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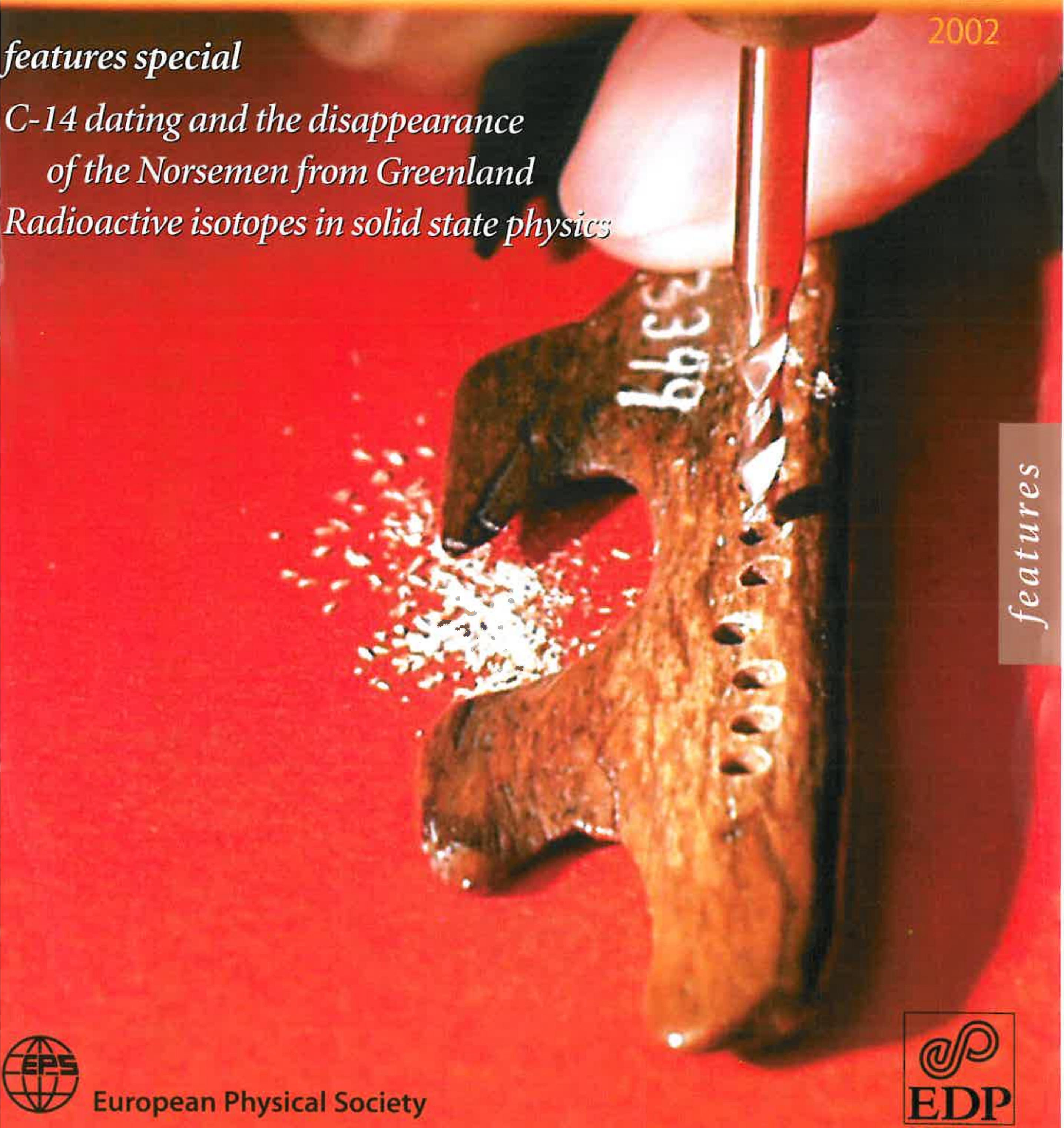

features

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Editor
David 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

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Directeur de la publication
Jean-Marc Quilbé

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Martin Huber President Elect

Martin C.E. Huber, 66, Swiss, Professor at ETH Zürich, former Head of ESA's Space Science Department and ESA Science Advisor was elected as President Elect of the EPS at this year's Council meeting in Berlin. He will serve one year as Vice-President and take up office as President of the Society in April 2003. Currently, he is Visiting Scientist at the International Space Science Institute (ISSI) in Bern, and recently worked as a Research Scholar at the Smithsonian Astrophysical Observatory.

Until the mid-seventies, he worked at the Harvard College Observatory in laboratory astrophysics, *i.e.*, on the measurement of astrophysically relevant atomic data, as well as on the instrumentation and the radiometric calibration of the Harvard instruments flown on the Orbiting Solar Observatory (OSO-6) and, later, on the Apollo Telescope Mount (Skylab, 1973-74). After returning to Europe—to a position in the newly created group of Atomic Physics and Astrophysics at ETH Zürich—he turned to work in laser-excited plasmas, developed astronomical optics and participated in ESA studies of potential solar-physics missions.

When Switzerland joined ESO in 1980, Martin Huber became a member, and later chairman, of its Observing Programme Committee. Later, he was involved in the definition of ESA's long-term science programme 'Horizon 2000' as member of ESA's Space Science Advisory Committee and chair of its Solar System Working Group. In the EPS, he chaired the Astrophysics Division, and transformed it into the Joint Astrophysics Division (JAD) of the EPS and EAS (the European Astronomical Society) when the EAS was founded in 1990.

Here is his election statement: The European Physical Society—with its 38 national member societies comprising 80,000 physicists, with 3500 individual members and the more than 50 public and industrial organisations adhering as associated members—is now making its voice heard in Europe, and provides important services to professionals through its Divisions, Interdivisional Groups, and Committees. And we have the prospect of 2005, the World Year of Physics. This provides an opportunity to entice young people to go into science, to make the case of the benefits of physics to society and, last but not least to insist on the recognition of European contributions to physics. To help lead such an effort is an attractive challenge for me.

The EPS will have to continue increasing its visibility in the EU, in order to further pursue its policy goals as a professional organisation. This includes a continued effort to form closer connections between the physics communities throughout Europe. I also believe that substantial benefits would accrue, if the EPS were to occasionally provide a forum for reaching out to other scientific disciplines: joining the talents and knowledge of two or more scientific disciplines frequently opens new perspectives and thus gradually unlocks new fields of investigation and deeper insights. The latest issue of Europhysics News, which I had the honour to edit, substantiates this fact.

By working at the European level and, through its member societies, at the national level, the EPS has the obligation to make people—and, in particular, opinion leaders—aware that physics, and science in general, is part of European culture. In a time, when striving for short-term economic gain is exceedingly admired, and the pursuit of science is often exclusively justified by the expected reward in applications, we must remind our politicians that if there is no new science, there will be no new science to apply in the future. Let us underscore, too, that findings in basic science have a more fundamental outcome: they guide us in our view of the World.

I am convinced that my experience in international scientific collaborations, be it as an individual physicist, in national and international advisory structures or as staff member of ESA—one of Europe's International Research Organisations—and in major Europe-wide educational events, such as 'Physics on Stage', will serve me well in furthering the goals of the EPS.

Martin C.E. Huber

Advertising Manager Susan Mackie
Address 250, rue Saint-Jacques, 75005 Paris, France
tel +33 155 42 80 51 *fax* +33 146 33 21 06
email mackie@edpsciences.org

Production Manager Agnes Henri
Address EDP Sciences, 17 avenue du Hoggar, BP 112 PA de Courtabœuf, F-91944 Les Ulis Cedex A, France
tel +33 169 18 75 75 *fax* +33 169 28 84 91

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C-14 dating and the disappearance of Norsemen from Greenland

J. Arneborg[1], J. Heinemeier[2], N. Lynnerup[3], H.L. Nielsen[2], N. Rud[2] and Á.E. Sveinbjörnsdóttir[4]
[1]SILA – The Greenland Research Center at The National Museum of Denmark, DK-1220 Copenhagen, Denmark
[2]AMS ^{14}C Dating Laboratory, Institute of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark
[3]Laboratory of Biological Anthropology, The Panum Institute, University of Copenhagen, DK-2000 Copenhagen, Denmark
[4]Science Institute, University of Iceland, IS-107 Reykjavik, Iceland

Direct counting of ^{14}C atoms by Accelerator Mass Spectrometry (AMS), introduced in 1977, allows radiocarbon (^{14}C) dating of samples of less than 0.1 mg carbon—10.000 times smaller than required for traditional ^{14}C-dating based on beta-decay counting [1,2]. The AMS ^{14}C Dating Laboratory in Aarhus participates in a study of the Norse (Viking) culture in Greenland with special emphasis on the time development of human diet—quantified via ^{14}C dating and measurements of stable-isotope composition of bone collagen. This example of applied physics is described in the following.

The Norse colonies in Greenland

In the Middle Ages European civilisation was brought to Iceland and Greenland by Norsemen—people closely related to the Vikings who some generations before had raided and settled in Britain and on the coasts of the European continent. The settlers took land in Iceland from about AD 900, and from Iceland they founded colonies in Greenland. The first settlers in Iceland were farmers from Norway and the northern British Isles who crossed the sea in their longships loaded with families and cattle, sheep, goats, horses, pigs, cats and dogs. According to the tradition Icelandic settlers led by the outlaw Erik the Red sailed further west in 985 to establish a new colony on the South West coast of Greenland. The adventurous story of the first Norse settlers in Greenland is told in colourful detail in the sagas, a treasure of literature written down in Iceland around 1200. However, a no less fascinating story of the Norse settlers emerges from the application of the methods of physics to their remains, unearthed through a century of archeological excavations in Greenland.

In Greenland the Norsemen established colonies with farms, churches, cloisters and a bishopric: the Eastern Settlement near the southern tip of Greenland and the Western Settlement further north, near the present-day capital Nuuk. The total population was not more than a few thousand at any time. In spite of their harsh surroundings, these remote outposts maintained good connections back to Europe—there were—at least in the first centuries—regular ship crossings between Greenland, Iceland, Norway and the rest of Europe. Already in the early days of the colonies, Norsemen visited North America, nearly five centuries before Columbus [3]. However, the adventure only lasted about 450 years—the Norsemen seem to have disappeared completely from Greenland some time during the late 1400's. But why did the Norsemen succumb while the Eskimos prospered? Exactly what happened is still a mystery and has been a subject of heated debate for many years. Arguments have been made for causes such as deteriorating climate, overgrazing, epidemic diseases, inbreeding, English pirates, hostile Eskimos, a dwindling market for export of walrus tusks—or a combination of these.

In the following we describe a physics approach to the problem of the Greenland Norse made possible through a joint interdisciplinary effort [4].

As a result of 80 years of excavations in Greenland, The Danish National Museum possesses a large collection of bones from burials in churchyards in the old Norse colonies. Stable-isotope analysis of selected parts of this bone material has enabled us to determine which kind of food each individual has eaten - or more precisely: the balance between terrestrial and marine diet (Box 3). At the same time, we have ^{14}C dated the bones by the AMS technique (Box 1 and 2). We cannot claim to have solved the enigma of the disappearance of the Norsemen from Greenland, but we can at least exclude some hypotheses. The isotope analysis indicates that the Norsemen changed their dietary habits. The diet of the first settlers consisted of 80% agricultural products and 20% food from the surrounding sea. But seafood played an increasing role, such that the pattern was completely turned around towards the end of the period—from the 1300's the Greenland Norse had 50-80% of their diet from the marine food chain. In simplified terms: they started out as farmers but ended up as hunters/fishers. Some archeologists have claimed that the Greenland Norsemen succumbed because they—being culturally inflexible—either could not or would not adapt to changing conditions and therefore came to a catastrophic end, triggered by deteriorating climate. This hypothesis may now be refuted.

Fig. 1: The tandem accelerator at the Institute of Physics and Astronomy, now used mainly for AMS ^{14}C dating. About 1000 samples are ^{14}C dated annually. Sample sizes down to as little as 0.1 mg of carbon can be handled.

features

So far, our knowledge of the development of the Norse culture in Greenland has mainly been based on written sources and excavations of Norse buildings, farms and churchyards. Excavations of kitchen middens at the farms have indicated an economy based on animal husbandry and seal hunting, but the results are difficult to quantify. It is not certain what proportion of bones from the various food sources actually ended up in the midden and if so, to what extent they have survived decomposition. For example, the absence of fishbone in the middens does not prove that the Norse did not eat fish. Not only will fishbone rapidly decay in a midden, more likely they never got there in the first place—fishbone is a food source highly appreciated by, e.g., birds, dogs and pigs. In fact, the isotopes have revealed that dogs are often more marine than their masters.

Carbon-14 dating of human bone

To determine the subsistence pattern and a possible time trend that might have been caused by, e.g., adaptation to changing living conditions a more direct approach is needed, preferably analysis of the remains of the people themselves by physics methods. Human bone is essentially the only datable material in the graves, since occurrence of grave goods virtually ceased with Christianity. This precious bone material—skeletal parts of about 450 individuals—has been brought to light by Danish excavations since 1921. Nearly all churchyards known from the written sources are represented. However, since a traditional ^{14}C dating would consume a major part of, for example, a human thighbone, researchers have practically refrained from that type of dating.

Box 1

The carbon-14 method

The ^{14}C dating of material of biological origin is based on measurement of the isotopic ratio of radioactive ^{14}C to stable carbon (^{12}C and ^{13}C). The ^{14}C is produced by cosmic-ray bombardment of the atmosphere in a quasi-stationary equilibrium resulting in an approximately constant atmospheric $^{14}C/^{12}C$ value of $\approx 1.2 \cdot 10^{-12}$. Since atmospheric CO_2 via photosynthesis in plants enters the entire food chain, nearly the same isotopic ratio applies to the carbon of all living organisms. When the organism dies, the equilibrium is broken and the $^{14}C/^{12}C$ ratio decreases exponentially with a 5730 years half-life. Thus, from a measurement of $^{14}C/^{12}C$ value for the remains of the organism, the age can be determined. However, since the atmospheric $^{14}C/^{12}C$ has varied considerably (more than 10%) in the past, the exponential decay law cannot be used directly. Instead, the age is determined from a comparison with precise $^{14}C/^{12}C$ data for tree rings of known (dendrochronological) age. This so-called tree-ring calibration reaches 10,000 years back. Due to varying ^{14}C production rate the $^{14}C/^{12}C$ value of tree-rings does not decrease monotonically with age, there are 'wiggles' superimposed on the exponential curve. Thus, for a given uncertainty in the measured $^{14}C/^{12}C$ for the sample to be dated, the uncertainty in the calibrated age depends on the location on the calibration curve. By tradition, ^{14}C laboratories also report the so-called 'conventional ^{14}C age' calculated from an assumed standard value for atmospheric $^{14}C/^{12}C$ and the so-called 'Libby ^{14}C half-life' of 5568 years. The ^{14}C dating method reaches 40-50,000 years back, corresponding to a residual ^{14}C activity of only 2‰.

Fig. 2: A complete rib bone from an Iron Age infant and a small bone fragment. The small fragment represents all that is needed for ^{14}C dating with the AMS method. Not even the entire skeleton would provide sufficient material for a traditional ^{14}C dating.

The introduction of the AMS technique (Box 2) for ^{14}C dating has caused a break-through in Norse research in connection with the development of the AMS ^{14}C Dating Laboratory in Aarhus. A dating measurement with the AMS method requires less than one milligram carbon. This means that even small bone fragments can be dated (Fig. 2) with negligible destruction of invaluable archeological material.

The aim of our project was to carry out ^{14}C dating and stable isotope research on remains, mainly human bones from the entire Norse period in Greenland from both colonies, Eastern and Western Settlement. For this purpose, 27 human bones, 6 textiles and one ox bone were selected.

There were obvious difficulties: to establish a chronology within such short period (the colonisation lasted only 400-500 years) requires high dating accuracy. When dating humans, there is an added basic difficulty: the marine food chain has an apparent ^{14}C age about 400 years greater than the corresponding terrestrial food chain because carbon resides on the average 400 years longer in the ocean than in the atmosphere and the terrestrial biosphere. The difference is called the 'reservoir age'. This means that the bones of a Norseman who lived on salmon and seal will appear about 400 years older (when ^{14}C dated) than his twin brother, who lived on mutton and milk. If we were unable to account for the reservoir effect, a very "marine" Norseman from the end of the period might appear to be from the Landnam (initial settling) period.

