moved to Bartholomew Hospital Medical School as professor of physics, until his retirement in 1976. In 1947 he organized the "Atomic Train", two railway carriages filled with exhibits and demonstration experiments, aimed at educating the public about nuclear energy and its risks.

Rotblat's concern about the danger posed by nuclear weapons was shared by Bertrand Russell. In 1955 the two organized the "Russell-Einstein Manifesto", which called attention to this problem and urged scientists to work towards its resolution. Rotblat was one of the 11 signatories. An outcome of the manifesto was the first of the Pugwash Conferences of scientists on nuclear arms problems, sponsored by Cyrus Eaton and held at his estate in the village of Pugwash in Nova Scotia. The Pugwash Conferences have become the chief forum for scientific discussions about nuclear disarmament, and more recently other arms-control and ecological problems. In its now nearly 50 years of activity, more than 300 conferences have been held all over the

world, bringing together scientists and others from different nations, to discuss and to try to understand these common problems.

Rotblat was the initiator of Pugwash and its leader – committed, devoted, moderate and extraordinarily capable both in his understanding of the issues and in maintaining a collaborative spirit of participants despite conflicting nationalities and divergent opinions. In focusing on specific problems, Pugwash can be credited with contributing to the Partial Test Ban Treaty of 1963, which prohibited atmospheric nuclear weapons tests, and the Anti-Ballistic Missile Treaty of 1972, which prevented an accentuation of the nuclear arms race.

Rotblat was Pugwash secretary-general until 1973, and became its president in 1988. It was clear to him that the only solution to the nuclear weapons threat as well as to nuclear weapons proliferation is the global elimination of nuclear weapons. A common response to this, especially from the Americans around the table, was that nuclear weapons cannot be disinvited. Rotblat countered this by dividing the question into two: was a world free of nuclear weapons (1) desirable and (2) feasible? Unfortunately, the answer to the first question from the nuclear weapons states, in particular the US, has been negative.

Rotblat attended almost all of the Pugwash meetings, and was its undisputed leader. In 1995, Rotblat and Pugwash were awarded the Nobel Peace Prize, and he immediately gave his share of the money to the organization. In addition, Rotblat was repeatedly honoured for his academic and humanitarian achievements, including Commander of the British Empire, 1965; the Bertrand Russell Society Award, 1983; the Albert Einstein Peace Prize, 1992; Fellow of the Royal Society, 1995; and many honorary academic degrees. He was knighted in 1998.

Rotblat's death is a very sad event and a great loss to many of us. Unfortunately he left us before his great dream of a world free of nuclear weapons has been realized. It is up to those of us who are left to continue his important struggle until the goal is reached. *Jack Steinberger, CERN.*



## OBITUARIES

# John Bahcall 1935–2005

John N Bahcall, a renowned leader in the fields of astrophysics and neutrino physics, passed away on 17 August 2005 from a rare blood disorder. He was 70 years old. Bahcall was a pioneer in the field of solar-neutrino studies, calculating neutrino fluxes and detection reactions that led to the original measurements by his long-time colleague Ray Davis and other subsequent measurements. His perseverance in resolving the flux deficit known as the "solar-neutrino problem" motivated the field and significantly advanced particle physics and solar physics.

Bahcall was born in Shreveport, Louisiana, and educated at Louisiana State University, the University of California at Berkeley (AB, 1956), the University of Chicago (MS, 1957) and Harvard University (PhD, 1961). He was a research fellow at Indiana University from 1960 to 1962 before joining the faculty at Caltech. He became a member of the Institute for Advanced Study in Princeton in 1968, and was named Richard Black Professor of Natural Sciences in 1997.

Bahcall had a very strong influence on the development of solar-neutrino measurements and was regarded as the premier theoretical physicist in the detailed understanding of the solar interior. This work began when he was at Caltech in the 1960s. His early papers on solar-neutrino fluxes and the sensitivity for neutrino detection with chlorine led to the development of the Homestake detector and the first clear observations of solar neutrinos, for which Ray Davis received the Nobel Prize in 2002. For more than 30 years, Bahcall and his collaborators refined their theories of the Sun, seeking to understand the flux deficit observed in the chlorine experiment and in subsequent measurements by Kamiokande (led by Masatoshi Koshihira, who shared the Nobel Prize with Davis), SAGE, GALLEX/GNO, Super-Kamiokande and the Sudbury Neutrino

Observatory (SNO). Although the solar models continued to provide remarkable agreement with all known solar properties, including very detailed measurements of sound speed profile through helioseismology, the neutrino deficit remained.

Bahcall and his collaborators also explored particle-physics processes beyond the Standard Model that eventually provided the basis for a clear explanation of the deficit through direct measurements of neutrino flavour-change by SNO. These measurements also confirmed the accuracy of the solar-model calculations they made. Bahcall's perseverance, careful development of theoretical calculations for the Sun, encouragement and support of experimental initiatives, and his broad consideration of all physics possibilities marked him as an active leader throughout his long career. He deserves tremendous credit for the significant advances in neutrino and solar physics that have been made through solar-neutrino studies.

Bahcall's work in astrophysics includes many major contributions, such as the standard model for a massive black hole surrounded by a cluster of stars – the Bahcall–Wolf model – and the widely quoted model for our galaxy, the Bahcall–Soneira model. In the 1960s he and Edwin Salpeter suggested the use of quasar light for the study of intervening regions of space, studies that he pursued himself with the Hubble Space Telescope. His collaboration with Eli Waxman set limits for the fluxes of high-energy cosmic neutrinos now being sought by neutrino telescopes.

In addition to producing an extensive body of published work, involving more than 600 scientific and technical papers, Bahcall was an influential force in the development of astrophysics. He was noted as an exceptional mentor of young scientists, particularly during postdoctoral experience with his group at the Institute for Advanced Study. He was a leader in



the development of the Hubble Space Telescope and the Space Science Institute, and helped set directions for neutrino astrophysics through his strong support of new detectors. He was president of the American Astronomical Association and led the team that produced the 1990 National Research Council *Bahcall Report*, setting scientific and instrumental priorities for astrophysics in the US for a decade. At the time of his final illness, he was president-elect of the American Physics Society.

Bahcall received numerous awards and prizes including the 1998 National Medal of Science; the Hans Bethe Prize of the American Physical Society; the Dan David Prize of Israel; the Gold Medal of the Royal Astronomical Society; the Fermi Award (with Raymond Davis); and the Benjamin Franklin Medal in Physics (with Raymond Davis and Masatoshi Koshihira). He received honorary doctorates from the universities of Pennsylvania, Chicago, Notre Dame and Milano, and the Hebrew University of Jerusalem.

Bahcall and his wife Neta, a professor of astrophysics at Princeton, collaborated on more than 30 scientific papers. They were the only married couple in the National Academy of Sciences of the United States. They have three children, all scientists.

*Art McDonald, Queen's University, Kingston, Ontario, Jeremiah Ostriker, Princeton University, and Alexei Smirnov, ICTP, Trieste.*



## VACUUM VALVES

[www.vatvalve.com](http://www.vatvalve.com)



# RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.

Tel: +44 (0)117 930 1196. Fax: +44 (0)117 930 1178 E-mail: sales@cerncourier.com.

Rates per single column centimetre: standard \$94/€75/£52, academic \$88/€71/£49, courses and calls for proposals \$85/€68/£47.

Please contact us for more information about colour options, publication dates and deadlines.



## Indiana University POSTDOCTORAL FELLOW POSITION



The Indiana University High Energy group on the DØ experiment at the Fermilab Tevatron Collider and ATLAS experiment at the Large Hadron Collider seeks outstanding applicants for a postdoctoral fellow, beginning immediately or at a negotiated time. Applicants should have a Ph.D. in high energy physics with experience in large scale computing, as well as in the area of physics analysis, preferably on a colliding beam experiment.

The DØ Indiana group is active in the area of B-physics analyses at the Tevatron, and plans for processing increased data bandwidth off-site from Fermilab. The ATLAS Indiana group is responsible for the barrel transition radiation tracker, tracking software, and operating a Tier 2 site at the university. Successful candidates would be expected to work on both software/hardware and physics analyses.

Applicants should send a curriculum vitae, a list of publications, a statement of research interests and at least three letters of recommendation to:

**DØ/ATLAS Postdoc Search, Physics Department,  
Indiana University, Bloomington, IN 47405. Fax: (812) 855-0440**

The group consists of Profs. Rick Van Kooten, Andrzej Ziemiński, Hal Evans, and Harold Ogren.

For further details and contact information, visit

<http://hep.physics.indiana.edu/~rickv/postdoc.html>.

*Indiana University is an Affirmative Action/Equal Opportunity Employer.*

## epcc

### MSc in High Performance Computing UK/EU studentships available

EPCC, the Edinburgh Parallel Computing Centre, at the University of Edinburgh offers a one-year taught MSc in High Performance Computing (HPC). This well established programme provides an excellent grounding in HPC technologies and their practical application.

EPCC is an Institute within the School of Physics at the University of Edinburgh. It has an international reputation as a leading centre of expertise in HPC and Grid computing. EPCC is the lead partner in the HPCx consortium, which provides world-leading supercomputers for the UK research community, and also hosts many other machines including the first IBM Blue Gene system to be installed in Europe.

This MSc will appeal if you have a keen interest in programming and would like to learn about HPC and parallel programming. The course has a strong practical focus and you will have access to leading-edge HPC platforms and technologies.

Applications are encouraged from people who are competent programmers in Java, C++, C or Fortran, and are graduates in science, engineering, computer science and mathematics or are currently working in a relevant field.

The entrance requirement is a good honours degree or equivalent work experience. No prior HPC knowledge is assumed.

The closing date is 28 February 2006 for UK/EU nationals and 31 January 2006 for non-UK/EU nationals.

For more information and application details see

<http://www.epcc.ed.ac.uk/msc/> or email

[msc@epcc.ed.ac.uk](mailto:msc@epcc.ed.ac.uk)

The MSc in HPC is supported by EPSRC, who offer a number of funded studentships for UK/EU students.



## TENURE TRACK and POSTDOCTORAL positions in NEUTRINO ASTROPARTICLE PHYSICS

The NESTOR Institute for Astroparticle Physics, which recently became part of the National Observatory of Athens (NOA), invites interested physicists to apply by November 21 for the tenure track position of Associate Researcher (grade gamma). Furthermore, the NESTOR/NOA Institute will have a number of tenured (Research Director or Principal Researcher levels) or other tenure track openings in the near future, inquiries are encouraged.

The NESTOR Institute has been awarded a Center of Excellence grant by the General Secretariat for Research and Technology.

