

europ physics news

September/October 2002

Institutional subscription price: 91 euros per year

33/5

2002

features special

Probing theories with cosmic rays

The physics of hypernuclei

Spin qubits in solid-state structures

The value of useless studies

features



European Physical Society



New Books from Springer



P. Papon; J. Leblond; P.H.E. Meijer

The Physics of Phase Transitions

Concepts and Applications

This work deals with broad classes of phase transitions in fluids and solids. It contains chapters on evaporation, melting, solidification, magnetic transitions, critical phenomena, superconductivity, etc.. It serves as an introduction and an overview as well for graduate students in physics and engineering as for scientists. End-of-chapter problems and complete answers are included.

2002. XVII, 397 p. 175 illus. (Advanced Texts in Physics) Hardcover
€ 69,95; £ 49,-; sFr 116,50 ISBN 3-540-43236-1

R.A. Bertlmann; A. Zeilinger (Eds.)

Quantum [Un]speakables

From Bell to Quantum Information

This outstanding collection of essays in commemoration of John S. Bell is the result of the "Quantum [Un]speakables" conference organised by the University of Vienna. The book leads the reader from the foundations of quantum mechanics to quantum entanglement, quantum cryptography, and quantum information.

2002. XXII, 483 p. 145 illus., 4 in color. Hardcover
€ 79,95; £ 56,-; sFr 133,- ISBN 3-540-42756-2

L. Marchildon

Quantum Mechanics

From Basic Principles to Numerical Methods and Applications

This advanced text on quantum mechanics focuses on: the development of numerical methods for obtaining specific results; the presentation of group theory and the systematic use of operators; the introduction of the functional integral and its applications in approximation; the discussion of distant correlations and experimental measurements. Numerous exercises with hints and solutions, examples and applications, and a guide to key references help the student to work with the text.

2002. XVI, 560 pp. 50 figs. With 252 Exercises and Selected Answers. (Advanced Texts in Physics) Hardcover € 69,95; £ 49,-; sFr 116,50 ISBN 3-540-43342-2

R.G. Hunsperger

Integrated Optics

Theory and Technology

In this fifth edition all chapters have been revised and updated. The chapters on Polymer and Fiber Integrated Optics, Optical Amplifiers, Micro-Optical-Electro-Mechanical Devices, and Photonic and Microwave Wireless Systems are completely new. Problems help the students to deepen their knowledge.

5th ed. 2002. XXII, 446 p. 285 illus. Solutions Manual for Instructors on Request Directly from Springer-Verlag. (Advanced Texts in Physics) Hardcover
€ 79,95; £ 56,-; sFr 133,- ISBN 3-540-43341-4

Please order from

Springer · Customer Service

Haberstr. 7 · 69126 Heidelberg, Germany

Tel.: +49 (0) 6221 - 345 - 0 · Fax: +49 (0) 6221 - 345 - 4229

e-mail: orders@springer.de

or through your bookseller

All Euro and GBP prices are net-prices subject to local VAT, e.g. in Germany 7% VAT for books and 16% VAT for electronic products. Prices and other details are subject to change without notice. d&p · 8839/MNT/SF

F. Schwabl

Quantum Mechanics

3rd edition

From the reviews

"Any student wishing to develop mathematical skills and deepen their understanding of the technical side of quantum theory will find Schwabl's Quantum Mechanics very helpful." *Contemporary Physics*

3rd ed. 2002. XVI, 418 pp. 123 figs., 16 tabs., Numerous Worked Examples, and 127 Problems. (Advanced Texts in Physics) Hardcover
€ 49,95; £ 35,-; sFr 86,- ISBN 3-540-43109-8

W. Magnus; W. Schoenmaker

Quantum Transport in Submicron Devices

A Theoretical Introduction

The aim of this book is to resolve the problem of electron and hole transport with a coherent and consistent theory that is relevant to the understanding of transport phenomena in submicron devices.

2002. XVII, 270 pp. 40 figs. (Springer Series in Solid-State Sciences. Vol. 137) Hardcover € 69,95; £ 49,-; sFr 116,50 ISBN 3-540-43396-1

J.-L. Starck; F. Murtagh

Astronomical Image and Data Analysis

Using information and scale as central themes, this comprehensive survey explains how to handle real problems in astronomical data analysis through a modern arsenal of powerful techniques. The coverage includes chapters or appendices on: detection and filtering; image compression; multichannel, multiscale, and catalog data analytical methods; wavelets transforms, Picard iteration, and software tools.

2002. XII, 289 p. 110 illus., 27 in color. (Astronomy and Astrophysics Library) Hardcover € 59,95; £ 42,-; sFr 99,50 ISBN 3-540-42885-2

T. Cebeci

Convective Heat Transfer

2nd edition

Explores the equations that govern heat and momentum transfer in laminar and turbulent boundary-layer flows with small temperature differences and buoyant flows. Numerical solutions, a large number of homework problems and several computer programs based on differential and integral methods are included.

2nd ed. 2002. XII, 345 pp. 113 figs., 64 tabs., with CD-ROM. Hardcover
€ 99,95; £ 70,-; sFr 166,- ISBN 3-540-42881-X

TOC

For all these titles the Complete Table of Contents (PDF) is available online! Simply visit the Springer website and enter the ISBN number into the search facility. Then click on the title's catalogue entry and go to the "Table of Contents".



Springer

europsychics news is the magazine of the European physics community. It is owned by the European Physical Society and produced in cooperation with EDP-Sciences. The staff of EDP Sciences are involved in the production of the magazine and are not responsible for editorial content. Most contributors to **europsychics news** are volunteers and their work is greatly appreciated by the Editor and the Editorial Advisory Board.

EditorDavid Lee **email:** d.lee@uha.fr**Science Editor**George Morrison **email:** g.c.morrison@bham.ac.uk**Designer**Paul Stearn **email:** p.stearn@uha.fr**www.europsychicsnews.com**

© European Physical Society and EDP Sciences

Directeur de la publication

Jean-Marc Quilbé

European Physical Society**President** Martial Ducloy, *Villetaneuse***Executive Committee**

President-Elect Martin Huber, *Berne*
Secretary Christophe Rossel, *Zurich*
Treasurer Peter Reineker, *Ulm*
Vice-Treasurer Maria Allegrini, *Pisa*
Members David Brown, *Solihull*
 Gerardo Delgado Barrio, *Madrid*
 Karel Gaemers, *Leiden*
 Dalibor Krupa, *Dubna*
 Zenonas Rudzikas, *Vilnius*
 Christophe Zerefos, *Thessaloniki*

EPS Secretariat

Secretary General David Lee
 d.lee@uha.fr
EPS Conferences Patricia Helfenstein
 p.helfenstein@uha.fr
Accountant Pascaline Padovani
Address EPS, 34 rue Marc Seguin, BP 2136
 F-68060 Mulhouse Cedex, France
Phone +33 389 32 94 40
Fax +33 389 32 94 49
Web site www.eps.org

The Secretariat is open from 08.00 hours to 17.00 hours French time everyday except weekends and French public holidays

EDP Sciences

Managing Director Jean-Marc Quilbé
Address EDP Sciences, 17 avenue du Hoggar
 BP 112, PA de Courtabœuf
 F-91944 Les Ulis Cedex A, France
Phone +33 169 18 75 75
Fax +33 169 28 84 91
Web site www.edpsciences.org

**cover**

A detector station of the Auger Observatory in the Argentine Pampa.
 "Probing theories with cosmic rays" (page 162).

features

- 157 The physics of hypernuclei**
Aldo Zenoni and Paola Gianotti
- 162 Probing theories with cosmic rays**
Murat Boratav
- 166 Spin qubits in solid-state structures**
Guido Burkard and Daniel Loss
- 170 The value of useless studies**
D. Weaire

activities

- 156 EPS-12 General Meeting**
David Lee
- 179 EPS-12 General Conference 'Trends in Physics'**
M.C.E. Huber and C. Rossel
- 180 Lise Meitner Prize 2002**
Wolfram von Oertzen

REPORTS

- 174 NANO 2002: 10th Anniversary**
Andrey Bychkov
- 176 Women and science in Europe**
Teresa Rees
- 178 The Johann Bernoulli globe electrical machine**
Henk Kubbinga

NEWS AND VIEWS

- 181 Noticeboard**
- 182 Book reviews**

EPS 12th General Meeting

David Lee, EPS Secretary General

The General Meeting of the EPS was held on Wednesday 28 August 2002 during the 12th EPS Trends in Physics Conference in Budapest. The General Meeting is the supreme governing body of the EPS, and all members are represented: individuals, national societies and associates.

Martial Ducloy, President of the EPS opened the meeting stating that it is important to review the actions of the Society and to allow all members the chance to provide their ideas and debate open issues. The Society has changed enormously over the past 34 years, expanding to admit new national societies. Since the last General Meeting, the Georgian Physical Society and the Yugoslav Physical Society have joined. As well, to keep abreast of the changes in physics, new divisions and groups have been created, notably the field of Physics of Life Sciences, and another in Environmental Physics. These structural changes have made comprehensive constitutional review necessary.

The changes in the political situation in Europe led to a new Strategy Plan for Science, adopted by the Council in 2000. Its political goals are to permit the EPS to represent the entire European physics community, and to increase the visibility of physics and the EPS.

Representing the physics community means first encouraging scientific excellence. Here, the activities of the EPS Divisions and Groups are most important. They have been very successful especially through their conferences and prizes. The need to increase the visibility of physics has led to many public understanding of science initiative, particularly in co-operation with European Science Week and Physics on Stage. The EPS is working in many other areas as well to attract new students to physics.

The EPS needs to work with other European Learned Societies and International Organisations. The 2005 World Year of Physics is an example of a broad international collaboration of physics societies around the world. This initiative is aimed at increasing the public awareness of physics through a series of conferences and other activities.

The EPS is also trying to establish relations to the EU, and the ESF in order to

ensure that there is input from the physics community in European science policy.

P. Reineker, the EPS treasurer presented an overview of the accounts of the Society. The accounts reflect the 5 main fields of the Strategy Plan: Scientific Issues in Physics; Physics in Profession; Physics Education; East West Co-operation and Physics for Development; and Public Awareness. The financial situation of the Society remains satisfactory. The move from Geneva to Mulhouse has allowed more of the Society's income to be allocated to activities. The Society has built up some reserve funds, the majority of which are reserved for divisional activities. However, income has not been increased over the past 7 years, either from increased membership or increase in fees.

C. Rossel, the EPS Secretary presented the current staff in Mulhouse and Budapest. He mentioned that in Mulhouse, the staff of 6 would increase to 8 very shortly. This is necessary to handle the workload from the CLEO®/Europe—EQEC 2003 conference.

C. Rossel also thanked G. Morrison for his work on improving Europhysics News, the principal communications tool of the EPS. He urged all members, especially Divisions and Groups and National Societies to send in news on their activities and items of interest to the physics community.

The web page (eps.org) is also a good means to communicate. However, to keep people coming back, it needs to be constantly updated. The news items would also be of interest here. One of the most exciting developments on the website was provided by the EPS Technology Group Chairman, F. Bourgeois and consists of a guide to industrial property for physicists.

Finally, C. Rossel provided an overview of the plans for the construction of the new office building for the EPS on the campus of the Université d'Haute Alsace, in Mulhouse. When the EPS moved to Mulhouse, the authorities agreed to provide the EPS with office space. The French Government, together with the Regional and Municipal governments made a sum of Euro 750 000 for this purpose in 2001. The design of the building has been chosen, and construction should begin this year and end late in 2003, or early in 2004.

Editorial Advisory Board

Chairman George Morrison, Alexis Baratoff, Giorgio Benedek, Marc Besancon, Carlos Fiolhais, Bill Gelletly, Frank Israel, Thomas Jung, Karl-Heinz Meiwes-Broer, Peter Oelhafen, Jens Olaf Pepke Pedersen, Jerzy Prochorow, Jean-Marc Quilb , Christophe Rossel, Claude S benne, Wolfram von Oertzen

Advertising Manager Susan Mackie

Address 250, rue Saint-Jacques, 75005 Paris, France
Tel +33 1 55 42 80 51 **Fax** +33 1 46 33 21 06
Email mackie@edpsciences.org

Production Manager Agnes Henri

Address EDP Sciences, 17 avenue du Hoggar, BP 112, PA de Courtab euf, F-91944 Les Ulis Cedex A, France
Tel +33 1 69 18 75 75 **Fax** +33 1 69 28 84 91

Printer RotoFrance, Lognes, France

D p t l gal: septembre 2002

Schedule

Six issues will be published in 2002. The magazine is distributed in the second week of January, March, May, July, September, November. A directory issue with listings of all EPS officials is published once a year.

Subscriptions

Individual Ordinary Members of the European Physical Society receive *europhysics news* free of charge. Members of EPS National Member Societies receive *europhysics news* through their society, except members of the Institute of Physics in the United Kingdom and the German Physical Society who receive a bi-monthly bulletin. The following are subscription prices available through EDP Sciences: **Institutions** 600 French francs or 91 euros (VAT included, European Union countries); 600 French francs or 91 euros (the rest of the world). **Individuals** 380 French francs or 58 euros (VAT included, European Union countries); 380 French francs or 58 euros (the rest of the world). Contact subscribers@edpsciences.com or visit www.edpsciences.com.

ISSN 0531-7479

ISSN 1432-1092 (electronic edition)

europhysics news SEPTEMBER/OCTOBER 2002

The physics of hypernuclei

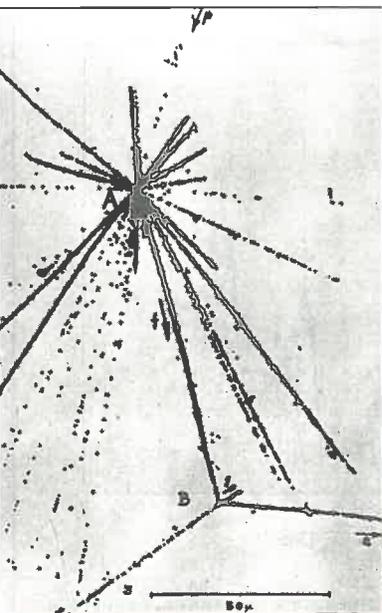
Aldo Zenoni, Università di Brescia and INFN Sezione di Pavia, Brescia, Italy

Paola Gianotti, INFN Laboratori Nazionali di Frascati, Frascati, Italy

Hypernuclear physics was born 50 years ago, in 1953, when the Polish physicists M. Danysz and J. Pniewski [1] observed, in a stack of photographic emulsions exposed to cosmic rays at around 26 km above the ground, the event shown in Figure 1. A high energy proton, colliding with a nucleus of the emulsion, breaks it in several fragments forming a star. All the nuclear fragments stop in the emulsion after a short path, but one disintegrates, revealing the presence inside the fragment, stuck among the nucleons, of an unstable particle decaying weakly, the Λ hyperon. For this reason, this particular nuclear fragment, and the others obtained afterwards in similar conditions, were called hyperfragments or hypernuclei.

The Λ hyperon is a baryon, like the nucleons (proton and neutron), with mass $1115.684 \pm 0.006 \text{ MeV}/c^2$, 20% greater than the mass of the nucleon, zero charge and isospin $I=0$. It carries a new quantum number, not contained normally inside the nuclei, the strangeness $S=-1$. The Λ hyperon is unstable and decays with lifetime $263 \pm 2 \text{ ps}$, typical of the weak interaction that doesn't conserve strangeness and makes a free Λ mainly disintegrate in a nucleon-pion system.

However, since strangeness is conserved in the strong interaction and the Λ particle is the lighter particle in the family of hyperons (baryons with strangeness), it can stay in contact with nucleons inside nuclei and form hypernuclei. The mere existence of hypernuclei is of great scientific interest; it gives indeed a new dimension to the traditional world of nuclei by revealing the existence of a new type of nuclear matter and generating new symmetries, new selection rules, etc. Hypernuclei represent the first kind of flavoured



◀ **Fig. 1:** The first hypernuclear event observed in a nuclear emulsion [1]. (A)

indicates the star of the primary interaction of the high energy cosmic ray (p) colliding with a nucleus of the emulsion; (f) is the track of the produced hyperfragment; (B) is the vertex of the decay of the hyperfragment. The other non-strange nuclear fragments stop in the matter.

nuclei (with new quantum numbers), in direction of other exotic nuclear systems (charmed nuclei and so on).

A hypernucleus is generally indicated with the symbol of the parent nucleus with the suffix Λ , indicating that a Λ particle has replaced a neutron. ${}^{\Lambda}_{12}\text{C}$ means a nuclear system composed of 6 protons, 5 neutrons and one Λ particle. Three events of double hypernuclei were observed, in which 2 nucleons are substituted by 2 Λ particles. One example is ${}^{\Lambda\Lambda}_{6}\text{He}$, a system composed of 2 protons, 2 neutrons and 2 Λ particles.

The concept of hypernuclei can be extended to nuclei where a nucleon is replaced by hyperons other than the Λ one. Experimental evidence was claimed of the existence of Σ -hypernuclei, in which a nucleon is replaced by a Σ hyperon. This is rather surprising since, in nuclear matter, the Σ can decay through a strong interaction process ($\Sigma + N \rightarrow \Lambda + N$) giving very large widths for the hypernuclear states, unless a strong suppression mechanism is at work. However, the experimental evidence of the existence of narrow Σ -hypernuclei is rather controversial and only the case of ${}^{\Sigma}_{4}\text{He}$ is considered unambiguous.

After the very first evidence of hyperfragments in cosmic ray interactions with nuclei, starting from the end of the Sixties, the installation of beams of K^- mesons at particle accelerators made it possible to study the formation of hypernuclei in the laboratory. Hypernuclei were produced copiously with little background, the required negative strangeness for Λ hyperon production being present in the beam. The typical reaction utilized was the "strangeness exchange reaction", where a neutron hit by a K^- is changed into a Λ hyperon emitting a π^- ($K^- + n \rightarrow \Lambda + \pi^-$). The experimental techniques used in these experiments were photographic emulsions and bubble chambers (filled with He or heavy liquids) exposed to K^- beams. These experiments mainly measured the hyperon binding energies, by means of the kinematical analysis of the disintegration star, and observed the principal decay modes of the hypernuclei.

Starting from the Seventies, the study of hypernuclei was continued with K^- beams by means of counter techniques with magnetic spectrometers and the introduction of new particle detectors (multiwire proportional chambers and drift chambers). The identification of well defined excited hypernuclear levels, by means of the kinematical analysis of the production reaction, was one of the most important results of a first series of experiments started at CERN and continued at Brookhaven (USA). The physical interpretation of these spectra was possible in terms of microscopic descriptions of the Λ -nucleus and Λ -nucleon potentials.

In the Eighties, a new technique for hypernucleus production was introduced at the Brookhaven laboratory, by means of intense beams of high energy π^+ . With this technique the Λ hyperon is produced inside the nucleus by an "associated production reaction" ($\pi^+ + n \rightarrow \Lambda + K^+$). This reaction has a reduced cross section, compared to the "strangeness exchange" reaction, however this drawback is over compensated by the greater intensities of the π^+ beams. The technique was fully exploited at the KEK laboratory in Japan where, for more than ten years, a great wealth of excellent hypernuclear data were produced, concerning both spectroscopy and decay of hypernuclei.

The interest in these new data has triggered the attention of the nuclear physics community and, in the last few years, different laboratories around the world have started a hypernuclear physics program: COSY at Jülich in Germany, TJNAF at Newport News in USA, Nuclotron in Dubna (Russia). In particular, it is worth mentioning the Italian hypernuclear project, the FINUDA experiment (acronym of Fisica NUcleare a DAΦne) at the Laboratori Nazion-

ali di Frascati of INFN, which is going to start collecting data next year. The experiment, which has an ambitious physics program, has some special features compared to traditional hypernuclear physics experiments. In fact, interestingly enough, it will operate at a e^+e^- collider, rather than on an extracted beam. What follows will describe it in some detail.

Structure of Λ -hypernuclei

A Λ -hypernucleus ${}^A_\Lambda Z$ is a bound state of Z protons, $(A-Z-1)$ neutrons and a Λ hyperon. The ground state of such a system is made by the $(A-1)$ nucleons accommodated in the ground state of the nucleus $(A-1)Z$ and the Λ hyperon in its lower energy state. The Λ hyperon, carrying the strangeness quantum number, is a distinguishable baryon and is not subject to the limitations imposed by the Pauli principle, therefore it can occupy all quantum states already filled up with nucleons. This feature makes the Λ hyperon, embedded in a hypernucleus, a unique means to explore nuclear structure.