Stable carbon isotopes: a key to diet

The solution to the problem was to measure the stable carbon isotope ratio in terms of the quantity $\delta^{13}C$ (Box 3) from which the percentage of marine food can be determined. This in turn leads to an accurate reservoir-age correction to the ^{14}C age. The basic assumption is that any two persons with similar diet also exhibit identical $\delta^{13}C$ values. This is strongly supported by the compilation of $\delta^{13}C$ values of archeological bones, measured by international laboratories and in our laboratory (Fig. 4). This shows that the "terrestrial" people from inland Norway and Sweden cluster around a $\delta^{13}C$ value of -21‰. In contrast, Eskimos coinciding in time and place with the Greenland Norse show a narrow, "marine" distribution with a much higher $\delta^{13}C$ of

-12.5‰, consistent with archeological expectations of an almost pure marine subsistence. Note that early Indians from the coast of British Colombia, although very marine, had greater access to terrestrial food, so that their spread in $\delta^{13}C$ is greater because of individual freedom in the choice of food.

The $\delta^{13}C$ values of the Greenland Norse are also shown in Fig. 4. These high-precision measurements were made with the mass spectrometer at the Science Institute in Reykjavík. The result is striking: The Norse data nearly cover the entire range between the terrestrial people from Norway and Sweden and the marine Eskimos from the Southwest coast of Greenland. Translated into diet composition, the corresponding range of marine food is as large as 20-80%. This variation in diet is exceptionally high for a single culture in a very limited period of time. It could be due to individual preferences, possibly in connection with social differences, or it might reflect a temporal trend caused for example by a steady deterioration of the regional climate during the period as evidenced by recent ice-core research [5]. Resolving this question requires accurate ^{14}C dates corrected for the reservoir effect of the content of "old" marine food calculated for each individual.

How to get accurate ^{14}C dates

An important key to this question came from a particularly useful find from the churchyard at the locality identified as Herjolfsnes—the most southerly of the Norse settlements. During the excavation in 1921 [6], three skeletons were found laying close together, all wrapped in woollen clothes, which had been used for the burials presumably because of shortage of wood for coffins and fortunately preserved by permafrost through the intervening period. The textiles provide a unique opportunity to control the reservoir corrected ^{14}C age of the bones. The ^{14}C dates on a single thread of wool from each dress show that the graves are contemporaneous as expected from their relative positions.

Since sheep's wool is of terrestrial origin, there is no reservoir correction and the graves are reliably dated to AD 1430 with an uncertainty of only ±15 years—which makes it the youngest date so far with solid evidence of Norse presence in Greenland. One of the skeletons, a young woman (20-25 years), had an uncorrected ^{14}C age which was 420 years older than her clothes and would place her shortly after Landnam. The two other skeletons, a child and an older woman, were approximately 250 years older than their clothes. However, the $\delta^{13}C$ values of the bones indicated a marine content of nearly 80% for the young woman and about 55% for the two others. The actual calculation can be simplified as follows: By subtracting the corresponding fraction of a fully marine reservoir age of 450 years from the bone ^{14}C date of each of the three individuals we obtain reservoir corrected dates, which then become identical with those of their clothes in all three cases. Thus, despite greatly differing marine contents, we feel confident that the method really is applicable for detailed individual corrections.

With the parameters fixed by this procedure, we could then correct all the bone dates of the project in a similar manner. They are shown in calibrated calendar years on the x-axes of Fig. 5, while the y-axes show the measured $\delta^{13}C$ values and the inferred marine fractions in percent.

Box 2

Carbon-14 dating with a tandem accelerator

In the traditional ^{14}C method one determines the ^{14}C concentration by counting beta particles from the radioactive decay. Due to the long ^{14}C half-life and ensuing low decay rate this method is ineffective, requiring a sample size of at least one gram of carbon and long counting times. In Accelerator Mass Spectrometry (AMS) the ^{14}C atoms are counted directly. Because of the extremely low $^{14}C/^{12}C$ value, even in modern samples ($\approx 1.2 \cdot 10^{-12}$), so far only tandem accelerators have been successful in providing sufficiently selective and accurate mass separation of the carbon isotopes. With a detection efficiency approaching 10% of the ^{14}C atoms in a sample, the AMS method allows dating of samples of less than 0.1 mg carbon—10,000 times smaller than required for the traditional beta counting method. The uncertainty in an AMS-measurement can be as low as 0.2%, corresponding to 20-30 ^{14}C years.

Box 3

Stable isotopes

Stable carbon is a mixture of 99% ^{12}C and 1% ^{13}C. Conventionally, the isotopic ratio of a carbon sample is expressed in terms of $\delta^{13}C$, defined as the relative deviation (in per mille) of the $^{13}C/^{12}C$ ratio of the sample from the $^{13}C/^{12}C$ ratio of a standard (PDB, a carbonaceous rock of marine origin). Since the rate constants of chemical reactions are slightly mass dependent, $\delta^{13}C$ undergoes changes (isotope fractionation) in natural processes such as photosynthesis. Terrestrial plants assimilate carbon from atmospheric CO_2 while marine plants assimilate from dissolved bicarbonate, leading to different $\delta^{13}C$ values for plant material from terrestrial and marine environments. This difference persists throughout the two food chains. Thus, typical $\delta^{13}C$ values for human bone collagen are -21‰ if pure terrestrial food has been consumed, and -12.5‰ if the food was purely marine.

Similarly, isotope fractionation of stable nitrogen isotopes is expressed via $\delta^{15}N$, the relative deviation of the $^{15}N/^{14}N$ ratio from a standard (air). The $\delta^{15}N$ value of bone collagen gives information on trophic level of the food (position in the food chain).

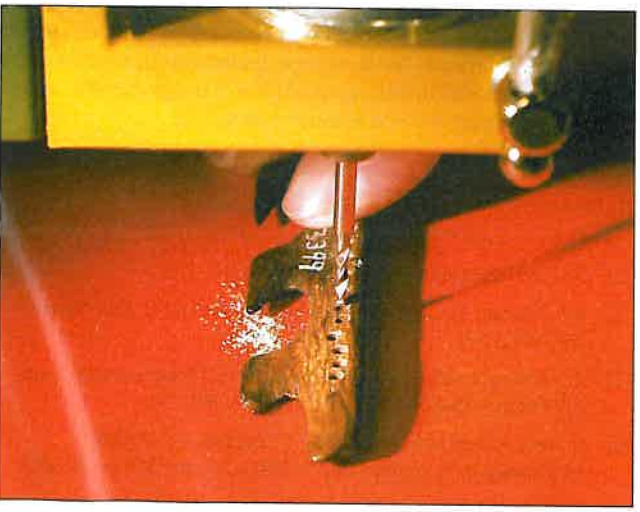

Fig. 3: Drilling of a sample for AMS ^{14}C dating from the tip of a harpoon made of deer antler. Samples of bone are drilled in the same way. Bone collagen is extracted from the sample and combusted into CO_2 for isotope analysis and dating. Experience shows that collagen preserves the carbon isotopic ratios intact.

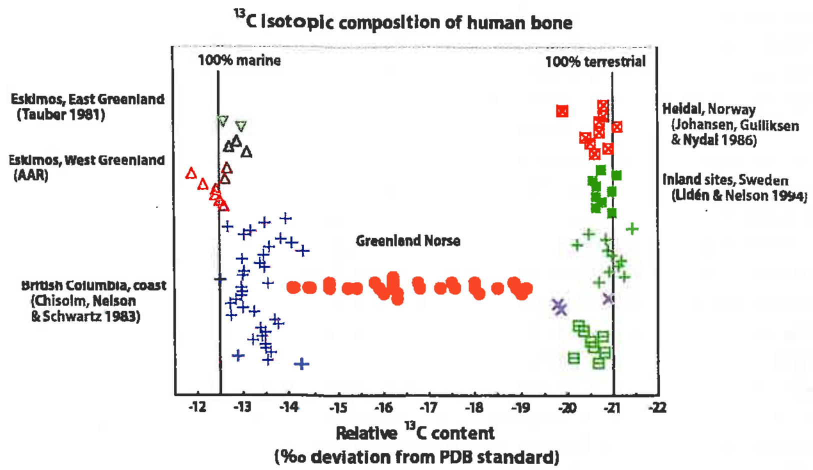

Fig. 4: The plot shows how $\delta^{13}C$ (x-axis) clearly distinguishes people who have eaten terrestrial food from those who have eaten marine food (the y-axis only indicates grouping of the individual data series). Prehistoric people from inland Norway and Sweden cluster at the extreme right end of the plot close to $\delta^{13}C$ = -21‰, taken to be the purely terrestrial value. Greenland Eskimos and Indians from the West Coast of Canada are far to the left on the plot with the most marine values around -12.5‰. The Greenland Norse data cover nearly the full range between these extremes. In our interpretation, the marine fraction of the food intake of this population ranges from 20% and up to 80% marine food—an exceptionally wide span in dietary habits for a population so concentrated geographically, culturally and chronologically.

Note that the earliest dates on human bones fall in the Landnam period (the 980's according to the written sources). These bones have been excavated from the churchyard around a tiny structure, which the archeologists have identified as the remains of the a church from around AD 1000 [7]. According to the sagas, Thjodhilde, the wife of Erik the Red, had it built close to their farm at Brattahlid and naturally the small church was named *Thjodhilde's Church*. Be it *Thjodhilde's Church* of the saga or not the church is one of the earliest archeologically known Norse constructions in Greenland. The ^{14}C date of an ox bone (terrestrial animal—no correction needed) from a grave in the same churchyard supports the early dates of human bones. Even though the early human bones are only about 20% marine, it is absolutely essential to apply the corresponding correction. Otherwise, the dates would place the first settlers some 150 years earlier than historically acceptable.

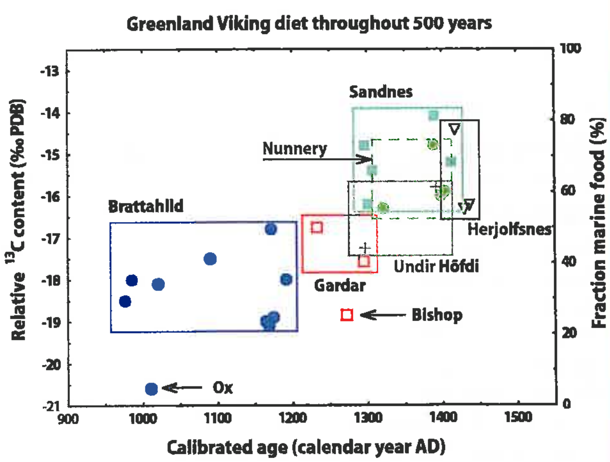

Fig. 5: The $\delta^{13}C$ values of Greenland Norse skeletons as a function of time of death determined by ^{14}C dating. On the right y-axis, the $\delta^{13}C$ has been translated into percentage marine content in the person's diet. The symbols refer to the results for the individual churchyards (framed). The plot shows that the large differences in dietary habits reflect a striking increase in the Norse exploitation of marine resources in the course of their colonisation of Greenland. The very terrestrial skeleton from Gardar is a bishop (buried with his crozier and ring), whose bone composition is probably still influenced by the diet of his Norwegian homeland.

The Norse turn to sea food

With a firm chronology thus established, we can read from Fig. 5 that the observed large differences in the marine content of the Norseman bones represent a striking increase in the Norse population's dependence on sea food during the period from Landnam till the depopulation of the settlements 4-500 years later. In the beginning, the diet of the settlers is approximately 20% marine—more or less like that of contemporaneous Norwegians. Towards the end of the period, an adaptation to marine resources has taken place—if only up to 80% of the level that we observe for contemporaneous Eskimos. Whether or not this dramatic change in the ways of life of the Norse in the course of only a few hundred years is due to the strain of a changing climate, or simply because more seals were available for the Norse hunters [8] must be left to future research to decide. But the present research at least can refute current speculations that the Norse finally succumbed because they were unable or unwilling to adapt to harsher climatic conditions by exploiting the rich resources of the sea.

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Radioactive isotopes in solid state physics

Manfred Deicher
Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany
The ISOLDE Collaboration, CERN, CH-1211 Geneva 23, Switzerland

Nuclear physics has developed a number of experimental techniques for detecting particles or γ-radiation emitted during the decay of radioactive isotopes. The radioactive decay also opens the possibility to detect with high sensitivity the interaction of nuclear moments with external electromagnetic fields. Many of these techniques have successfully entered the field of condensed matter physics often labelled as "nuclear solid state physics" [1,2]. The first application of radioactive isotopes in solid-state physics research dates back to 1920, when radioactive Pb atoms were used by G. v. Hevesey to study self diffusion in lead [3]. Hevesey also first used radioactive atoms to study biologic systems by tracking the flow of radioactive tracers from plant roots to the leaves. The "radio tracer diffusion" technique was born. Nowadays it is a common method for investigating atomic diffusion processes in solids. An important advantage of employing radioactive nuclei is the ability of detecting signals from very small amounts of impurity atoms. This is particularly important for the characterization of semiconductors or surfaces where already a very low concentration of impurity atoms has a significant influence on the properties of the system. An especially useful tool represents the nuclear transmutation process caused by the β-decay of radioactive atoms since this process effects a change of the chemical properties of the respective atoms in a solid on a well-known time scale determined by the decay constant and therefore all properties (i.e. conductivity, luminescence) connected to the chemical nature of the impurity atoms should also change. The choice of a radioactive atom for a specific experiment is on the one hand determined by its chemical nature and on the other hand by its nuclear properties. The host system under study can be doped with these radioactive "probe" atoms either by diffusion, nuclear reaction or ion implantation. The probe atoms interact with their lattice surroundings and the information on these interactions is transmitted to the outside world by the emitted decay products and gives access to internal electric and magnetic fields in crystals, to lattice sites of the probe atoms, to diffusion processes, and to interactions between the probe atoms and other defects present in the crystal.

The ongoing experiments in solid state physics using radioactive ion deal with a wide variety of problems involving bulk properties, surfaces and interfaces in many different systems like semiconductors, superconductors, surfaces, interfaces, magnetic systems, metals, and ceramics. This article can highlight only a few examples to illustrate the potential of the use of radiaoctive isotopes for various problems in solid state physics. For more extensive reviews of the field see [2,4].

Getting the radioactive isotopes

The radioactive isotopes used can be produced at reactors or accelerators. For a few lucky cases of combinations of probe atoms and host lattices the samples can be doped directly via nuclear reactions inside the material. However, research in solid state physics demands a large variety of combinations of probe atoms and host lattices. Long-lived isotopes can be produced at cyclotrons and radio chemically separated from the target material. Then these isotopes can be either diffused or implanted into the material under study. The most versatile procedure is ion implantation: Depending on the implantation energy, the concentration of dopants, their lateral and their depth distribution can be controlled easily. Any unwanted co-doping by other elements is only determined by the purity of the ion beam and ion implantation is a process not limited by thermal equilibrium, therefore doping is possible beyond any solubilities. But, the energies used for implantation (keV to MeV) are much higher than typical binding energies of atoms in a crystal (eV) so that high concentrations of intrinsic defects (vacancies, interstitials, antisites, dislocations, even amorphous layers) are created. A thermal annealing treatment of the implanted crystal is required in order to remove these defects.

The most versatile "isotope factory" is represented by an online isotope separator facility such as ISOLDE at CERN in Geneva [5]. Here, the production, the chemical separation, the mass separation and the implantation of radioactive isotopes are integrated into one device (figure 1). At ISOLDE the radioactive isotopes are produced by spallation, fragmentation or fission reactions in solid or liquid targets hit by an external high energy proton beam. More than 600 different isotopes of 70 elements can be produced. The big success of the on-line mass separation technology at ISOLDE in many fields, nuclear and atomic physics, astrophysics and solid state physics, triggered worldwide interest in installing similar facilities for the production of radioactive ion beams [6].