IN ADDITION: The Physics Departments of the Universities of Athens and Cyprus, the Institute of Nuclear Physics at the National Center for Scientific Research "Demokritos" and the NESTOR Institute for Astroparticle Physics/NOA are seeking candidates for a number of postdoctoral Research Associate positions (at varying seniority levels) in the field of Neutrino Astroparticle Physics. Candidates should have experience in the fields of Experimental Particle, Nuclear or AstroPhysics.

The groups mentioned above play leading roles in the NESTOR experiment, hosted by the NESTOR Institute, or the KM3NeT (Cubic kilometer Deep Sea Neutrino Telescope) collaboration and form a significant part of the proponents for the KM3NeT Design Study which has been recently funded by the 6th FP of the E.U. Successful applicants will participate in the ongoing NESTOR experiment and/or the design and development of the KM3NeT project. Further information for all the above positions can be obtained at the NESTOR Institute ([www.nestor.org.gr](http://www.nestor.org.gr)) or by contacting the Institute at email: [secretary@nestor.org.gr](mailto:secretary@nestor.org.gr)



STANFORD LINEAR ACCELERATOR CENTER

## Faculty Position in Theoretical Elementary Particle Physics

The Stanford Linear Accelerator Center at Stanford University invites applications from outstanding candidates from all areas of elementary particle theory for a tenure-track faculty appointment.

Candidates should have demonstrated their ability to carry out independent research in theoretical particle physics at the highest level. The position includes opportunities for classroom teaching and supervision of Stanford graduate students. The position allows a close interaction with the experimental program at the Stanford Linear Accelerator and with the program of the new Kavli Institute for Particle Astrophysics and Cosmology.

Applicants should submit a curriculum vitae, publication list, and statement of current research interests and future plans, and should arrange for four letters of recommendation to be sent to: **Professor Lance Dixon, Theory Search Chair, MS 81, SLAC, P.O. Box 20450, Stanford, CA 94309-0450.** All material should arrive by **February 1, 2006.**

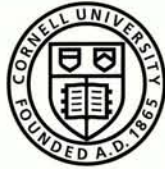
*Stanford University is an equal opportunity employer and is committed to increasing the diversity of its faculty. It welcomes nominations of and applications from women and members of minority groups, as well as others who would bring additional dimensions to the university's research and teaching missions.*

## Cornell University Director of Elementary Particle Physics

Cornell University has initiated a search for a Director of Elementary Particle Physics. The person in this new position will be responsible for a physics program at Cornell that includes completion of the CESR-c and CLEO-c program, participation in the CMS collaboration, accelerator and detector R&D for the International Linear Collider, and the elementary particle theory group. The renewable five-year term can begin as early as July 1, 2006. The successful candidate will be appointed as a tenured Professor of Physics at Cornell University.

The search committee welcomes nominations or applications for this position, preferably accompanied by curriculum vitae and other information bearing on the candidate's qualifications for the directorship. Relevant qualifications include scientific stature, leadership, and management skills. Communications should be sent as soon as possible, preferably before January 15, 2006, addressed to:

Professor David G. Cassel, Chair  
Director Search Committee  
Newman Laboratory  
Cornell University  
Ithaca, NY 14853, USA



Cornell is an equal opportunity, affirmative action employer.

## LEDERMAN FELLOWSHIP EXPERIMENTAL PARTICLE or ACCELERATOR PHYSICS

The Fermi National Accelerator Laboratory (Fermilab) has an opening for a postdoctoral Lederman Fellow in experimental particle physics or accelerator physics. We are looking for candidates who have demonstrated outstanding ability in research. In recognition of Leon Lederman's commitment to the teaching of physics at all levels, the successful candidate will be also expected to participate, for a fraction of his/her time, in physics outreach. The Lederman Fellow will have a choice among experiments, which include Tevatron and LHC collider experiments, neutrino experiments, other fixed target experiments and astroparticle physics experiments, or research on accelerators. See <http://www.fnal.gov/> for more information.

Candidates should have obtained a Ph.D. in experimental particle or accelerator physics after November 15, 2004. The appointment is normally for three years with an extension possible. To apply, write to: **Dr. Vaia Papadimitriou (Chair of Lederman Fellowship Committee), Fermi National Accelerator Laboratory, MS 306, P.O. Box 500, Batavia, IL 60510-0500 - vaia@fnal.gov.** Applicants should send a letter including their research experience and noting any experience or interest in teaching and outreach, a curriculum vita, publication list and the names of at least four references. Applications will be accepted through January 27, 2006.



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

HadronPhysics I3



HadronPhysics I3  
Study of Strongly Interacting Matter

European Commission

## Transnational Access to Research Infrastructures

The Integrated Initiative "HadronPhysics I3", financed by the European Commission and coordinated by the Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Italy, combines in a single contract several activities, Networking, Research Projects and Transnational Access. The Transnational Access activity involves 9 infrastructures among those operated by the participants in HadronPhysics I3. Its objective is to offer the opportunity for European research teams, performing or planning a research project at these infrastructures, to

### APPLY FOR EC FUNDED ACCESS

to these infrastructures, to cover subsistence and travel expenses.

The only eligible teams (made of one or more researchers) are those that conduct their research activity in the EU Member States or in the Associated States. Information about the modalities of application and the **Calls for Proposals** can be obtained by visiting the web site of each infrastructure:

- A1. INFN-LNF, <http://www.inf.infn.it/cee/tarifp6/>
- A2. DESY-HERMES, <http://www-hermes.desy.de/I3HP-TA-HERMES/>
- A3. FZJ-COSY, <http://www.fz-juelich.de/ikp/tmr-life.html>
- A4. FZJ-NIC/ZAM, <http://www.fz-juelich.de/nic/i3hp-nic-ta/>
- A5. GSI-SIS, [http://www.gsi.de/informationen/users/EC-funding/I3/SIM\\_e.html](http://www.gsi.de/informationen/users/EC-funding/I3/SIM_e.html)
- A6. U Mainz-MAMI, <http://www.kph.uni-mainz.de/en/eu/>
- A7. ZIB, <http://www.zib.de/i3hp>
- A8. LU-MAXLAB, [http://www2.maxlab.lu.se/members/proposal\\_nucl/index.html](http://www2.maxlab.lu.se/members/proposal_nucl/index.html)
- A9. UU-TSL, <http://www4.tsl.uu.se/tsl/tsl/infrastr.htm>

This announcement can also be found at the following URL: <http://www.infn.it/eu/i3hp>

## NUCLEAR PHYSICIST Paris, France

We are looking for a Physicist or Engineer, specialized in radiation measurement, to work on R&D projects in our industrial laboratory in Paris, France.

**We are:** a dynamic multinational company with offices in over 55 countries, employing 4,500 people. We are growing rapidly and developing new technologies to meet our clients' needs.

**You are:** a Physicist or Engineer with a PhD in experimental nuclear physics. You have very good knowledge of radiation interaction and the associated electronics and instrumentation including pulse-shaping and spectroscopy electronics. You have good familiarity with sources and detector physics, in particular scintillation counters. Work experience in development of radiation detection systems, including detectors, photomultiplier tubes, signal conditioning and spectroscopy is an advantage.

**The job is:** to be in charge of the development of instrumentation for radiation measurements in challenging environmental conditions. This includes system specification and definition including detector and shielding, and the organisation of experiments for validation of prototypes, including the interpretation of associated results.

We offer a competitive salary and benefits package to the right applicant, and assistance with relocation to Paris. Reply, with your CV, to: [recruitment@oxshott.demon.co.uk](mailto:recruitment@oxshott.demon.co.uk)



## Hall D Group Leader

Jefferson Lab, located in Newport News, Virginia, USA, is a world-class scientific laboratory centered around a high-intensity, continuous wave electron beam, which provides a unique capability for nuclear physics research. The lab is managed for the Department of Energy by the Southeastern Universities Research Association.

Currently, we have an excellent opportunity for a Hall D Group Leader to provide overall management of Hall D including the physics program and experimental equipment project from the R&D phase through construction and operation. Incumbent will serve as a member of the 12 GeV Upgrade Project Team with responsibility for planning and delivering the Hall D scope of work within cost and on schedule; provide coordination and communication between the GlueX collaboration management and the Laboratory; provide scientific leadership in developing an experimental program of high scientific relevance at Jefferson Lab, and present it to the larger nuclear physics and scientific communities. Incumbent will oversee the commissioning and operation of the Hall D experimental equipment, including the Hall D detector, beamline instrumentation, and other ancillary devices; and create/maintain a positive EH&S culture and implement and maintain a self assessment program. Incumbent will supervise the Hall D staff including scientific staff, postdoctoral researchers, and the engineering and technical staff; act as contact person for user groups.

### Minimum Qualifications:

Ph.D. in Experimental Nuclear or Particle Physics or the equivalent combination of education, experience, and specific training. At least ten years of professional experience in intermediate energy nuclear/particle physics or a closely related area, of which a minimum of three years is in management of an internationally recognized nuclear/particle physics research group. Technical experience with a broad variety of equipment, detectors, targets and experimental programs associated with nuclear/particle physics. Scientific excellence as demonstrated by extensive publication in nuclear/particle physics, and demonstrated supervisory, planning, problem solving, decision making, and communication skills. Capable of quickly acquiring a comprehensive knowledge of Hall D instrumentation and detailed familiarity with the Hall D physics program. Significant project management experience is highly desirable.

For prompt consideration, apply on-line at: [www.jlab.org/jobline/](http://www.jlab.org/jobline/)  
Fax: 757-269-7559

*An Equal Opportunity, Affirmation Action Employer*



## Dublin Institute for Advanced Studies Schrödinger Fellowship School of Theoretical Physics

A Post-doctoral Research Fellowship in Theoretical Physics is currently available in the Dublin Institute for Advanced Studies. This is a dedicated research position and does not involve any teaching or administrative duties. Candidates must have a proven record as independent researchers in one of the following fields of study – Quantum Field Theory, Conformal Field Theory, String Theory and Statistical Mechanics.

Further details on the positions together with the application procedures are available on the School's website at [www.stp.dias.ie](http://www.stp.dias.ie). Enquiries should be directed to the School Director, Prof. T. C. Dorlas at [dorlas@stp.dias.ie](mailto:dorlas@stp.dias.ie)

Appointments will be on the basis of a fixed-term contract up to five years. The attaching salary is €47,131 increasing by annual increments up to €52,578.

Applicants should submit a CV, a list of publications together with a research proposal and arrange for three letters of recommendation to be sent to: **The Registrar's office, DIAS, 10 Burlington Road, Dublin 4** to arrive **before 16 December 2005**. Electronic applications should be sent to [registraroffice@admin.dias.ie](mailto:registraroffice@admin.dias.ie). The search for a suitable candidate may be widened beyond the applications received.