The binding energy B_Λ of a Λ particle in the hypernucleus ${}^A_\Lambda Z$ in its ground state is defined as:

$$B_\Lambda = M_{core} + M_\Lambda - M_{hyp}$$

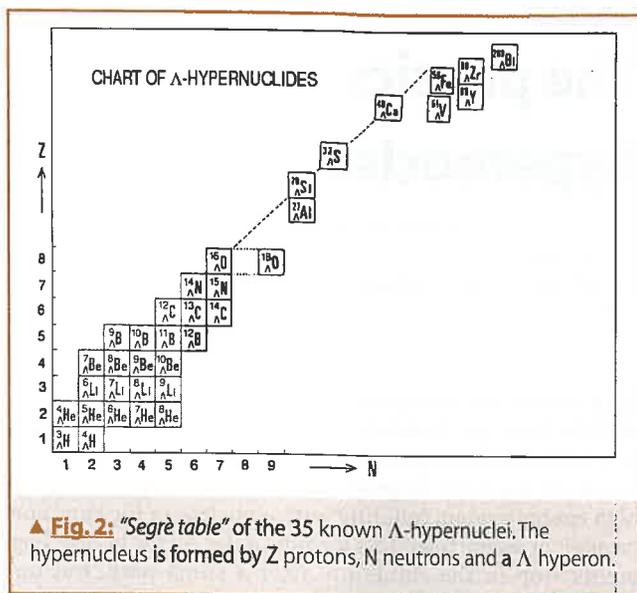
where M_{core} is the mass (in MeV/c^2) of the nucleus $(A-1)Z$, M_Λ is the mass of the Λ particle and M_{hyp} the mass of the hypernucleus ${}^A_\Lambda Z$, experimentally measured. B_Λ varies linearly with A with a slope of about $1 \text{ MeV}/(\text{unit of } A)$ and saturates at about 23 MeV for the heavy hypernuclei. This behavior suggests a simple model in which the Λ particle is confined in a potential well with a radius equal to the nuclear radius and a depth of 28 MeV , to be compared to the 55 MeV typical value of the nucleon potential well.

This is consistent with a Λ -nucleon interaction weaker than the nucleon-nucleon one. Indeed, in a meson exchange model of the interaction, the zero isospin of the Λ prevents the exchange of isovector mesons like the π or the ρ with a nucleon and determines the lack of strong tensor components in the interaction. The relative weakness of the Λ -nucleon interaction entails that the shell structure is not disrupted by the insertion of the Λ in the nucleus and the lack of Pauli effects allows all the nuclear single particle states to be populated by the Λ . In Figure 2, the so called "Segrè table" of the hypernuclei shows the 35 hypernuclei known at present.

Experiments of hypernucleus production by "strangeness exchange" and "associated production" processes can produce hypernuclei in which the Λ populates different single particle states. The latter technique is particularly suitable for populating low lying Λ states, thanks to the high recoil momentum transferred to the Λ particle in the reaction.

A beautiful representation of this process is given in Figure 3, where the excitation spectrum of ${}^{89}_\Lambda Y$, obtained by the "associated production" reaction ${}^{89}Y(\pi^+, K^+) {}^{89}_\Lambda Y$ at the KEK laboratory in Japan, is shown. The spectrum demonstrates how, starting from a neutron in the $g_{9/2}$ state, it is possible to accommodate a Λ particle in the hypernuclear states f , d , p and even in the ground state s .

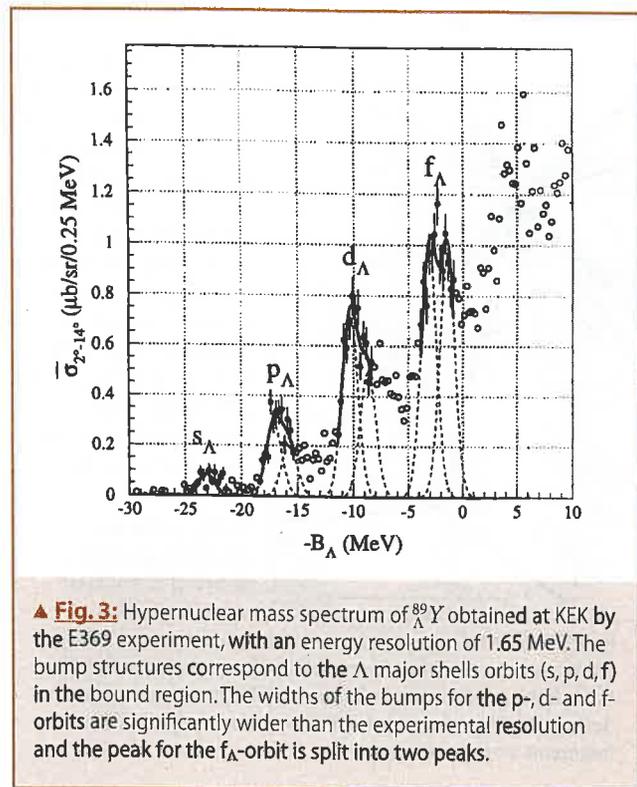
These measurements constitute the spectacular confirmation, at a textbook level, of the validity of the independent particle model or shell model of the nucleus. In non-strange nuclei, the observation of single particle states is only possible for the states of the most external nucleon orbits. In fact, due to the Pauli principle and pairing interactions, deeply bound nucleon single particle states are so fragmented as to be essentially unobservable. The present experimental data on hypernuclear binding energies and detailed spectroscopic features are limited in quantity and



quality, due to the limited beam intensities available for hypernuclear studies from the existing facilities and the modest energy resolution of the present experiments. Nevertheless, the gross features of the data are reasonably well reproduced by effective one-body hyperon-nucleus interactions constructed on potential models of the hyperon-nucleon YN interaction.

The starting point of these models is a good NN interaction generated by the exchange of nonets of mesons, with $SU(3)_f$ constraint for the coupling constants. Their predictions are fitted simultaneously to the abundant NN data and the very scarce YN free scattering data. However, until now, it has not been possible to obtain a reliable and unambiguous YN interaction model.

The improvement of the YN interaction models would need precise data on the free YN interaction, which are very difficult to



obtain, due to low hyperon beam intensities and short lifetimes of the hyperons. In particular, production and scattering in the same target are almost automatically required. At present, the experimental data on ΛN and ΣN scattering consist of not more than 850 scattering events, in the momentum region from 200 to 1500 MeV/c. The low energy data, in particular, fail to adequately define even the relative sizes of the dominant s-wave spin-triplet and spin-singlet scattering lengths and effective ranges.

This is the reason why a systematic and detailed spectroscopic study of hypernuclei with high resolution experiments, with single and even multiple strangeness contents, would offer the possibility of increasing the experimental information on YN interaction and, for the first time, allow both the study the dynamics of systems carrying $SU(3)_f$ flavour symmetry, in the non-perturbative QCD sector, and the generalization of the baryon-baryon interaction to the full $SU(3)_f$ family, including hyperons [2].

The spin dependent parts of the YN interaction are of major interest, since they are intimately related to the modelling of the short-range part of the interaction. In particular, for the ΛN interaction, the spin-orbit interaction was found to be smaller than that for the nucleon, which amounts to 3-5 MeV. In fact, experiments based on the hypernucleus formation kinematics, with the best energy resolution on the nuclear levels achieved until now of 1.5 MeV, were not able to measure any spin-orbit splitting.

Calculations of the spin-orbit component of the ΛN interaction using meson exchange theories, lead to predictions of the spin orbit splitting, for the $5/2^+ - 3/2^+$ doublet in ${}^9_\Lambda\text{Be}$, of 80-160 keV, depending on the interaction used [3]. On the other hand, when a quark model based spin-orbit force is used, which naturally accounts for the short range part of the interaction, much smaller values of 30-40 keV are obtained. The two types of models, in fact, predict different features for the antisymmetric part of the spin-orbit force. However, it needs to be said that quark models have yet to provide an extensive and satisfactory description of the YN interaction.

Figure 4 reports a recent measurement of the splitting of the $5/2^+ - 3/2^+$ doublet in ${}^9_\Lambda\text{Be}$ by the BNL-AGS E930 experiment [4], measuring γ rays emitted in the nuclear transitions with the new germanium detector array Hyperball. This new technique allowed the energy resolution on low lying hypernuclear levels to be improved from a few MeV to a few keV, even if the count rate resulting is still quite low, ~ 200 γ 's per month of data taking. The spacing of the two levels was measured to be 31 ± 2 keV, incompatible with the prediction of the meson exchange models.

At KEK the spin orbit splitting of the $3/2^- - 1/2^-$ doublet in ${}^{13}_\Lambda\text{C}$ was measured, though with a coarse resolution on γ rays [5], and a doublet spacing of $152 \pm 54(\text{stat}) \pm 36(\text{syst})$ keV was determined. The splitting predicted for this transition by meson exchange models is 390-780 keV, depending on the interaction used, and 150-200 keV by quark based models [3].

Nevertheless, other recent spectroscopic data seem to suggest a larger spin-orbit level splitting on heavy hypernuclei, especially at large values of the Λ angular momentum. The spectrum reported in Figure 3 for ${}^{89}_\Lambda\text{Y}$ is an example; it shows a splitting of the f_{Λ} level and the width of the other levels broader than the instrumental energy resolution.

The meson exchange models constitute the best description available, at present, for the strong interaction at low energy. The question whether they should be modified with the inclusion of explicit quark effects remains open.

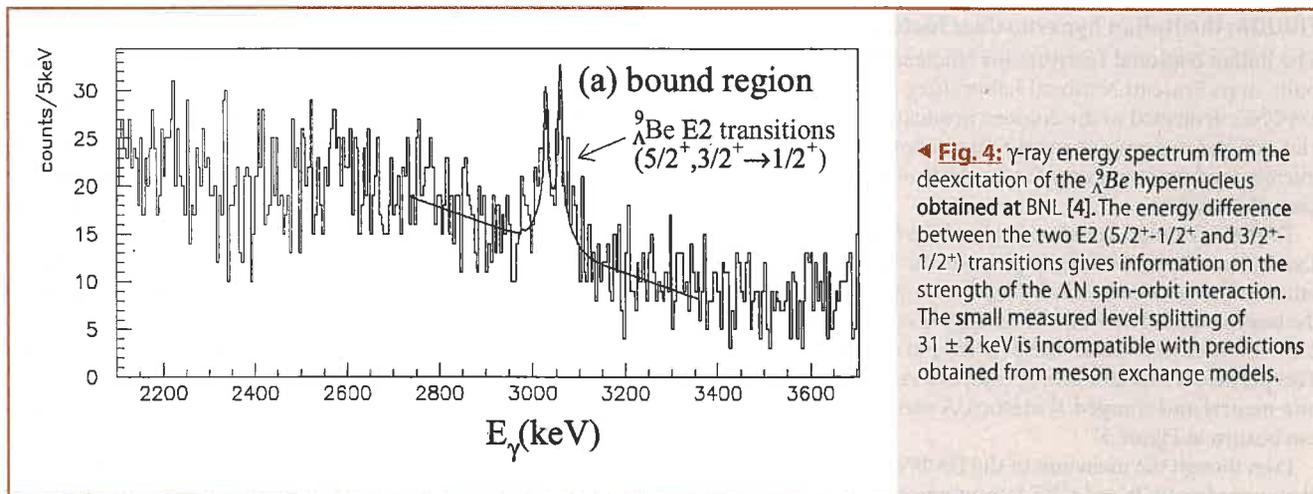
Decay of Λ -hypernuclei

In addition to information on nuclear structure and the YN interaction, hypernuclei may give access to experimental information not otherwise accessible by their decays, in particular the non-mesonic decay. Let us recall that a free Λ hyperon decays almost totally into a pion and a nucleon ($\Lambda \rightarrow p\pi^- (\approx 64\%), \Lambda \rightarrow n\pi^0 (36\%)$), with a release of kinetic energy of about 5 MeV to the nucleon, corresponding to a final momentum of about 100 MeV/c. The decay may occur, in principle, with isospin change $\Delta I = 1/2$ or $\Delta I = 3/2$. However, the experimental decay branching ratios of the Λ and other hyperons imply a dominance by a factor 20 of the $\Delta I = 1/2$ component over the $\Delta I = 3/2$ one. The origin of this empirical rule is essentially not understood in a fundamental way.

The situation described above changes dramatically when the Λ is imbedded in the nuclear medium, since the nucleon of the mesonic decay is emitted with a momentum much less than the nucleon Fermi momentum $k_f \approx 280$ MeV/c. Thus, the pionic decay modes are severely inhibited by Pauli blocking of the final state nucleon in all but the lightest hypernuclei and new, non-mesonic decay modes of the hypernucleus are introduced, through the weak interaction of the Λ with the nucleons ($\Lambda + n \rightarrow n + n + 176$ MeV, $\Lambda + p \rightarrow n + p + 176$ MeV). This process is possible only in hypernuclei, thanks to the unique beam of Λ 's, stable against the mesonic decay and strong interaction, which is available inside a hypernucleus.

The study of the non-mesonic weak decay is of fundamental importance, since it provides primary means of exploring the four fermion, strangeness changing, baryon-baryon weak inter-

features



◀ Fig. 4: γ -ray energy spectrum from the deexcitation of the ${}^9_\Lambda\text{Be}$ hypernucleus obtained at BNL [4]. The energy difference between the two E2 ($5/2^+ - 1/2^+$ and $3/2^+ - 1/2^+$) transitions gives information on the strength of the ΛN spin-orbit interaction. The small measured level splitting of 31 ± 2 keV is incompatible with predictions obtained from meson exchange models.

action $\Lambda N \rightarrow NN$. The non-mesonic process resembles the weak $\Delta S = 0$ nucleon-nucleon interaction, which has been studied experimentally in parity-violating NN scattering measurements. However, the $\Lambda N \rightarrow NN$ two body interaction mode offers more information, since it can explore both the parity-conserving and the parity-violating sectors of the $\Delta S = 1$ weak baryon-baryon interaction. In the weak NN system the strong force masks the signal of the weak parity-conserving part of the interaction.

In addition, the large momentum transfer in non-mesonic decay processes implies that they probe short distances and might, therefore, expose the role of explicit quark/gluon substructure of the baryons. Furthermore, the fundamental question as to whether the $\Delta I = 1/2$ rule, which governs pionic decay, applies to the non-mesonic weak decays may also be addressed.

One of the most important experimental observables of the non-mesonic decay of hypernuclei is the ratio of the neutron-induced ($\Lambda n \rightarrow nn$) over the proton-induced ($\Lambda p \rightarrow np$) decay rate Γ_{nm}/Γ_{np} , which is sensitive to the isospin structure of the interaction. In particular, it should be sensitive to the question of the validity of the $\Delta I = 1/2$ rule.

Notwithstanding the considerable physical interest, experimental data are scarce and affected by very large errors. This is mainly due to the tremendous difficulty in producing abundantly Λ hypernuclei in their ground state and detecting the products of their decay, in particular neutrons.

However, the comparison between the predictions of the theory and the scarce data available is particularly puzzling. In fact, whereas experimental data favour values of the ratio $\Gamma_{nm}/\Gamma_{np} = 1 - 2$ (although with errors of the order of 50%), the meson exchange models, involving one strong interaction vertex and a weak one, systematically underestimate the value of the experimental ratio [6]. In this type of models the $\Delta I = 1/2$ rule is generally enforced in the weak vertex.

Among the mechanisms explored to remedy the puzzle, direct quark model approaches have been adopted, in which the short range region is modelled by effective four quark vertices plus strong interaction corrections. These models are motivated by the large momentum transfer of the $\Lambda N \rightarrow NN$ reaction. The results of these calculations, which yield a large violation of the $\Delta I = 1/2$ rule, provide, on the contrary, significant larger values for the ratio Γ_{nm}/Γ_{np} . Could this be interpreted as a sign of explicit quark effects in nuclei or a consequence of a strong violation of the $\Delta I = 1/2$ rule? To answer these fundamental questions, a drastic improvement of the quality of the experimental data is certainly needed.

FINUDA: the Italian hypernuclear factory

The Italian National Institute for Nuclear Physics (INFN) has built, in its Frascati National Laboratory, a special accelerator, DAΦNE, dedicated to the copious production of $\phi(1020)$ particles, for the purpose of producing beams of extremely high intensity and precise energy for the study of the most rare subnuclear phenomena.

DAΦNE (Double Annular ring For Nice Experiments) [7] consists of two almost circular pipes, one for the electrons and the other for the positrons, that overlap in two straight sections where the beams collide head-on. The energy of each beam is set to 510 MeV in order to produce the $\phi(1020)$ particle in the collisions. This particle is unstable and decays, in a very short time, mostly into neutral and charged K mesons. A view of the DAΦNE hall can be seen in Figure 5.

Even though the main aim of the DAΦNE machine is the precision study of CP and CPT symmetries in the neutral kaon



▲ **Fig. 5:** A fish eye view of the DAΦNE hall at LNF (Frascati National Laboratory). The DAΦNE accelerator has a circumference of about 190 m and two interaction regions: IP1, on the right side of the picture, is presently occupied by the KLOE experiment devoted to CP violation studies; IP2, on the left, is the FINUDA interaction region. The FINUDA detector, the assembly with dark pink octagonal end-caps, will be moved onto the beam line next autumn.

system, K^- mesons can be used, as it has been seen before, to insert “strangeness” inside the nuclei and produce hypernuclei. FINUDA [8] is the experiment that, next year, will make the most of this facility and will try to shed new and brighter light on the world of hypernuclear physics.

Presently, DAΦNE is delivering something like 150 ϕ /s, half of which decay into a pair of opposite charged kaons with very low momentum, only 127 MeV/c. This low and almost monochromatic momentum value is a great advantage for hypernuclear studies, when comparing the main features of the different production techniques.

When K^- or π^+ beams are used for “strangeness exchange” or “associate production” reactions, thick targets of the order of some g/cm² must be employed to obtain sufficient event rates. Hence, the uncertainty regarding the point of interaction and the energy straggling of the emitted particles limit the resolution achievable on the hypernuclear levels. The same problem occurs in experiments using K^- at rest at proton machines. Here, intense fluxes of kaons are emitted from an external production target, but the distance between the kaon source and the experimental area must be of some tens of meters, due to radiation safety requirement. Therefore, kaons with momentum lower than 400-450 MeV/c cannot survive such a path in a number suitable to give a beam.

Consequently, experiments with stopped K^- must be performed using beams of 500-600 MeV/c, degraded in momentum with a moderator placed just before the production target. This introduces a great uncertainty on the interaction point that can negate any excellent capability of measuring the momenta of the emitted particles. On the contrary, the low momentum of DAΦNE kaons, allowing them to be stopped simply in 0.1 g/cm² of carbon, permits the accuracy achievable on the energy levels of the produced hypernuclei to be improved up to 750 keV. In addition, the large acceptance of the apparatus, typical of a collider experiment, allows for high acquisition rates of the order of 80 event/hour, for a typical hypernuclear level, at the design luminosity of the machine.

The FINUDA apparatus (Figure 6) is not only optimised to perform high resolution hypernuclear spectroscopy, but also to



▲ **Fig. 6:** A group of FINUDA collaborators is proudly depicted in front of the experimental apparatus. The leftmost lady squatting down is one of the authors.

The magnetic field of 1.10 Tesla, produced by a superconducting solenoid, is essential to bend charged particles allowing for a precise evaluation of their momentum. Each element of the FINUDA detector is a small masterpiece of mechanics and electronics. Since particles involved are of low energy, in order to perturb their properties as little as possible, only light materials have been employed in the construction. For the same reason the whole detector atmosphere is filled with Helium gas. In fact, if air is left in the detector, the momentum resolution $\Delta p / p$ would be worsened from 0.3% to 1.5%.

For more than 5 years, the design, assembling and installation of the FINUDA detector has involved some 50 physicists, mainly Italians, together with dozens of highly professional engineers and technicians. After such a long training period, all is now ready for the power-up.

References

- [1] M. Danysz and J. Pniewski, *J. Phil. Mag.* **44** (1953), 348
- [2] B.F. Gibson and E.V. Hungerford III, *Phys. Rep.* **257** (1995) 349
- [3] E. Hiyama et al., *Phys. Rev. Lett.* **85** (2000) 270
- [4] H. Akikawa et al., *Nucl. Phys.* **A691** (2001) 134
- [5] S. Ajimura et al., *Phys. Rev. Lett.* **86** (2001) 4255
- [6] W.M. Alberico and G. Gabarino, *Lanl nucl-th/0112036*, 2001 (To be published on *Phys. Rep.* 2002)
- [7] M. Preger for the DAFNE Team: "Status of DAFNE", presented at HEACC2001 - 18th International Conference on High Energy Accelerators, 26-30 March 2001, Tsukuba, Japan.
- [8] P. Gianotti, *Nucl. Phys.* **A691** (2001) 483c

study the hypernuclear decay processes. Charged particles, emitted following hypernucleus production or decay, are tracked into the FINUDA cylindrical magnetic volume (1 m radius, 2 m length) by means of four different sub-detectors, each one optimized for a different task: silicon microstrips detect with high accuracy the hypernucleus formation point; drift chambers and straw tubes reconstruct charged particle trajectories; plastic scintillators, detectors with nanosecond time response, are used to select hypernuclear events among other kaon-nucleus interactions and to detect neutrons produced by the hypernuclear decay.

Do you need access to world-class research facilities?



This EU Fifth Framework Programme offers European researchers fully-funded access to NMRC's state-of-the-art research infrastructure

The EU-funded 'Enhancing Access to Research Infrastructure' programme provides researchers throughout the European Union member and associated states access to NMRC's state-of-the-art facilities, equipment and expertise in areas

such as photonics, nanotechnology, microtechnologies and ICT/Bio. The programme pays researchers for the full cost of access and laboratory use (including training and technical support) and the full cost of travel to NMRC including subsistence.

About NMRC

NMRC was established in 1981 and is today one of Europe's premier information and communication technologies (ICT) research institutes. NMRC has a critical mass of over 200 researchers and a research infrastructure that is valued in excess of €100 million.