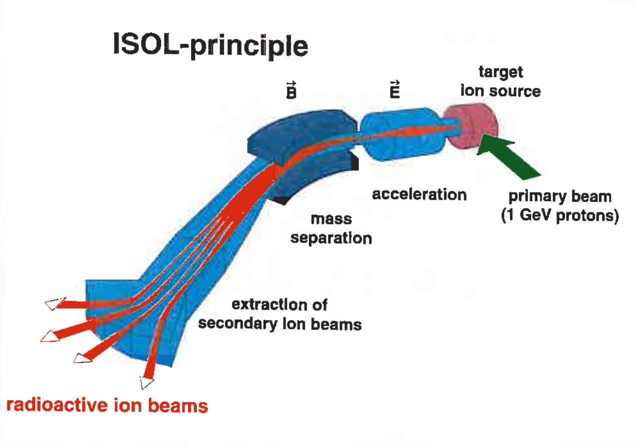

Fig. 1: The basic ISOL (Ion Separation On-Line) principle: Radioactive nuclides are produced by spallation, fission or fragmentation reactions triggered within a thick target by an external proton beam of 1 GeV. The target is kept at high temperatures permitting the rapid diffusion of the reaction products into the ion source where they get ionized by plasma, laser excitation or surface ionization. The singly charged ions are then accelerated, mass separated in a magnetic field and finally available for experiments at different beamlines.

Doping of semiconductors

Progress in semiconductor technology is driven by two requirements: Developing new materials with unique optical or electrical features and reducing the size of the individual constituents of an integrated device. These requirements demand a thorough understanding and control of defects responsible for the properties of these materials, both of intrinsic defects, such as vacancies, self-interstitials, or anti-sites, and of extrinsic defects, such as dopants and impurity atoms. As a consequence, a strong effort in basic and applied research is devoted to the investigation of defects and the electrical activation of dopant atoms for may different semiconductors: Elemental semiconductors (e.g. Si,, Ge, and diamond), III-V (GaAs, GaN), II-VI (ZnSe, CdTe), and IV-IV semiconductors (SiGe, SiC). Like stable isotopes, radioactive isotopes used as dopants influence the electronic and optical properties of semiconductors according to their chemical nature. Moreover, the properties of a semiconductor are not only determined by the chemical nature of a dopant but also by its location in the crystal lattice. Experimental and theoretical tools are needed for identifying the properties of defects, the diffusion mechanisms being responsible for the mobility of defects and the strengths of the mutual interactions between dopant atoms and intrinsic as well as extrinsic defects. Depending on the material and the smallest structural size used in a device, the electrical and optical properties can be already significantly altered by a defect which is present at a concentration as low as 10^{12} cm^{-3}. Therefore, the reliable control of the performance of semiconductors requires experimental techniques that combine high sensitivity to low defect concentrations with chemical sensitivity to the nature of the defects involved. Two of these techniques involving radioactive atoms will be presented here:

For decades, the most straightforward technique for locating impurity atoms within a lattice has been the so-called ion beam channeling effect, where an external ion beam (e.g. a He^+ beam with an energy of several MeV) is steered by small angle Rutherford scattering along atomic rows or planes of the crystal ('channels'). Using this technique, the detection of impurities is limited to concentrations of at least 10^{18} cm^{-3}. The sensitivity of techniques based on the channeling effect can be improved by several orders of magnitude by using radioactive impurity atoms located inside the crystal under study that emit charged particles (β^-, β^+, conversion electrons, α), the so called emission channeling technique [7]. Detecting the emission of these particles along different major lattice directions results in different emission yields compared to the observation along a random lattice direction (figure 2). For the case of electrons, an enhanced emission yield along a certain lattice direction is always the sign of an emitting atom residing on or near this lattice row which guides the electrons toward the surface. A reduced yield or the absence of an increased yield along a major axis hints at an interstitial site of the emitting atom. Observing the emission along different lattice direction allows the determination of the lattice site of the emitting atom with an accuracy of a few tenth of an Ångstrom.

Along with Fe, Ni, and Co, the element Cu is the most common but unwanted transition metal impurity in silicon devices. It interacts with various dopants and other defects, thereby changing the electrical effects of dopants. Positively charged Cu is the fastest known interstitial diffuser in Si. At high temperatures the solid solubility of Cu in Si is the highest among all transition metals but it is negligible at room temperature. As a consequence, Cu shows a strong tendency to react with various defects. Using the sensitivity of the emission channeling technique, the first direct determination of the lattice location of Cu in Si became possible (figure 3) [8]. The experiments showed, that after the implantation of ^{67}Cu into As-doped Si followed by an annealing at 600 °C, 90% of the Cu atoms are located close to substitutional lattice sites with a slight displacement of 0.5 Å

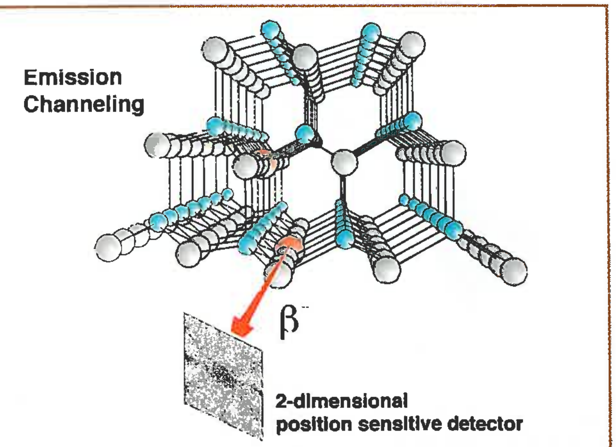

Fig. 2: Emission channeling of electrons (β^-) emitted from radioactive atoms on a lattice row: The electrons are steered along the lattice row leading to an enhanced emission yield (recorded by a 2-dimensional electron detector) along the lattice rows and planes compared to random lattice directions.

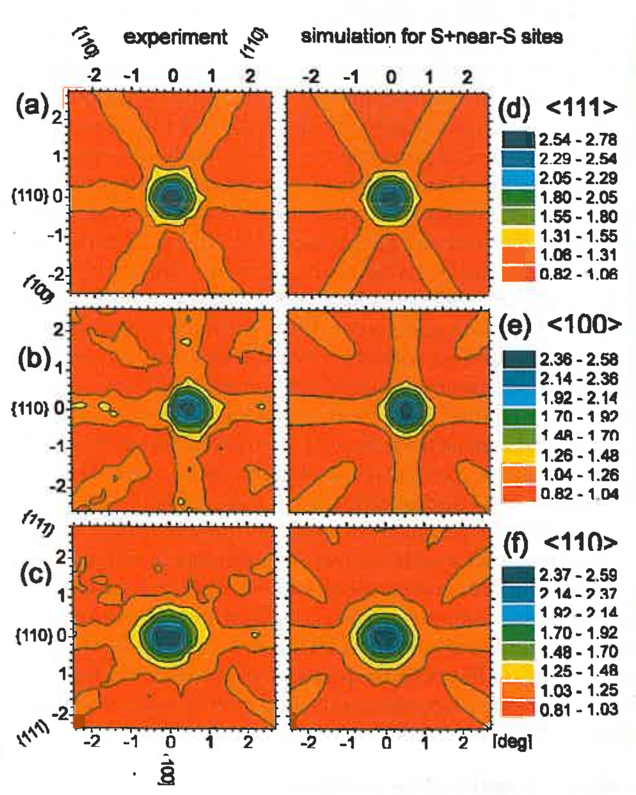

Fig. 3: Experimental emission yields of electrons emitted by ^{67}Cu in the vicinity of {111} (a), {100} (b), and {110} (c) directions in As doped Si after annealing at 600°C. Panels (d), (e), and (f) show simulated patterns of the experimental yields, corresponding to 90% of Cu close to substitutional lattice sites with a displacement of 0.5 Å [8].

From the application point of view, the electrical and optical properties of a semiconductor as determined by the presence of dopants and defects decide on the feasibility of a device. To determine these properties, a set of very accurate techniques like photoluminescence spectroscopy (figure 4) has been developed in semiconductor physics. All of them are perfectly feasible without any radioactive isotope, but they have often severe problems to identify the chemical nature of the defects which they are detecting. In combination with radioactive atoms, however, the element that gives rise to the observed electrical or optical properties can be unambiguously identified. If a change of an optical transition is due to a defect state in which the parent or daughter isotope is involved, the concentration of that defect will change according to the half-life of the radioactive decay. This time dependent change of the defect concentration has to show up in the corresponding intensity of the spectroscopic signal adding the lacking chemical information to the data delivered by photoluminescence spectroscopy.

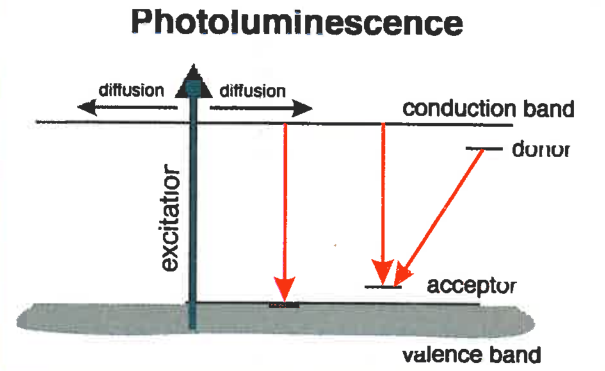

Fig. 4: Photoluminescence spectroscopy in semiconductors: At low temperatures, electrons are excited to the conduction band by a laser. The excited electrons diffuse through the lattice and finally recombine back to the valence band emitting light with an energy characteristic for the transition. The transitions can be a direct band-band transition, but can also involve donor or acceptor states present in the band-gap.

During the last years, there has been a great interest in the study of the wide band gap semiconductor GaN, mainly due to its potential applications in optoelectronics in the UV and blue spectral region. The aim of the following experiment, which will serve as an example for photoluminescence investigations with radioactive isotopes, was to uniquely identify the optical transitions created by Cd and Ag in GaN [9]. GaN was doped by ion implantation with radioactive ^{111}Ag at ISOLDE. In order to reduce the implantation induced damage, the sample was annealed at 1270 K. Figure 5 shows a series of photoluminescence spectra spectra recorded within 68 d after the doping. A strong photoluminescence band centered at 1.5 eV being not present before the doping became visible in the first spectrum recorded one day after implantation. Only weak luminescence could be observed between 2.4 eV and 3.3 eV. During the following 17 days, however, the intensity between 2.7 eV and 3.2 eV increased while the intensity of the 1.5 eV luminescence decreased. After 70 days, no luminescence at 1.5 eV could be detected any more and no further change of the spectrum has been observed. From this observations it is clear that the two energy regions, that exhibit a decreasing and increasing intensity as a function of time, have to be correlated with the elements Ag and Cd, respectively. Since no change should occur in the ^{111}Ag doped crystal besides the decrease of the Ag concentration and the increase of the Cd concentration, the vanishing luminescence at 1.5 eV has to be caused by recombination centers involving Ag. On the other hand, the two growing PL bands centered at 2.7 eV and 3.2 eV have to involve Cd defects.

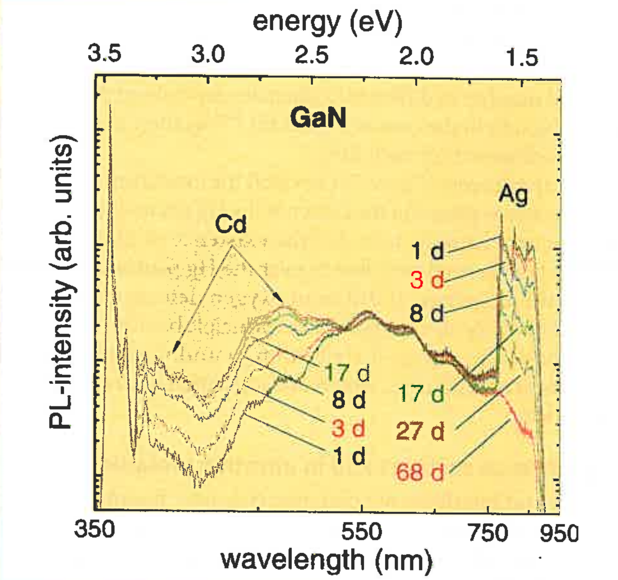

Fig. 5: Identification of optical states created by Ag and Cd in GaN: GaN has been doped with radioactive ^{111}Ag which decays to stable ^{111}Cd ($T_{1/2}$=7.45 d) and photoluminescence spectra have been recorded between 1 day and 68 days after the doping. The intensities of the photoluminescence transitions labeled Cd and Ag follow exactly the concentration changes due to the decay of ^{111}Ag and therefore these transitions must be caused by Ag and Cd, respectively [9].

High-T_c superconductors

Oxide materials have gained a great interest in fundamental and applied research due to their large variety of structural, electric and magnetic phenomena. Especially the discovery of the high-T_c superconductors triggered an intense experimental and theoretical research program for these systems. Among them, $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ represents the family of high temperature superconductors with the highest T_c. An exited nuclear state of the isotope ^{199}Hg can be used to characterize on an atomic scale the oxygen atoms (O_δ^{2-}), which are incorporated in the Hg-planes and dope the superconducting CuO_2 planes. So far, it has been shown that the doping concentration of O_δ^{2-} is about 1.5 higher than expected for the induced hole charge carriers. Furthermore, structural anomalies that are possibly related with the superconducting transition, have previously been observed (but not resolved) by neutron diffraction and EXAFS.

If the charge distributions around a nucleus in a lattice (^{199}Hg in this case) has a symmetry lower than cubic, an electric field gradient (EFG) is created at the site of the nucleus. This situation exists in non-cubic crystal lattices or in the presence of defects in the neighbourhood of the probe atom. The EFG, defined as the second spatial derivative of the electric potential and, therefore, being a tensor, contains information on the symmetry and the orientation of the charge distribution in respect to the crystal axis, and delivers information on the configuration of the defect causing the EFG. It interacts via the hyperfine interaction with the nuclear quadrupole moment of the probe nucleus and leads to a quadrupole splitting of the *m*-substates of the involved nuclear levels. A technique being especially suited for detecting EFG is the perturbed $\gamma\gamma$ angular correlation spectroscopy (PAC) [1]. In a PAC experiment (figure 6), the precession frequency of the nuclear spin I is measured, which depends on the magnitude of the EFG. In addition to the EFG, the spin I and the nuclear quadrupole moment Q of the intermediate nuclear state of the isotope define the values of the observed frequencies. The observed number of different frequencies depends on the number of *m*-sublevels, in the case of $I = 5/2$ for ^{199}Hg, there are three frequencies observed for each EFG.

The experiments (figure 7) provided the local identification of single O_δ atoms placed in the center of the Hg planes [10]. In addition, the experiments revealed the existence of other, not yet identified oxygen-related defects near the Hg planes. The results proved the existence of different oxygen defects near the Hg planes. This work also triggered first-principle band structure calculations of the charge distribution in undoped and oxygen doped lattice structures, which are consistent with the experimental data.

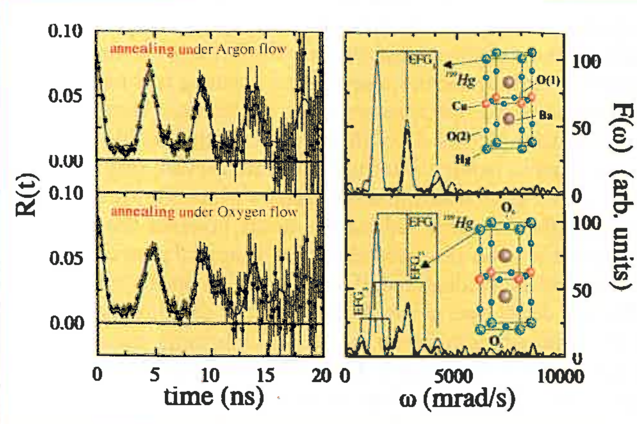

Fig. 7: Local environment of Hg atom in the high-T_c superconductor $HgBa_2Ca_{n-1}Cu_nO_{2n+2+\delta}$ observed by PAC spectroscopy using the isotope ^{199}Hg: PAC time spectra R(t) (left) have been measured under Argon flow (undoped material) and under oxygen flow (oxygen doped material). The pictures on the right show the corresponding Fourier transforms of the R(t) functions. In the R(t) and the Fourier spectra the blue lines represent the fit function and the Fourier transform of the fit function, respectively. The electric field gradient EFG2 could be assigned to oxygen sitting in the centre of the Hg channel, EFG3 is due to a still unknown oxygen related defect [10].