*DIAS is an Equal Opportunities employer*



## UNIVERSITY OF OXFORD

Mathematical and Physical Sciences Division

Department of Physics in association with Wadham College

### University Lecturer in Theoretical Particle Physics

The Department of Physics proposes to appoint a University Lecturer in Theoretical Particle Physics with effect from 1st June 2006 or as soon as possible thereafter. The successful candidate will also be offered a Tutorial Fellowship by Wadham College, under arrangements described in the further particulars. The combined University and College salary will be according to age on a scale up to £47,078 p.a., plus additional College benefits.

Applicants should have a strong background and active research programme in theoretical particle physics, in areas that complement and enhance the existing strengths of the Particle Theory Group with some preference for the areas of collider physics and Beyond-the-Standard-Model physics related to the LHC programme. The successful candidate will be expected to participate actively in research, undergraduate and graduate teaching and relevant administration.

Further particulars, containing details of the application procedure and of the duties, may be obtained from Miss M Barnes, The Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, Oxford OX1 3NP, England, e-mail: [margaret@thphys.ox.ac.uk](mailto:margaret@thphys.ox.ac.uk) or by visiting <http://www.physics.ox.ac.uk> The closing date for applications is 16th January 2006. Please quote reference DR05/003 on all correspondence. Applicants should ensure that their referees send letters by this date.

The University is an Equal Opportunities Employer.



## Looking for a new challenge or taking your first step into employment?

Visit the **JobsWatch** section on [cerncourier.com](http://cerncourier.com) and sign up now for the **FREE** jobs e-mail alerting service.

All of the latest jobs posted on **JobsWatch** will be e-mailed directly to you, giving you the advantage of viewing new vacancies immediately.

**Don't delay – sign up today!**

[cerncourier.com/jobs](http://cerncourier.com/jobs)



## Positions in Grid Computing and LIGO Gravitational Wave Data Analysis

The Penn State Center for Gravitational Wave Physics (CGWP) has funding for several positions at the postdoctoral scholar level or higher to take part in the development and support of the LIGO Virtual Organization, a charter member of the Open Science Grid, and in the use of the VO's resources for the analysis and interpretation of observations from the Laser Interferometer Gravitational Wave Observatory (LIGO).

LIGO has critical production requirements to process 300 TBytes of data per year of fundamental and pressing scientific importance. This is one of the earliest and most intensive tests to date of grid computing concepts using real-world geographically dispersed, heterogeneous, high performance data processing resources with different local management and technical histories. Working in this environment will provide invaluable experience in the realities of grid computing, extraordinary opportunity to influence the future of grids and computing in general, and participation at the birth of the exciting new field of observational gravitational wave physics.

The Penn State LIGO Scientific Collaboration (LSC) group is part of the LIGO Global Grid Virtual Organization, contributing local resources of 312 processors and 34 TB storage (approximately 1/5 of the aggregate resources of the VO). The Penn State gravitational wave group is the largest and most active in the country with seven faculty, eleven postdocs and technical staff members, and eight graduate students. It plays a leading role in the analysis and interpretation of LIGO data, including analysis in collaboration with other gravitational wave detector experiments worldwide. It is part of the larger Penn State Institute for Gravitational Physics and Geometry, which is the largest and most active relativity group in the country with over twenty faculty, sixteen postdocs, twenty graduate students, and seven undergraduate students engaged in research in all areas of gravity.

Penn State is also home to the Center for Gravitational Wave Physics (CGWP), funded by the National Science Foundation as part of its Physics Frontier Centers program. The mission of the CGWP is to foster research of a truly interdisciplinary character linking the highest caliber astrophysics, gravitational wave physics and experimental gravitational wave detection in the pursuit of the scientific understanding of gravity and the development of gravitational wave observations as a tool of observational astronomy.

Each year the CGWP hosts at Penn State several major workshops and conferences addressing all areas of gravitational wave physics and astrophysics.

Academic background in physics with Ph.D. in hand and a strong interest in computing will be preferred for these positions. Applicants with a computer science background and demonstrated experience in computing for large scale experimental physics will also be favorably considered and do not require a Ph.D. Applicants should send a CV, statement of research interests and relevant experience, and arrange for three letters of recommendation to be sent to:

**Grid Computing/LIGO VO Search  
Center for Gravitational Wave Physics  
104 Davey Laboratory, PMB 89  
University Park, PA 16802  
USA**

Applications will be considered beginning 15 January 2006 and will continue until the available positions are filled. For more information contact [lsfinn+grid@psu.edu](mailto:lsfinn+grid@psu.edu) or see our websites at <http://gravity.psu.edu> and <http://ligo.aset.psu.edu>.

Penn State is committed to affirmative action, equal opportunity and the diversity of its workforce.

## Yale University Faculty Position in Experimental Particle Physics

Yale University Department of Physics is seeking candidates for a faculty position in experimental particle physics. The department will consider candidates at both the untenured junior level and the tenured senior level. The position is intended for a physicist who, at the junior level, has the ability and potential, or at the senior level, the experience and demonstrated track record, of leading a sustained research program at the frontier of particle physics, including, but not restricted to the Large Hadron Collider, neutrino physics, direct dark matter searches, etc. In addition the successful candidate is expected to participate actively and effectively in teaching at the undergraduate and graduate levels.

Interested applicants should send a letter, curriculum vita, publication list, teaching statement, and a brief description of proposed research to *Lillian Vinston*, Department of Physics, Yale University, PO Box 208120, New Haven, CT 06520-8120, or electronically to [Lillian.Vinston@yale.edu](mailto:Lillian.Vinston@yale.edu).

The applicant should also arrange for at least three letters of recommendation to be sent.

To ensure full consideration application files must be complete by January 1, 2006.

*Yale University is an Affirmative Action/Equal Opportunity Employer, and applications from women and minority scholars are strongly encouraged.*



## Experimental Research Associates

The Stanford Linear Accelerator Center (SLAC) is one of the world's leading laboratories supporting research in high energy physics. The laboratory's program includes the physics of high energy electron-positron collisions, high luminosity storage rings, high energy linear colliders and particle astrophysics.

Post doctoral research associate positions are currently available. Areas of research opportunity may include:

- B physics with the BaBar detector at PEP II.
- The particle astrophysics program focused on the gamma ray telescope GLAST and the dark energy experiment LSST.
- R&D toward a future linear collider detector.
- Neutrino-less double beta decay experiment EXO.
- SLAC participation in ATLAS.

These positions are highly competitive and require a background of research in high energy physics and a recent PhD or equivalent. The term for these positions is two years and may be renewed.

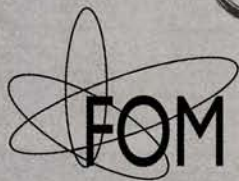
Applicants should send a letter stating their physics research interests along with a CV and three references to **Jean Lee**, [jeanlee@SLAC.Stanford.EDU](mailto:jeanlee@SLAC.Stanford.EDU), Particle and Particle Astrophysics, SLAC M/S 75, 2575 Sand Hill Road, Menlo Park, CA 94025 USA.

# cerncourier.com

## Foundation for Fundamental Research on Matter

The Foundation for Fundamental Research on Matter (FOM) promotes physics research of international standard/calibre in the Netherlands. It conducts scientific research and plays a stimulating and co-ordinating role on a national level in (para)academic physics research. FOM employs about 1100 people, consisting primarily of scientists (including PhD students) and technicians. These operate in four research institutes and approximately 200 research groups at general and technical universities.

FOM is chiefly financed by the NWO (Netherlands Organisation for Scientific Research) Governing Board and NWO Physics and can be considered as the Physics Division of NWO. In addition to the government funds of NWO, FOM acquires financial means from the European Union and through collaboration with the industry and universities. For additional information see <http://www.fom.nl>



NIKHEF is searching for candidates for permanent positions in

# Experimental particle and astroparticle physics



NIKHEF is the national institute for subatomic physics in the Netherlands, in which the funding agency FOM, the Universiteit van Amsterdam, the Vrije Universiteit in Amsterdam, the Radboud Universiteit in Nijmegen and the Universiteit Utrecht participate. The institute co-ordinates and supports major activities in experimental subatomic physics in the Netherlands.

NIKHEF participates in the preparation of experiments at the Large Hadron Collider at CERN, specifically in Atlas, LHCb and Alice. NIKHEF is also actively involved in experiments in the USA (D0 at FNAL, BaBar at SLAC and STAR at RHIC), and Germany at DESY (Zeus, Hermes). Astroparticle physics is an integral part of NIKHEF's scientific programme, in particular through participation in the Antares deep-sea neutrino detector project. Moreover, participations in ultra-high energy cosmic ray experiments and gravitational wave detectors are being explored. Detector R&D and data-analysis take place at the NIKHEF laboratory located in Science Park Amsterdam as well as at the participating universities. NIKHEF has a theory group with an independent research programme and which maintains close contacts with the experimental groups. The academic staff consists of about 120 physicists of whom more than half are PhD students and postdoctoral fellows. Technical support is provided by well-equipped mechanical engineering, electronic engineering and information technology departments with a total staff of about 100.

### Specific requirements

Candidates should have an international reputation in research and should have at

least several years of post-doctoral experience. The successful applicant is expected to join the present experimental programme in Astroparticle Physics (notably Antares) or B-physics (notably LHCb).

### General requirements

Candidates should have both broad and deep knowledge of physics. Further qualifications include: creativity, competence in detection techniques and knowledge of modern information technology. The successful candidate has excellent communication skills, ability for teamwork and leadership capability.

### Information

Information about the scientific and educational activities at NIKHEF can be found at: <http://www.nikhef.nl/> Further information about the Astroparticle Physics programme can be obtained from Prof. dr. G. van der Steenhoven (telephone: +31 205922145 / email: [gerard@nikhef.nl](mailto:gerard@nikhef.nl)), about the B-physics programme from Prof. dr. M.H.M. Merk (telephone +31 205925107 / email: [marcel.merk@nikhef.nl](mailto:marcel.merk@nikhef.nl)).

### Applications

Letters of application, including curriculum vitae, list of publications, the names of at least three references and the experimental programme you are interested in, are to be sent before January 15th, 2006 to Mr. T. van Egdom, P.O. Box 41882, 1009 DB Amsterdam, the Netherlands (or by email: [teusve@nikhef.nl](mailto:teusve@nikhef.nl)).

All qualified individuals are encouraged to apply.

## Are you looking for highly numerate, computer-literate, practical problem solvers with a wide technical knowledge?

### Yes? Then you need CERN Courier.

The use of physical methods and applied mathematics as tools for understanding the financial markets is widely known in the physics community. Practical information is combined with more complex aspects of physics in finance to bring new and interesting results to economists, mathematicians and physicists working in financial institutions, as well as academics.