How to Apply

For more information about the programme and facilities available, contact Paul Roseingrave at paul.roseingrave@nmrc.ie or +353 21.490.4268.



www.nmrc.ie/access/

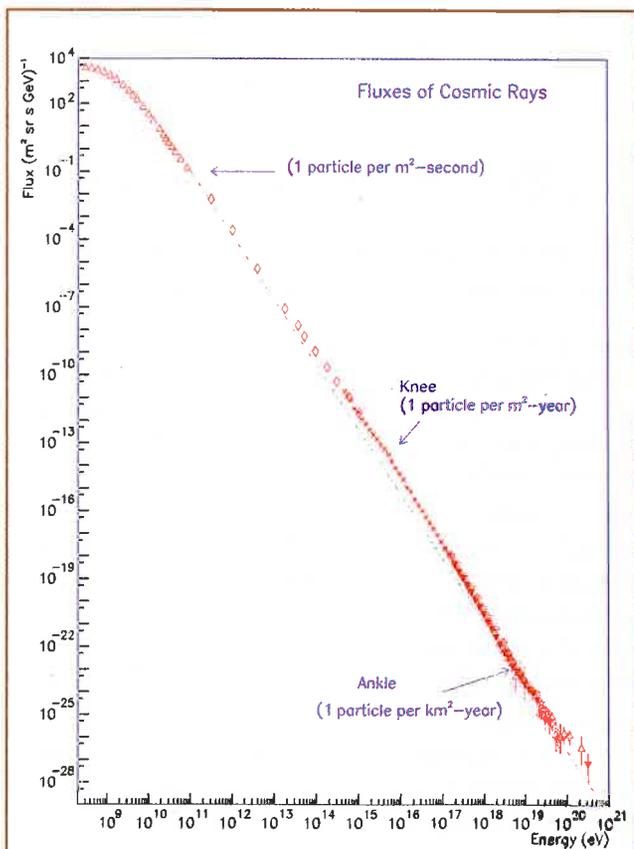


Probing theories with cosmic rays

Murat Boratav, LPNHE/IN2P3 – Université Paris 6, France

Although most people are not aware of it, our body (or any surface on earth) is crossed by hundreds of particles of cosmological origin every second. These “cosmic rays”, discovered almost a century ago (in particular by Victor Hess), are one of the very few means available to an earth based observer to study astrophysical or cosmological phenomena. The knowledge of their incoming direction, their nature and their energy spectrum are the bits and pieces of a complex puzzle which, put together, can give us strong information on the mechanism that produced them at the origin, unfortunately distorted by many effects they can undergo during their journey over large distances. Needless to say that this discipline called “particle astrophysics” or “astroparticle physics” is delicate, difficult and very often controversial.

The cosmic ray energy spectrum (see Fig.1) extends from 1 GeV to somewhat above 10^{20} eV (or 100 EeV, the prefix “E” being for exa, i.e. 10^{18}). Over this energy range the intensity (rate of arrival on earth per unit surface, solid angle and time) decreases



▲ **Fig. 1:** The all-particle spectrum of cosmic rays (from S. Swordy). The arrows and values between parentheses indicate the integrated flux above the corresponding energies.

by 24 orders of magnitude. It is important to note that at the extremity of the spectrum, the flux becomes very low: one particle/km²-year above 10 EeV. The energy spectrum is remarkably regular: a simple power law (roughly a E^{-3} dependence). This is actually quite well understood in the framework of the conventional acceleration mechanisms for charged particles. However, although they are barely visible on this figure, there exist at least three irregularities in this otherwise simple form of the spectrum. One around 10 PeV called “the knee”, another around a few EeV called “the ankle”, and a final one—not visible on this figure but probably the most mysterious of them all—around a few tens of EeV and inevitably called “the toe”. The two first structures are not totally understood, but reasonable hypotheses exist as to what is their cause [1]. The last one which appears at the extreme end of the spectrum (see Fig.2) is not understood at all, and it is widely agreed that the answers brought to the many open questions raised by this “toe physics” will no doubt open new windows in the fields of astrophysics, cosmology and/or fundamental interactions [2].

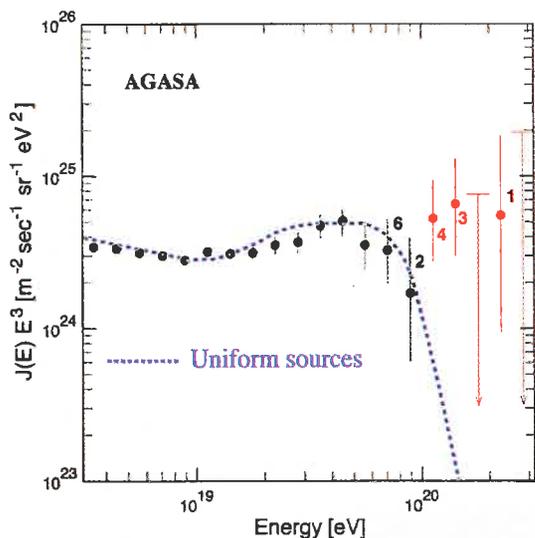
Mysteries are the staple diet of scientific progress. In the field of particle astrophysics, the ultra-high energy cosmic rays (UHECR: in this article, we'll use this acronym for the cosmic rays with energies around and above 10^{20} eV) have certainly played this role during the past 40 years or so. What makes the UHECR special is that we do not know what is their origin and nature. Many people working in the field use words such as “puzzle”, “mystery” or “enigma” as to their origin. It is symptomatic of the unknown nature of the UHECR and of their origin that some authors coined neologisms such as *uhecrons* or the *toenail clipplings of the universe* (natural continuation of the “knee”, “ankle” and “toe” features of the spectrum) for the particles themselves or *Zevatrons* for the mechanisms at their origin (the ZeV is for “zetta electron-volt” i.e. 10^{21} eV).

There are a few observational facts to prove that the UHECR are indeed a mystery as of today. The fact that their sources (whatever they are) are expected to be in our close neighbourhood and yet we do not see them; that their energy is so huge that no conventional astrophysical acceleration mechanism seems capable of producing them; that during more than four decades of observation we did not succeed in giving them an identity (what kind of particles they are?). Let us shortly develop these three essential points. The interested reader can complete his information through more complete recent reviews [3].

The propagation puzzle: the GZK cutoff

The chemical composition of the UHECR is unknown. However, the number of stable particles which can propagate over cosmological distances without losing most of their energy is quite limited in numbers: heavy or light atomic nuclei, photons and neutrinos. Photons and neutrinos (neutral particles) cannot be accelerated by any conventional (electromagnetic) mechanism: they can only be produced as secondary products in the interaction of a still higher energy charged particle. We'll see below that if photons and neutrinos were to be found as dominant components of the UHECR, then we would be on the eve of one of the most important discoveries of the century. Therefore, in the framework of conventional astrophysics, we are left with atomic (light or heavy) nuclei as the most likely candidate UHECR. A

Mysteries are the staple diet of scientific progress



▲ Fig. 2: A zoom on the highest energy range of the cosmic ray spectrum (from the AGASA experiment). For better visibility, the spectrum is made flat by multiplying it by E^3 . The dotted line shows the expected cutoff if the cosmic ray sources were uniformly distributed in the universe. The few events above the cutoff have no explanation as to their origin in the framework of conventional astrophysics.

very interesting fact is that all such particles must undergo a surprising, although well established, phenomenon called the GZK spectral cutoff.

Shortly after the discovery of the 2.7K cosmic microwave background (CMB, the cooled down remnant of the Big-Bang radiation) by Penzias and Wilson in the sixties, Greisen and independently Zatsepin and Kuzmin predicted that at very high energies, the universe would become opaque to light or heavy nuclei. There is nothing mysterious in this: the cutoff can be observed in a laboratory experiment quite easily. When you send a photon of a few hundreds of MeV on a target proton at rest, you reach the threshold of inelastic photoproduction of pions. Now, as far as the center-of-mass energy budget is concerned (which is the only significant one) this occurs identically with the CMB photons, whose average energy is about 10^{-3} eV, in a collision with a proton of about 50 EeV. Since in each such inelastic collision, protons leave a large part of their energy (of the order of 20% on average), their energy goes below 10 EeV after a few tens of Mpc¹, whatever it was at the source. As an example, if the largest energy cosmic ray ever detected (320 EeV, i.e. more than 50 joules!) were a proton produced with an initial energy of 10 ZeV, the distance of its source should be less than 50 Mpc. One can generalize the GZK effect to heavy nuclei which lose their nucleons by spallation on the CMB photons at a quick rate. To be short, unless the UHECR are some yet unknown species of particles, they cannot come from distances larger than a few tens of Mpc. Although such distances may look enormous to pedestrians (50 Mpc are roughly 150 millions of light-years!), at cosmological scales they are more or less the size of the local super-cluster of galaxies, i.e. the suburbs of the Milky Way. This cutoff effect is visible on Fig.2 where the dotted line shows the way the energy spectrum is expected to end.

One could then say: “Well if the UHECR cannot come from large distances, then their source has to be nearby. So, where is

the puzzle?” To fully understand the reason why the UHECR physics is a thrilling one, you have to take into account two more facts. The first is that the astrophysicists have the greatest difficulties in modelling cosmic accelerators able to reach the post-GZK energies. The rare models that were proposed in the past all end up in some exceptional acceleration engines. It is impossible to imagine that such remarkable engines, if in our neighbourhood, will not be visible by some exo-energetic counterparts (visible spectrum, radio waves, X-rays...). The second fact is that in the relevant energy range a proton has such a momentum that the effect of galactic or extra-galactic magnetic fields on bending its path is almost negligible: the incident direction of the UHECR should point back to its source within a few degrees. Here is the puzzle: the sources should be nearby; they are expected to be exceptional, therefore visible by some astrophysical counterpart; there is nothing visible (within a few tens of Mpc) in the direction of all the UHECR detected up to now.

Many ways were explored in order to “violate the GZK cutoff”: supersymmetric (new) particles; non-standard neutrinos within the framework of recent developments based on extra-dimensions and exchange of spin-2 bosons or gravitons; violation of the Lorentz invariance of Special Relativity and so on. Of course, if true, each of these hypotheses would be a window open on a new unexplored sector of physics. However, all such models solve the problem of the propagation of the UHECR, but would explain nothing on how these have reached the extraordinary energies that we detect.

The energy puzzle: reaching the joules from below

To be accelerated at high energies, let us say 10^{21} eV (just above the highest energy cosmic ray ever detected on earth), i.e. at least several tens of joules, a cosmic ray has to be submitted to powerful electromagnetic fields. Such energies cannot be reached by any one-shot mechanism since there are no known sites where zetta-volt potentials exist under stable conditions. Therefore, the acceleration mechanisms are of the same nature as the ones envisaged by the physicist Enrico Fermi in the late forties. The simplest is the stochastic and repetitive scattering by magnetic fields (second-order Fermi acceleration) where plasma clouds

A particle... can be scattered back, much like a tennis ball hit by a racket, with an energy larger than its initial value.

roughly play the role of a magnetic mirror. A particle penetrating such a cloud from the front can be scattered back, much like a tennis ball hit by a racket, with an energy larger than its initial value. However, such a process is a very slow one and to reach the energies we are interested in under normal conditions, the necessary acceleration time often exceeds the age of the universe. A more efficient and faster process is acceleration by crossing shock fronts generated in explosive phenomena (first-order Fermi mechanism)

such as supernovae. However, a very simple dimensional argument shows the kind of difficulties encountered even by the most violent phenomena in the universe. We all know how a high energy accelerator works. Typically a synchrotron is a closed loop where accelerating cavities (electric fields) alternate with bending magnets. In cosmic accelerators the accelerating cavities are

features

replaced by magnetic fields which vary in time therefore generating electromotive forces. However such an accelerator has to reach a natural limit in its accelerating power due to the fact that the more energetic are the particles, the larger are their Larmor radius and/or the highest are the magnetic fields necessary to confine them within the limits of the acceleration site. If the Larmor radius of the particle exceeds the size of the "accelerator" then the particle escapes from the site: it has reached its maximum energy. There is a very simple relation between those three quantities: the coherent magnetic field B needed to contain the cosmic ray within the accelerating site, the size of the accelerator R (which must be larger than the Larmor radius of the particle) and the maximum energy E_{\max} that a particle can reach inside this given site: $E_{\max} = ZBR$ where Ze is the charge of the particle, E is measured in EeV units, B in microgauss and R in kiloparsecs. Setting aside all technicalities, let us summarize the general consensus by saying that the product BR large enough to suit the ZeV energy range exists in no known standard astrophysical object.

Of course the imagination of the theorists knows no limit, therefore many models with extreme parameters or assumptions were proposed in the past. They mostly rely on (ultra)relativistic shock acceleration such as in hot spots of powerful radio-galaxies and gamma-ray bursts (GRB). In the first case, relativistic jets are produced perpendicular to the accretion disk around a super-massive black hole in the central part of an active galactic nucleus. The shock of the jets several hundreds of kpc from the central engine on intergalactic media is considered as being able to accelerate particles up to the highest energies. This hypothesis needs, however, to be completed by some further and necessary ingredients since such powerful galaxies are rare objects and should be clearly visible in the 50 Mpc distance authorized by propagation arguments. The second fashionable model relates the UHECR to another long-lasting astrophysical puzzle: the Gamma Ray Bursts. These are characterized by the emission of huge amounts of energies (typically a non-negligible fraction of the mass energy of our Sun) over a very short time (minutes), observed up to now as gamma rays but with, in some cases, X-ray and optical counterparts. Their distribution is cosmological and uniform over the sky. GRBs happen at a rate of 2-3 per day. However, their distribution within the "GZK sphere" does not seem to fulfill the conditions required by the UHECR observations. Other objects were proposed as putative sources of UHECR, such as rapidly rotating compact objects (young black holes, neutron stars or "magnetars") which possibly are the sources of the most intense magnetic fields in the universe (field values up to the peta-gauss have been envisaged). The capability of such systems to reach the required ZeV energies is controversial, to say the least.

The jackpot: reaching the joules from above

A simple idea is the following: since we cannot find any way of accelerating particles at ZeV energies, let us imagine that actually they are not accelerated at all, but reach the energies from above. Reaching the ultra-high cosmic ray energies from the top, i.e. as a result of the decay of a super-heavy particle is indeed quite easy, provided one can justify the existence of such particles, their sur-

vival up to the present time and the observed fluxes. If we extrapolate what we know of particle decays from the ordinary sector, a likely scenario would be the following. The mass of the particles should be typically in the Grand-Unification Theory energies ($\sim 10^{25}$ eV). They would have been created when the temperature of the universe was of the same order of magnitude, i.e. roughly 10^{-35} second after the Big-Bang. They would have survived up to now by some yet unknown mechanism (a very weakly violated quantum number, particles trapped inside huge potential wells called topological defects...). They would have accumulated by gravitational attraction in the halo of galaxies (therefore escaping the GZK cutoff). Their decay into some 10,000 secondary particles (mainly pions) by hadronization of quark-antiquark pairs would easily produce the ZeV energies we need and their decay products would then be dominated by photons (coming from the decay of neutral pions) and neutrinos (decay of charged pions). Indeed this scenario needs a series of hypotheses to work all together, but none of them calls for any extravagant model or

theory. The important point is that there are a few experimental consequences of this model which constitute, if observed, a unique and irrefutable signature of the existence of the Grand Unification, a horizon toward which all the modern quantum field theories are supposed to converge. These are: a very specific energy spectrum shape extending well above the ZeV, and dominant proportions of post-GZK photons and neutrinos in the UHECR composition.

Now that we have described the contours of the puzzle, let us see how we can come out of it.

Extensive air showers and their detection

Based on very scarce observations spread over 40 years, we know that post GZK cosmic rays arrive on earth at a rate of a few per square kilometer and *per century*. On the other hand, we know that statistics are the

sinew of war to solve the UHECR mystery. We need many observations to identify the incident cosmic rays, to find if their incoming directions point back to discrete sources or local mass distributions, to reconstruct precisely the shape of their energy spectrum which is, as we have seen, a specific signature of the production mechanism. The inevitable conclusion we then reach is that if we are to answer the fundamental question on the origin of the UHECR within a reasonable time, we need a detector covering a surface on earth of several thousands of square-kilometers, let's say twice the surface of Luxembourg (the State, not the Paris garden!) or one-fifth of Belgium. This was actually the conclusion reached by two physicists during a meeting in 1991, Alan A. Watson of the University of Leeds (UK), and the Nobel Prize Laureate James W. Cronin of the University of Chicago (USA) (see Fig.3). This (crazy) dream come true is the Pierre Auger Observatory, presently under construction.

Because of their very low flux, cosmic rays at the highest energies (above the PeV range) cannot be detected directly before they interact with the Earth's atmosphere (i.e. with balloon or satellite



▲ **Fig. 3:** Alan Watson and James Cronin, the two promoters of the Pierre Auger project. The first ideas about solving the UHECR puzzle by building a giant ground detector were envisaged during a conference in Dublin in 1991 where they met, and consolidated by an international workshop they organized in Paris in 1992. Ten years later a first piece of a future 3000 km² detector has started to take data in the southern hemisphere (Argentina).



▲ **Fig. 4:** One of the detector stations of the Auger Observatory in the Argentine Pampa (the Andes in the background). The complete ground array will have 1600 such stations spread over a surface of 3000 km². A typical cosmic ray induced airshower in the relevant energy range covers an area of several tens of km² with some 100 billions of secondary particles (mainly photons and electrons) that reach the ground level. The detector stations (tanks filled with 12 tons of pure water where the charged particles produce Cherenkov light) sample the shower particles, count their number and put a time tag on them. It is then possible to reconstruct the energy and direction of the primary cosmic ray. Each station is autonomous, powered by solar panels, and communicating with a central computer more or less through cellular-phone-like techniques.

borne detectors). The necessarily large-aperture detectors are therefore ground based. They must reconstruct the properties of the primary cosmic ray (nature, energy, direction) indirectly by measuring the effects of the secondary particles created by the chain reaction which results from the interaction of the cosmic ray with atmospheric atoms. The object of the observation is what is called the *extensive air-shower* (EAS) associated with the cosmic ray. Among several observational techniques that can be used, mainly two are presently operational. The first technique is based on the detection, by a system of mirrors and phototubes, of the fluorescence light generated by the charged secondaries (mainly electrons) in the EAS. It is currently referred to as the "Fly's Eye" technique from the name of the first detector built by a team of the University of Utah in the early eighties. With such a detector, the EAS is observed in its longitudinal development and its energy is measured as in a calorimeter by the amount of UV light deposited in the atmosphere (excitation of the nitrogen molecules by the shower electrons). The second and most frequent detection technique is based on an idea first used by Pierre Auger in the late

The object of the observation is what is called the *extensive air-shower* (EAS) associated with the cosmic ray.

thirties. It consists of a network of particle detectors (scintillators, water Cherenkov tanks, muon calorimeters) installed on the ground. The properties of the primary cosmic ray can be deduced from the lateral distribution of the secondaries in a cross section of the EAS. The parameters of such a ground array (altitude, surface area, spacing between the detector stations) must be adapted to the energy range aimed for. The largest, presently operating ground array is called AGASA. It is situated near the town of Akeno in Japan and covers a surface of 100 km². A detector using a combination of two (or more) of these techniques (e.g. fluorescence telescopes with a ground array) is called *hybrid*. The Pierre Auger Observatory is precisely the unique hybrid cosmic ray detector.

FIG4

The full Observatory will consist of two sites of 3000 km² each (one in each hemisphere). The ground array stations (see Fig.4) are to be distributed over the site with a regular spacing of 1.5km between each. The two sites were chosen on the basis of a list of specifications of which the most important were the size (and flatness of the landscape for easier hertzian communication), the latitude (between 35 and 40° North and South for optimum sky coverage), the altitude (around 1400 m, an altitude close to the shower maximum for a vertical shower to minimize statistical fluctuations), dry atmosphere, clear skies and low light pollution for the optical component (and partly for the solar power). The southern site is situated in Argentina, near the small town of Malargüe, Mendoza. There, a prototype detector with 40 detector stations and two fluorescence telescopes has been taking data for one year. The full detector (1600 stations and 24 telescopes) is expected to be finished in the beginning of 2005, but the data taking will go on during the construction years. We expect that with a few years of data taking with the Auger Observatory, we should have enough elements if not to solve fully the UHECR puzzle, at least to give strong indications on which paths to follow to find the right answer. But whatever the outcome, we are sure to start exploring a new domain of physics.

References

- [1] A.D. Erlykin, A.W. Wolfendale, *Europhysics News* 32 No 6 (2001) 246
- [2] For a recent review on the cosmic rays of extreme energies, see A.A. Watson, *Europhysics News* 32 No 6 (2001)
- [3] A.V. Olinto, "Ultra High Energy Cosmic Rays: the theoretical challenge", *Phys. Rep.* 333-334 (2000) 329; P. Bhattacharjee and G. Sigl, "Origin and propagation of extremely high energy cosmic rays", *Phys. Rep.* 327 (2000) 109; M. Nagano and A.A. Watson, "Observations and implications of the ultra high energy cosmic rays", *Rev. of Modern Phys.* 72 (2000) 689; X. Bertou, M. Boratav and A. Letessier-Selvon, "Physics of extremely high energy cosmic rays", *Int. Journ. of Modern Physics A* 15 (2000) 2181.