Magnetism at surfaces and in ultrathin metallic layers

Surfaces and interfaces of solid materials have become a field of tremendously growing interest in several areas of physics, in particular in ultrathin metallic layer magnetism. The information on the variation of magnetic properties from atomic layer to atomic layer of ultra-thin multilayer systems or even from atom to atom in such a monolayer is of fundamental interest. Therefore, local structural and electronic properties of surfaces and at interfaces measured on the atomic scale are in the centre of many investigations [11].

One beam-line connected to the ISOLDE separator is designed for ultra-high vacuum, a prerequisite for surface and thin layer experiments. PAC spectroscopy can also detect magnetic hyperfine interactions with the high sensitivity which is required for studies of surfaces, ultrathin layers and interfaces [12]. Three pioneering experiments performed at ISOLDE have concentrated on Ni/Pd thin-layer systems, where induced magnetic interactions in Pd were investigated. The possibility to use different radioactive probe atoms on the same systems, for example *sp*-elements as ad-atoms on a nickel surface, allows the experimental test of detailed theoretical predictions. Recently, within epitaxially grown Pd layers on Ni surfaces, Pd or Cd PAC probe atoms were positioned in a controlled way at different distances from the interface. The different probe atom locations in such experiments are illustrated in figure 8. The measured static magnetic hyperfine interactions at Pd revealed a ferromagnetic ordering of

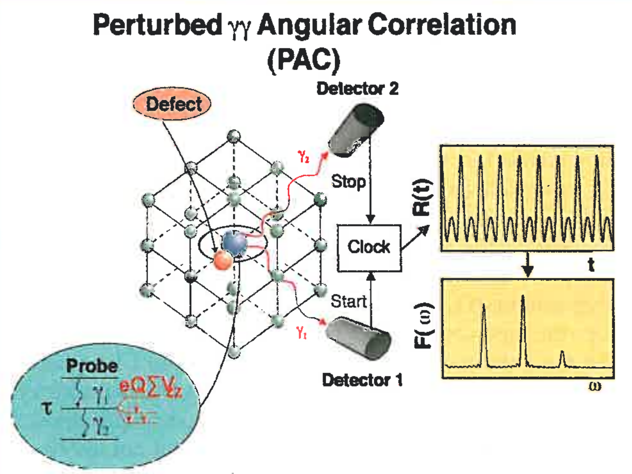

Fig. 6: A local electric field gradient V_{zz} created by a defect present in the neighbourhood of a radioactive probe atom interacts with the nuclear quadrupole moment of the probe nucleus. This interaction causes a precession of its nuclear spin which can be detected by recording the γ-quanta γ_1 and γ_2 in coincidence (perturbed angular $\gamma\gamma$ correlation, PAC). This results in a time spectrum R(t) which can be analyzed by calculating its Fourier transform F(ω). The observed frequencies are characteristic for a specific defect configuration.

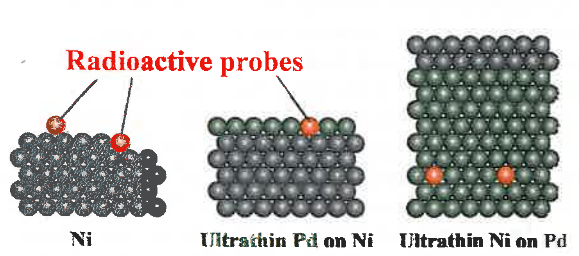

Fig. 8: Outline of three pioneering experiments using radioactive atoms performed at metallic surfaces and interfaces. Left: Radioactive probe atoms were positioned at different surface structures of Ni (e.g., terraces, steps) and, using PAC, the magnetic hyperfine fields were measured with an unsurpassed structural resolution. Centre: The 'ferromagnetic' behaviour of ultrathin Pd grown on Ni was investigated with different radioactive probe atoms. Right: Magnetic properties in Pd, induced by a coverage of an ultrathin Ni layer on Pd, were measured for different distances from the Ni/Pd interface.

the Pd layers of rather complex nature. By contrast, discrete hyperfine fields were measured for Cd probe atoms which could be attributed to specific lattice locations [13].

Conclusion

Radioactive isotopes are used in many different fields of solid state physics: semiconductors, surfaces and interfaces, magnetism, high-T_c superconductors, metals, ceramics. They provide as nuclear probes unique information about their local surroundings on an atomic scale. Due to the high sensitivity of the used spectroscopic techniques, they constitute an important tool for the determination of chemical nature, lattice location, thermodynamical properties, dynamical, electronic and optical behaviour of intrinsic and extrinsic defects in solids.

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Making quark matter at Brookhaven's new collider

Peter Jones, School of Physics and Astronomy, University of Birmingham, Birmingham, UK

The vast majority of visible matter in the universe consists of the protons and neutrons that are found in atomic nuclei. According to our understanding of the structure of matter, protons and neutrons are not fundamental particles in their own right, but are composite particles made of quarks. Quarks are believed to come in six flavours, only the lightest of which, the up and down quarks, are found in protons and neutrons. Particles formed from some of the heavier quarks have only been observed in particle accelerator experiments. Curiously, although a wide variety of particles like the proton and neutron are now known to exist, isolated quarks have never been observed. They appear to exist only in the presence of other quarks.

The reason for this communal existence ultimately has to do with the nature of the strong nuclear force. Quarks are thought to carry one of three so-called colour charges and interact with each other by the exchange of bi-coloured gluons, a process that is described by Quantum-chromodynamics (QCD), a gauge field theory for the strong interaction. What is peculiar about the strong interaction is that the particles that mediate the force, the gluons, are also colour charged. This is not the case for the electromagnetic interaction for example, where the force is mediated by the exchange of photons, which are electrically neutral. This difference is ultimately responsible for the confining property of the strong interaction. Importantly, it is also responsible for determining its short-distance behaviour, which has profound consequences for the structure of matter under extremes of high temperature and density.

As quarks are brought closer together, the force between them decreases dramatically, vanishing as the separation becomes very small. For this reason QCD is said to be an asymptotically free theory. This suggests that quarks may become unbound if the density of quarks could be increased by squeezing a nucleus. In the dense medium formed when the nucleons begin to overlap, another effect comes into play: the interaction between any two quarks in a nucleon becomes screened by their interactions with quarks in neighbouring nucleons. Under these conditions, it becomes meaningless to think of matter as being made up of individual nucleons. The nucleons would have "melted", their constituent quarks now free to roam the extended volume of the compressed nucleus.

The situation described above would mark a significant change in the structure of matter corresponding to a change of phase, rather like the transition from solid to liquid, but in this case from quark confined matter, to a quark-gluon plasma (QGP). This new state of matter has important cosmological and astrophysical implications. It would have been the natural phase of matter until approximately 10 microseconds after the Big Bang, when the temperature of the universe would have been around 2×10^{12} kelvin (about 150 000 times hotter than the centre of the Sun). It may also exist today in the core of cold but dense stellar objects, such as neutron stars.

Recreating the early universe

Very little is known about this high temperature and high density phase of matter. Theoretical guidance comes from Monte-Carlo simulations of QCD performed on a discrete space-time lattice. Calculations such as these suggest that the energy density needed to observe the phase transition is around 1 GeV/fm^3, approximately 8 times that of normal nuclear matter. If sufficiently high densities and temperatures could be achieved in the head-on collision of two heavy nuclei at very high energy, it may be possible to recreate this form of matter in the laboratory, albeit over a small volume.

If created in this way, the plasma phase, would be too short-lived to be observed directly. Rather, its existence would have to be inferred from the hundreds of new particles created out of the energy brought into the collision. Theorists have put forward various "signatures", which might be indicative of QGP

features

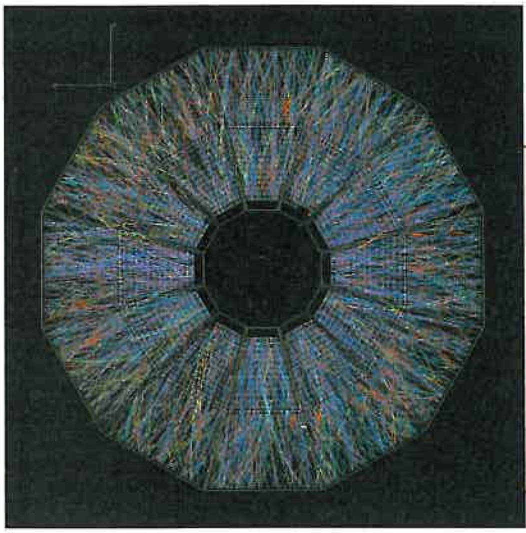

Fig. 1: The head-on collision of two gold nuclei as seen in the STAR experiment. End view of the STAR experiment's main tracking detector, a Time Projection Chamber. The 4 m high detector is a gas filled cylindrical chamber, which records the trail of ionisation left by charged particles as they pass through the device. The two gold beams enter and leave through the centre of the cylinder and collide approximately mid-way along its 4 m length. The detector is operated in a magnetic field, which causes positive and negative particles to bend in opposite directions. High momentum particles are bent less than low momentum particles. Each particle trajectory or "track" is colour coded according to its momentum. The detector is designed to measure only those particles emanating from the hot fireball created in the centre of mass of the collision. Approximately 1500 tracks are recorded in a head-on collision of two gold nuclei.

formation. In general terms, these are predictions that certain types of particles may be made more easily (or be destroyed) in a QGP, leading to an enhancement (or suppression) of particles in some channels. The experimental challenge is to establish these signatures in the testing environment of high energy heavy ion collisions and to investigate other more conventional explanations for any anomalies that are found.

Attempts to recreate the QGP have been underway at the Brookhaven National Laboratory (BNL) in the United States and at CERN in Switzerland since the mid-1980s. Initially, studies were made colliding rather light projectiles such as oxygen (^{16}O), silicon (^{28}Si) and sulphur (^{32}S) on a variety of stationary nuclear targets. These first fixed-target experiments demonstrated that it was technically feasible to measure the multiplicity of particles produced in the most violent collisions, but that larger projectiles would be needed to be certain of achieving quark deconfinement over a large enough volume for its effects to be seen. The first truly heavy-ion collisions started in the early 1990s when ions of gold (^{197}Au) and lead (^{208}Pb) were accelerated at Brookhaven and CERN respectively. Although similar size ions were used in each case, the highest energy collisions were achieved at CERN where the centre-of-mass energy was more than a factor of three times higher than at Brookhaven. (The centre-of-mass energy is the important quantity here, since it is approximately the amount of energy available for the creation of new particles.)

In February 2000, nearly fifteen years after the start of the heavy-ion programme, CERN announced that compelling evidence had been found for a new phase of matter, which might be the QGP. The evidence, based on a number of key signatures, seemed to indicate that the critical energy density lies between the energies of CERN and Brookhaven. CERN has subsequently embarked on a series of lower energy measurements in an attempt to locate the threshold at which the phase transition occurs. Meanwhile, in the summer of 2000 a new facility was commissioned at Brookhaven that would enable the study of heavy ion collisions at even higher energies.

The Relativistic Heavy Ion Collider (RHIC) is the first facility to be designed primarily to study matter under extremes of high temperature and high density. As a collider of like particles, RHIC consists of two concentric particle accelerators, which the ions traverse in opposite directions. The pre-existing accelerator complex at Brookhaven now serves as an injector to the facility, which is capable of producing ions ranging in mass from protons to gold, at centre of mass energies almost 12 times higher than previously possible in fixed-target experiments at CERN. The two beams are brought to collide at 6 points along the 3.8 kilometre circumference of the collider. Four of these interaction regions are currently being used by experiments that have been constructed by international teams of physicists. The four experiments, called STAR, PHENIX, PHOBOS and BRAHMS, have complementary physics goals, but they also share certain common capabilities that provide an important means of comparison between them.

> Theorists have put forward various "signatures", which might be indicative of QGP formation.

Nuclear stopping power and matter-antimatter symmetry

During the first experimental run in the summer of 2000, RHIC collided gold ions at a maximum centre-of-mass energy some 7.5 times higher than that previously achieved at CERN. Last year, the beam energy was increased to its design value, corresponding to energies nearly 12 times higher than CERN. At these unprecedented energies, between 4000 and 5000 charged particles are produced in the most violent events, when the nuclei collide head-on (see Figure 1). Under these conditions, the expectation is that the signatures of quark-gluon plasma formation already observed at CERN will be more pronounced. This is because matter will be created at a higher initial temperature. It is also expected that the system of newly created particles will contain almost equal amounts of matter and antimatter, as would have been the case in the Big Bang.

In the early universe, only a very small asymmetry between matter and antimatter, corresponding to an extra baryon for every 10^{10} antibaryons, resulted in the universe we see around us. Baryons are the matter particles of the universe. Each baryon contains 3 quarks, whereas an antibaryon contains 3 antiquarks. In heavy-ion collisions, there is an imbalance between matter and antimatter due to the baryons (protons and neutrons) which are brought in with the colliding nuclei. In high energy collisions, nuclei do not completely stop each other, but carry a significant amount of energy away from the interaction. What is left between the two receding nuclei is a hot dense fireball of newly created particles. Since the total number of baryons is conserved in the strong interaction, for every new antibaryon a new baryon must also be created, a process known as pair production. It is only the stopping of some of the incoming baryons that gives rise to the imbalance between the number of baryons and antibaryons in the centre-of-mass. If none of the baryons initially contained in the colliding nuclei stop in the collision, the fireball is said to be baryon-free. This means that the fireball contains an equal number of quarks and antiquarks. Such a system will ultimately materialise into an equal number of baryons and antibaryons, as well as other particles, called mesons, which contain both a quark and an antiquark. Together baryons, antibaryons and mesons comprise the family of strongly interacting particles known as hadrons.

One way to quantify the symmetry between matter and antimatter is to measure the ratio of antiprotons to protons, as shown in Figure 2. The value of this ratio at RHIC is found to be around 0.6, whereas at CERN the ratio was around 0.1, and much less in the lower energy experiments at Brookhaven. To give these numbers some meaning, the CERN antiproton to proton ratio implies that 9 times more baryons are transported into the centre-of-mass than are produced, creating a fireball which is rich in baryons. By contrast, the value of the ratio at RHIC implies that 1.5 times more baryons are made by pair production than are stopped in the collision. Although the ratio is clearly approaching unity at RHIC, there is still an excess of matter over antimatter, even at this higher energy. Nevertheless, the conditions created at RHIC are much closer to those of the early universe.

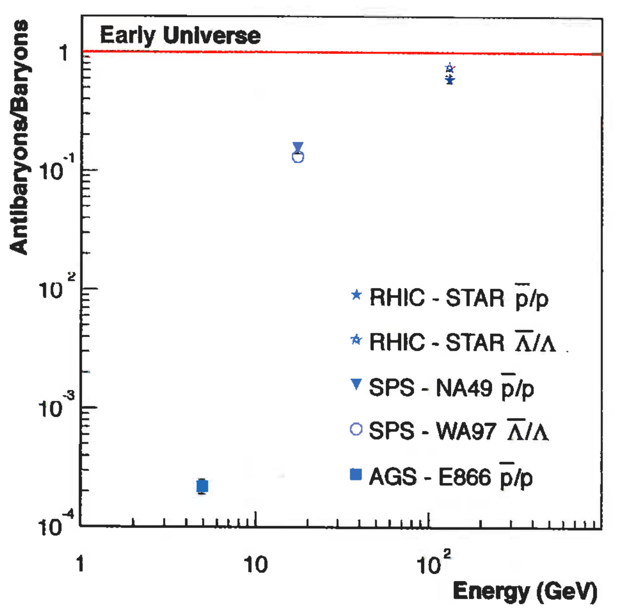

Fig. 2: The asymmetry between matter and antimatter measured by the antibaryon to baryon ratio and plotted as a function of centre-of-mass energy. Almost equal amounts of matter and antimatter were produced in the Big Bang, so that the ratio of antibaryons to baryons would have been very close to unity. Although the number of baryons are conserved in the strong interaction, the fact that nuclei consist of baryons leads to an excess of baryons over antibaryons in heavy ion collisions. This asymmetry depends on the amount of nuclear stopping, which is a function of the centre-of-mass energy of the collisions. Ratios of antiprotons and protons, and antilambdas and lambdas (baryons which also contain a strange quark) are shown, measured at the Brookhaven Alternating Gradient Synchrotron (AGS), the CERN Super Proton Synchrotron (SPS) and at the Brookhaven Relativistic Heavy Ion Collider (RHIC). All measurements are made of the fireball created at the centre-of-mass of the colliding system. The ratio of antibaryons to baryons is clearly approaching unity at RHIC, indicating that conditions similar to those that would have prevailed during the early universe are being created.