For detailed information about how CERN Courier can assist you with suitable advertising options, including magazine advertising and online exposure, please contact Adam Hylands.

E-mail: [adam.hylands@iop.org](mailto:adam.hylands@iop.org) Tel: +44 117 930 1027

Explore

Link

Digest

Browse

Search

Bookmark

**cerncourier.com**

## **PARTICLE PHYSICIST (VN2772)**

The Particle Physics Department at the CCLRC has a pivotal role in the development of computing and detector infrastructure for large particle physics experiments at CERN in Geneva (Switzerland). One of these experiments, LHCb, based at CERN's Large Hadron Collider (LHC) is presently under construction. The CCLRC is a principal collaborator in the development of both detectors and software for the LHCb experiment and now plans to expand its involvement in LHCb studies, of CP violation in B meson decays, to probe the Standard Model.

We are looking for a highly motivated individual, with a PhD in particle physics and subsequent research experience, to lead the CCLRC LHCb physics analysis effort and coordinate the CCLRC contribution to LHCb RICH detector and software commissioning and operation. On a time scale of two to three years the successful candidate could expect to take overall leadership of the CCLRC LHCb group.

The successful candidates should have:

- The ability to lead a team or project, including supervision of PhD students;
- Effective written and oral communication skills;
- Made a principal contribution to a particle physics research project;
- Some knowledge of CP violation physics;
- Experience in data analysis or Monte Carlo simulation for particle physics experiments;
- Experience of high level computer languages in a Unix environment;
- Up to date general knowledge in the field of particle physics and relevant technologies.

For candidates who, in addition, possess some of the following qualities, the transition to group leadership might be accelerated, and the appointment made at the higher end of the salary range:

- Experience in leading a particle physics research team;
- Experience in leading particle physics R&D or analysis projects;
- An established and substantial record of research in particle physics.

The successful candidate should be willing to travel to CERN and other collaborating institutes in the UK and abroad.

Salary will be in the range £32,114 to £41,529 dependent on experience. In addition we offer an excellent index-linked final salary pension scheme and generous leave allowance.

For further information about this post or the Particle Physics Department, please contact Dr. John Morris J.V.Morris@rl.ac.uk or visit [hepwww.rl.ac.uk/pub/ppd.html](http://hepwww.rl.ac.uk/pub/ppd.html)

Closing date for applications is 9 January 2006.

Interviews will be held on 25 January 2006.

---

## **TWO RESEARCH ASSOCIATES IN THE CMS AND ATLAS GROUPS (VN2775)**

The Particle Physics Department at the CCLRC Rutherford Appleton Laboratory has two vacancies for Research Associates to work on software for the ATLAS and CMS tracking detectors and on LHC physics analysis. These are three-year fixed-term appointments, starting immediately, which should therefore overlap data-taking at the LHC.

Applicants must have a PhD in experimental particle physics or in "e-science" with particle physics. Further information about these posts can be obtained from the websites <http://www.cclrc.ac.uk/Activity/VNInfo;section=9209> and <http://www.cclrc.ac.uk/Activity/VNInfo;section=9210> for ATLAS and CMS respectively.

Salary is in the range £22,605 to £26,911 (pay award pending), dependent on experience. In addition we offer an excellent index-linked final salary pension scheme and generous leave allowance.

Closing date for applications is 9 January 2006.

Interviews will be held on 26 & 27 January 2006.

---

## **TWO RESEARCH ASSOCIATES IN THE LCFI AND ATLAS LEVEL - 1 TRIGGER GROUPS (VN2770)**

The Particle Physics Department at the Rutherford Appleton Laboratory has immediate vacancies for 2 three-year fixed-term positions within the LCFI and ATLAS groups. Both appointments are ideal for recent PhD graduates seeking to develop their expertise working as part of an international collaboration.

The LCFI post will involve the development and testing of new silicon pixel sensors for the ILC vertex detector, and its optimisation through physics simulations. Further details can be obtained at <http://www.cclrc.ac.uk/activity/VNInfo;section=9213>

The ATLAS post will involve the commissioning and calibration of the level-1 calorimeter trigger, leading to physics studies with first LHC beam. Further details can be obtained at <http://www.cclrc.ac.uk/activity/VNInfo;section=9214>

Applicants must have a PhD in experimental particle physics or related discipline.

Salary is in the range £22,605 to £26,911 per annum (pay award pending), dependent on experience. An excellent index linked pension scheme and generous leave allowance are also offered.

Closing date for applications is 9 January 2006.

Interviews will be held on 2 and 3 February 2006.

---

Application forms for any of the above positions can be obtained from: Human Resources, CCLRC, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or e-mail: [recruit@rl.ac.uk](mailto:recruit@rl.ac.uk). Please quote the relevant reference number.



[www.cclrc.ac.uk](http://www.cclrc.ac.uk)



## Opportunities within ASTeC Daresbury Laboratory

The Council for the Central Laboratory of the Research Councils, CCLRC, is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide.

Due to retirements, vacancies exist for two Group Leaders to join the Accelerator Science and Technology Centre (ASTeC), to be based at Daresbury Laboratory in Cheshire. The Centre undertakes particle accelerator research and development and the team you would join are world experts in the design, construction and development of advanced systems for particle accelerators. ASTeC supports the development of both UK and international accelerator projects, including the proposed light source 4GLS, for which a prototype superconducting energy recovery linac is presently under construction, and major International Linear Collider Research & Development (R&D) programmes.

### Group Leader in the Radio Frequency (RF) and Diagnostics Group (VND282/05)

*The RF and Diagnostics Group is an expanding group of specialists providing the RF and diagnostic expertise to design, develop and support a wide range of accelerator projects. Underpinning this is an expanding series of R&D programmes within the Laboratory, including the development of superconducting RF (SRF) structures operating in the cw mode. The Group is involved in a number of collaborations both with industry and with overseas laboratories and has a strong international reputation. The new Group Leader would be expected to build on this success and develop the Group in an exciting period of growth in the world accelerator scene.*

### Group Leader in the Vacuum Science Group (VND283/05)

*The Vacuum Science Group is a small team of specialists, which provides the vacuum expertise to inform and support the work of the Centre. It has a strong international reputation and is involved in a number of international collaborations. Underpinning this is an expanding series of R&D programmes within the Vacuum Science Laboratory which, is soon to occupy a new purpose built laboratory. Current programmes include the investigation of getter films, low outgassing surfaces and vacuum metrology.*

We are seeking highly motivated scientists/engineers with a proven track record of success in the design, commissioning and operation of large scale RF or Vacuum systems and in the technical assessment, specification and integration of RF and Diagnostic or Vacuum system components. Experience of accelerators would be advantageous, but not essential. For both vacancies you should have an independent outlook; will have demonstrated the ability to lead such a Group; and will have the necessary skills to work with the other Group Leaders as part of the ASTeC Management Team. These skills will include project planning; budget setting and control; and person management.

You should have at least a degree or equivalent professional qualification in a relevant science or engineering subject. Substantial relevant experience over a minimum period of 5 - 10 years in positions involving similar work is essential.

Starting salary is up to £41,529 on a pay range from £35,300 to £45,682 (Pay Award pending). Salary on appointment is awarded according to relevant experience. An index linked pension scheme, flexible working hours and a generous leave allowance are offered. Some assistance with relocation may be available.

Additional information is available from Sue Waller (s.waller@dl.ac.uk) or (01925) 603212 and also from [www.astec.ac.uk](http://www.astec.ac.uk)

A note providing more background information on the posts is available with application forms, which can be obtained from: Human Resources Division, Daresbury Laboratory, Daresbury, Warrington, Cheshire WA4 4AD. Telephone (01925) 603953 or email [recruit@dl.ac.uk](mailto:recruit@dl.ac.uk) quoting the appropriate reference number. More information about CCLRC is available from CCLRC's World Wide Web pages at <http://www.cclrc.ac.uk>

All applications must be returned by 16 December 2005.

The Council for the Central Laboratory of the Research Councils (CCLRC) is committed to Equal Opportunities and is a recognised Investor in People.

A no smoking policy is in operation.



COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

## CERN COURIER

### Classified advertising

is the perfect platform to promote a diverse range of events and important announcements, including:

- calls for proposals/research papers
- summer schools
- workshops
- courses
- equipment sales.

In 2005 *CERN Courier* has introduced a special classified advertising rate to assist in your communication needs. *CERN Courier* offers you access to readers in the world's major physics research sites and the opportunity to run a modest advertisement at a low cost. Many organizers have appreciated how *CERN Courier* has helped to raise the profile of their events and significantly increased the number of delegates.

For further information and consultative advice on classified advertising in *CERN Courier* and the Web options that we offer, please contact

**Adam Hylands.**  
Tel:  
**+44 (0)117 930 1027**  
E-mail:  
**[adam.hylands@iop.org](mailto:adam.hylands@iop.org)**

Access **JobsWatch**  
**@cerncourier.com**





### RESEARCH SUPPORT SPECIALIST III VACUUM ENGINEER

#### Cornell University

The Laboratory for Elementary-Particle Physics (LEPP) at Cornell seeks a Research Support Specialist III (Vacuum Engineer) to supervise the operation and maintenance of all LEPP vacuum systems, including a large storage ring operated 24/7 for extended periods of time. The incumbent will also manage the LEPP vacuum laboratory; establish procedures to be used for the fabrication, testing, and maintenance of ultrahigh and extreme high vacuum systems; consult laboratory wide on cost effective vacuum technology to meet specific requirements; and assist in the design, construction, conduct, and interpretation of vacuum experiments in the ultrahigh and extreme high vacuum realm.

Qualifications: An MS degree in Physics or a closely allied engineering field, with a minimum of three years experience working directly with ultrahigh vacuum systems. Candidates with a BS degree and more extensive direct ultrahigh vacuum experience will be considered. Experience with codes such as AutoCAD and ANSYS for the design, thermal, and stress analysis of ultrahigh vacuum systems and components is required. The candidate must have strong written and oral communication skills. Experience managing personnel and budgets is highly desirable.

Visa sponsorship is not available for this position.

Please apply online at [www.ohr.cornell.edu/jobs](http://www.ohr.cornell.edu/jobs). For more information and a detailed job description, go to <http://www.ins.cornell.edu/public/positions.html#vaceng>

Cornell University is an equal opportunity employer.

### SCHOOL OF ENGINEERING AND DESIGN

## Research Fellows

Brunel University has an established record of excellent research achievement with '5' ratings in both General Engineering and in Applied Mathematics in the most recent UK Research Assessment Exercise.

The HEP Group is heavily involved in the preparation of the CMS detector and the MICE experiment which will measure muon ionisation cooling. These PPARC-funded posts are to support our commitments to these collaborations.