Footnotes

- (1) Mpc or Megaparsec. The "parsec" is an astronomical distance unit equivalent to 3.26 light-years or roughly 3×10^{16} m. The diameter of the Milky Way is 30 kpc, the distance to the nearest large cluster of galaxies (Virgo) is about 20 Mpc. The distance of the farthest galaxies seen, our horizon, is roughly 1 Gpc.

Spin qubits in solid-state structures

Guido Burkard and Daniel Loss
 Department of Physics and Astronomy, University of Basel,
 Klingelbergstrasse 82, CH-4056 Basel, Switzerland

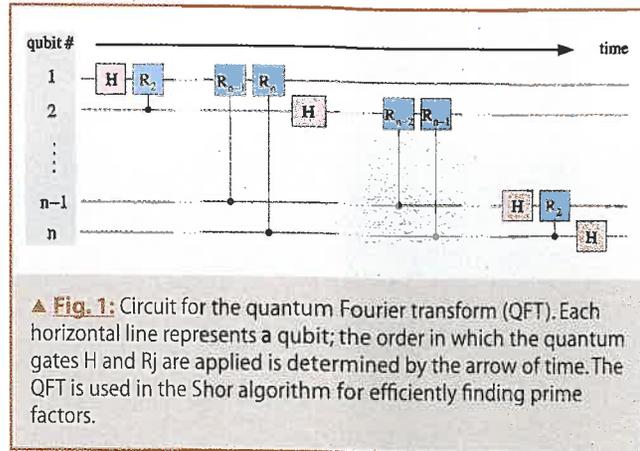
It is remarkable that today's computers, after the tremendous development during the last 50 years, are still essentially described by the mathematical model formulated by Alan Turing in the 1930's. Turing's model describes computers which operate according to the laws of classical physics. What would happen if a computer was operating according to the quantum laws? Physicists and computer scientists have been interested in this question since the early 1980's, but research in quantum computation really started to flourish after 1994 when Peter Shor discovered a quantum algorithm to find prime factors of large integers efficiently, a problem which is intrinsically hard for any classical computer (see [1] for an introduction into quantum computation). The lack of an algorithm for efficient factoring on a classical machine is actually the basis of the widely used RSA encryption scheme. Phase coherence needs to be maintained for a sufficiently long time in the memory of a quantum computer. This may sound like a harmless requirement, but in fact it is the main reason why the physical implementation of quantum computation is so difficult. Usually, a quantum memory is thought of as a set of two-level systems, named quantum bits, or qubits for short. In analogy to the classical bit, two orthogonal computational basis states $|0\rangle$ and $|1\rangle$ are defined. The textbook example of a quantum two-level system is the spin 1/2 of, say, an electron, where one can identify the "spin up" state with $|0\rangle$ and the "spin down" state with $|1\rangle$. While several other two-level systems have been proposed for quantum computing, we will devote the majority of our discussion to the potential use of electron spins in nanostructures (such as quantum dots) as qubits.

Shor's factoring algorithm

We return to Shor's algorithm, since it allows us to explain many important concepts. At the heart of it lies the quantum Fourier transform (QFT). Given n qubits with an orthonormal basis $|0\rangle, \dots, |2^n-1\rangle$, the QFT is a unitary $2^n \times 2^n$ matrix U_{QFT} such that

$$U_{\text{QFT}}|j\rangle = 2^{-n/2} \sum_{k=0}^{2^n-1} e^{2\pi ijk/2^n} |k\rangle. \quad (1)$$

The QFT can be decomposed into a series of elementary operations, as shown in Fig. 1. The elementary operations, or "gates", used here can be described as follows. The Hadamard gate H acts on a single qubit (represented by a horizontal line in Fig. 1). It transforms $|0\rangle$ into $(|0\rangle + |1\rangle)/\sqrt{2}$ and $|1\rangle$ into $(|0\rangle - |1\rangle)/\sqrt{2}$. The gate R_j denotes a rotation of the qubit by an angle of $2\pi/2^j$ about the z axis. The vertical line which connects the box with R_j to another qubit means that this is a controlled rotation, i.e. the target qubit (below the box) is rotated if the control qubit (marked with the dot) is in state $|1\rangle$ and left unchanged otherwise. This description defines the controlled- R_j gate uniquely for all initial states of the



▲ Fig. 1: Circuit for the quantum Fourier transform (QFT). Each horizontal line represents a qubit; the order in which the quantum gates H and R_j are applied is determined by the arrow of time. The QFT is used in the Shor algorithm for efficiently finding prime factors.

control and target qubits since it determines its operation on a basis of products of $|0\rangle$ and $|1\rangle$.

The controlled- R_j is an example for a two-qubit quantum gate. Quantum gates acting on more than one qubit are necessary in order to perform non-trivial quantum logic. Fortunately, it is possible to make use of only one two-qubit gate (e.g., the controlled-NOT) in combination with single-qubit gates for doing any quantum computation. Controlled-NOT (also called XOR) is similar to controlled- R_j , but with the qubit rotation replaced by an inversion $|0\rangle \leftrightarrow |1\rangle$.

The number of elementary quantum gates in the QFT circuit shown in Fig. 1 grows as the square of the number $n = \log_2 N$ of qubits which are required to store the input N , whereas the classical fast Fourier transform (FFT) takes roughly $n2^n$ steps. It was Shor's idea to apply period finding with the QFT to factor a number $N = 0, \dots, 2^n - 1$: the period of the function $f(x) = a^x \bmod N$ can be used to find a prime number not equal to 1 or N which divides N . Here, a is a random number between 1 and $N - 1$ which has no common divisor with N (if it has, the problem is solved). Everything taken together, the number of elementary operations needed for finding a prime factor of N with the Shor algorithm essentially scales with n^2 , while the most efficient classical algorithm known presently requires exponentially more, on the order of $\exp(n^{1/3} \log^{2/3} n)$. In order to illustrate the difference between power law (quantum) and exponential (classical) scaling, let us assume for the moment that we had both a classical computer and a quantum computer running Shor's algorithm, and that both of them required one hour for factoring a number with 100 decimals. To find a prime factor of a number with 1000 decimals would then take about a week on the quantum computer while using the classical computer, it would require about 10^{12} years, longer than the estimated age of the universe!

Beyond Factoring

Besides finding prime factors, the QFT can be used to solve other problems efficiently for which there is no efficient classical method. Consider for example the problem of discrete logarithms (which, as the factoring problem, has applications in cryptography): given integers a and $b = a^s$, find the value of the integer s . There is a whole class of problems of this kind which relate in some way to the problem of finding the period of a discrete function.

Another class is represented by Grover's algorithm which finds an element in an unsorted database containing N entries. Solving this problem is like knowing a phone number and looking up the corresponding name in a phone book having N entries. Grover's algorithm requires $\propto \sqrt{N}$ elementary gate operations, while the fastest classical method requires $\propto N$ steps.

One of the early ideas is to use a controlled quantum system (quantum computer) to simulate another quantum system. When quantum systems are simulated on classical computers the computation time generically scales exponentially with the size of the system. Given a local Hamiltonian defined on a discrete (or discretized) system and some initial state, there is a quantum algorithm that computes the final state up to an accuracy ϵ with a number of elementary quantum gates which scales as a power of $1/\epsilon$.

State of the Art

Recently, Shor's algorithm was implemented using nuclear magnetic resonance (NMR) with an ensemble of molecules in solution containing $n = 7$ nuclei with spin-1/2 addressed individually with rf fields [2]. This machine was able to factor the number 15. Nobody was particularly surprised that the answer was $15 = 3 \cdot 5$, but the experiment is still remarkable and represents the current state of the art of quantum computation. The regime where quantum computers could "boldly go where no classical computer has gone before" (and, e.g., break RSA encryption keys) starts at around $n = 1000$ qubits and millions of elementary quantum gates. It is fair to say that nobody knows whether there will ever be a quantum computer which will accomplish this. On the other hand, it is quite certain that room-temperature liquid NMR will never reach this stage. The most important reason for this is that only ensemble averages are experimentally accessible and at the temperatures available these average signals decrease exponentially as the number of qubits increases. It also is not obvious how to make molecules or similar structures with, say, a thousand spins which can be individually addressed. Moreover, there have been theoretical arguments whether NMR quantum computing is really "quantum" (see [3] and references therein).

There are other systems, in which elementary quantum operations have already been performed experimentally [3], the most prominent examples being ion traps and high-Q optical cavities. Although, in contrast to NMR, these two implementations allow

the manipulation and read-out of individual qubits, it appears rather difficult to scale them up to a large number of qubits.

Electron Spins as Qubits

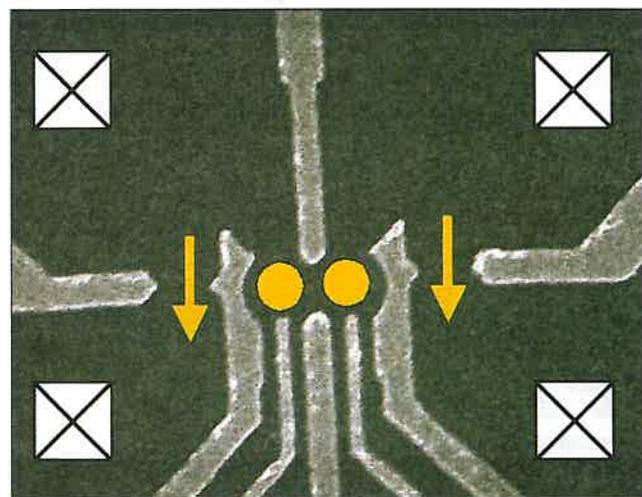
Motivated by the rapid upscaling of microelectronic semiconductor devices, several solid-state implementations of quantum computing have been proposed. The analogy with the development of classical circuits even led some researchers to call the ion trap a "vacuum tube quantum computer" (the fate of the vacuum tube was to be superseded by a solid state device—the transistor). Here, we concentrate on the idea put forward in early 1997 by Loss and DiVincenzo to use the spin 1/2 of electrons in confined nanostructures, e.g. quantum dots, as qubits (see chapter 8 in [4] for a review). Many solid-state implementations for quantum computing have been proposed subsequently [3], including superconducting qubits, nuclear spins of donor atoms in silicon, and charge qubits in quantum dots.

The electron's spin is a "natural" representation of a qubit since it comprises exactly two levels. Unlike for charge states in an atom or quantum dot, there are no additional degrees of freedom into which the system could "leak". Another great advantage of spins as compared to charge qubits is that in typical semiconductor materials like gallium arsenide (GaAs) or silicon (Si), the time over which the spin of a conduction-band electron remains phase coherent can be several orders of magnitude longer than the corresponding charge decoherence times. Of course these numbers have to be compared with the time it takes to perform an elementary gate operation. Even considering this, single spins seem to be very well suited as qubits. The transverse decoherence time T_2 , which is most relevant in the context of quantum computing, is defined as the characteristic time over which a single spin which is initially prepared as a coherent superposition of "spin up" and "spin down" coherently precesses about an external magnetic field. The transverse dephasing time $T_2^* \leq T_2$ of an ensemble of spins in n-doped GaAs can exceed 100 ns, as demonstrated by optical measurements [5], while switching times are estimated to be on the order of 10–100 ps. The longitudinal (energy) relaxation time T_1 determines how long it takes for a non-equilibrium spin configuration to relax to equilibrium. T_1 can be much longer than T_2 (and particularly long in confined structures), but while suppression of spin relaxation is necessary for quantum computation, it is not sufficient.

In the battle against decoherence, physics is also helped by the results of fundamental research in quantum information theory. Error correcting codes have been developed which in principle allow arbitrary long quantum computations to be performed even in the presence of decoherence and imperfect quantum gates, as long as the error rate does not exceed a certain threshold. This threshold depends on the error model and the code; typical numbers are around 1 memory or gate error in 10^4 cycles.

Quantum Dots

Semiconductor quantum dots are small islands of electrons in an otherwise depleted region. The largest degree of control can be obtained with quantum dots that are electrically confined in a two-dimensional electron system (2DES) formed e.g. at the interface between a GaAs and an AlGaAs layer or in a quantum well formed by an AlGaAs-GaAs-AlGaAs "sandwich". Using metallic gates at the top of the heterostructure, electrons can be laterally confined to a region with a size on the order of the Fermi wavelength (around 40 nm in a typical GaAs/AlGaAs 2DES), leading to a discrete energy spectrum (quite like in atoms). A quantum dot can be connected to external leads via tunneling



▲ **Fig. 2:** Scanning electron micrograph of a semiconductor structure with two coupled quantum dots (yellow disks) formed by applying a negative bias to the metallic contacts (grey) which define the quantum dots. The electron number in each dot can be controlled down to one, and it can be measured by quantum point contacts (yellow arrows). [courtesy of L. Kouwenhoven, TU Delft]

contacts which are likewise formed in the 2DES by electrical gating. In these systems, the Coulomb blockade effect, i.e. the quantization of the electronic charge on the dot which leads to pronounced peaks in the conductance as a function of an applied gate voltage, can be observed.

Adjacent quantum dots can be coupled, as shown in Fig. 2. In the Coulomb blockade regime, adding and removing single electrons is easy, however, removing all but one electron is very hard and has been achieved only recently in lateral dots like those in Fig. 2.

In order to use electron spins for quantum computation, one would like to label them in order to be able to address a certain qubit at any time during the computation and for the read-out of the final result. If the electrons carrying the spin qubits were free like in a metal or 2DES, then this would be impossible due to the indistinguishability of identical particles in quantum mechanics. However, if the electrons carrying the quantum information were localized in an array of quantum dots (Fig. 3) then they could be distinguished by their position.

Exchange Coupling

As mentioned earlier, for quantum computing qubits need to be coupled using a two-qubit gate. In the case of localized spins the required coupling can be obtained via tunneling between adjacent dots. This can be understood in terms of a simple Hubbard model with a tunneling amplitude t between adjacent sites and an on-site Coulomb repulsion energy U . With one electron per dot, one finds in the limit $t \ll U$ that the low-energy physics of the system is described by the spin Hamiltonian

$$H = \sum_{1 \leq i < j \leq n} J_{ij} \mathbf{S}_i \cdot \mathbf{S}_j + \mu_B \sum_{1 \leq i \leq n} g_i \mathbf{B}_i \cdot \mathbf{S}_i, \quad (2)$$

where $\approx = 4t^2/U$ is the exchange energy and \mathbf{S}_i denotes the spin 1/2 operator at site i . We have also included the Zeeman energy due to an external magnetic field \mathbf{B}_i at site i , where μ_B is the Bohr magneton and g_i is the Landé g -factor. Even if the external field is constant and homogeneous, both the exchange for each pair of spins and the Zeeman term for each individual spin (see below) can be controlled by electrical gating. Applying a gate voltage at

the surface will increase the potential barrier for electrons between adjacent dots, and J will be reduced exponentially. This effectively provides a mechanism for switching on and off the coupling between two qubits while all other interactions are off (this is required for a circuit as e.g. Fig. 1). In NMR however, all interactions are on all the time, and one has to apply refocusing techniques in order to “effectively” switch off the unwanted interactions.

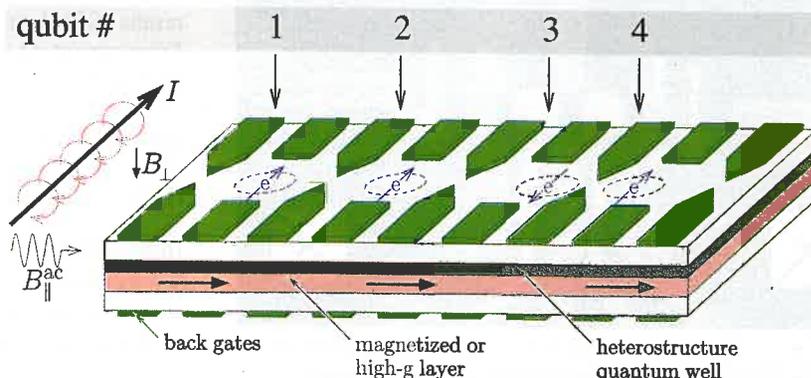
One can use the analogy between quantum dots and atoms and treat the coupled system as an artificial hydrogen molecule. Since the exchange energy is just the energy difference between the lowest spin singlet and triplet states of a two-electron system, we can find a good estimate for J by applying the Heitler-London method from molecular physics. For more details and for a number of improvements to the Heitler-London method we refer the interested reader to chapter 8 in [4]. Molecular states in quantum dots have been observed in the Coulomb blockade regime, but further evidence is required to distinguish between single-electron states (“ H_2^+ molecules”) and the two-electron states discussed here (“ H_2 molecules”).

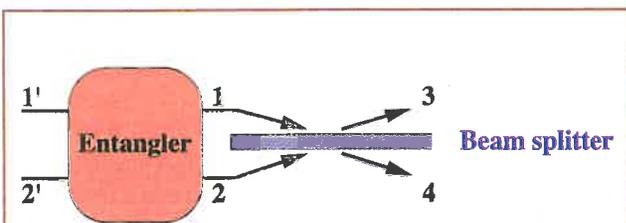
Quantum dot quantum logic

If the exchange coupling between two neighboring spins is switched on for a finite amount of time and the time-integrated exchange energy (divided by \hbar) equals exactly π then the states of the two spins are swapped. For quantum computation, the “square-root of swap” ($\sqrt{\text{SWAP}}$), obtained by applying a time-integrated exchange of only $\pi/2$, is much more interesting: it can be used to produce a maximally entangled state of two spins from a product state. An example is the spin singlet state $|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle$. Entanglement is one of the essential features of quantum mechanics and thus plays a key role in quantum computing (the connection between entanglement and the efficiency of quantum algorithms is still not fully understood). $\sqrt{\text{SWAP}}$ can be combined with single-qubit gates into the controlled-NOT gate. As a consequence, the exchange interaction between spins plus the ability to rotate single spins is sufficient for quantum computation.

During the short time of the switching process (not in between), the spin of the electrons in the coupled quantum dots is coupled to the charge via the Pauli exclusion principle, and we have to avoid charge excitations. The relevant energy scales are the

► **Fig. 3:** Sketch of a linear array of quantum dots (dashed circles), each containing a single (excess) spin 1/2 (blue arrow) representing a qubit for quantum computing. Localized spins can be labeled and addressed individually. The metal gate electrodes (green) are used to define the quantum dots and the couplings between them. For single-qubit operations, a local difference in Zeeman splittings could be achieved electrically, e.g. by applying a gate potential between the top and the bottom of the structure; any electron can then be shifted individually towards a magnetized or high- g layer (red). Likewise, such local Zeeman splittings could be generated by a static inhomogeneous magnetic field, e.g. produced by a current I (red circles). Single-qubit rotations could be performed using electron spin resonance (ESR) with a homogeneous oscillatory field $B_{\text{eff}}^{\text{ac}}$ with a frequency matching the local Zeeman splitting of the desired qubit. The exchange coupling between adjacent spins could also be controlled electrically by gate electrodes. We have sketched a situation where the qubits 3 and 4 are coupled.





▲ **Fig. 4:** Setup for detecting entangled electrons which are injected from the entangler into Fermi leads 1 and 2. Two-particle interference at the electronic beam splitter leads to distinct statistical effects for entangled singlet or triplet pairs in the noise correlations between the outgoing leads. In the case of the singlet, the noise enhancement allows to uniquely detect the entangled state.

level spacing δE on a single quantum dot and the on-site Coulomb repulsion energy U . Typically, both of these energies are several tens of Kelvin, while for smaller quantum dots, they can even approach room temperature. The operating temperature of the quantum computer should not exceed these energies. Furthermore, the switching of external parameters leading to a time-dependent exchange $J(t)$ should not be too fast. One can find optimal switching pulse shapes (e.g. $1/\cosh$) and lower bounds for the switching times (for typical lateral dots around 100 ps) [4].

Rotating spins

Rotating single spins may seem easier than coupling two spins. However, one finds that applying a field of, say, 1 Tesla to a particular spin without rotating neighbors at a distance of only about 50 nm would require huge field gradients. Although some technologies allow to apply strongly localized magnetic fields (hard disk read/write heads, magnetic force microscope tips), it appears very difficult to achieve large gradients. It seems more realistic to apply electric gate voltages locally, as shown in Fig. 3, changing the vertical position of the localized electrons, which, in combination with a spatially varying Zeeman effect (using either magnetic or g -factor modulated materials), can change the effective magnetic field in which a spin is precessing. This is in principle sufficient for performing arbitrary single-spin rotations—completing the required set of operations for our quantum computer. Modulation of the g -factor by electrical gating was in fact recently demonstrated experimentally at UC Santa Barbara (see [4], chapter 5).

Alternatively, individual spins could be rotated using a homogeneous oscillatory magnetic (ESR) field in combination with a static gradient which allows to select a certain spin by its distinct resonance frequency. Yet another interesting possibility for fast spin manipulation was investigated in Awschalom's group (UCSB). Spin-polarized electrons were rotated using a femtosecond optical pulse which acts like an effective strong magnetic field via the optical Stark effect ([4], chapter 5).

A “computer science” trick to perform universal quantum computation using solely the exchange interaction $J\mathbf{S}_i \cdot \mathbf{S}_j$ is based on encoding each logical qubit into three spins instead of one. In addition to this overhead the “exchange only” implementation would require on the order of ten times more operations.