Discovery of jet-quenching?

Initially, the RHIC experiments will explore how the earlier measurements made at CERN scale with the increased collision energy. They will also look for new reaction features, which may provide a better understanding of the properties of deconfined matter. What is new at RHIC, is that a significant number of particles are thought to originate from the hard scattering of quarks and gluons during the initial stages of the collision. Hard scattering is characterised by a large momentum transfer, leading to a high momentum parton (quark or gluon) travelling transverse to the beam. By the process of confinement, hard-scattered partons fragment into a narrow cone or "jet" of hadrons. At RHIC, jet production is thought to be the main source of particles with a large transverse component of momentum.

They will also look for new reaction features, which may provide a better understanding of the properties of deconfined matter.

A large momentum transfer results from a close encounter between quarks or gluons. Since the strength of the interaction decreases with shorter distances, the cross-section for such processes can be reliably calculated by QCD in a perturbative framework. Furthermore, recent theoretical work has suggested that hard-scattered partons are extremely sensitive to the medium through which they travel. In a dense quark deconfined medium, as in the case of QGP formation, the partons are expected to suffer significant energy loss as they escape the system, leading to a depletion of particles at high transverse momentum. The pattern of energy loss, also known as jet-quenching, is in principle sensitive to the density profile of the surrounding matter, its state of confinement and its overall size. In this way, hard-scattered partons are tomographic probes, rather like annihilation gamma ray photons used in positron imaging, providing information on the distribution of matter formed during the earliest stages of the collision.

The most direct way to search for evidence of jet-quenching is to compare the production rate of high transverse momentum hadrons in heavy-ion collisions with that in proton-proton collisions where there is no surrounding matter to influence the production of jets. Hard scattering is an incoherent process that is expected to scale with the total number of independent nucleon-nucleon collisions (also called binary collisions). The number of binary collisions occurring in a gold-gold collision can be calculated from the overlap integral of the two nuclei. This provides a number by which the proton-proton data can be scaled to obtain the expected transverse momentum distribution of hadrons in the absence of jet-quenching or any nuclear effects. This scaling naively assumes that a collision between two nuclei is a superposition of independent nucleon-nucleon collisions. By dividing the transverse momentum distribution of hadrons in heavy-ion collisions by the scaled proton-proton distribution, we have a simple way to test for a suppression or enhancement of particles at high transverse momentum. A value of the ratio greater than unity would correspond to an enhancement with respect to a superposition of independent nucleon-nucleon collisions, whereas a value less than unity would correspond to a suppression.

This study has been performed by the STAR and PHENIX collaborations. Figure 3, shows the the transverse momentum distribution of charged particles in gold-gold collisions measured by PHENIX, divided by the scaled proton-proton measurements taken from previously published data. The measured ratio is found everywhere to be lower than the expected value of unity, indicative of a suppression of particles at all transverse momenta. A suppression of particles is to be expected at low transverse momentum where collective effects dominate particle production, which scale with the total number of participating nucleons rather than the number of collisions. Hard processes are only thought to become important above 2 GeV/c, but even here the measured ratio falls approximately a factor of two below the binary-scaling limit.

This observation is made even more striking when compared to CERN data (shown by the dotted lines) where the opposite trend is found. At the lower CERN energy hard scattering does not dominate particle production at large transverse momenta. The enhancement is thought to be due to the multiple scattering of partons in the projectile as they traverse the target nucleus. It is noteworthy that this "normal" nuclear effect works in the opposite direction of jet-quenching, making the observed suppression at RHIC all the more significant.

If these first indications of parton energy loss are confirmed by further studies, researchers will have discovered a promising new tool for studying the properties of the deconfined phase of matter. Over the next few years, the RHIC experiments will undertake a systematic study of jet-production in proton-proton and proton-nucleus collisions as well as in heavy-ion collisions, in order to understand more fully the interplay between nuclear effects and those of parton energy loss. This will be undertaken in parallel with studies of the other signatures of quark-gluon plasma formation already established at CERN, to provide a comprehensive understanding of matter as it would have existed during the first fraction of a second after the Big Bang.

After a successful start-up, RHIC promises to make significant steps toward unravelling the mystery of how quarks and gluons become confined in protons and neutrons. It will remain the world's highest energy heavy-ion collider until around 2008, when CERN aims to complete its next generation particle accelerator, the Large Hadron Collider (LHC).

Further Reading

New State of Matter created at CERN.
http://press.web.cern.ch/Press/Releases00/List.html

The Relativistic Heavy Ion Collider.
http://www.bnl.gov/rhic

Midrapidity antiproton-to-proton ratio from Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV, C. Adler *et al.*, Phys. Rev. Lett. **86**, 4778 (2001)

Effects of jet-quenching on high p_T hadron spectra in high energy nuclear collisions, X.N. Wang, Phys. Rev. **C58**, 2321 (1998)

Suppression of hadrons with large transverse momentum in central Au+Au collisions at $\sqrt{s_{NN}}$ = 130 GeV, K. Adcox *et al.*, Phys. Rev. Lett. **88**, 022301 (2002)

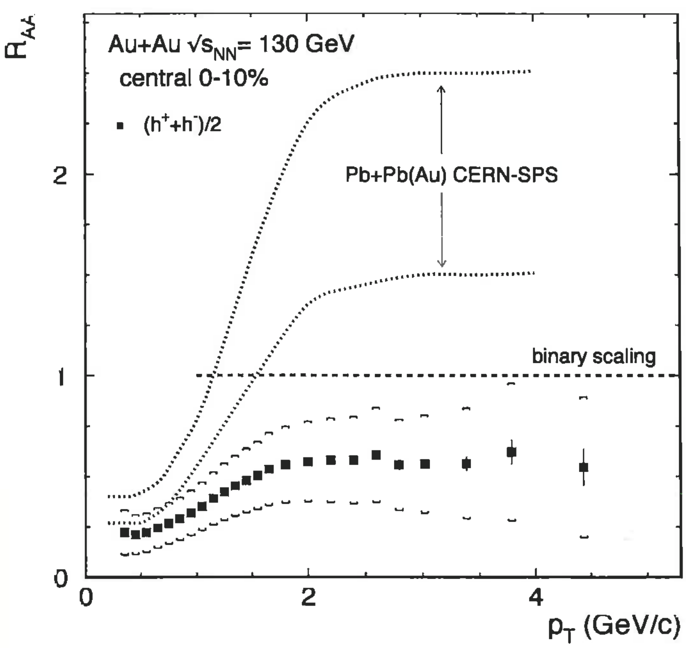

Fig. 3: Evidence for the suppression of high transverse momentum (p_T) hadrons in Au+Au collisions at RHIC, published by the PHENIX collaboration. The ratio R_{AA} is the distribution of particles produced as a function of transverse momentum (perpendicular to the beam direction) measured in gold-gold and proton-proton collisions. The proton data has been scaled by the number of nucleon-nucleon collisions that are expected in the head-on collision of two gold nuclei. This is thought to be the appropriate scaling for hard scattering processes. A value of the ratio less than unity would indicate a suppression of particles relative to a superposition of independent nucleon-nucleon collisions. The data points, which represent the measured ratio for charged hadrons, all fall below unity. The square brackets indicate the overall uncertainty of the measurement. Hard scattering processes are thought to become important only for transverse momenta greater than 2 GeV/c. For comparison the same ratio has been calculated for measurements made at lower energy at CERN, where hard processes are not important. Only the limits of the measurement are shown by the dotted lines. Here, an enhancement is found at high transverse momentum, making the suppression at the higher RHIC energy even more striking.

A violation of *CP* symmetry in *B* meson decays

Yannis Karyotakis[1] *and Gautier Hamel de Monchenault*[2]
[1]*Laboratoire de Physique des Particules d'Annecy-le-Vieux and Stanford Linear Accelerator Center*
[2]*Service de Physique des Particules, Saclay*

Thirty-seven years after the surprising discovery of a small amount of *CP* violation in neutral kaon decays, two international teams in the US and in Japan announced in summer 2001 the observation of large CP asymmetries in the decay of neutral *B* mesons. New results from both experiments have been presented recently at the Rencontres de Moriond 2002, a yearly conference in Les Arcs in the French Alps.

The *C*, *P* and *T* discrete symmetries

Most theories of modern physics are based on the invariance of the equations describing a physical system under symmetry operations. In quantum mechanics, symmetries of physical laws correspond to conservation laws, and are associated with conserved quantum numbers. There are continuous symmetries and discrete symmetries. Three space-time discrete symmetries play an essential role in particle physics: charge conjugation, *C*, in which particles are replaced by their anti-particles; parity inversion, *P*, in which all three spatial coordinates are reversed; and time reversal, *T*.

The *CPT* theorem states that all fundamental interactions must be invariant under the succession of the three operations, *C*, *P* and *T*, taken in any order. (The *CPT* theorem rests on Quantum Field Theory with minimal assumptions; it implies that particles and antiparticles, which have opposite quantum numbers, must have exactly the same mass and lifetime.) The fact that the combination of all three symmetries, *CPT*, is an exact symmetry does not require however that any of the three individual symmetries is also exact. In fact, only three out of the four fundamental interactions do respect individually the *C*, *P* and *T* symmetry operations: the laws of gravitation, of electro-magnetism and of strong nuclear force.

The fourth interaction is the weak nuclear force, which is responsible for the β decay of certain unstable nuclei. The weak interactions do not respect the *C* and *P* symmetries. In fact, these symmetries are maximally violated in weak interactions. To understand what this means, let us consider the neutrino, a spin 1/2 charge-less extremely light particle that interacts only through the weak force. There are three kinds of neutrinos; the one associated with the electron is produced left-handed together with a right-handed positron (anti-electron), while its anti-neutrino is produced right-handed together with a left-handed electron. (Here, left-handed means that the projection of the spin on the line of flight is opposite to momentum.) Applying parity *P* to a left-handed neutrino gives a right-handed neutrino, a particle that is not observed in Nature. Applying charge conjugation *C* to a left-handed neutrino gives a left-handed anti-neutrino, a particle that is not observed either. Hence, the parity and charge conjugation symmetries are both maximally violated. However, if the combination of parity and charge conjugation *CP* is applied to a left-handed neutrino, then one obtains a right-handed anti-neutrino, which is a physical particle observed in Nature. Therefore, the *CP* symmetry, which transforms a left-handed neutrino into a right-handed anti-neutrino, is a good symmetry of the weak interactions. At least as far as leptons are concerned.

Leptons and quarks

In the Standard Model of particle physics, elementary particles are classified into three families of leptons and quarks. One of the ingredients of the model is the electroweak theory, unifying electromagnetism and weak interactions, which is based on an internal symmetry called the weak-isospin symmetry. Under this symmetry, a left-handed charged lepton—electron, muon or tau—and its associated neutrino are viewed as two possible quantum states of the same entity. In each family, there is a weak-isospin doublet of left-handed leptons (an electrically-charged lepton and an associated charge-less neutrino), and weak-isospin doublet of left-handed quarks (an up-type quark of charge +2/3 and a down-type quark of charge −1/3), and corresponding doublets of right-handed antiparticles.

Like leptons, quarks are spin 1/2 particles and appear as point-like, but with fractional electric charge. Quarks experience both weak and strong interactions and are the fundamental constituents of the strongly interacting particles, the hadrons. Quarks are not observed as free particles and are always confined inside hadrons: either baryons consisting of three quarks, or mesons consisting of a quark-antiquark pair. There are six so-called flavours of quarks.

The first family is composed of the *u* and *d* quarks, which constitute the nucleons of ordinary matter, protons and neutrons, as well as light mesons such as the charged and neutral pions π.

The *s* quark, down-type quark of the second family, is contained in hadrons such as the charged and neutral kaons. The so-called strange particles are copiously produced in strong interactions, but can only decay via weak interactions, which explains their relatively long lifetimes. This is expressed by a quantum number, called the strangeness S, which is conserved in the associated strong production of particles of opposite strangeness, but violated in the weak decay of strange particles into non-strange particles.

The remaining three quarks are the "*c*", up-type quark of the second family, and the "*b*" and "*t*", down and up-type quarks forming the third family. The *c* quark had been predicted to explain the absence of certain neutral kaon decays, and was discovered in the mid-1970's simultaneously at SLAC (Stanford Linear Accelerator Center), and at BNL (Brookhaven National Laboratory). Even before the *c* quark hypothesis was confirmed experimentally, two Japanese theorists, Makoto Kobayashi and Toshihide Maskawa, proposed that the four-quark pattern be extended to six quarks in order to accommodate the possibility of *CP* violation. The discovery of the *b* quark came shortly thereafter. It took more than fifteen years (and several experiments!) to finally observe the very massive top quark, in proton-antiproton collisions at FNAL (Fermi National Accelerator Laboratory).

CP violation in kaon decays

At the time of the discovery of *CP* violation, in 1964, particle physicists generally accepted the assumption that *CP* is an exact symmetry of weak interactions. It was therefore a real sensation when the observation of a small violation of *CP* symmetry was reported in the decay of neutral kaons.

The neutral kaon K^0 is a strange meson that contains an anti-s quark bound with a d quark. The K^0 and its anti-particle, called the $\bar{K}^0$, have common final states: both can decay to either 2 or 3 pions by the weak interactions, with $|\Delta S| = 1$. There is therefore a possibility of transition between a K^0 and a $\bar{K}^0$. This $|\Delta S| = 2$ process (second-order in weak interactions) is called $K^0\bar{K}^0$ mixing: starting with a pure K^0 state, at any later time one would have a superposition of both K^0 and $\bar{K}^0$. In fact, the physical states that decay by weak interactions are not the states of well-defined strangeness at production, K^0 or $\bar{K}^0$, but states that are distinguished by the value of the *CP* quantum number of their decay modes: either the 2-pion decay mode, which has a $CP = +1$, or the 3-pion decay mode, with predominantly $CP = -1$. These particles are called the K^0_S (short-lived neutral kaon) and the K^0_L (long-lived neutral kaon). Because the decay into 3-pions is strongly suppressed by kinematics, the K^0_L has a much longer lifetime, 500 times larger, than the K^0_S. The $K^0\bar{K}^0$ system oscillates with a characteristic time of the order of the K^0_L lifetime (50 nanoseconds).

In their famous 1963 experiment at BNL, James Christenson, James Cronin, Val Fitch and René Turlay observed that about one out of every 500 of the long-lived K^0_L (those with *CP* number -1) decays into 2 pions. If *CP* were an exact symmetry, such decay would be absolutely forbidden. What a surprising result! Since then, *CP* violation in K^0_L decays has been studied with great precision. Recently, the NA48 collaboration at CERN (European Laboratory for Particle Physics) and the KTeV collaboration at FNAL have even confirmed the existence of a very infrequent phenomenon in kaon decays, called *direct CP* violation [1].

CP violation is one of the three necessary conditions to achieve a mechanism that can generate the global asymmetry in the Universe.

So, why has *CP* violation, a tiny effect, been the subject of such sustained attention by experimentalists and theorists for so many years?

One implication of *CP* violation makes it fascinating: within the strong constraint that *CPT* is an exact symmetry it implies that the time reversal symmetry *T* is also violated. Another fascinating aspect is that *CP* violation is one of the three necessary conditions to achieve a mechanism that can generate the global asymmetry in the Universe between matter and antimatter, starting with symmetric initial conditions at the time of the Big Bang. Most theorists today are convinced that the amount of *CP* violation that is observed experimentally in the quark decays is too small by several orders of magnitude to explain the observed matter-antimatter asymmetry of the Universe. However, there is a strong link between this phenomenon and the dynamics of the early Universe.