**Post 1:** This post is to contribute to the development and commissioning of software associated with monitoring the operation and data quality of the silicon tracker of the CMS detector. **Ref: DCL0228-1**

**Post 2:** This post is to contribute to the planning and implementation of software for MICE and to work on the design of the muon beam line. **Ref: DCL0224-1**

**Committed to equal opportunities and representing the diversity of the community we serve**



Applicants will have, or be about to receive, a PhD in particle physics, computer science or a closely related subject. Applicants should be experienced in Object Oriented programming using C++ or Java languages, and be familiar with large scale computing for data analysis. The salary will be within the RA1A/1B scale (£20,235 to £30,607 pa plus £1,990 pa London Weighting) for a maximum of two years. The salary and initial contract period will be dependent on qualifications and experience.

For a downloadable application form and further details please visit the Brunel web pages.

**Brunel**  
UNIVERSITY  
WEST LONDON

Alternatively e-mail to address below quoting the vacancy reference number and post title in the subject line.

Email: [recruitdea@brunel.ac.uk](mailto:recruitdea@brunel.ac.uk)

<http://www.brunel.ac.uk/about/job/>



University of California,  
Los Angeles

**UCLA**

### Assistant Professor in Accelerator and Beam Physics

The Department of Physics and Astronomy at UCLA invites applications for an opening at the Assistant Professor level in the physics of beams and accelerators. The successful candidate will add to the present vigorous, multidisciplinary program in advanced accelerators and beam-based light source physics at UCLA. A research background with strengths in core experimental areas (microwaves, plasma physics, lasers, ultra-fast diagnostic techniques) is desirable, as is expertise in computational methods. Prospective applicants should submit a curriculum vita, statement of research interests, publications list and arrange to have at least three letters of recommendation sent to **Chair, Accelerator Search Committee, Department of Physics and Astronomy, University of California, Los Angeles, CA 90095-1547** by the deadline of January 1, 2006.

The University of California is an Equal Opportunity/Affirmative Action Employer.



### Faculty Position in Experimental Particle Physics Drexel University

The Department of Physics at Drexel University invites applications for a tenure-track faculty position in Experimental Particle Physics starting in the Fall of 2006. We seek a candidate who will establish an active research program while participating in our ongoing neutrino physics program in KamLAND or Double Chooz. The successful candidate must also be committed to excellence in education at both undergraduate and graduate levels. The appointment is expected to be made at the level of Assistant Professor, but an appointment at a more senior level may be considered.

Applicants should send a Curriculum Vitae, a Plan of Research, a Statement of Teaching Philosophy, and arrange for 3 letters of reference to be sent to:

**Particle Physics Search Committee, Department of Physics, Drexel University, 3141 Chestnut St., Philadelphia PA 19104, USA**

Applications received by January 15, 2006 will receive full consideration.

For more information, see <http://www.physics.drexel.edu/hiring>

Drexel University is an Affirmative Action/Equal Opportunity Employer.

## Classified advertising

CERN Courier and [cemcourier.com](http://cemcourier.com) offer the only print and online recruitment service that has a direct route to highly skilled job seekers in high-energy physics and related areas.

"CERN Courier is one of the best media to reach and attract the cutting-edge scientific profiles we're looking for at the ESRF.

Advertising in CERN Courier adds value to our recruitment." **Cécile Davan**, Recruitment advisor, ESRF

"DESY has chosen CERN Courier to advertise in because of the popularity of the magazine – it is read all over the world. It is a great opportunity to advertise in such a prestigious publication and to reach outstanding scientists and fellows." **Christina Grimm**, Human Resources, DESY

For further information please contact **Adam Hylands** Tel: +44 (0)1179 301 027 Fax: +44 (0)1179 200 726 E-mail: [adam.hylands@iop.org](mailto:adam.hylands@iop.org)



**US Department of Energy**  
Office of Science  
Office High Energy Physics

**Director, Research and Technology Division**

Announcement Number PN-ES-SC25-625

The U.S. Department of Energy, Office of Science, Office of High Energy Physics (HEP), is seeking applicants to fill the Research and Technology Division Director position with a salary range of \$107,550 to \$162,100 per annum. HEP supports research in the study of the basic nature of matter, energy, space and time, seeking an understanding of the ultimate constituents and structure of matter and the fundamental forces of nature. This program includes the management and administration of basic physics research and the development, design, construction, operation, and maintenance of large, highly technologically advanced particle physics facilities. The Research and Technology Division is responsible for managing and administering basic research that will provide discoveries and new insight that advance our scientific knowledge of high energy physics processes and for R&D activities to advance the high energy physics facilities in areas such as instrumentation, detectors, and accelerator technology. This position manages and directs the activities of this Division. For further information on the program please go to <http://www.science.doe.gov/hep/index.shtm>.

For further information about this position and the instructions on how to apply and submit an application, please go the following website: <https://jobsonline.doe.gov/>. To be considered for this position you must apply online. This announcement closes February 16, 2006. It is imperative that you follow the instructions as stated on the announcement (PN-ES-SC25-625) located at the website indicated above for DOE JOBS.

*The Department of Energy is an Equal Opportunity Employer.*



**US Department of Energy**  
Office of Science  
Office High Energy Physics

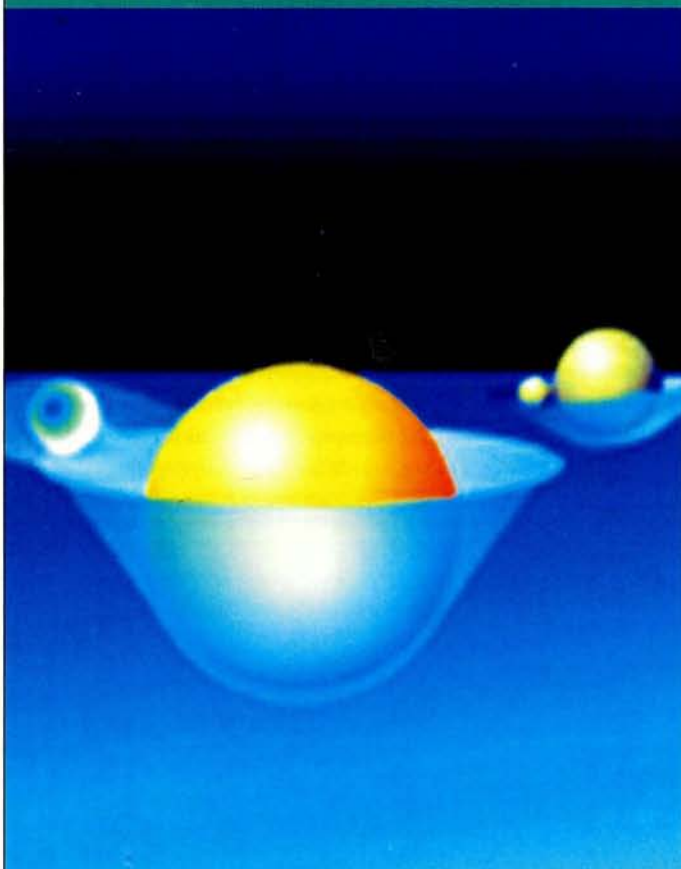
**Director, Facilities Division**

Announcement Number PN-ES-SC25-626

The U.S. Department of Energy, Office of Science, Office of High Energy Physics (HEP), is seeking applicants to fill the Facilities Division Director position with a salary range of \$107,550 to \$162,100 per annum. HEP supports research in the study of the basic nature of matter, energy, space and time, seeking an understanding of the ultimate constituents and structure of matter and the fundamental forces of nature. This program includes the development, design, construction, operation, and maintenance of large, highly technologically advanced particle physics facilities and the management and administration of basic physics research. The Facilities Division is responsible for planning, constructing, upgrading, and operating the HEP program user facilities. This position manages and directs the activities of this Division. For further information on the program please go to <http://www.science.doe.gov/hep/index.shtm>.

For further information about this position and the instructions on how to apply and submit an application, please go the following website: <https://jobsonline.doe.gov/>. To be considered for this position you must apply online. This announcement closes February 16, 2006. It is imperative that you follow the instructions as stated on the announcement (PN-ES-SC25-626) located at the website indicated above for DOE JOBS.

*The Department of Energy is an Equal Opportunity Employer.*



# Celebrate Einstein Year with Classical and Quantum Gravity



Your first choice for the latest research in gravitational physics  
[www.iop.org/journals/cqg](http://www.iop.org/journals/cqg)



Image courtesy NASA/JPL-Caltech; Albert Einstein™, www.albert-einstein.net

**Institute of Physics PUBLISHING**

# BOOKSHELF

## Warped Passages: Unravelling the Universe's Hidden Dimensions

by Lisa Randall, Allen Lane, Penguin Books. Hardback ISBN 0713996994, £25. (In the US, HarperCollins, ISBN 0060531088, \$27.95.)

They say you should never judge a book by its cover, which is advice worth considering if you're thinking of buying Lisa Randall's *Warped Passages*. The violent pink with the title scrawled graffiti-like across it (in the Penguin edition) makes the book jump off the shelf, screaming "I'm no ordinary popular-science book." Don't be put off. Randall does break the mould, but not by filling the book with graffiti. She delivers a bold journey from the origins of 20th-century science to the frontiers of today's theoretical physics. It's bold because, despite her protestations that the book is about physics and not personalities, it turns out to be a very personal journey in the company of one of the field's most cited practitioners.

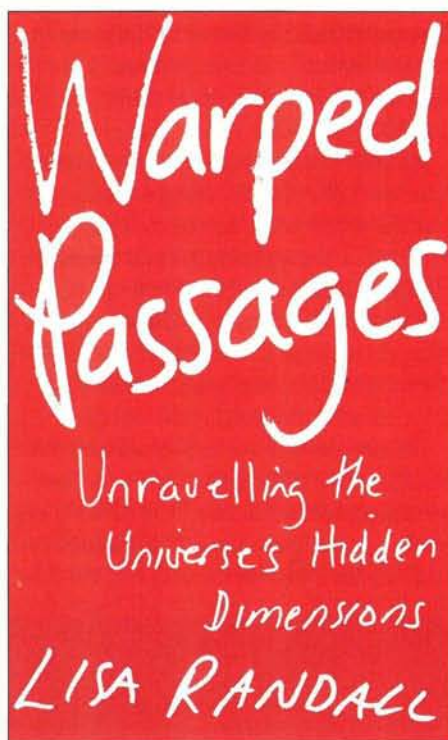
This is most true at the beginning, where Randall tells us a little about who she is and why she has devoted her life's work to the science of extra dimensions. She begins with the words: "When I was a young girl, I loved the play and intellectual games in math problems or in books like *Alice in Wonderland*." Thereafter, she affords us a glimpse of who she is through her choice of musical snippets at the beginning of each chapter, and the Alice-inspired story of Ike, Athena and Dieter, which unfolds throughout the book, one episode per chapter. The result is that the reader gets not only a competent review of a difficult subject, but also a feeling for what drives someone at the cutting edge of science.