Input and Output

A quantum computer would be useless if it were impossible to prepare it initially with some input data and finally to read out the result. Using single-qubit rotations, initializing the system can be

reduced to preparation in some fixed known state, such as $|00\dots 0\rangle$. The latter can be produced by applying a homogeneous magnetic field and letting the system relax.

Reading out single spins directly is difficult. As for single-spin rotations, it might be easier to transform the “magnetic” problem into an “electric” one (spin-to-charge conversion). For readout, spin-dependent tunneling to an adjacent empty quantum dot would be monitored using an electrometer (sensitivity orders of magnitude smaller than a single electron charge). The presence or absence of an electron in the adjacent dot after a finite amount of time would then allow one to tell whether there was a spin up or spin down electron in the read dot.

Quantum Communication

It is hard to predict at the moment to what degree and up to which scale quantum computation can ever be realized. Another related field of research, quantum communication, is about to yield new implementable technologies. The most advanced application appears to be quantum key distribution (QKD). The cryptographic keys used nowadays are not unconditionally secure, i.e. they rely on some assumptions which are believed to be true with high confidence, e.g. the widely used RSA scheme for encryption is safe as long as factoring large integers cannot be performed efficiently. The BB84 protocol for QKD, invented by Bennett and Brassard in 1984, is based on the transmission of single qubits (e.g. the polarization of photons) from one party to the other, while a protocol put forward by Ekert in 1991 is based on each of the two parties possessing one qubit of an entangled (or EPR) pair. Quantum teleportation and superdense coding are also based on the use of such entangled pairs. Roughly speaking, two qubits are in an entangled state if their total quantum state cannot be written as the product of quantum states of each qubit separately. So, while $|0\rangle_1 |1\rangle_2$ and $|0\rangle_1 |0\rangle_2 - |0\rangle_1 |1\rangle_2 - |1\rangle_1 |0\rangle_2 + |1\rangle_1 |1\rangle_2$ are not entangled, the singlet state $|0\rangle_1 |1\rangle_2 - |1\rangle_1 |0\rangle_2$ is entangled.

All of the concepts mentioned above have been successfully tested using entangled photons from parametric downconversion [1]. There have been several theoretical suggestions to produce, transport, and detect spin entangled electrons in mesoscopic wires [4, 6] and there is increasing experimental effort towards realizing this challenging idea. Actually, entangled states are rather the rule than the exception in condensed matter physics. Particularly interesting are systems which possess entangled ground states (a simple example being two tunnel-coupled quantum dots), since in such a state the entanglement is robust against external perturbations once the system is cooled to low enough temperatures.

The big problem is to harness such entangled states. Using adiabatic pumping, such states could be injected into electrical leads which are attached to quantum dots. Another possible implementation of an “entangler” is a tunnel contact between a conventional BCS superconductor and a normal metal. The ground state of the superconductor consists of a condensate of Cooper pairs which are in the spin singlet. By biasing the superconductor-normal junction, Cooper pairs can be broken and the two resulting electrons can tunnel into the normal metal. In order to be useful for quantum communication, the two electrons have to be extracted in two separate leads while remaining entangled. It has been shown (chapter 8 in [4]) that the fraction of the electrons emerging in separate leads can be drastically increased by connecting the superconductor to two normal quantum dots which are connected to the normal leads such that the on-site Coulomb repulsion in each quantum dot prevents two electrons from simultaneously moving into the same lead.

How can a spin entangler for electrons be tested for its functionality? A solution is to use statistical properties. Due to the Fermi statistics, an electronic spin singlet state has a symmetric orbital wavefunction, and it can be expected that it exhibits “particle bunching” familiar for Bosons in suitable two-particle interference (Hanbury Brown-Twiss) experiments. Consider injecting the electrons from the entangler into an electronic beam splitter (Fig. 4) and then measuring the current autocorrelations in one of the outgoing arms (3 or 4). It can be proven [4, 6] that when the electrons injected are in the entangled spin singlet state, a particle bunching effect will be seen, i.e. the probability for both electrons to emerge in the same (different) outgoing lead will be enhanced (suppressed). This leads to a measurable enhancement of the noise-to-current ratio by a factor of two. Another important issue is whether the spin entanglement becomes degraded owing to electron-electron interactions during transport in the mesoscopic leads. The probability of recovering an entangled pair transmitted through an interacting electron system scales with z_F^2 where $0 < z_F \leq 1$ is the quasiparticle weight. This quantity can be evaluated for a two-dimensional electron system using Green’s functions. For typical GaAs samples, $z_F \approx 0.7$, so about 25% of the pairs can be recovered. For weak spin-flip scattering (as seen experimentally e.g. in GaAs), the entanglement of those pairs which are recollected after transmission is still maximal.

Because photons typically interact with their surroundings much more weakly than electrons, they are ideal for long-distance transmission of quantum information, but it is rather hard to couple them to spin-based quantum computer hardware. Besides being of fundamental interest, electron spins, transported over micrometer distances in a solid, serve as a “bus” for the spin-based

quantum computer. On the theoretical side, the Fermi statistics for electrons has led to a further generalization of the notion of entanglement.

Outlook

New concepts of quantum information processing are being investigated on the “small scale” with NMR, quantum optics, and trapped ions. Theoretical work on solid-state quantum computing, in particular the spin-based scheme outlined here, has motivated considerable experimental efforts towards solid-state qubits. Regardless of whether a large-scale solid-state quantum computer will emerge from these efforts, it is already now exciting to follow these developments since new and interesting results in both fundamental and applied physics can be expected.

References

- [1] M.A. Nielsen and I.L. Chuang, *Quantum Computation and Quantum Information* (Cambridge University Press, 2000).
- [2] L. M. K. Vandersypen *et al.*, *Nature* **414**, 883 (2001).
- [3] *Fortschritte der Physik* **48**, Special issue on *Experimental Proposals for Quantum Computation*, eds. H.-K. Lo and S. Braunstein (Wiley-VCH, Berlin, 2000).
- [4] *Semiconductor Spintronics and Quantum Computation*, eds. D.D. Awschalom, D. Loss, and N. Samarth, (Springer, Berlin, 2002).
- [5] J. M. Kikkawa and D. D. Awschalom, *Phys. Rev. Lett.* **80**, 4313 (1998).
- [6] G. Burkard, D. Loss, and E. V. Sukhorukov, *Phys. Rev. B* **61**, R16303 (2000).

Cecil Powell Memorial Lecture
EPS General Meeting, Budapest, 2002

The value of useless studies

D. Weaire, *Physics Department, Trinity College, Dublin, Ireland*

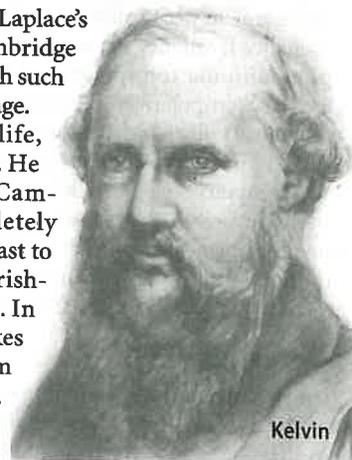
This lecture is a celebration of two men from the extreme Western fringe of Europe, in fact two Irishmen— Lord Kelvin and George Francis Fitzgerald. My title is taken from a letter to *Nature* by Fitzgerald in 1892. It sticks persistently in my mind and provokes a lot of questions about the meanings of “value” and “useless” and hence in which pure and applied physics interact with each other, as they did in the lives of these two men.

These people appeal to me because, while they lived in a bygone age, I have no difficulty at all in understanding them. Their life-spans include that period in which physics emerged as a distinct professional discipline, and they played their part in shaping it. Its value is under question today. This debate is not a new one: it goes right back to the very dawn of our Western culture, in Greece, and it was certainly active in the time of Kelvin and Fitzgerald. The value of useless studies has always been questioned, but rarely more than today.

Kelvin was born as William Thomson in 1824, of the Scottish Covenanter stock that had settled in Northern Ireland in the 17th century. His father James, who taught mathematics in Belfast, was a talented and industrious man. William and his brother James both inherited their father’s academic ability and he fostered this assiduously, both before and after the family moved to Glasgow University, where the father took up the Chair of Mathematics.

From an early age James and William were tutored by their father and they attended lectures at the university while still very young, surpassing all the other students. So when William went to Cambridge at the age of sixteen he had already been fully immersed in university education at Glasgow, and had devoted his previous summer to Fourier’s *Théorie Analytique de la Chaleur* and Laplace’s *Mécanique Céleste*. Few Cambridge Freshmen can have arrived with such heavyweight intellectual baggage.

Kelvin enjoyed college life, including athletic pursuits. He formed an attachment to Cambridge but was not completely seduced by it. This is in contrast to his good friend and fellow Irishman George Gabriel Stokes. In later life he was to warn Stokes that he should move away from “London and Cambridge, those great juggernauts under which so much potential



energy for original discovery is crushed". But Stokes—a famously shy man, remained cocooned in his college for life. Their lifelong friendship—when Stokes was buried Kelvin said that his heart was in the grave with him—was an attraction of opposites. Stokes was a classic example of the dedicated, distracted, introverted but admirable professorial type. JJ Thomson praised the clarity of his lectures and his enthusiasm, which in 1898 after fifty years of lecturing, sometimes led him to forget the time and go on uninterruptedly for as much as three hours. Rayleigh recalled something similar from his undergraduate days: if the sun was shining and Stokes able to use its rays for demonstrations, he would ignore the clock and the timetable. But his audience forgave him: "With complete ease and accuracy and with the expenditure of about two pence he performs the most valuable and decisive demonstrations of his theories. His astonishing faculty for doing without costly apparatus must be a heaven-sent gift to the impoverished university." Stokes even got carried away writing a letters to his fiancée, and provided her with many pages of explanation of the details of his mathematical research. He almost lost her. *I regularly advise graduate students not to do this.*

A year after his graduation in mathematics, in which he somehow managed to come only second in the list, Kelvin returned to Glasgow as Professor of Natural Philosophy, and refused all offers (including the Cavendish chair in Cambridge, three times) to move south again. He had already published twenty scientific papers.

At this point one wonders what to say about the vast range of his accomplishments over his entire career. It ranges across all of physics, and from the fundamental to the applied. His output of more than 600 papers and many books and patents was spread evenly over his long life, rising smoothly like the parabolic trajectory of a projectile, from a few papers a year in his late teens to more than ten a year in mid career and declining again to a few every year in his eighties. Let us mention thermodynamics, optics, elasticity, electricity and magnetism, hydrodynamics, navigation, geophysics and the properties of materials. He was surely the last great classical physicist, and he's sometimes portrayed as a conservative figure in his later years. Which of us will not be so, if we make it to the age of 83? It is true that he declared airplanes to be a complete impossibility, but that did seem to be the clear prediction of theory at the time.

In fact, he was as fond of speculation as anybody, and his many wild ideas about atoms and the ether exhibit as much *chutzpah* as the more imaginative writers of *Phys Rev Letters* today.

He gathered a long list of honours, including foreign membership of the Hungarian Academy of Sciences, awarded in the same year that Eotvos Lorand was admitted—1873. But as he became Sir William Thomson and then Baron Kelvin, he did not let it propel him into too many other activities—that was the advantage as he saw it, of staying in his remote fastness in Glasgow. He could even retreat to the palatial property that he built on the coast, or his yacht, to contemplate his latest challenge in peace. There and indeed everywhere else, he could jot down fresh thoughts all the time in his many notebooks, which now rest in Cambridge.

Kelvin was an adept mathematician but, as Fitzgerald said, "his mathematics is for the sake of the result and not for the sake of the mathematics." He himself said, together with PG Tait, in the preface to their textbook (Thomson and Tait, known at the time as "T and T prime"): "Nothing can be more fatal than too confident reliance on mathematical symbols: for the student is only too apt to take the easier course, and consider the formula and not the fact to be the physical reality'.

When he did have recourse to mathematics he was eager to see its results in a tangible form. When he produced an ideal cell for

foam as a model for the ether, he had a wire model made immediately, and a stereo picture for viewing—and he even got his wife to make a pincushion of the required shape. Kelvin always brought his work home, indeed his house is said to have been the first in the world to have a full domestic electric lighting system.

This idea that physics has to be something that you *feel* with your hands is a robust and valuable tradition can be associated with British natural philosophy in general, and set against the more formal and abstract approach of many French mathematical physicists such as Poincaré. There is still a contrast today, *et vive la différence*. Kelvin said that model-making was to be regarded as more than a "rude mechanical illustration" of a physical effect—it was a sort of consistency test of a theory, based partly on the notion that physics was the same on all length scales. Not that he was uninterested in mechanical illustrations—he performed them with dramatic effect for his classes, using for example a muzzle-loading elephant gun for demonstration of momentum conservation. He was particularly fond of the trick with two eggs, one boiled and the other not, which behave so differently when you spin them on a surface.

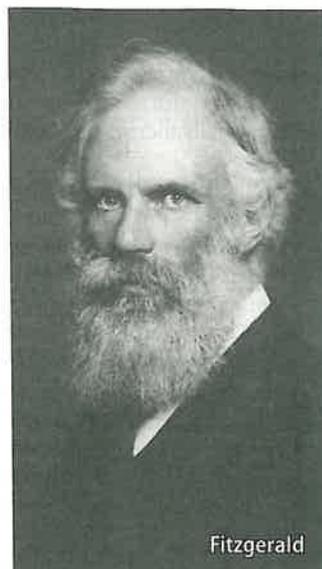
At times Kelvin took his down to earth approach too far—he was unhappy with Maxwell's theory, in particular, and right to the end of his days he saw the ether as a "real thing" (to be fair, so did Maxwell!). This material ether might be a jelly as Stokes had suggested—he wrote to Stokes to say that his *chocolat au lait* in a Paris café had congealed into something like the jelly that Stokes had been talking about. His own conception of ether was as a foam. (Incidentally Osborne Reynolds, yet another Irishman, thought it was a granular material, like sand—and both granular and foam models are mentioned in the latest conceptions of space-time on the Planck scale today, in an ironic twist of history, which I much enjoy and would enjoy better if I could understand quantum gravity...).

At the opposite pole of speculation on ether was Larmor—yes, yet another Irishman—who took field theory to the extreme of trying to describe the electron as no more than a singularity in a very mathematical sort of ether, of the kind Kelvin found distasteful.

So Kelvin was a mathematician who became a physicist—and then an engineer. What else are we to call a man whose seventy practical patents had a profound effect on the advance of technology. Let me quote Fitzgerald:

"If one were asked to point out a typical example of the kind of intellect that has changed the face of society so that our whole industrial system has been utterly revolutionised and with it the conditions of life of the majority of civilized nations, the first name that would occur would be that of Lord Kelvin"

So when we teach the second law of thermodynamics, and struggle with entropy (a word he did not like to use himself—I suppose because he could not feel it with his hands) and the absolute scale of temperature, we should tell our students that the same man that debated and helped to originate these concepts can also be said to have invented the heat pump, air cooling by refrigeration.



Fitzgerald

eration and other useful tricks that depend on the laws of thermodynamics. But his most prolific area of invention was electricity. In the dusty corridors of older physics department, glass cases still contain the many instruments that he designed. Incidentally there is now an excellent museum devoted to him in Glasgow.

Out of this came his climactic achievement in the field of telegraphy—not startlingly original—important inventions do not have to be so, and they usually are not.

In its time the telegraph was as exciting as the Web is today. Almost overnight, it was said, the world was shrunk to a global village. The masters of the arcane knowledge of telegraphy had high salaries, there was tension between private investment and government regulation, there was concern over security, a rush to invent peripheral devices (Edison made his first fortune from a ticker tape machine), and many investors got their fingers burned.

Indeed the first Transatlantic cable did not survive much beyond the exchange of greetings between Queen Victoria and the President. These messages were not as peremptory as is sometimes said. The Queen sent one of 99 words. It took 16 1/2 hours to transmit it. No wonder that early telegraphic technologists were already very interested in compression; many codes were invented to achieve it. In one of these the single word GNAPHALIO meant “Please send supply of light clothing”.

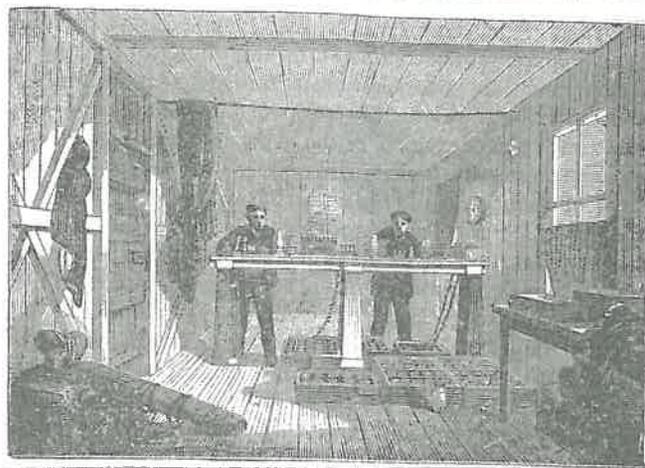
The rapid failure of the first Atlantic cable was a commercial disaster and the improvement of its technology a demanding imperative. It suffered from electrical breakdown. Kelvin made a rapid diagnosis and recommendation for the second attempt, which included using lower voltages than proposed, thicker cables, and more sensitive detection. For this he developed a sensitive mirror galvanometer, very like the ones that were used in university teaching labs until not very long ago. I hope you have not thrown all of them out!

The compelling force of his personality overcame the opposition of the ignorant and the amateurs, and a new system based on his ideas worked wonderfully well in 1866. It made the amazing sum of one thousand pounds on its first day of operation. So he became rich and famous...

Towards the end he described his career as a failure, which is quite preposterous. Admittedly the piece of physics that he took most pride in—his estimate of the age of the earth—went badly wrong, on account of the unknown effects of radioactive decay. I suppose he shared some of the feelings expressed in Russell McCormack’s *Night Thoughts of a Classical Physicist*, that his beloved classical physics was incomplete.

There are many parallels in the career of George Francis Fitzgerald, although we shall see that this symmetry was eventually broken. He too was born into an academic family, and rose to become Professor of Natural Philosophy at an early age in a provincial capital—in his case Dublin. Both were athletic, and were said to be superb lecturers and fond of demonstrations. Both made important advances in the introduction of laboratory classes: Kelvin’s were certainly among the earliest in the world—1848—and Fitzgerald, having improvised a student laboratory, fought for modern facilities up to his death. The indirect effect of their practical teaching must have been immense: one example of a Kelvin student is Gerard Philips, who founded the Philips lighting company. Fitzgerald’s protege Lyle founded the first physical laboratory south of the equator, in Melbourne.

To continue with the search for symmetry; both men were very prominent in the British Association and both were Editors of Philosophical Magazine. Fitzgerald, like Kelvin, was mathematically gifted, and he too preferred realistic physics to formal theory,



▲ The receiving station of the Atlantic telegraph at Valentia in Ireland.

and gradually developed strong interests in the industrial applications of physics. Both had powerful personalities, Fitzgerald’s even the more so perhaps.

There is however a stark contrast in the directly measurable output of the two men. Fitzgerald published only a few dozen significant papers, and no books. He fostered an inventive spirit among his protégés but he himself did little in applied physics. He could be accused of being a mere dabbler, as when he flew (if only just) the Lilienthal glider in the university grounds—the first one to do this in the British Isles. He seems to have lost interest in it thereafter, or taken fright.

Even his theoretical work was often left tentative and incomplete, as when he conjectured that length contraction could account for the Michelson-Morley experiment, sent a brief letter to an obscure American journal and forgot about it until Lorentz published something similar several years later. It took a long time for historians to work out that Fitzgerald’s idea, which came to him while sitting in Oliver Lodge’s house in Liverpool, was not just a wild guess but had its roots in the mathematical expression of electromagnetic theory, on which he was conducting an extensive correspondence.

Through that correspondence Fitzgerald’s indirect influence was immense, and his reputation grows with every retelling of his period by the historians of science, especially in the book *The Maxwellians*, by Bruce Hunt. Often in incidental remarks in his letters and writings he showed extraordinary insight and he offered it freely to everyone. For example when writing a review in praise of Boltzmann he speculated on the nature of gravity, to the effect that it was probably a change in the structure of the ether, what we would just call space today, produced by the presence of matter. Another example: when asked what would happen when velocity exceeded the speed of light and the already familiar expression in maxwellian theory—square root of one minus v over c squared—ceased to exist as a real number, he said that it might well be that the velocity of light was the limit to the velocity of a body. And so on.

He was the acknowledged leader of an international team—what we would today call an invisible college—calling themselves the Maxwellians—the subject of Hunt’s splendid book. So unlike Kelvin he was a devoted and visionary disciple of Maxwell. The Maxwellians included Oliver Lodge, Joseph Larmor, Oliver Heaviside, and Heinrich Hertz, with others such as JJ Thomson on the fringes. Hertz in particular complained that Maxwell was



of funds for science. "A company can be promoted with a capital of a hundred thousand pounds for almost any conceivable object, but it is quite hard to get ten or twenty to try experiments. I look forward to the time when eager capitalists and energetic government departments will importune inventors to be allowed to work out their discoveries." One cannot escape the conclusion that the fault lay partly with himself, and he recognised his own tendency to flit around from topic to topic: "I admire from a distance those

◀ Applied physics:
Fitzgerald prepares
to fly the Lillenthal
glider before his
admiring students.

who contain themselves till they worked to the bottom of their results but as I am not in the very least sensitive to having made mistakes I rush out with all sorts of crude notions in hope that they may set others thinking and lead to some advance."

not readily accepted by conservative German physicists, so he eagerly joined the list of Fitzgerald's correspondents.