Charged weak currents

The basic symmetry of the electroweak theory implies the existence of four fields, called gauge fields, and their associated quanta, called vector bosons. The boson of the electromagnetic force is the photon, with zero mass and infinite range. The bosons of the weak force are the Z^0, W^- and W^+ particles, which play a role similar to that of the photon, except that their range, which is inversely proportional to their mass, is extremely short. The *W* bosons connect left-handed particles (or right-handed anti-particles) inside weak-isospin doublets: they are vectors of the charge-changing weak interactions.

Both leptons and quarks participate in the charge-changing weak interactions. The patterns, however, appear to be radically different. Each charged lepton undergoes charge-changing transitions to or from its own associated neutrino. On the other hand, the quarks participate in a rich pattern of charge-changing transitions. This pattern is summarised in the Cabibbo-Kobayashi-Maskawa (CKM) matrix.

The Cabibbo-Kobayashi-Maskawa matrix

The CKM matrix is a 3×3 unitary matrix, entirely defined in terms of four real parameters. This is a remarkably concise description of all we know at present about the weak interactions of quarks. One of the parameters of the CKM matrix is a phase, called the KM phase, which makes the CKM matrix complex. *CP* violation in the Standard Model requires that this phase be non-zero.

The unitarity requirement leads to nine equations that relate the CKM matrix elements. Six of these equations can be represented by triangles in the complex plane. All six triangles have the same area, which is proportional to the strength of the KM phase and is therefore a measure of the amount of *CP* violation in the theory. One of the triangles has come to be called *the* Uni-

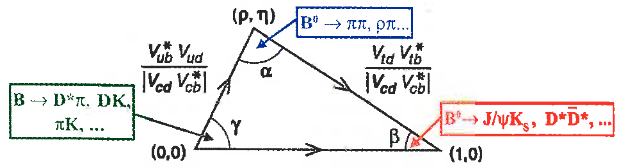

Fig. 1: The Unitarity Triangle is a geometrical representation of one of the unitarity relations that relate the elements of the Cabibbo-Kobayashi-Maskawa matrix CKM. The CKM matrix is a 3×3 unitary matrix whose nine complex elements measure the strength of the transitions of down-type quarks of charge $-1/3$ to up-type quarks of charge $+2/3$ with emission of a W^- particle. Thanks to the unitarity constraints that connect its different elements, the CKM matrix can be described by a set of four real parameters. Two of the parameters, which are the less-well known, are taken as the real and imaginary parts of a complex number $\rho + \imath\,\eta$ that defines the coordinates of the apex of the Unitarity Triangle in the complex plane. The argument of this complex number, called the KM phase γ, is the origin of all *CP* violation effects in the Standard Model. The size of the sides of the Unitarity Triangle can be deduced from measurements of various *B* meson decay rates and from the frequency of $B^0\bar{B}^0$ mixing oscillations. The interpretation of these measurements however are ultimately limited by theoretical uncertainties. In contrast, the measurement of angle β from time-dependent *CP*-violating asymmetries in the $B^0 \to J/\psi K^0_S$ decay mode is free from theoretical uncertainty. The *CP* parameter $\sin 2\beta$ is now measured by the BABAR and Belle experiments with an combined accuracy of 10%. The measurement of angle α is not only challenging experimentally, because it involves extremely rare decay modes such as $B^0 \to \pi^+\pi^-$, but also very uncertain theoretically. Likewise, the direct extraction of angle γ necessitates very large statistics of *B* mesons and complex theoretical analyses. Progress on the knowledge of the two angles α and γ are among the main goal of the two experiments in the future years. Over-constraining the Triangle tests the Standard Model explanation of *CP* violation, and may lead to the discovery of new physics.

tarity Triangle because it has the nice feature that the lengths of its three sides are of the same order theoretically, and therefore its angles are neither close to 0 nor π (see Figure 1).

The experimental goal is to perform a test of the description of *CP* violation in the Standard Model by providing an over-constrained set of measurements of the sides and angles of the Unitarity Triangle, or any other quantity that can constrain the apex of the Triangle. Inconsistency in triangle measurements would constitute an important clue of new physics beyond the Standard Model.

As it turns out, most of the physics quantities linked to the Unitarity Triangle are related to transitions that involve the *b* or *t* quarks. The physics of mesons that contain a *b* quark, *B* mesons, is therefore an important key to understanding *CP* violation.

The physics of mesons that contain a *b* quark, *B* mesons, is therefore an important key to understanding *CP* violation.

CP violation and *B* mesons

B mesons contain a anti-*b* quark associated with either a *u* (for the B^+), a *d* (for the B^0), or an *s* quark (for the B^0_s). (The corresponding anti-mesons are the B^-, the $\overline{B}^0$ and the $\overline{B}^0_s$.) The primary decay of the *b* quark is to the *c* quark. The strength of this transition is quite weak, which is one of the reasons why *B* mesons have relatively long lifetimes (1.5 picoseconds) despite their large mass (approximately 5 times that of the proton). As for the $K^0\overline{K}^0$ system, the neutral B^0 and $\overline{B}^0$ mesons can mix, with a characteristic time that is of the order of the B^0 lifetime. Some of the states that can be reached either by a B^0 or a $\overline{B}^0$ are called *CP* eigenstates because they have a well-defined value of *CP*. For instance, in the decay of a B^0 to a J/ψ and a K^0_S (the J/ψ is the lightest vector meson made of a $c\bar{c}$ pair), the $J/\psi K^0_S$ system is in a $CP = -1$ state.

Some of the *CP* asymmetries in the neutral *B* meson decays are expected to be large. How can *CP* violation be observed in practice? *CP* violation always involves quantum mechanical interference. This occurs for instance when there are two paths for a particle to decay into a given final state. The interference between the mixing-induced amplitude ($B^0 \to \overline{B}^0 \to f$) and the decay amplitude ($B^0 \to f$) to a *CP* eigenstate *f* leads to a time-dependent *CP* asymmetry that can be interpreted in terms of the angles of the Unitarity Triangle. This interpretation is simple theoretically if a single amplitude dominates the decay process. This is the case for the $B^0 \to J/\psi K^0_S$ decay, also called the golden mode. Here, *CP* violation is parameterised in terms of the sine of an angle, $\sin 2\beta$, where β is one of the angles of the Unitarity Triangle. *CP* violation occurs if and only if $\sin 2\beta$ is different from zero. Asymmetries in other modes, such as $B^0 \to \pi^+\pi^-$, are linked to another angle of the triangle, α, but the interpretation is not as clean theoretically.

The experimental challenge comes from the fact that *B* decays to *CP* eigenstates such as $J/\psi K^0_S$ have very small branching ratios and in general low efficiencies for complete reconstruction of the final state. It is therefore necessary to produce a very large sample of *B* mesons to perform a *CP* measurement.

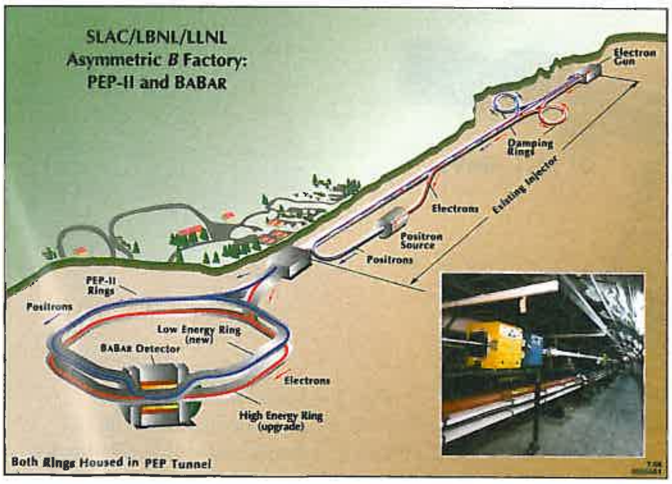

Fig. 2: The SLAC site of the linear accelerator and the PEP-II Asymmetric *B*-Factory. Electrons and positrons are stored in two rings and collide at one point where the *BABAR* detector is installed.

Dedicated experiment at the $\Upsilon(4S)$ resonance

The cleanest way to produce *B* mesons is to operate at an e^+e^- collider at a center of mass energy equal to the mass of the $\Upsilon(4S)$ resonance. The $\Upsilon(4S)$ is a $b\bar{b}$ bound state, which decays with equal probability into a $B^0\overline{B}^0$ or a B^+B^- pair. Neutral *B* meson pairs are produced in a well-defined coherent quantum state. Quantum coherence implies that after production the two *B* mesons oscillate in phase in such a way that at any instant the mesons have either opposite flavour (*i.e.*, there is exactly one B^0 and one $\overline{B}^0$ meson) or opposite *CP*. This holds until one of the mesons decays.

For *CP* analyses, one selects rare *B* decays to *CP* eigenstates, such as $B^0 \to J/\psi K^0_S$. Approximately one B^0 meson in a thousand decays in this final state. Only about 10% decay into final states with a clean experimental signature that can be reconstructed. Including selection criteria to reject backgrounds with efficiencies around 50%, one is left with the selection of about thirty fully reconstructed decays out of one million *B* meson pairs.

One needs to measure the time difference Δt between the two *B* decays. As the $\Upsilon(4S)$ mass is just above the production threshold of a pair of *B* mesons, the latter are produced almost at rest in the $\Upsilon(4S)$ rest frame. It is not possible to measure the distance between the two decay vertices in that frame. To make the measurement possible, a new type of e^+e^- collider, called Asymmetric *B*-Factory, has been designed. In Asymmetric *B*-Factories, the e^- and e^+ beams have unequal energies, typically 9 and 3 Giga electron-Volts. The *B* mesons are produced at the interaction point with a boost in the laboratory frame and their decay vertices are well separated. One deduces Δt from the measurement of the distance Δz along the boost axis between the *B* decay vertices. A time interval of the order of the *B* lifetime is translated into an average distance of 260 microns.

An important ingredient of the analysis is flavour tagging, which is the determination of the flavour of the B^0 meson at a given time. This is done by looking at the accompanying *B* meson, which, thanks to the quantum coherence, has the opposite flavour at the time of its decay. One looks typically at high-energy leptons in the decay products. A positively-charged lepton in the decay products tags a B^0 while a negatively-charged lepton tags a $\overline{B}^0$.

There are three main effects that complicate this picture and lead to a dilution of the experimental time-dependent *CP* asymmetry. First, the measurement of the time difference Δt is imperfect. Second, the flavour tagging sometimes gives the wrong answer. Finally, there is some background under the signal. The *BABAR* detector on the PEP-II *B*-Factory is optimised to minimise these sources of dilution.

PEP-II and the *BABAR* experiment

The PEP-II Asymmetric e^+e^- *B*-Factory and the *BABAR* [2] experiment are located at the Stanford Linear Accelerator Center in California. It took about 5 years to build the accelerator and the experiment designed to study *CP* violation with *B* mesons. Since the first data in May 1999, *BABAR* has collected more than 70 million $B\bar{B}$ pairs.

The 9 GeV electron beam and 3 GeV positron beam, accelerated by the 2-mile long linear accelerator, Figure 2, are injected and stored in two different storage rings, which constitute the PEP-II *B*-Factory. Electrons and positrons collide with a center of mass energy equal to the mass of the $\Upsilon(4S)$ resonance at a single interaction point, where the *BABAR* detector is installed. Thanks to the high currents stored in the rings, about 1 A for the electrons and 1.8 A for the positrons, as much as one $B\bar{B}$ pair is produced per second.

The *BABAR* experiment consists of a series of sub-detectors surrounding the interaction point in a 1.5 T solenoidal magnetic field. Figure 3 shows schematically the detector. Charged tracks, which are used to located the *B* meson decay point, are reconstructed and their momenta measured in a five layer silicon vertex tracker surrounded by a 40-layer cylindrical wire drift chamber. The silicon vertex tracker consists of 340 double-sided silicon micro-strip sensors totalling about 150,000 read-out channels. The transverse position is measured on one side and the *z* coordinate on the other. The drift chamber is composed of 30,000 3 metre-long wires forming 7,100 drift cells. Charged hadrons are identified in a ring imaging Cherenkov detector surrounding the drift chamber, called the DIRC. The Cherenkov radiator of the DIRC is a barrel of 144, 5 metre-long, 1.7 centimetre-thick, quartz bars; the Cherenkov light is detected by an array of 10752 photomultipliers located at one end of the quartz bars inside a 6m³ tank filled with ultra-pure water for optimal optical match. Electrons and photons are detected and their energy measured in the 6,580 Cesium Iodide crystal calorimeter surrounding the DIRC. Any hadrons which have not interacted with the crystal calorimeter are filtered in an iron shielding, allowing for muon identification.

> This enormous amount of data... is processed off-line by hundreds of computers running sophisticated pattern recognition software

The data acquisition system accepts more than 1,000 events per second, which are reduced to 130 events by a farm of 60 computers running elaborate selection algorithms. The average event size is 30 kilo-bytes. This enormous amount of data (40 tera-bytes per year) is processed off-line by hundreds of computers running sophisticated pattern recognition software, and made available for worldwide physics analysis by the 550 *BABAR* collaborators.

The *BABAR* detector fulfils all the requirements for *CP* analysis: operational efficiency close to 100%, precision on Δz in the range 100-200 microns—better than the average distance between two *B* decay vertices—, superb calorimetry, and excellent particle identification, which allows for good flavour tagging efficiency, corresponding to 30% of perfect tags.

There is another Asymmetric *B*-Factory in Japan, called KEK-B, which hosts Belle [3], an experiment very similar to *BABAR*,

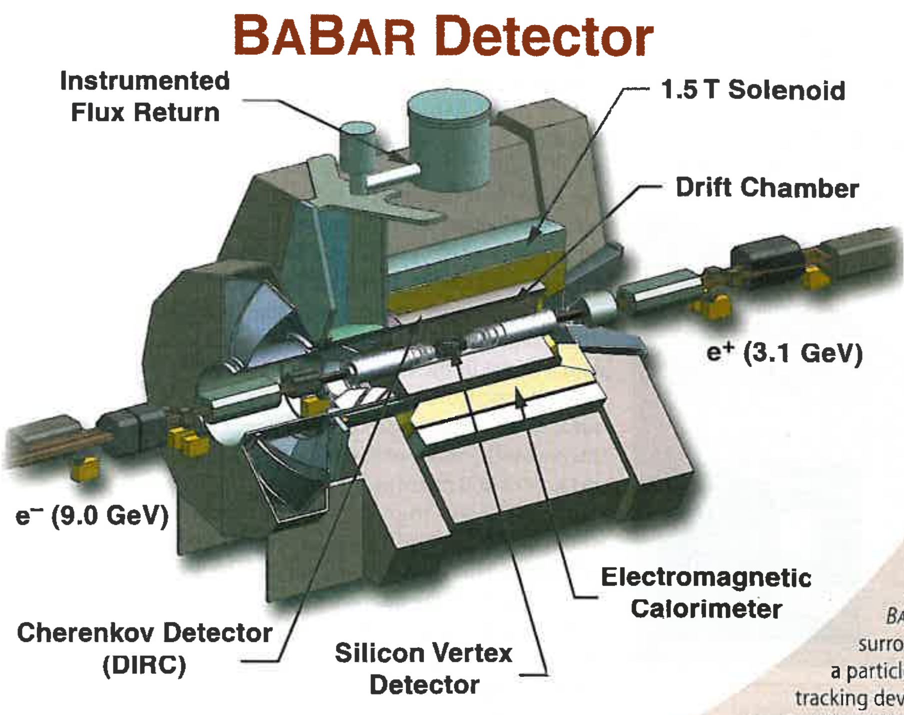

Fig. 3: A schematic view of the *BABAR* detector. A super-conducting coil surrounds a Cesium Iodide crystal calorimeter, a particle identification detector, and a precise tracking device formed by a cylindrical drift chamber and a silicon strip detector. The iron flux return is instrumented with Resistive Plate Chambers.