I have to confess that I read the story of Ike, Athena and Dieter from cover to cover before embarking on the book proper, and having done so would recommend that course of action. Should physics cease to be a fruitful career, Randall could perhaps turn her hand to fiction. Coupled with the What to Remember and What's New sections at the end of each chapter, the story gives a pretty good overview of what the book is about.

The personality that emerges as the book progresses is not the kind of physicist who would be lost for words at a party if asked what she does. As well as being, according to her publisher, the world's most influential physicist thanks to the citations-index-

## Christmas Bookshelf

The World Year of Physics has seen many events take place around the globe, in particular honouring Albert Einstein and his *annus mirabilis* of 1905. This issue, *Bookshelf* looks to Einstein's legacy and to modern ideas about the physics of our universe – and others. Here, physicists who communicate to the wider public give their opinions about books aimed at non-specialist readers, which in this festive season might make suitable presents for family or friends.



topping paper she published with Raman Sundrum in 1999, Randall is also a woman with a life. She has broad interests, she is cultured and she climbs mountains in her spare time. In short, she's the sort of role model science needs.

Clearly conscious of the "no equations" school of science communication, she tries early on to put the reader at ease by promising that the descriptions will never be too complicated. Inevitably she cannot hold this promise throughout, and there are places where even the most dedicated amateur scientists will be baffled, but that is more the nature of the subject than the author. If Niels Bohr thought that quantum mechanics was

profoundly shocking, what would he have made of hidden dimensions? In places, Randall goes so far to try to make things easy that the tone verges on the patronizing, and in others, she hides difficult stuff in a "math notes" section at the end of the book. On balance, however, she has done a good job of making a difficult subject accessible.

Bohr is on record as saying to a young physicist, "We are all agreed that your theory is crazy. The question which divides us is whether it is crazy enough to have a chance of being correct." Could the same be true of extra dimensions? If you do not already have an opinion, this book will certainly help you to make up your mind. Don't let the cover, or the publisher's hype, put you off.

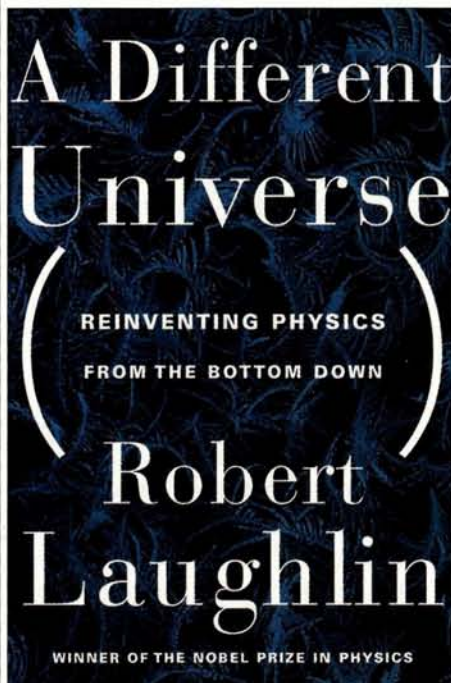
James Gillies, CERN.

## A Different Universe: Reinventing Physics

from the Bottom Down by Robert Laughlin, Basic Books. Hardback ISBN 046503828X, \$26 (£15.50).

Despite the fact that the author has a Nobel Prize in Physics, this is rather an easy book to read. While not as funny as Richard Feynman's jokes, and fortunately not as exquisitely informal (this is an understatement) as João Magueijo's *Faster than the Speed of Light*, it is quite nicely written, good humoured and even sprinkled with poetic eloquence. I actually enjoyed reading the innumerable biographical anecdotes (at least the first 50 or so), even though most seemed rather irrelevant for the purpose of the book, which could easily be half as thick without any loss in real content.

Let me do justice to the book by wandering myself. We often hear at CERN that particle physics deals with the most fundamental level, the "ultimate theory", from which everything else should, in principle even if not in practice, be derivable. But systems above certain levels of complexity exhibit "emergent" laws that cannot be derived through such a "bottom-up" approach. It is particularly interesting to note that superconductivity cannot be derived from fundamental principles, especially when we see how crucially dependent we are on superconductivity to perform our "fundamental" studies at CERN. A little modesty would not harm some particle physicists. We can't always learn how a toy works by breaking it to pieces; sometimes all we learn is that the broken



toy doesn't work any longer.

This is the central point of Laughlin's thought-provoking book: there's a different universe out there, which we can easily see if we care to look, and where certain things are more than the sum of their parts.

This is surely not a new idea. "More is different" claimed Philip Anderson 33 years ago, at a time when Jacques Monod argued that the higher levels of reality are not necessarily determined by the lower levels.

What I enjoyed most in Laughlin's "different" book were the descriptions of several eye-opening experimental observations – such as the von Klitzing and Josephson effects – which intrinsically depend on collective behaviour (the effects disappear in very small samples) but provide today's most accurate measurements of the fundamental constants  $e$  and  $h$ .

Unfortunately these fascinating issues are not really described in much detail, while too many pages, especially at the end of the book, are devoted to less relevant topics, seemingly motivated by polemic fights with "hard-boiled reductionists" who are accused of believing that nothing fundamental is left undiscovered. However, don't miss chapter 15, which is about a "cast of characters" trying to define what "emergence" means; this is particularly hilarious if you have read Arthur Koestler's *The Call-Girls* (1972).

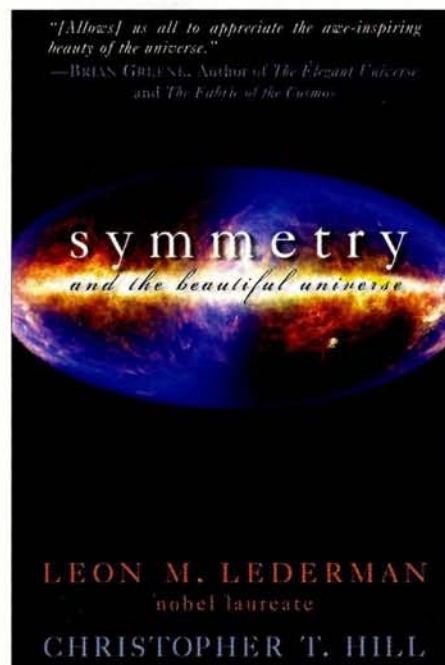
Laughlin's book is definitely worth reading,

although I was disappointed; there is a lot of talking but in the end not much physics really gets reinvented. It is a pity that Laughlin spends much of his energy fighting reductionism rather than detailing his own new ideas. And a little modesty would also not harm his arguments. Emergence and reductionism are equally important in our quest for understanding the (single) universe around us – as Freud said, on psychology and biology, "Some day the two will meet." If you are interested in these topics, read Koestler's *The Ghost in the Machine* (1967) and Stuart Kauffman's *At Home in the Universe* (1995).  
*Carlos Lourenço, CERN.*

**Symmetry and the Beautiful Universe** by Leon M Lederman and Christopher T Hill, Prometheus Books. Hardback ISBN 1591022428, \$29.

A tribute to mathematical genius Emmy Noether (1882–1935) is long overdue. Noether's theorem, which neatly linked symmetries in physical laws to constants of nature, heralded the most important conceptual breakthrough of modern physics and yet her name is rarely found in books on the subject. *Symmetry and the Beautiful Universe* attempts to right that wrong.

This popular-science book is presented as being accessible to "lay readers" and "the serious student of nature". So is it? Well, any treatise on symmetry begs for pictures but we find very few until near the end, and often we



get the proverbial thousand words instead. Also there are more mathematical equations than appear at first sight, as some are embedded in the text. So, I suspect that the going would be easier for the serious student than for lay readers.

The range of topics and styles is humongous, from cartoon character Professor Peabody with angular momentum worthy of a dervish (smoking a pipe), to Feynman diagrams for first-order quantum corrections in electron–electron scattering. The short biography of Noether is good and her theorem is well praised, although the chapter devoted to explaining it is rather long-winded.

More than once the reader is first given an esoteric example of some process or other and only later a more familiar example; momentum conservation starts with radioactive neutron decay and goes on to colliding billiard balls. Then there are "gedanken" experiments. These are familiar devices to scientists but will a lay reader believe that space is isotropic because a hypothetical experiment is said to show that it is? And sometimes the book is mystifyingly US-centric. What are EPA rules? And why is Kansas special?

However, the undeniable enthusiasm of the authors for their subject, indeed for almost any subject, shines brightly throughout. Even leaving aside the 60 or so pages of notes and appendix, the book brims over with facts, figures and fun fictions, often straying far from the subject of symmetry. I estimate that a smart cut-and-paste editor could produce three good books out of the material on offer, each at a quite different level. Find your own.

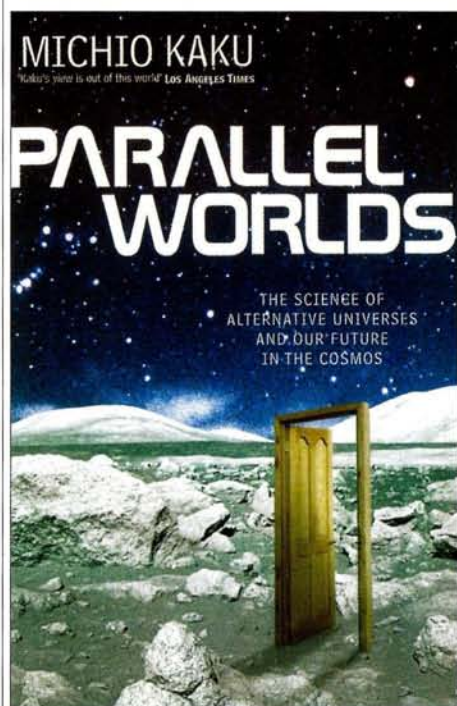
Reviewing a book that has one Nobel laureate as an author and two among the constellation of stars glowingly quoted on the dust jacket is a daunting task. I was once told that "astounding" conveys an acceptable amalgam of the polite and the honest when one is overwhelmed. This book is astounding.  
*Peggie Rimmer, CERN.*

**Parallel Worlds: The Science of Alternative Universes and our Future in the Cosmos** by Michio Kaku, Allen Lane, Penguin Books. Hardback ISBN 0713997281, £20.00. (In the US, Doubleday. Hardback ISBN 0385509863, \$27.95.)