Fitzgerald above all others saw the full, dramatic implications of Maxwell's theory, as redrafted by the extraordinarily eccentric and self-effacing Oliver Heaviside and others. (It was Heaviside that first wrote Maxwell's Equations, not Maxwell himself, and his contributions went largely unrecognised, because of his reclusive nature. Fitzgerald, although he had met him only once, was responsible for getting him a state pension to save him from poverty, by petitioning the Prime Minister.)

He still felt some need for some interpretation of the nature of the ether, even though he expressed the hope that a material ether could be dispensed with. So he built a mechanical model to show how Maxwell's theory worked in the ether. Alas, my Department seems to have lost this precious icon in the 1950's: I still harbour a faint hope that it may turn up.

In one of his most significant insights, Fitzgerald foresaw the generation of electromagnetic waves of longer wavelength than light by electrical circuits, publishing a characteristically brief note on this. When, some years later, Hertz announced his experimental results, Fitzgerald was exultant (although he must have felt foolish for not doing such an experiment himself)

He described the achievement of the young German to the British Association on 1888.

It was a great step in human progress when man learnt to make material machines,

When he used the elasticity of his bow and the rigidity of his arrow to provide food and defeat his enemies,

It was a great advance when he used the chemical action of fire: when he learnt to use water to float his boats and air to drive them: when he used artificial selection to provide himself with food and domestic animals.

For two hundred years he has made heat his slave to drive his machinery.

Fire, water, earth and air have long been his slaves; but it is only within the last few years that man has won the battle lost by the giants of old, has snatched the thunderbolt from Jove himself, and enslaved the all-pervading ether.

Unlike Kelvin, Fitzgerald never quite got down to consistently applying his insights, as in this instance. He complained bitterly about the government's ignorance and inappropriate application

He really should have played a greater part in the development and commercial exploitation of radio, especially since Marconi did such crucial work in Ireland. It may have been the intense hostility of the Maxwellian Oliver Lodge towards Marconi that kept Fitzgerald out of the action. I had intended to admit to you frankly at this point that Marconi was certainly *not Irish*, but to my surprise I find that he was, or at least almost so, for he was the son of an aristocratic Irish lady and married another one!

But there is no hint of jealousy in his praise of Kelvin's success in Fitzgerald's praise for him on the 50th anniversary of his professorship:

"He has advanced civilization by making the all-pervading ether available to us, by enabling us to measure its properties, and by teaching us how to lay the nerves of civilization in the depths of the oceans. He has helped to unify humanity, to modify competition by co-operation, to push forward the federation of the world."

There is a hint here of his strong sense that science has a positive moral content. Here he is again, in a speech in which he advocated the setting up of industrial laboratories, not to be governed by the decisions by "mere officials" but by scientific advisers in touch with scientific advance and enthusiastic believers in it.

"Hope is the great incentive to exertion. Without it a nation is dead. Without it we lose all belief in the possibility of improvement, and improvement at once becomes impossible. The history of electrical engineering, the utilization of the all-pervading ether for the service of man, should strengthen our hope and belief in the possibility of improvement. For has it not revolutionized society and enabled high and low, rich and poor to lead better lives, by making life less hard and grimy, and this improved the well-being of man both materially and, what is more important, morally as well?"

This confident sense of the power for their work for the common good, founded on traditional religion reconciled with science, is another symmetry between the two. Differences of personality and circumstances led to one being highly successful in realising the direct applications of science, and the other not. Both deserve to be better recognised: their lives demonstrate the value of "useless" studies.

References

Lord Kelvin Demonstrated, J T Lloyd, The Physics Teacher, January 1980, 16-24

Kelvin the Man, A G King, Hodder and Stoughton, London 1925

Creators of Mathematics: the Irish Connection, ed K Houston, University College Dublin Press, 2000



NANO 2002: 10th Anniversary

Andrey Bychkov, St. John's College, Oxford University

Last year at the 9th International Symposium on Physics and Technology of Nanostructures, St. Petersburg, Russia (see EPN Sept/Oct 2001, p. 186), the organizers promised they would hold the following Symposium on a boat. They kept their word; the 10th Anniversary Symposium was essentially a 3-day tour on board the Kronstadt, a snow-white four-deck ship going along the rivers and lakes of northern Russia stopping only at Kizhi, Valaam, Svirstroy, places of genuine history and faith hidden amid the woodlands of Karelia. This was the backdrop to three long days in June, when it never gets dark, spent exchanging ideas on physics and life in general.

It was not just a leisurely journey though. When Zhores Alferov, Physics Nobel Prize 2000, wished in his opening speech that the boat escape would help us better concentrate on work, I guess I knew what he meant: there would be physically no escape from work. The following speaker Klaus von Klitzing, Physics Nobel Prize 1985, who reviewed the physics and applications of the Quantum Hall effect, immediately set the pace. The last of the three talks in the Opening Session was by Gerhard Abstreiter, Technical Univ. Munich. The subject of his presentation, the control of charge and spin in novel semiconductor nanostructure devices, defined very well the scope of this Symposium.

Overall, there were about 170 contributed reports covering virtually all aspects of nanostructure physics and technology. In the following, I would like to briefly touch upon just some of them, which I found particularly fascinating.

Pierre Petroff, Univ. of California at Santa Barbara, gave a very comprehensive account of semiconductor self-assembled quantum dots. Fabricated by lattice strain engineering, the dots can be either grown randomly or positioned in a lattice having one or a few dots in a primitive cell. Their optical properties can be accurately tuned by an appropriate choice of materials. Once this has been done, a variety of quantum dot applications open up. The ones realized by the researchers include a long-time (up to a minute) optical storage device, a single-photon source, and a spin-injection light-emitting diode.

Optical memory in self-assembled quantum dots was also covered in a talk by Christian Kapteyn, Technical Univ. Berlin. The operation principle of the memory device is based on the fact that in InAs/GaAs quantum dots, the thermal activation energy of

electrons (80-90 meV) is considerably smaller than that of holes (160-250 meV). At the write-in stage, one excites a biased quantum dot with a resonant photon. At a certain temperature, the electron of the generated electron-hole pair escapes, whereas the hole remains in the dot. The readout is implemented by switching off the bias; the electron relaxes into the dot and recombines with the hole emitting a photon back. The storage time is hence limited by the hole retention time in the dot, which in InAs/GaAs at room temperature is only a few picoseconds. Whether it can be improved in a different material is subject to further study.

◀ The Kronstadt: venue of the Symposium.

Irina Yugova, St. Petersburg State Univ., presented work on a gateable spin memory in InP quantum dots. Intrinsic doping of the quantum dot sample changes the electron content of the conduction band, which can be further varied by an applied electric field such that only one excess electron occupies each dot. If the dot is then excited quasi-resonantly, a complex system of two electrons and one hole – called a trion – is formed. The researchers have found in this case a long-lived circularly polarized component in the photoluminescence that was virtually time-independent within the span of the recombination lifetime (about 1 ns). The amplitude of the long-lived component, however, rapidly decreased with voltage and vanished at the negative voltage when the dot becomes neutral. The proposed explanation of the effect has to do with the fact that only one of the two electrons in the trion is spin-correlated with the hole. In other words, the present excess electron ‘makes sure’ that only one circularly polarized optical transition takes place, but not the other, whereas both transitions are equally possible in a neutral quantum dot. The spin-memory device can be switched on and off by changing the gate voltage.

Alexander Chaplik of Novosibirsk Inst. of Semiconductor



▲ Professor Alferov and his wife enjoying the weather on deck.

Physics extended theoretically the conventional Aharonov-Bohm effect (e.g. oscillatory dependence of conductance in the loop on the amount of enclosed magnetic flux) to the excitons and trions in quantum rings and electrons in nanotubes. His analysis suggests that the Aharonov-Bohm effect occurs in these complex systems as well and may be observed in the case of excitons as oscillations of the binding energy with the universal period of the magnetic flux quantum.

Noboru Miura, Univ. of Tokyo, presented a magneto-optical and cyclotron resonance study of semiconductor nanostructures



▲ Professors von Klitzing and Eaves.

in very high magnetic fields. At fields of 100 T, the extension of the electron wavefunction is decreased down to 2.6 nm, which is smaller than the typical size of potential confinement in nanostructures. As a result of the shrinkage of electron and hole wavefunctions by the magnetic fields, the recombination time increases, the photoluminescence of the quantum dots experiences a red shift, as well as other effects. The generation of ultra-high pulsed magnetic fields (over 600 T) by destructive and semi-destructive techniques is interesting by itself. The speaker presented a video showing explosions well in the spirit of the Die Hard movies. I wonder what his next-door neighbours feel about the research.

Traditionally for the NANO Symposium, many talks were on lasers and optoelectronic devices. Connie Chang-Hasnain, Univ. of California at Berkeley, shared with us a new look at quantum dot devices and their enabling applications. Using the MEMS (Micro-Electro-Mechanical Systems) technology they have fabricated a cantilever a few tens of micrometers long, with a Bragg mirror of a few tens of microns in diameter at the end. Another mirror had been grown on the substrate, thus forming a Fabry-Perot cavity. The cantilever bends when a voltage is applied to the contact on its top, changing the air gap between the mirrors. The device was pumped with photons to realize a VCSEL (Vertical Cavity Surface Emitting Laser) with a fast tunable wavelength range of a few tens of nanometers.

The quite intense scientific program of the Symposium, with sessions starting at 9 a.m. and continuing sometimes till midnight, allowed for a more diverse content than the previous symposia. Many new topics were included in the program for the first time, like a report by Pulickel Ajayan, Rensselaer Polytechnic Inst., on the amazing growth architectures with carbon nanotubes, and one by Jan Schmidt of Univ. of Leiden on the spectroscopy of single light-harvesting complexes (used in photosynthesis to efficiently convert light into chemical energy.)

The section on quantum computing was more popular in comparison to the last year, too. Guido Burkard, Univ. of Basel, reviewed the field of spintronics and quantum information processing in nanostructures. His talk combined a brief tutorial on quantum information science and theoretical works of the group derived from the almost classic by now idea of Loss & DiVincenzo on quantum computations with electron spins in quantum dots.

The author of this article presented work carried out with Dik Bouwmeester, now at Univ. of California at Santa Barbara, on a single-photon quantum memory device based on a single quantum dot. Different to the memory devices mentioned above, the aim of our proposal is to store quantum states of single photons encoded in their polarization. Such a device would be extremely useful to realize a quantum repeater, an essential component of long-distance quantum communication schemes. The storage time would of course be limited by the coherence time of excitons in quantum dots. Paola Borri, Univ. Dortmund, reported it to

be 630 ps at 7 K, measured in InGaAs self-assembled quantum dots by a four-wave mixing technique. However, putting a quantum dot in a photonic bandgap environment might considerably extend the exciton lifetimes due to the effective suppression of the density of states around the emitter. Exciting developments in photonic bandgap crystals make us optimistic about this idea.



▲ A visit to the 18th century churches of the Kizhi ensemble.

Manfred Bayer, also at Univ. Dortmund, gave a talk on entangled exciton states in quantum dot molecules. These artificial molecules consist of two vertically stacked self-assembled InAs quantum dots separated by a GaAs barrier. When the width of the barrier was reduced to 5-8 nm, the carrier wavefunctions on the two dots started to overlap and the corresponding splitting of the photoluminescence peaks into bonding and anti-bonding states was observed. The researchers believe that the resulting tunneling of the optically generated electrons and holes between the two dots has produced entangled exciton states.

...everyone
from graduate
student to Nobel
Prize winner was
in the same boat

The three excursions to the orthodox monasteries on the way, the peaceful landscape, fresh air, and the inevitable jazz-band in the bar at night surely helped us digest the tremendous information flow and just feel great. The 10th Symposium on Nanostructures has been a big success, most memorable for the atmosphere created during the trip, when everyone from graduate student to Nobel Prize winner was in the same boat, discussing with each other.

Ten is a good number for an international conference in a new field. Now that it has come of age, let's wish the Symposium a smooth transition to its prime, which is certainly ahead in the future. Congratulations, and the best of luck to the organizers!

For more information, please refer to the Symposium website: <http://www.ioffe.ru/NANO2002/>

The photos of the Symposium can be found at: http://web.edu.ioffe.ru/photo_gallery/photos.php?theme=theme_01-07-02_16-58-33

euromphys news SEPTEMBER/OCTOBER 2002

Women and science in Europe

Teresa Rees, Cardiff University, UK

There is a growing interest across Europe in the issue of women and science. As economies rely increasingly on their human resources for competitiveness, then any waste or under-utilisation of skills and knowledge becomes a cause for concern.

A recent report published by the European Commission is a first attempt to quantify this issue, and to compare national policies on women and science (Rees 2002). It focuses on women 'getting in, getting on and getting up': identifying the pattern of attrition of women at each level of the academic hierarchy and exploring policies individual countries have developed that are designed to address the problem. Although 30 countries are covered in the report, there is an extraordinary consistency overall. Women appear to drop out of scientific careers in disproportionate numbers at every level—a phenomenon known as the 'leaky pipeline'.

The report arose out of the work of the 'Helsinki Group on Women and Science' (so-called because the first meeting of the Group took place in Helsinki in November 1999 during the Finnish Presidency of the European Union). The Group is made up of national civil servants and gender experts from the 15 member states of the European Union and 15 other countries associated with the Fifth Framework Programme of the European Community for research, technological development and demonstration activities (1998-2002). The latter are all candidate countries for membership of the EU, with the exception of Iceland, Israel and Norway. The meeting was convened by the Women and Science Unit of the Research Directorate of the European Commission, as part of its programme of activities designed to promote research on women, for women and about women. The Group has met twice a year since 1999 and is working on the harmonisation of statistics, the development of indicators and benchmarking national policies.

Inevitably there is considerable diversity among the countries in terms of scientific infrastructure, equality measures and the climate for women pursuing scientific careers. However, it is clear that there are also commonalities, most startlingly of all, the lack of women in decision-making positions about the development of science policy, and indeed among those that determine what constitutes 'scientific excellence'. This observation echoes the findings presented in the European Technology Assessment Network (ETAN) report *Science Policies in the European Union: Promoting excellence through mainstreaming gender equality* (Osborn et al. 2000), also commissioned by the Women and Science Unit of the Research Directorate. The ETAN report analysed the gender make up of research councils and other funding bodies, learned soci-

eties and prize-giving committees and found them universally to be overwhelmingly male dominated and not particularly transparent or open in their recruitment processes. Male scientific elites on these bodies tend to be self-perpetuating as a result of arrangements for succession rather resembling the closed shop. The more open the recruitment procedures, the more likely there will be at least some women in these top positions.

The Helsinki Group has acted as a prompt in some countries to the establishment of National Steering Committees on Women and Science to focus attention on these issues. Some of these committees cross Government Departments. They have become the focus for the development of policies of two kinds: positive action—to address specific blockages in the system, and gender mainstreaming—to integrate gender equality into all policies and processes, systems and structures.

Examples of positive action measures include supporting networks of women scientists, encouraging the development of role model and mentoring schemes and in a few cases establishing targets and quotas. There are a couple of examples of countries experimenting with earmarking funds for designated chairs for women, and research funds and prizes targeted at women. The establishment of chairs in areas of research that especially attract women, such as gender studies in particular fields, has balanced up the allocation of top positions along the spectrum of subjects.

Gender mainstreaming is the main strategic approach of the European Commission to promoting gender equality, alongside equal treatment legislation and positive action measures. It is specifically identified as such in the

Commission's Communication *Women and Science – Mobilising women to enrich research* (CEC 1999). However, it is an approach that is rather ill-understood! Nordic countries have made the most progress in implementing gender mainstreaming, but many of the mainstreaming tools, such as gender disaggregated statistics and equality indicators, gender impact analyses of policies and engendered budgets, are being increasingly used across the European Union and elsewhere.

One of the gender mainstreaming tools is a measure, sometimes legislation, to ensure a gender balance on public bodies. The stipulation is that both genders should constitute a minimum of 30% (or in one country 40%) of members of all public bodies. This legislation covers funding councils and in some countries, university and research institute academic and scientific committees. The Commission has committed itself to a 40% minimum for both genders on its own evaluation and monitoring committees. While this target has not yet been reached, the gender balance on its own committees has improved considerably and is approaching this target.

Some countries report on activities designed to 'modernise' human resource management practices in universities, practices that were described in the ETAN report as being 'medieval' in some countries. This has led to more transparency in recruitment and promotion processes, awareness raising and equality training and the use of gender mainstreaming experts to advise on gender proofing policies and practice. Measures to facilitate a better work life balance benefit men and women and are badly needed in universities where the long hours' culture is especially entrenched. Those more sophisticated human resource strategies that reward excellence, rather than the expenditure of time and longevity, will assist in this.

Women appear to drop out of scientific careers in disproportionate numbers at every level...

In a couple of countries there is a demographic crisis looming in the university sector as a consequence of expansion some years ago leading to a large number of retirements at the same time. Countries such as Germany faced with this demographic crisis are doing their utmost to attract back well trained scientists that have in effect been excluded from scientific careers as a consequence of taking a career break for raising children. There are many such scientists in the UK, unable to resume their careers. The Daphne Jackson Foundation helps some. In Germany, considerable resource is being expended in programmes to update the knowledge base of these women and ease them back into research.

The statistical work of the Helsinki Group has allowed for the first time comparisons of women in science across 30 countries. The technical appendix of the Helsinki Group report was prepared by Ruth Springham of Eurogramme and provides baseline, harmonised data for each country. This was an ambitious project, given the national differences in nomenclatures and definitions. It represents the beginning of a larger project involving Eurostat. As ever, it was particularly difficult to obtain data for scientists in the private sector, so most of the focus is on the public sector. The data show, as is well known, that women now constitute the majority of the undergraduate population in every country, but that patterns of gender segregation emerge by subject. Women are the majority of those enrolled for biological and medical scientists, but remain a minority in physics, engineering and some other disciplines. Most striking are the 'scissors' diagrams for each country, which plot the percentage of men and women through from undergraduate days to senior professorships. While women are the majority in the early years, they are a tiny minority as the top end. This scissors diagram was first produced using data for Germany in the ETAN report; however, the general pattern seems to hold across countries, even though the position of the cross over point of the scissors varies by country. Universally, then, the position of women in science remains 'the higher, the fewer'.

Gender Studies is a new field making a contribution to our understanding as to how social relations and institutions themselves are 'gendered'. It assists a better understanding of forms of direct but also indirect institutional sexism. The murder of Stephen Lawrence and subsequent Macpherson Report raised the public's awareness of how organisations could be 'institutionally racist', without individual people necessarily holding particularly racist views. The way in which systems and structures were designed in the Metropolitan police force led to racist outcomes. This is a similar phenomenon to 'institutional sexism'.

Contributions to our understanding of how women are, in effect, excluded from scientific careers are valuable and are coming from an increasing number of Helsinki Group countries. This has led to a more sophisticated understanding of the gendering of scientific networks, and indeed of science itself. What is commonly held to be 'gender neutral' is in fact often subtly sexist. This was revealed in the Wennerås and Wold article that appeared in *Nature* in 1997. It showed how members of the Medical Research Council in Sweden had rated men much more highly than women with the same objective 'excellence score' (rated by published papers etc). Patronage and

nepotism was found to be interfering with the workings of the peer review system. The board was sacked and procedures reviewed. Many other funding bodies have also reviewed their systems since this finding, one that was only made possible because of Swedish laws allowing public access to public records.

Gender Studies research has led to a more sophisticated understanding of what part patronage and nepotism play in the allocation of positions, whether it be appointments for jobs, membership of elite bodies or learned societies. It has also facilitated our understanding of the exclusionary mechanisms or 'chill factors' used by members of elite organisations to maintain the social characteristics of the existing membership. Significantly more resource is being made available under the Sixth Framework Programme for research in this area.

The Women and Science Unit is pursuing an ambitious programme of work in the field of women and science. As well as co-ordinating the activities of the Helsinki Group, it has recently published a series of reports that look at the gender dimension of research in the Fifth Framework Programme. The reports show that too often the gender dimension is ignored, threatening the validity of the research. The Unit has also set up two more ETAN projects—one on women and science in the private sector—and one on women and science in the Eastern European candidate countries. The Sixth Framework Programme will be characterised by much more attention to the gender dimension—among people involved in vetting the applications—and in the research that it funds. All this activity should assist women to make a larger contribution to the development of science, and science to offer better careers to women.