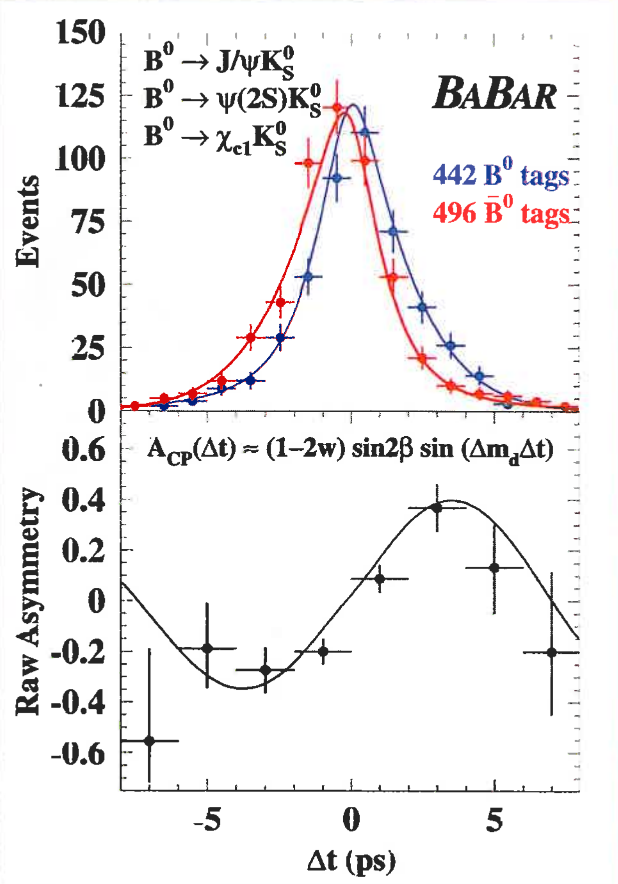

Fig. 4: Proper decay time difference (Δt) distributions for B^0 (in blue) and $\bar{B}^0$-tagged (in red) events. For a given Δt value, the decay rate to the same *CP* eigenstate depends on whether the decaying meson was tagged as a B^0 and $\bar{B}^0$ at the time the accompanying *B* meson decayed. This is a spectacular illustration of *CP* violation in the *B* system; matter and antimatter are clearly behaving differently. The corresponding raw asymmetry follows approximately a sine wave at the $B^0\bar{B}^0$ mixing frequency, whose amplitude is proportional to the *CP* parameter sin 2β.

and running simultaneously, producing physics results of equivalently high quality.

Observation of *CP* violation by *BABAR* and Belle

In July 2001, at the International Europhysics Conference on High Energy Physics in Budapest, the *BABAR* collaboration reported a measurement of the *CP* parameter sin 2β that was significantly different from zero: sin $2\beta = 0.59 \pm 0.14 \pm 0.05$ (the first error is statistical, the second error is experimental). At the Lepton-Photon Conference in Rome, two weeks later, the Belle collaboration reported an even larger value of sin 2β with the same experimental uncertainty: sin $2\beta = 0.99 \pm 0.14 \pm 0.05$. Each result, based on samples of 30 million *B* meson pairs, established *CP* violation in the neutral *B* meson system. The two reports, both published in the Physical Review Letters issue of August 27 2001 [4] [5], are the first compelling observations of *CP* violation in any system other than the neutral kaon system (see detailed reports in [6] and [7]). The discrepancy between the two results at the time of the Summer 2001 Conferences is now understood to be purely statistical. Updated measurements have been presented in early March 2002 at the Rencontres de Moriond, a yearly conference of particle physics [8] [9]. *BABAR* now measures sin $2\beta = 0.75 \pm 0.09 \pm 0.04$ and Belle sin $2\beta = 0.82 \pm 0.12 \pm 0.05$, based on samples of 55 and 42 million *B* meson pairs, respectively. The measurements are now in very good agreement and can be combined. The new World average is sin $2\beta = 0.78 \pm 0.08$ (the error combines statistical and experimental contributions). This value is in excellent agreement with Standard Model predictions based on available experimental data. The evidence for *CP* violation is dramatically illustrated in Figure 4 where the Δt distributions for B^0 and $\bar{B}^0$-tagged events are clearly distinct. Our experiment can unambiguously determine which is the B^0 and which is the $\bar{B}^0$ sample, and therefore whether the detector, the laboratory, the physicists and the planet on which the experiment was performed are made of matter or antimatter.

Conclusions

After less than three years of operation of the new Asymmetric *B*-Factories, the *CP* parameter sin 2β is measured with an accuracy of the order of 10%. The present data are consistent with the four-parameter CKM description of *CP* violation in quark decays, which puts strong constraints on sources of *CP* violation introduced by any extension of the Standard Model. For the next 3 to 4 years, *BABAR* and Belle will increase their samples by a factor of five, and continue a rich program of *CP* violation and *B* physics. Experiments at large hadron colliders at FNAL and at CERN, as well as new experiments looking for extremely rare kaon decays, will provide important and complementary measurements. The aim of the substantial worldwide effort focused on *B* physics and *CP* violation is to perform as many redundant measurements as possible of quantities that determine the values of CKM matrix elements, and to search for hints of new physics beyond the Standard Model.

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IUPAP Conference: Woman in Physics—Paris 2002

Gillian Gehring, Department of Physics and Astronomy, University of Sheffield, UK

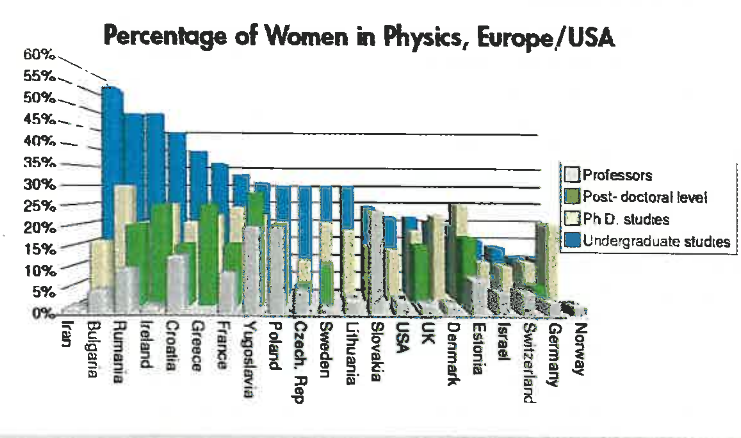
At international conferences the delegates are there because of real interest in their subject. This is not stated explicitly—it is there in the excitement of the new results and the many hours of labour that have been dedicated to the work reported. Some delegates at international conferènces are women and in this environment the women discuss the area of physics that most interest them and personal lives are kept private. I guess most of us always felt that to raise women's issues would mean that we were labelled as eccentric and not taken seriously as physicists.

67 countries represented from both the developed and developing worlds

The Paris conference was a great contrast—a new experience for all of us. About 300 women physicists mostly from academia but with a few from industry and a small number of men met to discuss how conditions might change to enable more women to make contributions to the subject. If anything the men present were more anxious to promote real changes. There was a substantial fraction of younger women present: some as part of their countries delegation and others as part of an EU initiative to fund young researchers to attend. Altogether there were 67 countries represented from both the developed and developing worlds. The Europeans were well represented comprising approximately half of the conference. Passion for physics that had sustained these women shone through the meeting. Women who told of their experiences in discussion spoke of their determination, single-mindedness or stubborn nature.

Some life histories of the older delegates were awesome. The majority and probably nearly 100% of those from the developing world had children. Almost none of them had taken a career break; one of the US delegation remarked that she had taken one weekend maternity leave for each of her two children! The overwhelming view that is was certainly extremely hard work combining kids with 'physics in the fast-lane' but the rewards of success made it well worth-while. One life history was very memorable for me because it is so often remarked that it is wise to delay children until after obtaining a permanent position. Catherine Cesarsky became pregnant during her PhD and combined a happy family life with a very distinguished career as an astronomer—she now directs the European Southern Observatory. Not all were so fortunate and told of a much less happy lifestyle, enforced childlessness or divorce. The view was that life was equally tough for the unmarried women. Some women stated that they had chosen this lifestyle so that they could compete with men only to find themselves left behind because of the operation of an old boys network. If married a supportive husband was deemed essential. Those of us who can choose our own husband were advised to choose a man who would respect and encourage us. So many women physicists are married to male physicists that the problems of managing dual careers for couples, 'the two-body problem', was much discussed and recommendations were made that this should be made easier because it is usually the woman who suffers if there is only one position.

The obvious problem for women physicists wanting an academic career in Europe is the long apprenticeship served on a succession of short-term contracts involving frequently changing institutions and often national boundaries often continuing until age 35 or even 40. This period coincides with the time when many women are establishing long term relationships which seriously restrict their mobility and is also a time for pregnancy. However, France is different. Young scientists move straight from PhD into a permanent CNRS or University post after a short (1 or 2 years) post-doc period and the percentage of women hired on permanent position at university or CNRS roughly corresponds to that of women's Ph.Ds. The situation is summarised in the figure, although it should be realised that the averaging is over different periods 3-5 years for students, circa 30 years for faculty and that faculty or professors mean different things in different countries.



Data collected for the conference and analysed by K Wiesner (Karoline.wiesner@fysik.uu.se)

There were other areas of disquiet. In MIT the women professors had assumed that any problems they might have were due to ill-luck or even their own shortcomings. However, when a committee was empowered to look at the working conditions of all the women faculty they found that the women had been excluded from the power structure and were very seriously disadvantaged in space, research funds and access to information compared with their male colleagues. The President of MIT commented at the start of the report[1] 'I have always believed that contemporary gender discrimination within universities is part reality and part perception. True, but I now understand that reality is by far the greater part of the balance.' There was the Swedish study that showed that women scientists suffered substantial discrimination in the award of research grants[2]. These two examples made delegates very uneasy. It seemed that wherever, one looked carefully at data for bias against women it had been found. Where else might it be?

The reaction of the conference was to call strongly for full transparency in all areas. Too much power was believed to be in the hands of establishment male figures who networked effectively among themselves to the exclusion of women. Within academic institutions clear guidelines for permanent appointments should be made and all jobs should be advertised and criteria for promotion should be known. Women should be involved, if possible, on appointment and promotion panels. The peer review process should be clearer and women should be involved (the EU has a target of 40% female representation on its committees and comes close to meeting this even in physics). Affirmative action was discussed, of course, but most delegates rejected it. Instead the conference delegates were strongly in favour of much more transparency and real equality of opportunity. It was felt that it was essential to have more women involved in the decision making bodies of universities and funding councils.

There was a need for more reliable data so that the effects of any initiative could be monitored. It was also clear that education systems varied widely between countries and so comparing one country with another was neither easy or really instructive. However, it was important to do monitoring as a function of time within any given country. In Japan there had been extensive studies over a period of time and kinks in the curves were clearly identified with social or legal changes. Each country produced a two page summary in advance of the conference. Reading those from Europe gives indication of a strong correlation between the number of active women physicists and the availability of good state organised child-care.

The EU commissioned the very widely acclaimed ETAN[3] report. In its development of human resource programmes it has been concerned with moving post docs over national boundaries. Physicists who work in laboratories in another EU country gain enormously. My personal view is that women are less likely to be able to benefit from a scheme to go abroad in their early 30's than one to allow them to study for at least part of their PhD abroad in their 20's. Funding students to work abroad would be a way of increasing the European experience of women physicists. Another imaginative scheme would be one that allowed mature scientists to travel for periods of say up to one year or two years if they had been prevented from travelling abroad earlier either because of responsibilities of care or because they came from one of the candidate countries where foreign travel had been impossible in their youth. At least as far as the women are concerned I believe that there is a great release of time and energy after children have become independent and that short enrichment experiences for these women would pay dividends in terms of their future productivity. I hope that the EU will introduce such a scheme in the future.

The EU funded a number of young researchers to attend. One of them told me 'I had a chance to meet many successful women physicists, and it was heartening to realise that it can be done. I also had a chance to discuss many of the concerns I've had—until now—about the possible course my career might take, especially those which are taboo in a male environment'.

Another one commented 'It was wonderful to meet all these women from so many places. The conference clearly showed that the lack of women physicists is a global phenomenon across diverse countries (true even within Europe).'

Almost all women worked in environments where there were very few female colleagues. This was what gave the conference a real feeling of euphoria—suddenly we were not alone but met really inspiring women from widely varying backgrounds. We determined to establish links between our physics societies, an enduring Women in Physics web site and a proposal has gone to the EPS council to establish a European Woman in Physics Group. This will allow more mentoring and networking and also facilitate academic visits across Europe

The conference passed resolutions and more detailed recommendations directed at various types of organisation. These can be read in detail on the web[4]. The delegation from each country was limited to 3-5 with a recommendation that one male delegate be included. This meant that there were rather few men in the Paris conference although those who were present were very supportive. Now is the time for the whole community to be involved as many of the structural changes can only occur with the good will of all active physicists as well as organisational bodies.

New working group established

The European Physical Society has established a Working Group on Gender Equality in Physics. The Chairman is Professor Gillian Gehring (G.Gehring@sheffield.ac.uk). The Working Group will follow up on the issues discussed at the IUPAP Conference: Women in Physics, specifically from a European perspective. Professor Gehring will be contacting participants from the conference to become members.

The Group would begin with the following tasks:

1. To establish email and web links between the women in physics groups in the various countries where these exist.
2. To produce a list of possible seminar/conference speakers from each country. Listed by subject area and by seniority. (This list would be made available to conference organisers if they requested help in locating women speakers)
3. To provide a list of those who would be prepared to offer help and advice to those from a different European country.
4. A Marie Curie list of those who had held/hosted Marie Curie fellows who would be prepared to be called upon for advice by would-be fellows.
5. To exchange information on initiatives taken in the respective countries to increase the participation by women.
6. To agree among ourselves what might be the best way in which the EU could support women in physics (and other sciences) and act as a pressure group to the EU to ensure that more women friendly policies were adopted.

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ESO-CERN-ESA Symposium

M. Jacob, Chairman of JAD

Astrophysics, particle physics, cosmology and fundamental physics in space, have thriving interfaces and most interesting multi-disciplinary research topics bring together scientists from these different domains. New results and open questions call for meetings covering all that has become referred to as "cosmo-physics"[1]. There have been joint CERN-ESO symposiums in the past and, two years ago, the first ESA-CERN workshop took place [2]. This year saw the first symposium jointly organised by ESO, CERN and ESA. Taking place in Garching/Munich on 4-7 March and bringing together about 200 participants, it consisted of invited talks covering different topical issues with about 50 posters also on display. While an actual review of the whole meeting is out of the question here, it is hoped that a rapid summary will whet the reader's appetite for reading the proceedings[3]. Short but authoritative surveys of several of the questions covered in Garching, and in particular those related to astrophysics and cosmology, can also be found in a recent special issue of Europhysics News on "Physics and the Universe"[4].

As emphasised by Martin Rees in his brilliant talk which concluded the meeting, we are at a very exciting time. Indeed: The existence of extra solar planets is now firmly established and, in particular, a system of 3 planets around a near by star, is now ascertained.

Neutrinos have tiny masses but which are definitely non zero. This is the first clear departure from the Standard Model.

With the large scale homogeneity and isotropy of the Universe now confirmed by the properties of the Cosmic Microwave Background (CMB), one can study the global properties and evolution of the Universe in terms of a very few parameters and their gross values have been established in a remarkably short time. The Universe is flat and has therefore a critical density (Omega=1), but baryons constitute only about 5% of it. Dark non-baryonic matter represents 25% of the overall density, whereas about 70% of it corresponds to "dark energy" with a negative pressure accelerating the expansion of the Universe. All these separate contributions to the global density should be known precisely within a decade. One can but be impressed by the "cosmic concordance" of the values already obtained through very different types of measurements! But this now raises the question of "Why are they that way?" and, more specifically, why are the dark matter and dark energy densities so similar now?

Mrs. Cesarsky, the DG of ESO, opened the symposium stressing that the important pace of discoveries is likely to continue and therefore to call for successive meetings of this type, with the three organisations finding important domains of common interest.

Present knowledge about the global properties of the universe were covered in the first sessions. The first talk by N. Turok had as a title "the very early universe" but he added to it, somewhat provocatively, "past and future", proposing actually a universe with a succession of big bangs and big crunches. After presenting the different contributions to Omega, with a global value of one (a flat universe) implied by the recent observation of the first three acoustic peaks in the angular analysis of the CMB, Turok stressed that one should be aware that "theory is the bottom line", namely that each particular measurement has little value by itself unless it is assessed within a particular theoretical framework, a framework which we should keep challenging despite the impressive convergence of the values found for all the global parameters. The properties of the CMB were then reviewed from an experimental point of view by P. de Bernardis. Whereas the key result is the flatness of the universe, the second and third peaks allow one to pin down the baryonic density (5%) and the scale independence property of the temperature fluctuations. It was however stressed that present measurements were made with a very limited sky coverage only.