While reading Michio Kaku's latest book, *Parallel Worlds*, I left it for a few days on the coffee table at home. At this time we had a

visitor who, although interested in science in general, is not a physicist. After browsing through the book, he started reading it and was disappointed to see it disappear one day when I went away on a trip. He has been inquiring about getting the book back ever since. Although based on limited statistics, this is an excellent recommendation for *Parallel Worlds* – you do not need to be a physicist to find the book fascinating.

But what does a (non-theoretical) particle physicist think about the book? Well, I really



enjoyed it. It is a rather complete book on cosmology for the layman, taking us from Einstein to M-theory in a language that manages to be understandable without being trivial. If you, like me, would like to know the difference between 10- and 11-dimension string theory or find it difficult to explain to your fascinated friends (or to yourself) the concept of the holographic universe, this book will give you plenty of ammunition.

Kaku discusses all of the important theories, observations and experimental results that have shaped our understanding of the universe over the past century, and mainly the past 30 years. A big portion of the book discusses string theory, which is close to Kaku's heart, in an informative and understandable way. The book is also full of Kaku's accounts of his favourite science-fiction stories (when he wants to demonstrate

a point that happens to have excited the imagination of science-fiction writers) as well as excerpts from the works of poets, other writers and Nobel laureates.

A large portion of the book, as its name suggests, revolves around the many different sorts of parallel universes that might exist and their relation (and possible interaction) with ours. The discussion eventually leads to ideas about how our distant descendants might try to escape a dying or inhospitable universe. Ironically, this was for me the least interesting part of the book, however it does devote a few pages to fascinating subjects such as the question of consciousness, the anthropic principle and religion.

Minor gripes include Kaku's insistence on not using scientific notation: a trillion electronvolts means to me much less than 1 TeV, and how long exactly is 30 billionths of an inch? Surely Kaku's intended audience would be less perplexed by  $10^{18}$  than by "a million trillion". Another point is his assertion that particle physicists have introduced "hundreds of point-like particles" to the theory. Three families of four fermions each do not make hundreds of particles.

The book also includes a useful index and a glossary, and has notes with further explanations, which unfortunately I found only after I had finished reading the book. It would have been helpful to include note numbers in the text.

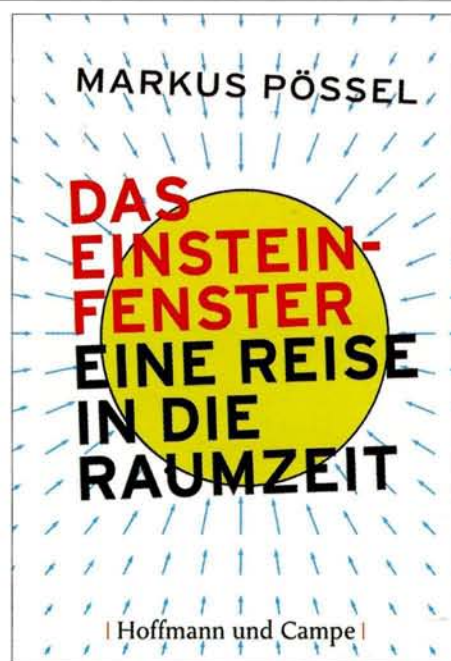
Should you go out and buy this book for Christmas? The answer is yes. *Parallel Worlds* is an excellent read. Just do not leave it on the coffee table.

Mike Koratzinos, CERN.

**Das Einstein-Fenster – Eine Reise in die Raumzeit** by Markus Pössel, Hoffmann und Campe Verlag. Hardback ISBN 3455094945, €30.

"Can only a genius understand Einstein? No..." claims author Markus Pössel on the back cover of his new book, which is aimed at the reader who is interested in modern science. Among the many books to mark the 100th anniversary of Einstein's *annus mirabilis*, this one appeals immediately because of its high-quality design and the many colourful photos and illustrations. But can it deliver on its promise?

In the first part we are led to the basic concepts of special and general relativity, following a more phenomenological approach.



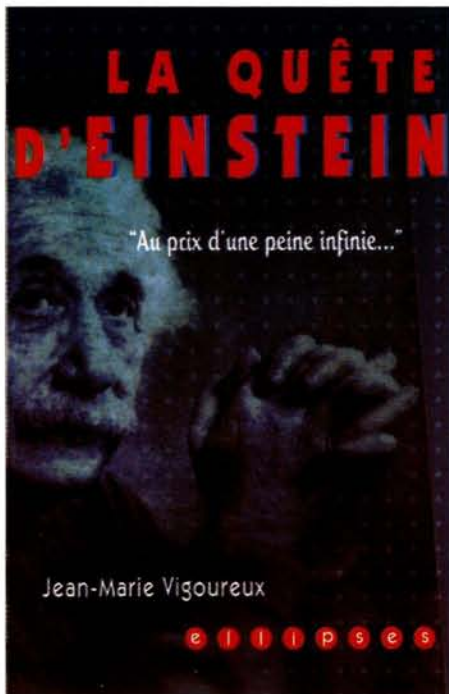
With the help of facts, many pictures and stories relating to everyday life, Pössel manages to give us a flavour of this new world of extremes. Numerical examples substitute for mathematical equations and give a notion of reality. Minkowski diagrams are introduced and used wherever possible. In the context of general relativity, emphasis is put on the correct development of the geometrical principles, which is done with great care.

The second part covers the applications of relativity: our solar system, gravitational waves, stars, black holes and cosmology. The comparatively short third part is a surprisingly detailed discussion of gravitational-wave detection, which puts the reader at the forefront of this exciting field of research.

The chosen approach to relativity is similar to that of university textbooks, where all mathematical equations are substituted by pictures and numerical examples. This disguises the essential principles and occasionally makes it a cumbersome read. It is also questionable whether the sometimes awkward embellishments to the explanations serve the purpose of clarity. Nevertheless, Pössel takes the reader on an exciting journey through space-time.

"Can only a genius understand Einstein?" With this book in hand, average readers can understand him too, provided their curiosity is strong enough to help them find the necessary patience and stamina.

Thilo Pauly, CERN.



**La quête d'Einstein: "Au prix d'une peine infinie..."** par Jean-Marie Vigoureux, Editions Ellipses. Broché ISBN 2729823557, €19.50.

Un de plus! Cette année 2005 aura vu la multiplication d'ouvrages dédiés à Albert Einstein. Certains développent prioritairement l'histoire de l'homme et de sa vie, d'autres s'intéressent à sa théorie de la relativité.

Le présent livre commence par clarifier la question de la gravitation à l'aube du 20<sup>e</sup> siècle, avec ses grands succès (pendule de Foucault, découverte de la planète de Le Verrier) et ses échecs (problème à trois corps, périhélie de Mars), ces derniers semblant indiquer le besoin d'une "nouvelle physique".

La partie de l'ouvrage la plus intéressante est l'introduction qui traite des débats philosophiques sur la notion de force agissant à distance à travers le vide, et sur les concepts d'espace et de temps avec les critiques de Ernst Mach pour qui l'espace est impensable sans la matière nécessaire pour le définir. Alors, Einstein arrive.

Le livre est très documenté, il comprend deux pages entières de bibliographie. Il ne comporte pratiquement aucune équation, même pas les transformations de Lorentz, ce qui est un bon point pour certains lecteurs. Cela limite cependant la compréhension globale, et les propriétés induites par la théorie (dilatation des temps, contraction des longueurs) sont données sans explication claire.

Le choix des conséquences abordées de

la relativité est un peu arbitraire. L'auteur ne débat pas de la fameuse équation  $E = mc^2$ , à peine citée, mais 10 pages sont consacrées aux tentatives infructueuses de Joseph Weber pour mettre en évidence les ondes gravitationnelles. Les acquis récents de la cosmologie (fond cosmologique, énergie noire) ne sont pas présentés, et aucune perspective n'est indiquée. La dernière partie relate la vie à Princeton d'un anticonformiste solitaire, berçant le rêve d'une théorie du tout.

Il existe sur le marché des biographies d'Einstein plus vivantes et des exposés plus complets de la relativité et de ses conséquences. Cet ouvrage donne l'impression d'un travail un peu impersonnel d'érudit. Ce qui peut gêner est le point de vue souvent hagiographique: on lit le récit de la vertueuse vie de Saint Albert, savant et philosophe en quête d'harmonie, et le sous-titre du livre "au prix d'une peine infinie" va jusqu'à lui conférer les palmes du martyr... ce qui peut paraître très exagéré.

Malgré tout, le livre vaut par de petits exemples bien expliqués qui aident à concrétiser la démarche d'Einstein vers l'élaboration de sa grande théorie de la relativité.

François Vannucci, Université de Paris7 and IN2P3.

**The Artful Universe Expanded** by John D Barrow, Oxford University Press. Hardback ISBN 019280569X, £20 (\$30).

One contender for the premier division of popular-science writers is cosmologist John Barrow. He now has a long list of impressive titles to his credit, notably *The Anthropic Cosmological Principle* (with Frank Tipler), which introduced a whole new slant on cosmology and has become a classic of modern science, and *The Left Hand of Creation* (with Joseph Silk), which was one of the first popular books on modern cosmology.

Some arrogant physicists condemn any science that is not quantum mechanics or relativity as being lightweight. This pompous attitude antagonizes scientists in other disciplines, and many non-scientists too. Barrow's imaginative literary work helps to demolish such preconceptions, breaking down barriers between specialist subjects and showing how far a mathematical approach can reach.

Barrow says that the popularization of

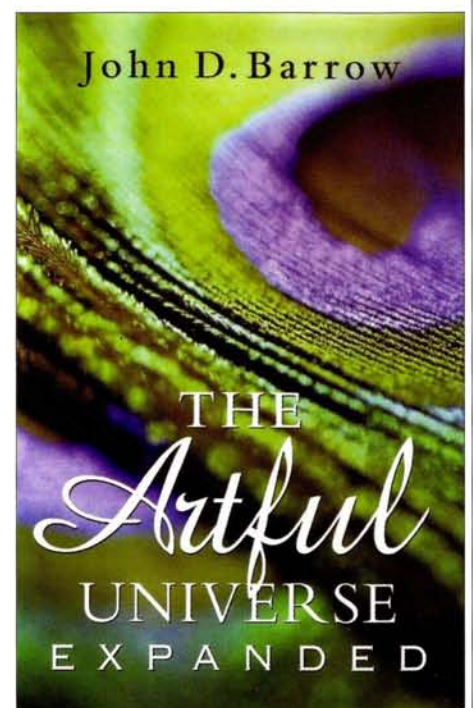
quantum physics and cosmology has been well exploited, and aspiring writers should look elsewhere for subject matter. Heeding this advice, *The Artful Universe Expanded*, an updated and enlarged edition of a book that first appeared in 1995, is a collection of largely self-contained pieces in which scientific arguments illuminate a range of topics that include art, music, evolution and tradition.