References

- Commission of the European Communities (1999) *'Women in Science': Mobilising with the same objective score* (rated by published papers etc.) *Women to Enrich European Research* COM (1999) 76 final, Communication from the Commission, Luxembourg: Office for Official Publications of the European Communities
- European Commission (2002) *Proceedings of the European Commission Gender and Research Conference held in Brussels 8th and 9th November 2001* Luxembourg: Office for Official Publications of the European Communities
- Osborn, M., Rees, T., Bosch, M., Ebeling, H., Hermann, C., Hilden, J., McLaren, A., Palomba, R., Peltonen, L., Vela, C., Weis, D., Wold, A., Mason, J. and Wennerås, C. (2000) *Science Policies in the European Union: Promoting excellence through mainstreaming gender equality*. A report from the ETAN Network on Women and Science, Luxembourg: Office for Official Publications of the European Communities
- Rees, T. (2002) *The Helsinki Group on Women and Science: National Policies on Women and Science in Europe* Luxembourg: Office for Official Publications of the European Communities
- Wennerås, C. and Wold, A. (1997) 'Nepotism and sexism in peer review', *Nature* 347, pp. 341-3.
- The European Commission documents can be downloaded from the European Commission's Research directorate women and science website: <http://www.cordis.lu/improving/women/documents.htm>

About the author

Teresa Rees is a Professor in the School of Social Sciences, Cardiff University and an expert adviser to the European Commission's Research Directorate.

The Johann Bernoulli globe electrical machine

Henk Kubbinga, University of Groningen.

As part of a non-classical program in the history of science, several interesting if not crucial experiments have been replicated at the University of Groningen. In 1996, for instance, on the occasion of the 75th anniversary of the Netherlands Physical Society and the 50th anniversary of the Dutch Foundation for Fundamental Research on Matter, Newton's optical *experimentum crucis* (1672) has been staged. The general idea behind these replications is to generate scientific conviviality and inspiration for the hard nosed physicists and their students, and serious entertainment for the laymen public.

Recently we finished the construction of a replica of a so-called globe electrical machine, which, in the beginning of the 18th century, opened the era of the generators of controlled static electricity. Later in that century, the globe became a cylinder and, finally, a circular plate (or a combination of the latter). Early in 1706, Francis Hauksbee Sr. demonstrated before his fellow members of the Royal Society, at Gresham College (London), what came to be known as an *electrical machine*, since it produced at will evidently electrical sparks among many other mysterious light effects. Hauksbee had been reworking experiments made, in 1700 and 1701, by the Swiss Johann Bernoulli (1667-1748) at the University of Groningen and reported, by Pierre Varignon, in

the *Mémoires* of the *Académie royale des Sciences*. Bernoulli had studied the light effect in the vacuum part of a mercury barometer, which can be observed when the barometer is shaken, e.g. during transport from one place to another. Not all barometers showed this effect and Bernoulli was quick to notice the importance of using pure mercury. In the process, he developed techniques to purify the mercury by washing with water (or alcohol) and subsequently drying by filtering through thick packs of linen. During the filling of the barometer, the mercury should not be dripped or poured into the tube: the contact with the air

The general idea... is to generate scientific conviviality and inspiration for the hard nosed physicists... and serious entertainment for the laymen public.

was such as to contaminate it immediately to a serious degree. Instead, it should be sucked up in an open tube, which is closed afterwards. The barometer of the beginning became an exhausted phial, that is: a long necked globe of thick glass, in which the mercury could be shaken around. The luminescence now became a continuous one. Bernoulli thought he had found a perpetual phosphorus, a perpetual light: one of his phials with mercury indeed worked for more than a year. In 1704-1705, Hauksbee reopened

the case where Bernoulli had closed it. Mercury wasn't an essential ingredient, he noticed: pieces of amber had the same effect. Shaking heavy phials with mercury wasn't otherwise that easy and Hauksbee developed an apparatus to facilitate that: an exhaustible glass globe, hanging in two forks and made to rotate around an horizontal axis by a crank or a multiplying wheel, some-what like a spinning wheel. Soon it turned out that neither mercury nor amber was necessary: dry open hands, held closely around the rotating globe sufficed to produce the purple-violet lighting effect. Sheep skin, too, appeared to have that effect, that is to say: the wool side. In admitting air to the globe, the luminescence gradually disappeared, and once at atmospheric pressure, sparks showed up, on the outside, between the hands and the globe. The electrical machine was born.

Our replica, in 18th century style (walnut, ebony, guaiacum and ashwood) and with a glass globe (diameter about 20 cm; with a cock) especially blowed for the purpose, indeed manifests the effects (hands, sheepskin) reported by Hauksbee in *Philosophical Transactions* 25 (307) 2277-2282 (1706/07). The experiments were made at room temperature, the pressure in the globe at optimum being about 10 mbar; a perfectly dark room is necessary. The effects have been shown on 24 June, 2002, on Dutch television, in the science program *Flogiston* of Wim T. Schippers (and Rob van Hattum).

Acknowledgement

I would like to thank Hendrik de Waard for his kind comments during the try outs.



The Bernoulli globe electrical machine and an engraved portrait of Johann Bernoulli (1743). In the background, from left to right: Henk Broer (mathematics; standing), Professor Emeritus Folkert van der Woude (physics; sitting left) and Henk Kubbinga (history of science).

[Photo: Reyer Boxem]

EPS-12 General Conference 'Trends in Physics' held in Budapest

M.C.E. Huber and C. Rossel

During the last week of August, 463 physicists from 41 countries took part in the 12th General Meeting of the EPS to review recent developments and future trends in physics and its multi-disciplinary applications in science and technology. In order to establish new links with the next generation of physicists, EPS12 was organised to overlap for two days with the 17th International Conference of Physics Students (ICPS2002). Thus about 200 physics students could meet and exchange ideas with their physicist colleagues. In particular, the second day of EPS-12 was scheduled as 'Young Physicists' Day' and devoted to oral presentations by the authors of prize-winning posters of the student conference.

The EPS-12 programme consisted of 21 plenary talks of general interest, twelve topical symposia and two poster sessions. For the first time in the history of the EPS conferences, a large part of the presentations was transmitted in real time through the internet, as a so-called EUROTRON conference. The transparencies and electronic presentation files shown during the plenary sessions will be accessible online at: www.eps12.kfki.hu/eurotron/.

In the opening talk, the Cecil Powell Memorial Lecture, Dennis Weaire (Trinity College, Dublin) discussed 'The value of useless studies' (see page 170), with reference to two famous Irish physicists, Lord Kelvin and George Francis Fitzgerald. Indeed, while often criticised by the public or politicians, so-called 'useless' studies have occasionally opened the way to major breakthroughs, such as wireless communication, that changed our world dramatically. The subsequent plenary talks were devoted to several key areas of contemporary solid-state physics, including semiconductor heterostructures, quantum cascade lasers, quantum dynamics of nanomagnets, spintronics and photonics. Modelling of collective human behaviour, social dynamics and crowd control also raised great interest in the audience.

In the second half of the week, reviews on gravitational physics and on the origin of cosmic rays preceded talks about deconfined nuclear matter, on nuclear and on fusion issues. In the morning of the last day, the participants listened to presentations of results from high-energy experiments, both in high-density plasmas and with elementary particles, and these were followed by a lecture on physics in Latin America. The afternoon then brought reviews on quantum interference and on many other, laser-induced quantum effects. In the concluding lecture, given in honour of the centennial of Eugene Wigner's birth, L. Tisza pondered the legacy of this renowned Hungarian physicist.

In the General Meeting of the society members, EPS President Martial Ducloy spoke on the state of the Society and, in particular, gave an outlook on the 'World Year of Physics 2005'. He also attributed the Gero Thomas Memorial Medal to E.W.A. Lingeman for his many valuable contributions to EPS. In the course of EPS-12 various other awards and prizes were attributed such as the prestigious Agilent Technologies Europhysics Prize, the EPS Public Understanding of Physics Prize and the newly created EPS-BPU Prize for Environmental Physics, to mention a few (see list of laureates at www.eps.org). As a new initiative in the history of EPS

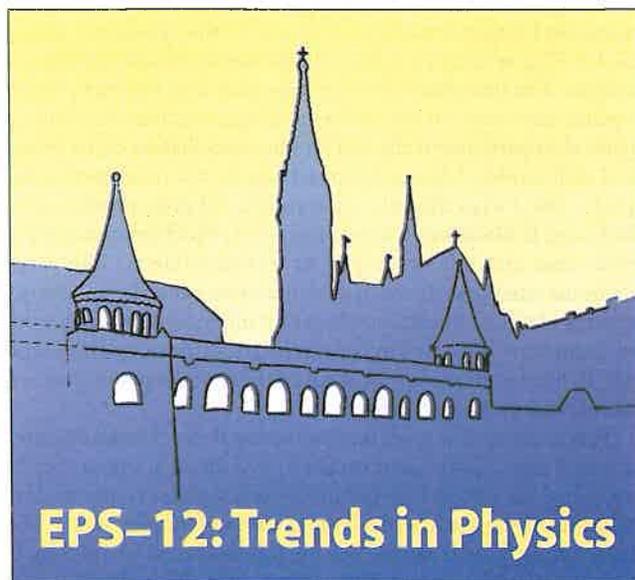
conferences, a well attended round table discussion about the future of European Research and Development took place on the second day. The panel of experts debated on questions related to

- Teaching of physics in schools and public understanding of physics,
- Large-scale experiments and large-scale research facilities,
- Globalisation of science,
- The future of physics publications (electronic publishing), and the
- Promotion of the European Research Area.

On the leisure side, it is worth mentioning the wonderful organ concert organised in the Matthias Church on the castle hill of Budapest. An excursion to a horse farm out in the puszta as well as the conference dinner in the Stefánia Palace provided relief from the intense sessions, and offered ample opportunities for social and informal professional interactions among participants.

The exciting scientific programme on 'Trends in Physics' was prepared by an International Programme Committee chaired by Norbert Kroó (Hungarian Academy of Sciences, Budapest); and the entire event was impeccably organised by an international Organising Committee under the indefatigable leadership of Denes L. Nagy (Roland Eötvös Physical Society, Budapest). They and their colleagues from the local organising committee deserve our warmest and heartfelt thanks for hosting such a stimulating meeting, which brought together young and established physicists!

As announced in the closing ceremony, the next general conference EPS13 will take place during 2005—the World Year of Physics in Bern, Switzerland, for the centennial celebration of Einstein's "annus mirabilis".



Lise Meitner Prize 2002

Wolfram von Oertzen,
Chairman of the Lise Meitner Selection Committee

The European Physical Society announces that the Lise Meitner Prize 2002 is awarded to Prof. James Philip Elliott, University of Sussex (UK) Prof. Francesco Iachello, University of Yale (USA) for their innovative applications of group theoretical methods to the understanding of atomic nuclei.

The physics case

The study of the discrete energy spectra of small quantum systems relates to fundamental symmetries in nature. These symmetries determine the "conserved quantities" describing the intrinsic properties of such systems and are needed in quantum mechanics to characterize the state of a system.

Symmetries in nuclei have played a dominant role in the development of the understanding of fundamental properties of

matter. Energy spectra of atomic nuclei reflect symmetries related to the properties of the two fundamental building blocks, the proton and the neutron, which carry a half integer spin and are thus characterized by the symmetries of fermions.

The special mathematical tool needed to describe symmetry in quantum systems is known as group theory. The symmetry of the nuclear force under rotations in spin and in isospin has led to the introduction of an even larger symmetry group (SU(4), intro-

duced by E. Wigner (Nobel Prize, 1963). The major contribution of J. P. Elliott in this field, came in the 1950's. It provided an understanding of the structure of the spectra of light nuclei in terms of an underlying symmetry, expressed by the symmetry group SU(3). This symmetry reflects the dynamics of a many fermion system. The introduction of this method into nuclear physics opened new ways to the understanding of nuclear structure in general, in particular it allowed for the reconciliation of the spherical shell model of Maria Goeppert-Mayer and H. Jensen (Nobel prize, 1963) with the collective and liquid drop models of A. Bohr and B. Mottelson (Nobel Prize, 1975) which existed as separate and distinct descriptions of the nucleus. The work demonstrated that dynamical symmetries occur in the energy spectra of nuclei, a concept which also influenced the early work of elementary particle physics on the structure of hadrons, and which has led to the application of these concepts in nuclear, atomic and molecular physics.

Following up this work the Interacting Boson Model or Interacting Boson Approximation (IBA) was the next major step in applying the concept of dynamical symmetries to the understanding of the spectra of a large number of atomic nuclei. The Interacting Boson Model has been introduced in 1975 by F. Iachello in collaboration with A. Arima of the University of Tokyo,



▲ The Lise Meitner Prize 2002 recipients, Professor James P. Elliott (left) and Professor Francesco Iachello (right).

both at that time at the Kernfysisch Versneller Instituut (KVI) in Groningen (Netherlands). In this model, nuclear structure is described in terms of degrees of freedom involving subunits of integer spins (bosons). The concept of dynamical symmetries used in these studies is based on the fact that a symmetry may be broken in such a way as to lift the degeneracy in the energies but not alter the wave functions. A combination of the fermion and the boson degrees of freedom has led to the introduction, by F. Iachello, of super-symmetry in nuclei which recently has been confirmed experimentally. Dynamic symmetries have also been applied by him, in the fields of elementary particle physics and molecular physics.

The description of nuclear structure based on the concepts, introduced by the two laureates, continues to play a pivotal role in the present nuclear structure studies in which large g-detector arrays like EUROBALL and Gammasphere are used. These concepts will be very important in the future studies of the newly accessible region of exotic nuclei (proton rich $Z \gg N$, or very neutron rich $N \gg Z$), when a new generation of radioactive beam facilities become operational.

For general public, Refs.:

- R. Casten and W. Feng, Phys. Today 11 (1984) 26
- Physics World, October 1999, p. 19; August 2001, p. 24
- J.P. Elliott, J. Phys. G 25 (1999) p.77

Symmetries in nuclei have played a dominant role in the development of the understanding of fundamental properties of matter.

noticeboard

Constitutional review

The Constitutional Review Working Group met during the EPS General Meeting in Budapest. Many important issues were discussed, including creating a category of student members and opening membership to other European Learned Societies. The Group is to prepare a report for the Executive Committee, and for Council. If you have any ideas on how to improve the EPS constitution, please let us know.

IAPS in Mulhouse

The International Association of Physics Students at its General Assemblée adopted statutes and by-laws to establish its permanent headquarters in Mulhouse. For the past three years, IAPS has had its postal address at the EPS. Now it will officially be co-located in Mulhouse.

Framework Programme 6

The FP6 Working Group met during the EPS General Meeting in Budapest. The Working Group was established to provide information and advice on FP6 to the Executive Committee and to EPS members. The Working Group will be advising on the most relevant web links for understanding FP6 and for obtaining information on calls, as well as trying to obtain call texts prior to publication for EPS comments. EPS Divisions and Groups will also be asked to provide their input on how the EPS could be most effective at the EU.

HEPP Public Outreach Prize

The EPS High Energy Physics Outreach Prize 2002 has been awarded to Professor Michael Kobel (Germany) for his work in bringing high energy particle physics into schools in Germany. In particular he has worked directly with educators to introduce particle physics into the curriculum, both through the creation of new materials and the imaginative use of concepts developed in other European countries. He has also been instrumental in promoting activities such as master classes.

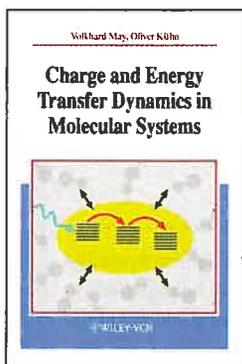
Agilent Technologies Prize

Nominations are open for the 2003 Agilent Technologies Europhysics Prize. The prize shall be given in recognition of a recent work by one or more individuals in the area of physics of condensed matter, specifically work leading to advances in the fields of electronic, electrical and materials engineering. The award may be given for either pure or applied research at the discretion of the Society. Only complete nominations will be considered. For a nomination to be complete, it must include:

- a complete CV
- a publication list (not more than 5 pages)
- an indication of the three most relevant papers to the nomination
- a description of the work justifying the nomination (up to 2 A4 pages)
- a suggested short citation

The deadline for the receipt of nominations is 15 October 2002. Nominations should be sent to David LEE, EPS, 34 rue Marc Seguin, BP 2136, 68060 Mulhouse Cedex, France, to the attention of the Agilent Technologies Europhysics Prize Selection Committee. Please keep your nomination confidential. Proposals will be acknowledged but not followed by any further correspondence.

BOOK REVIEWS



Charge and Energy Transfer Dynamics in Molecular Systems

Volkhard May, Oliver Kühn
Wiley-VCH, 2000
416 pages

The book gives an introduction to the conceptual and theoretical basis of an interdisciplinary field of research: charge and energy transfer processes in molecular aggregates, which play a role in physics, chemistry and biology. According to this goal, the first three chapters give an introduction to the conceptual and theoretical background of the field. After an introductory chapter, in chapter 2 electronic and vibrational molecular states are discussed. Chapter 3 gives the basis for the description of the dynamics of isolated and open quantum systems. Beginning with the description of time dependent processes in the framework of the Schrödinger equation, the density operator and on the basis of the projection operator formalism the reduced density operator, the quantum master equation and various approximations are introduced. Using these concepts, in the following chapters several applications are discussed. Chapter 4 considers the relaxation and redistribution of vibrational energy. Intramolecular electronic transitions are the subject of chapter 5. Here electronic transitions in connection with the emission and absorption of light and internal conversion are discussed. Chapter 6 is devoted to the electron transfer. After a classification of electron transfer reactions, theoretical models are presented and applied to the electron transfer in donor-acceptor complexes. Furthermore the nonadiabatic electron transfer in polar solvents and the photoinduced ultrafast electron transfer are discussed. This chapter concludes with some generalizations of the theoretical treatment of electron transfer. In addition to electron transfer, also proton transfer plays a very important role in various fields in biology, chemistry and physics. Because protons behave in many respects as quantum particles, in chapter 7 on proton transfer, the differences and similarities to electron transfer are worked out putting in this way the proton transfer in the general context of the book. The theory for the energy transfer via excitons shows also many formal similarities to the electron transfer theory. After the discussion of the Hamiltonian of the problem and the optical absorption of excitons, in chapter 9 first the incoherent exciton transfer is discussed on the basis of the Förster transfer rates. Then the general problem is treated in the framework of density matrix theory. In the concluding chapter a personal outlook of the authors on future developments is given. The book has more than 400 pages and 100 figures. Despite the considerable volume some - in the opinion of the referee - important aspects are missing. In connection with the discussion of experimental results, the Green's function method plays a wide spread role and in a future edition the discussion of the connection with the briefly mentioned correlation function method would be desirable. Furthermore, most of the present theoretical research work in connection with electronic degrees of freedom is formulated in terms of second quantization. Students starting

to work in this field should get some acquaintance with it. Triplet states should also be discussed more extensively and in that connection the information derived from spin resonance, which plays a major role in various aspects of the field, should not be missed. Another aspect, which could be improved, is the way in which references are treated in the text. There is a section on "Suggested Reading", but the relation with the text or in the opposite direction is not easily recognized.

Apart from these minor points which might be improved in a following edition and taking into account the subtitle "A Theoretical Introduction", the book represents a useful introduction into the field of charge and energy transfer dynamics in molecular systems. I am convinced that it is well suited for students of physics after they have learned quantum mechanics. Students of chemistry might have some problems and this holds even more for students of biology. Besides for students the book might also be of interest for researchers in the field for a fast brush up of basic knowledge.

Peter Reinecker, Ulm University, Germany

Books for review

From Semiconductors To Proteins : beyond the average structure

S.J.L. Billinge, M.F. Thorpe, *Kluwer Academic/Plenum Publ*, 2002, 287 pages

Information And Measurement (Second Edition)

J.C.G. Lesurf, *IOP Publishing*, 2002, 295 pages

Introduction To Dusty Plasma Physics

P.K. Shukla, A.A. Mamun, *IOP Publishing*, 2002, 270 pages

Introduction To Mesoscopic Physics (Second Edition)

Y. Imry, *Oxford University Press*, 2002, 236 pages

Matter & Interactions. Modern Mechanics (Vol. I)

R. Chabay, B. Sherwood, *Wiley*, 2002, 432 pages

Matter & Interactions. Electric and magnetic interactions (Vol. II)

R. Chabay, B. Sherwood, *Wiley*, 2002, 936 pages

Nano-Physics & Bio-Electronics : a new Odyssey

T. Chakraborty, F. Peeter, U. Sivan, *Elsevier*, 2002, 354 pages

Semiconductor Spintronics And Quantum Computation

D.D. Awschalom, D. Loss, N. Samarth, *Springer*, 2002, 311 pages

Silicon Wafer Bonding Technology for VLSI and MEMS Applications

S.S. Iyer, A.J. Auberton-Hervé, *IEE - INSPEC (EMIS Processing Series n°1)*, 2002, 149 pages

If you are interested in reviewing one of the above books, or in receiving books for review in general, please send us name, and contact co-ordinates, along with the your field(s) of specialisation to:

Book Reviews, EPS Secretariat
BP 2136, 68060 Mulhouse Cedex, France

europysics news recruitment

Contact **Susan Mackie** • EDP Sciences • 250, rue Saint Jacques • F-75005 Paris • France
Phone +33 (0)1 55 42 50 51 • fax +33 (0)1 46 33 21 06 • e-mail mackie@edpsciences.org

Call for proposals 2003

LURE : Synchrotron Radiation Laboratory - France

Description of the facility

LURE is one of the biggest European facilities dedicated to the use of Synchrotron Radiation (SR). It has two storage rings, DCI and SUPER-ACO and a linear accelerator which provides positron beams for filling both machines. DCI produces x-rays in the energy range 2-50 KeV, thanks in particular to a superconducting wiggler. In SUPER-ACO radiations are available from far infrared to soft x-rays (5 KeV).