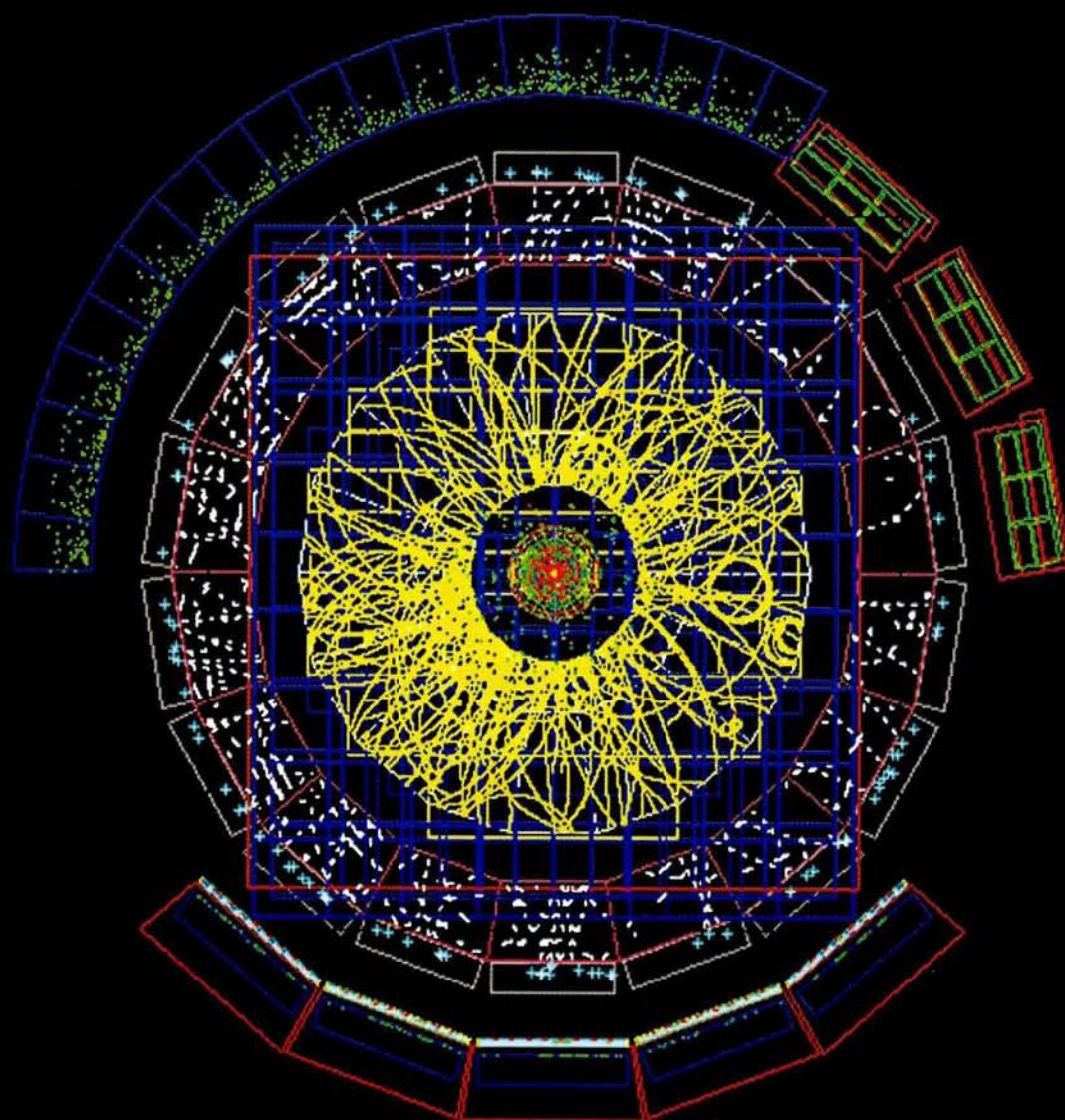
The result is a delightfully diverse package of thought-provoking and entertaining articles. Ploughing through even the best popular science demands a certain effort and motivation, but the compact articles in this book are accessible. It is a book to dip into and meet, for example, "Jack the Dripper" – the fractal-inspired Jackson Pollock.

While Barrow is particularly good at explaining the sizes of things, in a few places there is a sense of *déjà vu*. Barrow's figure 3.2 on the distribution of masses and sizes in the universe is the same as figure 5.1 in his *Between Inner Space and Outer Space*, published in 1999; and the customary illustrations of symmetry by Maurits Escher also appear in the book.

A mine of stimulating material, *The Artful Universe Expanded* anthology is a good choice for travellers or those simply looking for insight, and it is a prolific source of ideas for offbeat talks.

Gordon Fraser, Divonne-les-Bains.





# Journal of Physics G: Nuclear and Particle Physics

**FAST** publication and peer review (Referee reports in 38 days on average)

**FREE** papers online for 30 days from web publication

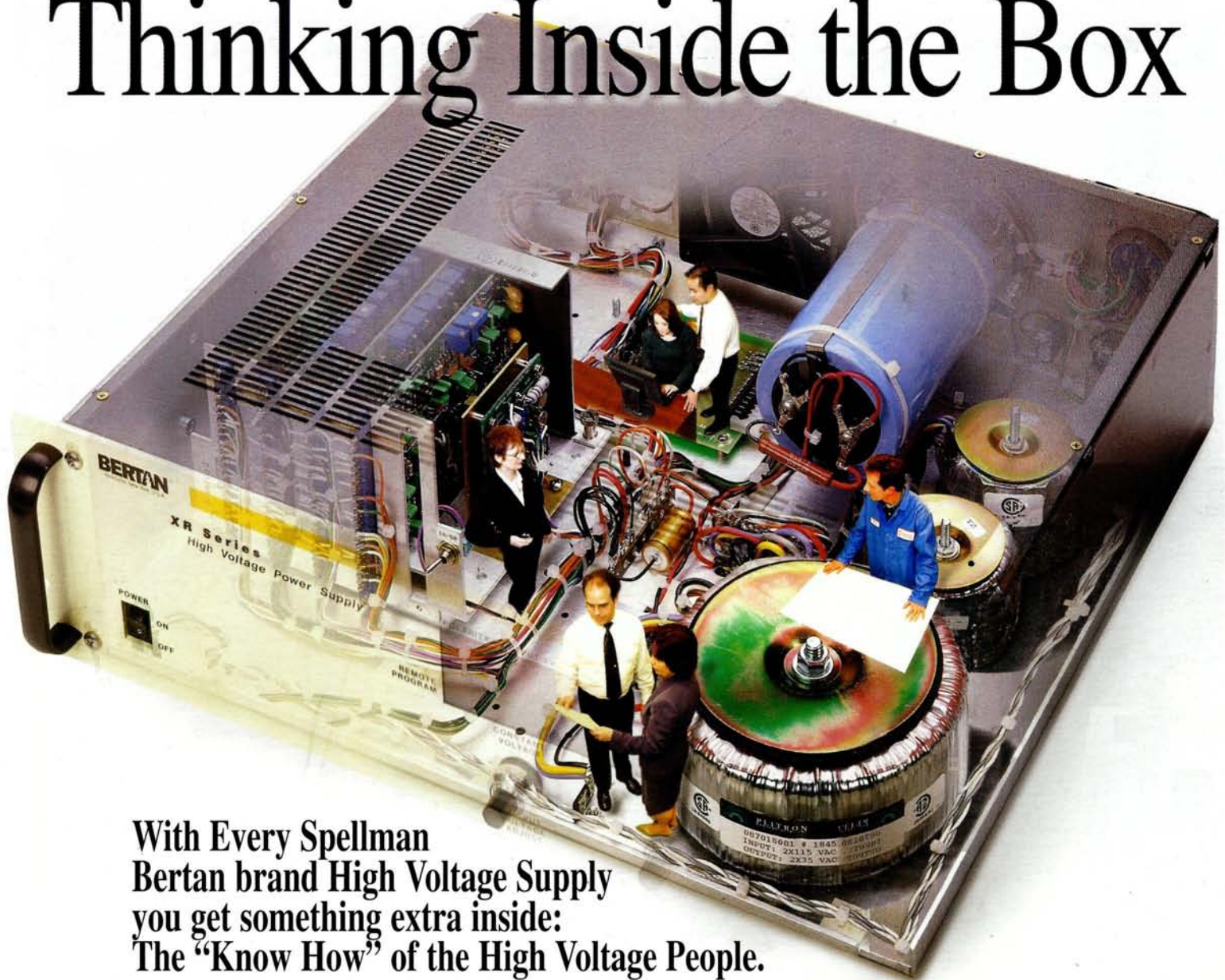
**EASY** online submission and article tracking

Publish your work in Journal of Physics G.  
Find out more about the services offered by visiting [www.iop.org/journals/jphysg](http://www.iop.org/journals/jphysg)

Image: Prototype display of a simulated event, courtesy of the ALICE collaboration.

Institute of Physics PUBLISHING

# Thinking Inside the Box



**With Every Spellman  
Bertan brand High Voltage Supply  
you get something extra inside:  
The "Know How" of the High Voltage People.**

For more than 50 years, Spellman is the innovator of the High Voltage industry. With our recent acquisition of the respected Bertan High Voltage brand, we offer the world's most comprehensive line of generators, rack instruments, modules and Monoblock X-Ray Sources®.

► **Application Know How:**

Whether your field is X-Ray Analysis, Semiconductor Processing, Security Detection, Medical Imaging, Electron Microscopy, or Mass Spectrometry, we make a high voltage supply to meet your needs.

► **Engineering Know How:**

We have the largest engineering team in the business and one of the most innovative design libraries in our industry.

► **Manufacturing Know How:**

We maintain world-class ISO9001 production facilities in the US, Europe and in Mexico.

**Voltage:** 250V to 360kV

**Power:** 1W to 120kW

**Ripple:** depending on Application  
<.001% p-p

**Package:** Rack, Module, PCB,  
Benchtop, NIM, Custom

**Interface:** Analog, RS232, USB,  
Ethernet, IEEE

**The High Voltage People of Spellman:** responsive, professional and situated globally to support you. Put their know how to work for you today. For more on the inside story of Spellman's innovative high voltage solutions, call us or visit our website [www.spellmanhv.com](http://www.spellmanhv.com)

MONOBLOCK® is a registered trademark of Spellman High Voltage Electronics Corp.

475 Wireless Blvd.  
Hauppauge, NY 11788  
tel: +1-631-630-3000  
fax: +1-631-435-1620  
e-mail: [sales@spellmanhv.com](mailto:sales@spellmanhv.com)  
[www.spellmanhv.com](http://www.spellmanhv.com)



USA

EUROPE

JAPAN

MEXICO

CHINA