Some 40 experimental stations, 20 on each ring, can be operated simultaneously. Most SR applications are possible with a special emphasis on molecular and atomic physics, surface sciences, absorption spectroscopy, diffraction and biology.

A special feature of LURE is the important use of the beam temporal structure at SUPER-ACO which operates 50% of the time in the two bunch mode.

SUPER ACO operates in average 4 days a week with a total of about 165 days per year. The corresponding figures for DCI are 5 days a week, 170 days per year.

Support of researchers from non French EU Member Countries and Associated States*

When a project has been accepted, the LURE, under the EC-program for the Access to Large Scale Facilities, can reimburse per diem expenses, under the following conditions : a researcher given access to the Facility is eligible to receive reimbursement of expenses, excluding travel, if he is normally working in one of the Member States of the Community or Associated States*.

Call for Proposals

Scientific experiment proposals are selected once per year by peer review panels (named programm committees by LURE) on the basis of scientific excellence.

For the experiments to be performed in 2003 proposals must be submitted by : **December 1st, 2002**

on forms which can be obtained (as well as general informations) from :

<http://www.lure.u-psud.fr>

PROJETS 2003

More information for applications can be obtained at

Laboratoire LURE

Centre Universitaire Paris-Sud

Bât. 209 D - B.P. 34

91898 ORSAY Cedex

Tel. 33 (0)1 64 46 80 14 - Fax. 33 (0)1 64 46 41 48

email. projets@lure.u-psud.fr

Overview

So far, and thanks to successive programs from the European Commission for the access to large scale facilities, scientists from the European Union (EU) Member States have completed more than 600 experiments at LURE.

* Associated countries include Bulgaria, Republic of Cyprus, Czech Republic, Estonia, Hungary, Iceland, Israel, Latvia, Liechtenstein, Lithuania, Norway, Poland, Romania, Slovakia, Slovenia.



General Director of SRON

The **Space Research Organization Netherlands SRON** is the National Institute for space research. SRON develops and exploits state-of-the-art instrumentation for front-line astrophysical and earth-oriented space research. SRON's leading role in the scientific utilization of space is based on a synergetic combination of in-depth knowledge of the science drivers, cutting-edge technologies for instrument development and system level know-how for payload procurement.

SRON is widely recognized as one of the leading institutions in Europe in its field. It has a long and successful track record of numerous scientific instruments on science satellites for ESA, NASA and other space agencies. SRON collaborates closely with universities, research institutes and industry, in the Netherlands and abroad.

The National Institute has establishments in Utrecht and Groningen, over 200 employees and a yearly budget of approximately € 15 million.

SRON is part of the Netherlands Organization for Scientific Research NWO.

Job description and requirements

- You are expected to initiate, stimulate and lead SRON's space research programme at the frontiers of science and technology. This demands a scientific stature on the level of a professorship in one of the relevant scientific or technical disciplines in combination with first-rate management skills. A solid understanding of device and instrument physics is a prerequisite, with demonstrated ample international experience in experimental (space) research.
- On the basis of a clear division of tasks between you and the Deputy Director, you are responsible for the integral management of the institute. You think strategically, have a visionary view on space research and possess initiating and diplomatic qualities in order to turn this vision into a coherent and feasible long-term research programme.
- You are expected to operate in a complex and varied national and international network. You have proven capabilities to build, maintain and productively use such network in an effective way. You represent SRON at its main stakeholders such as NWO, ESA, universities, industry and the ministry of Education, Culture and Science.
- You will report and be accountable to the Board of SRON.

Employment conditions: This is a full-time position. You will be employed by NWO. The initial appointment will be for five years with the possibility of reappointment.

The salary will be in agreement with the level and the responsibilities of the position. NWO offers excellent fringe benefits.

Information: For more information on SRON and the function of General Director of SRON, see www.sron.nl, where a full job description can be found.

Additional information can be obtained from Dr A.P.M. Baede, chairman of the SRON Board. (Tel +31 30 231 5292 e-mail: fons_baede@hetnet.nl).

Application: A letter of application including a full curriculum vitae should be sent to: Mr. W.G. Sillevius Smitt, Head of Personnel Office of NWO, P.O. Box 93138, 2509 AC The Hague, The Netherlands.

The closing date for applications is October 11, 2002.



Materials Research Society Spring Meeting Announcement &

call for papers

ABSTRACT DEADLINES

OCTOBER 18

for abstracts sent via fax or mail

NOVEMBER 1

for abstracts sent via the MRS Web site

LATE ABSTRACTS WILL NOT BE ACCEPTED.

CONTACT INFORMATION



Materials Research Society

506 Keystone Drive
Warrendale, PA 15086-7573 USA

Tel: 724-779-3003

Fax: 724-779-8313

(general)

724-779-3030

(abstract submittal)

E-mail: info@mrs.org

2003 MRS SPRING MEETING • APRIL 21-25, SAN FRANCISCO, CA

The 2003 Materials Research Society Spring Meeting will be held April 21-25, 2003, in San Francisco, California, at the San Francisco Marriott and Argenta Hotels. The meeting will include 25 symposia that highlight new advances in the understanding, synthesis, and application of materials in diverse fields.

SCHEDULED SYMPOSIA

ELECTRONIC AND OPTICAL MATERIALS

- A: Amorphous and Nanocrystalline Silicon-Based Films—2003
- B: Compound Semiconductor Photovoltaics
- C: New Applications for Wide-Bandgap Semiconductors
- D: CMOS Front-End Materials and Process Technology
- E: Materials, Technology, and Reliability for Advanced Interconnects and Low-k Dielectrics
- F: Chemical-Mechanical Planarization
- G: Integration of Heterogeneous Thin-Film Materials and Devices
- H: Flexible Electronics—Materials and Device Technology
- I: Optoelectronics of Group-IV-Based Materials
- J: Microphotonics, Nanophotonics, and Photonic Crystals

MOLECULAR MATERIALS AND BIOMATERIALS

- K: Molecular-Scale Electronics and Optoelectronics
- L: Organic and Polymeric Materials and Devices
- M: Nanotube-Based Devices
- N: Biomicroelectromechanical Systems (BioMEMS)
- O: Materials Inspired by Biology

NANOSTRUCTURED MATERIALS

- P: Self-Assembled Nanostructured Materials
- Q: Unconventional Approaches to Nanostructures with Applications in Electronics, Photonics, Information Storage, and Sensing
- R: Nanomagnetism
- S: Nanoscale Thermal Transport—From Fundamentals to Devices
- T: Nanostructuring Materials with Energetic Beams
- U: Mechanical Properties Derived from Nanostructuring Materials

GENERAL

- V: Semiconductor Spintronics II
- W: Multiscale Phenomena in Materials—Experiments and Modeling Related to Mechanical Behavior
- X: Frontiers of Materials Research
- Y: Advanced Optical Processing of Materials
- Z: Mechanisms in Electrochemical Deposition and Corrosion

For symposium descriptions, abstract submission instructions, and updated meeting information, visit the MRS Web site:

www.mrs.org/meetings/spring2003/

LABORATOIRE LEON BRILLOUIN

European Research with Neutron Beams

CALL FOR PROPOSALS

EUROPEAN COMMUNITY - ACCESS TO RESEARCH INFRASTRUCTURES
ACTION OF THE IMPROVING HUMAN POTENTIAL PROGRAMME
(CONTRACT N° HPRI-CT-2001-00170)



LLB has been recognized by E.U. as a major infrastructure dedicated to research on the structure and dynamics of condensed matter by neutron scattering or imaging. The neutron beams are supplied by Orphée, one of the highest flux and most modern reactors in Europe, equipped with one hot and two cold sources, making available neutrons of any wavelength between 0.7 and 15 Å.

THE 26 NEUTRON SCATTERING AND IMAGING FACILITIES AT LLB - ORPHEE - SACLAY
(including diffractometers for single crystals, powders, liquids and materials science, small-angle scattering instruments, reflectometers, triple-axis, time-of-flight and spin-echo spectrometers for inelastic scattering, and neutron radiography)

are open to Scientists from Member States in the European Union (France excluded) and from the Associated States (*), wishing to perform experiments with neutron beams in condensed matter physics, chemistry, materials science, biology or geosciences.

(*) : BULGARIA, CZECH REPUBLIC, REPUBLIC OF CYPRUS, ESTONIA, HUNGARY, ICELAND, ISRAEL, LATVIA, LIECHTENSTEIN, LITHUANIA, NORWAY, POLAND, ROMANIA, SLOVAKIA, SLOVENIA

Experimental proposals must be submitted in writing using Application Forms (which can be found on our web-site)

DEADLINES FOR PROPOSALS ARE : APRIL 1ST AND OCTOBER 1ST OF EACH YEAR

The written proposals will be examined by a peer review international Selection Panel on the basis of scientific merit and priority to new users and young scientists

- Access is provided free of charge for the selected user teams
- Travel and subsistence up to two users may be reimbursed by the programme

Application Forms, informations about the HPRI programme and the LLB facilities can be obtained from :

SCIENTIFIC SECRETARY - HPRI PROGRAMME
LABORATOIRE LEON BRILLOUIN, CEA / SACLAY
F - 91191 GIF-SUR-YVETTE, FRANCE

Phone : 33 (0) 1 69 08 60 38 Fax : 33 (0) 1 69 08 82 61
e-mail : experience@llb.saclay.cea.fr Web site : <http://www-llb.cea.fr>

UCD

UNIVERSITY COLLEGE DUBLIN

An Coláiste Ollscoile Baile Átha Cliath

University College Dublin was founded in 1854 and was established as a non-denominational University in 1908. With a student population of approximately 20,000 (1,500 from overseas), and ten faculties, UCD is the largest University in Ireland. The University graduates 5,000 students with primary and postgraduate degrees each year.

PROFESSOR OF MATHEMATICAL PHYSICS (APPLIED MATHEMATICS AND/OR THEORETICAL PHYSICS)

The Governing Authority of the University invites applications for the full-time permanent Professorship of Mathematical Physics in the:

FACULTIES OF ARTS AND SCIENCE

(Ref: 000973)

The Department of Mathematical Physics currently has 7 full-time academic staff. The Staff of the Department teach and carry out research in Applied Mathematics and Theoretical Physics. The principal teaching commitments are in the Bachelors of Arts and Science degrees (including special programmes in Mathematical Science and Theoretical Physics).

Applicants for the Chair shall possess:

- A doctoral degree awarded by a recognised University
- Teaching experience at university level
- A distinguished record of research in an area of Applied Mathematics and/or Theoretical Physics, as evidenced by publications in top ranking journals and contributions to international conferences
- A proven academic leadership record, including the supervision of Ph.D. students
- A proven record of attracting research funds

The salary scale is in the range of €83,850 to €107,737 (new entrants)

Prior to application, further information (including application procedure) should be downloaded from our website: www.ucd.ie/vacancies or obtained from:

**The Personnel Department,
University College Dublin, Belfield, Dublin 4, Ireland
(quoting the above reference number).**

Tel: +353-1-716 1653; Fax: +353-1-269 2472

Email: Orla.Cosgrave@ucd.ie

For more detailed information on the Department of Mathematical Physics please consult the Department's Website: www.ucd.ie/~math-phy/

Closing for receipt of completed applications is: 5:00pm on Friday, 1 November 2002.

UCD is an equal opportunities employer.



UNIVERSITY COLLEGE DUBLIN
NATIONAL UNIVERSITY OF IRELAND, DUBLIN



The forthcoming deadline for applications for magnet time allocation (February to July 2003) at the

GRENOBLE HIGH MAGNETIC FIELD LABORATORY

is **November 15, 2002.**

Scientists of EU countries and Associated States* are entitled to apply under the HPP Programme « Transnational Access to Major Research Infrastructures » to obtain a financial support according to rules defined by the EC. Application forms are available on request.

* Bulgaria, Czech Republic, Republic of Cyprus, Estonia, Hungary, Iceland, Israel, Latvia, Liechtenstein, Lithuania, Norway, Poland, Romania, Slovakia, Slovenia.

Please contact :

E. Mossang

Laboratoire des Champs Magnétiques Intenses,

Max-Planck-Institut für Festkörperforschung et Centre National de la Recherche Scientifique

B.P. 166

38042 Grenoble Cedex 9

FRANCE

Tel. : 33- 4.76.88.74.87

Fax : 33- 4.76.85.56.10

e-mail : mossang@grenoble.cnrs.fr

Ecole Polytechnique Department of Physics

Faculty Position

The Department of Physics of the Ecole Polytechnique, in Palaiseau (France), invites applications for two tenured positions of full Professor in Physics, the highest available position at the Ecole. The appointments would begin in the fall of 2003 and 2004 respectively. The successful candidates, of international reputation, will be expected to carry a vigorous research program within the existing research labs of the School. The position also requires a strong interest in teaching. The lectures may be initially delivered in English for a year or two. There is no restriction on the age or nationality of the candidate.

The Ecole Polytechnique is an internationally-oriented scientific undergraduate and graduate school, which offers start-up packages, chair support and excellent research and teaching facilities, together with many possibilities of collaboration with partner research, academic or industrial institutions.

Applicants should send as soon as possible and no later than February 15, 2003, a detailed curriculum vita, a description of their teaching and research experience and plans, and the name and e-mail addresses of at least three references from internationally-known researchers to Professor Edouard Brezin, Chair of the Search Committee, Département de Physique, Ecole Polytechnique, 91128 – Palaiseau Cedex, FRANCE, with an e-mail copy of all the material to edouard.brezin@ens.fr. Further information can be obtained from the department chair, or from the web site on www.polytechnique.edu.



Universiteit Antwerpen
Faculteit Wetenschappen
Departement Natuurkunde

Bachelor - Master
Education Program



The European Higher Education Area Advanced Academic Studies Master in Physics / Nanophysics Academic year 2002 – 2003

The Master program, organized by the University of Antwerp, is modular and starts with a basic module, after which the student chooses at least two out of the advanced modules:

- Experimental Nanophysics
- Electron Microscopy
- Theoretical Nanophysics
- Computational Nanophysics

Applications are invited from university graduate students in physics, chemistry and applied sciences and from persons who have been awarded equivalent non-university degrees.

Further information can be found on the web site
<http://www.ua.ac.be/nanophysics/master>

Postdoctoral fellowships at the Niels Bohr Institute, University of Copenhagen

The Niels Bohr Institute is part of the Physics Department of Copenhagen University (NBIfAFG) and has active theoretical and experimental research programs in particle physics, nuclear physics, and the physics of nonlinear and complex systems. The Institute shares building facilities with the independent Nordic research Institute, Nordita and there is considerable scientific collaboration with that Institute. More information about the Institute is available at <http://www.nbi.dk/>.

Applicants should submit a curriculum vitae, list of publications, a statement of research interests and goals, and arrange for 2-3 letters of reference, to be sent to

Niels Bohr Institute
c/o Ulla Holm
Blegdamsvej 17
DK-2100 Copenhagen
Denmark.
Fax +45 35325400
E-mail: postdoc@nbi.dk

Applications for the academic year 2003/2004 should arrive before 9 December 2002.

If you have and job vacancies why not
advertise them in

europhysics news

Reach over 29.000 physicists and related
professionals in almost every field in Europe
without wasting your budget on the wrong
audience!



www.edpsciences.org

Susan Mackie

250, rue Saint Jacques
F-75005 Paris • France
Tel. +33 (0)1 55 42 50 51
Fax +33 (0) 1 46 33 21 06
mackie@edpsciences.org



EURESCO Conferences

A Programme of the European Science Foundation
with the support of the European Commission

2003 PROGRAMME Physics, Engineering & Material Sciences

On line at: <http://www.esf.org/euresco/>

■ Solid/Fluid Interfaces*:

Euroconference on Complex Fluid Interfaces,
San Feliu de Guixols, Spain, 29 March - 3 April
Chair: R.K. Thomas (Oxford)

■ Advanced Environments and Tools for High Performance Computing*:

**Euroconference on Problem Solving
Environments and the Information Society,**
Albufeira, Portugal, 14 - 19 June
Chair: E. Houstis (Patras)

■ Biological Surfaces and Interfaces*:

**Euroconference on Understanding and
Improving Specific Interactions,**
Castelvecchio Pascoli, Italy, 21 - 26 June
Chairs: A.G. Thomas (Manchester) and
F. Jones (London)

■ Bionanotechnology*:

Euroconference on Biomolecular Devices,
Granada, Spain, 9 - 14 July
Chair: A.J. Turberfield (Oxford)

■ What Comes beyond the Standard Model?:

Symmetries beyond the Standard Model,
Portoroz, Slovenia (prov.), 12 - 17 July
Chair: N.S. Mankoc-Borstnik (Ljubljana)

■ Molecular Liquids*:

**Routes from Local Order to Large-Scale
Cooperativity Euroconference,**
Castelvecchio Pascoli, Italy, 5 - 10 September
Chair: R. Buchner (Regensburg)

■ Fundamental Problems of Mesoscopic Physics:

**Interactions and Decoherence in Mesoscopic
Systems,**
Granada, Spain, 6 - 11 September
Chair: I.V. Lerner (Birmingham)

■ Bose-Einstein Condensation*: Euroconference on the New Trends in Physics of Quantum Gases,

San Feliu de Guixols, Spain, 13 - 18 September
Chair: Y.G. Castin (Paris)

■ Surface Plasmon Photonics*:

Euroconference on Nano-Optics,
Granada, Spain, 20 - 25 September
Chairs: L. Martin-Moreno (Zaragoza) and
F. Garcia-Vidal (Madrid)

■ Quantum Optics*:

**Euroconference on Cavity QED and Quantum
Fluctuations: From Fundamental Concepts to
Nano-Technology,**
Granada, Spain (prov.), 27 September - 2 October
Chair: A. Lambrecht (Paris)

■ Fundamental Aspects of Surface Science: Manufacture and Properties of Structures with Reduced Dimensionality,

Albufeira, Portugal (prov.), 4 - 9 October
Chair: B. Poelsema (Enschede)

■ Electromagnetic Interactions with Nucleons and Nuclei*:

**From QCD to Low Energy Phenomena -
A Euroconference,**
Santorini, Greece (prov.), 6 - 11 October
Chair: E. DeSanctis (Frascati)

Conferences are open to researchers world-wide, whether from industry or academia.
Participation will be limited to 100.

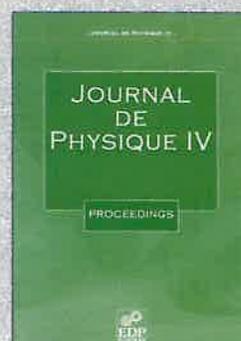
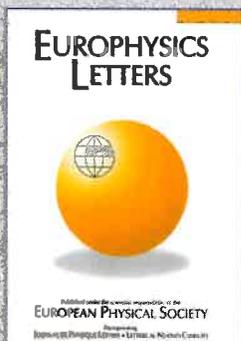
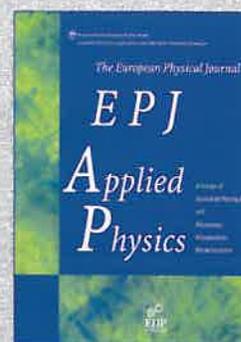
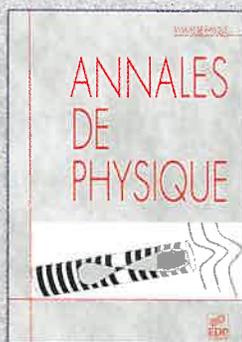
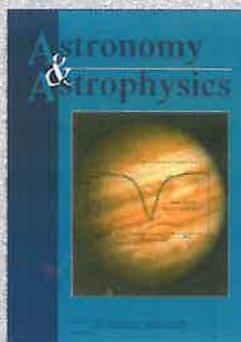
Deadline for applications: 3-4 months before a conference.

The registration fee covers full board and lodging. **Grants** are available (*EC support from the High Level Scientific Conferences Activity), in particular for nationals under 35 from EU or Associated States.

For information & application forms contact:

J. Hendekovic, EURESCO Office, ESF, 1 quai Lezay-Marn sia, 67080 Strasbourg, France
Fax: +33 (0)388 36 69 87 E-mail: euresco@esf.org <http://www.esf.org/euresco>

- Astronomy & Astrophysics
- Annales de Physique
- European Physical Journal (The) - Applied Physics
- European Physical Journal B (The)
- European Physical Journal D (The)
- European Physical Journal E (The)
- Europhysics Letters
- Europhysics News
- Journal de l'Enseignement des Sciences de l'Information et des Systèmes
- JP IV - Proceedings
- Revue de l'Électricité et de l'Électronique (REE)
- Revue de Métallurgie



europhysicsnews

July/August 2002

33/4

Institutional subscription price: 91 euros per year

2002

directory special

2002 EPS Directory 12 page pull-out

X-ray crystallography at subatomic resolution

Fossil structure in the galactic halo

Laser-induced nuclear physics and applications

directory



MADE SUD-OUEST



European Physical Society



PHYSICS LETTERS A

Nanoscience

Quantum physics

Condensed matter physics

Theoretical physics

Nonlinear science

Statistical physics

Mathematical and computational physics

General and cross-disciplinary physics
(including foundations)

Atomic, molecular and cluster physics

Plasma and fluid physics

Optical physics

Biological physics

www.elsevier.com/locate/pla