A key question in the evolution of the Universe is the present acceleration of its expansion. It can be parameterised in term of a cosmological constant or dressed up in a dynamical way as the case with the quintessence picture. It is very puzzling that the vacuum energy density is so tiny as compared with what to expect at any of the known scales (i.e. Planck scale or electroweak breaking scale). Present direct evidence for this relatively modest acceleration is based on the observation of 1a supernovae expected to be reliable candles. The present situation was very clearly surveyed by B. Leibundgut who stressed all that is still needed to understand the systematic uncertainties of the type 1a supernovae. This calls for a much larger statistics, probing to larger z, and also for the understanding of the explosion of type 1a supernovae. Of complementary importance is the determination of the matter density, as is possible through the cosmic shear due to weak gravitational lensing. This was reviewed by Y. Mellier.

A key question the evolution of th Universe is th present acceleratio of its expansio

L. Krauss, and later A. Vilenkin, came back on the determination of the global parameters with different measurements which are in good agreement with one another. Everything fits but why, once again, are all these parameters that way? Why has the cosmological constant such a "peculiar" value (so tiny as compared to the Planck scale), with a vacuum energy density now so close to the matter density? Vilenkin raised the possibility that our visible universe, where the initial inflation has long stopped, could be but a tiny piece of a super large universe where inflation is still going strong in some other regions!

P. Madau discussed the cooling and then re-ionisation of the early universe as the first stars were born thus bringing an end to the dark ages and he discussed the development of the early massive structures. H. Boehringer showed how the measured dark matter density tallies with the observation of X-ray galaxy clusters and also with nucleo-synthesis.

Direct searches for dark matter were reviewed by C. Tao. After recalling the first hints provided by the rotation curves of galaxies and the blame put on a halo of baryonic matter, she explained how MACHOs were searched through gravitational lensing and found but not enough in number to provide what was needed. WHIMPs (predicted by SUSY as stable neutralinos) have been extensively looked for in underground experiments but so far to no clear avail. The question of neutrino masses was reviewed by P. Hernandez. Neutrinos are no longer considered as providing an appreciable contribution to dark matter. Whereas their having non zero masses is now established, these masses are too small to be much relevant and seem to call for a new mass scale at the GUT level. Projects for neutrino experiments are numerous and ingenious.

Next came reviews of the Standard Model of particle physics and the great prospects for research at the LHC. This was very well done by Pich (low energy tests), F. Gianotti (high energy tests) and by J. Ellis who went beyond the standard model and considered the possibility of the opening up of extra dimensions at short distances as a possible rival to supersymmetry.

As the second day drew to a close, the programme left particle physics and went back to space with a beautiful and thorough review of gamma ray bursts by E.P.G.van den Heuvel. A beautiful example of serendipity since discovered while looking for something else (nuclear tests in the atmosphere), gamma ray bursts are now known as the most powerful cosmic explosions. They occur at the level of one per day, are usually beamed, and the energy output may reach that of a million supernovae. They last from seconds to minutes and appear at random in the sky, something natural since they are known to be at cosmological distances ($z=1$ to 2 and up to 4.5). With present satellite effort soon to pay off, they should be much better analysed and observable up to $z=12$.

The following morning was devoted to extreme events. This included very high energy gamma rays (H.J.Völk), cosmic rays of the highest energies (A. Watson), high energy neutrinos from astrophysical sources (F. Halzen) and the study of the X-ray background (G. Hasinger). With very high energy cosmic rays, the key question is the observation of a few events above 10^{11} GeV, therefore at an energy where they should be stopped by the CMB (GZK cutoff). Their occurrence is very puzzling and one can but hope for more results but the event rate is only at the level of one event per square km per century. This will be possible with the AUGER project on the ground and, later, with the EUSO project on the ISS.

The afternoon programme continued with astrophysics with a critical discussion of neutron stars (L. Woltjer); that of supermassive blackholes in galaxy centres (R. Bender); a view at the centre of the Milky Way (A. Eckart); and a review of sources of gravitational waves (B. Schutz).

It is now highly plausible that active very massive black holes at the centre of galaxies are fuelling the energy output of quasars (the power of 10^{12} to 10^{15} suns) and that all galaxies were once active. In nearby galaxies, the presence of a relatively quiet but yet giant black hole is inferred from the swift motion of stars around a dark centre. For instance, the black hole at the centre of the Milky Way has 3.10^6 solar masses. The central part of the Milky Way is now seen down to 3 light years of the centre, a distance where stars circle at velocities up to 1500 km/s. Much progress is expected soon about the motions of the inner stars.

Gravitational waves carry huge energies but interact very weakly, crossing the universe while almost unperturbed. The study of the evolution of the Hulse-Taylor binary tallies very well with expectations assuming the emission of gravitational waves but such waves have not been directly detected yet. When calculating their amplitudes, one finds the product of the gravitational potential of the source times its compactness factor, hence the picture of ripples on the fabric of space-time as deformed by the source. The merging of two black holes of a million solar masses at $z=1$ would give an amplitude 5 orders of magnitude higher than the detection threshold of LISA (2).

With gravitational waves at low frequencies (10^{-1} to 10^{-4} Hz), one enters the domain of fundamental physics in space, probing gravitation theory in the high field domain. This was the object of the second session in the afternoon. K.Danzmann presented experimental searches for gravitational waves where. the situation has evolved very favourably since the ESA-CERN workshop[2]. S. Vitale described other missions in fundamental physics under study at ESA. R.Battiston described the AMS findings on the properties of the cosmic ray flux and showed how a new mission on the ISS will bring down the anti-Helium over Helium ratio from 10^{-6} (present) to 10^{-9}, or find something.

The programme of that day closed with a special lecture on "Time" by J.C Carrière, well known director and author. In between the concept of time according to St Augustine and that of space-time according to Proust, he brilliantly exposed how the stage or film director emphasises effects in playing with the flow of time, when the spectator wrongly expects that the flow on the screen is identical to its own.

During the last day, the VLT early operations, with a resolution reaching 0.001 arc second, were presented by F. Paresce and illustrated with the observation of distant most interesting objects. The Symposium then turned to a study of planets and planet formation. E. van Dishoeck discussed the formation of a star and planetary system from a large molecular cloud of gas and dust, the formation of the solar system demanding 10^{+8} years. M. Mayor recalled that more than 80 extra solar planets have already been seen during a few exciting years, some of them with smaller masses, as observation techniques quickly gained in performance (one is now down at 50 times the mass of the earth). He discussed how planets are found through radial velocity surveys and now also through planetary transit, the latter approach giving direct evidence for gaseous giant planets such as Jupiter The huge observed diversity was not anticipated with, in particular, some planets with very short periods, elongated orbits or very large masses (10 times the mass of Jupiter). M. Perryman showed how missions under study could make it possible to search for earth-like planets. One could tentatively expect one earth-like planet for a thousand stars but many conditions are needed to make life possible on it. He defined a "habitable zone" but also stressing its needed continuity over a few billions of years, this implying the protection of a "Jupiter" against big collisions.

The last afternoon started with instructive and authoritative presentations of future perspectives at ESA, CERN and ESO. One has clearly to leave to the proceedings the long list of projects at ESA-Science, some in collaboration with NASA, which Southwood presented. L. Maiani, DG of CERN, could not be present and J. Ellis replaced him for his presentation heralding the discovery potential of the LHC. Also mentioned was the concept of "recognised experiments", through which collaborations with approved experiments in astroparticle physics can use CERN as a base. C. Cesarsky, DG of ESO, described the present shift of activities from La Silla to Paranal (the VLT) and new ESO-US projects, in the visible and in the infrared. It was clear to all that the good running of the installations in Chile represents a great success.

In all cases, the need for big increases in computing capabilities was clear. This is a domain in which heavy basic science is a driving force for a high technology which quickly find many other uses.

As has been said, the concluding lecture was given by M. Rees. which was a brilliant finale for this very interesting symposium. First discussing the great recent findings and, in particular, the measurement of the "Big Bang numbers", he could not avoid wondering who ordered that mixture? It would be impossible to properly summarise all the challenges (in theoretical physics, in astrophysics and in the formation of early structures in the universe) that he masterfully surveyed. Was there only one Big Bang and why that one?

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activities

Division on Physics in Life Sciences

Per-Anker Lindgård, Chairman of the Division

A new Division of the European Physical Society has been created. The purpose shall be the advancement and diffusion of knowledge on *the physics of biological systems and biological problems*; including the interesting new physics arising from the investigation of life processes. The proposed name is *The Division of Physics in Life Sciences (DPL)* in order to emphasise the many new possibilities, both experimentally, theoretically and simulation-wise, which have emerged recently. Primarily the aim is to coordinate efforts in biological physics. But the broader title indicates that there is a great potential for physics in fields related for example to medicine. Forming an organisation of those interests is a task, which could and should be undertaken subsequently.

There is no doubt that in the post-genomic era strong emphasis and considerable funding will be devoted to biological problems. Physics has a large and important role to play in this, in conjunction with the rapidly advancing modern biology. Hence there is a need to unite and coordinate the efforts in Europe. At present the EPS has no unit representing this development. It will be addressed mainly to physicists working in physics departments and natural members of physical societies, but with a growing interest towards the interdisciplinary area between physics and biology. The Division should provide links to and collaboration with other learned societies and organisations.

Scope

The aim of the Division is to provide a forum for presenting, discussing and coordinating new developments in all areas where the physics can be used to advance the understanding of biological systems and mechanisms, encompassing both model systems and the full complexity of biology. The fields include, but are not limited to, experimental, theoretical and simulation investigations of the following topics

- Single-molecule biological physics, proteins, RNA, DNA, molecular motors etc.
- Folding, structure, dynamics and function of proteins
- Physics on the scale of the cell, cell interactions and membranes
- Physics of bio-chemical and genetic networks
- Non-linear and non-equilibrium physics in biological context
- Ultra-fast dynamics at the molecular and cellular levels
- The scope may be organically adjusted as the division grows

Programme

The Division should serve the European physics community in the field of biological physics (BP) through activities as **a)** organise forums, workshops, topical and international conferences, summer schools, **b)** establish an e-mail list of the members; create an e-mail communication forum and web-site, **c)** organise a newsletter and/or provide links to related web pages and news channels, **d)** represent biological physics at the level of EPS, **e)** provide advice to research organisations or institutions (European Science Foundation, etc.), **f)** provide advice to funding agencies, **g)** establish and maintain links between the BP community and the European Union (EU), **h)** provide list of experts to EU, etc., **i)** coordinate relations with other learned European societies in biophysics, biochemistry..., **j)** attract students to BP and support work on setting up curricula for the education.

Organisation

A small 'reflection' committee consisting of Vincent Croquette *(Physics Dept, ENS, Paris)*, Marileen Dogterom *(AMOLF, Amsterdam)*, Thomas Duke *(Condensed Matter, Cambridge University)*, Henrik Flyvbjerg *(Graduate School of Biophysics, Niels Bohr Institute, Copenhagen)*, Hermann Gaub *(Physics, University of Munich)*, Frank Julicher *(Max Planck Institute for Complex Systems, Dresden)*, and Per-Anker Lindgård, Chairman *(Risoe)*, was set up in 2001 by the President of EPS to investigate the possibilities and the rationale for forming the new Division on biological physics. This group hence formulated the present proposal for the creation of such a Division. Strong support for the initiative has been obtained from a large number of contacted scientists in the field. A list of the first potential members has been formed. The committee has reached the conclusion, that there is indeed a need and an interest for uniting the efforts in Europe in this field—possibly in conjunction with the similar division in the American Physical Society, which at present has over 1200 members and is growing fast. At least a similar number of members should be expected for a European sister organisation within the EPS.

Board of the Division

- A board of the Division is elected according to the EPS rules, consisting of 10–12 delegates elected by the members of the Division, plus up to 6 co-opted delegates. By means of co-opting the Board will ensure representation of other interested groups inside or outside the EPS.

- For a start, the reflection committee designates the following members for the Board, representing a vide variety of scientific interests and geographical regions:
  M. Cieplak *(PL)*, V. Croquette *(FR)*, T. Duke *(UK)*, H. Gaub *(DE)*, A. Irbäck *(SE)*, P.-A. Lindgård, Chairman *(DK)*, A. Maritan *(IT)*, F. Parak *(DE)*, T. Vicsek *(HU)*, G. Zaccai *(FR)*

- Co-opted members representing biophysical organisations e.g. EBSA, and Divisions and Groups in the EPS, e.g. CMD and DSN will subsequently be sought by the board.

- Elections to the Board will be organised among the members according to the EPS rules after the EPS Council meeting at which the formation of the new Division is recommended.

The proposal was very well received by the EPS Council meeting in Berlin 23 March 2002.

The Division is hereby in operation. The acronym will be DPL. If you are a member of a National Physical Society or the EPS you can join the division for free and contribute to the establishment of this new, interesting field. For an application form, please visit www.eps.org and see under divisions, DPL. We are also, as the first EPS Division, setting up a direct electronic application procedure with the help of the PhysNet service—please use it—it simplifies everything for all of us.

The first EPS workshop of the Division on *Nanophysics of Life Systems* is planned 21–23 of June in Copenhagen in conjunction with the constituting meeting of the divisional board. The board members and others will be the speakers. It is limited to about 60 participants, so if you want to participate, please register soon. Look at the home page of the Division: www.DPL.risoe.dk or the link at www.eps.org for more information.

noticeboard

German-Polish EURO-Conference on Plasma Diagnostics for Fusion and Applications

Greifswald, Germany, September 4-6, 2002

Stimulated by the growing interest in the plasma physics and technology, as well as in scientific collaboration between Germany and Poland, the Max-Planck-Institut fuer Plasmaphysik (IPP) is sponsoring the 2002 German-Polish EURO-Conference on Plasma Diagnostics, to be held in Greifswald, Germany, on September 4-6, 2002. The Conference is designated for interested scientists, engineers, and students from all countries, and particularly for those from Central and Eastern Europe. The Conference is being organized to be one of the primary sources of community input to the assessment of different diagnostic methods referring to plasma physics and technology. The emphasis of the conference will be on applicability of the known measuring techniques in various facilities used for fusion- and technology-oriented experiments. Discussion of plasma diagnostics issues and the adaptation of the mastered diagnostic methods to different experimental conditions will be strongly encouraged. Topics include: Diagnostics of Plasma Core, Diagnostics of Plasma Edge and Divertor Diagnostics, Long Pulse Problems and Chances and Diagnostics of Low Temperature Plasmas. Prospective participants interested in making presentations in one of the topic areas or of more general nature, are invited to submit one-page abstracts before July 12, 2002 by e-mail to the organizers (hartfuss@ipp.mpg.de). All information and further announcements/updates will be available on the conference web site: http://www.ipp.mpg.de/gppd.

Nominations to the Board of the Quantum Optics and Electronics Division

The QEOD will organize elections to replace six outgoing members. Nominations are invited from members of the Division. Nominations including a 1/2 page cv, as well as a statement from the candidate should be should be addressed to David Lee, EPS, B.P. 2136, 34, rue Marc Seguin F - 68060 Mulhouse, France. The deadline for receipt of nominations is 30 June 2002. The resulting list of candidates and ballot papers will be mailed to Section Members who will be invited to vote by the deadline of 30 September 2002.

Nominations to the Board of the Condensed Matter Division

The Condensed Matter Division will organize elections to replace three outgoing members. Nominations are invited from members of the Division. Nominations including a 1/2 page cv, as well as a statement from the candidate should be should be addressed to David Lee, EPS, B.P. 2136, 34, rue Marc Seguin F - 68060 Mulhouse, France. The deadline for receipt of nominations is 30 June 2002. The resulting list of candidates and ballot papers will be mailed to Section Members who will be invited to vote by the deadline of 30 September 2002.

SINN02 invitation and call for papers

The 2nd International Technical Workshop of the project SINN and one day conference on 'Open Distributed Science Information Management' will take place on 6–8 November 2002 Oldenburg, Germany.

Hosted and organised by the Institute for Science Networking Oldenburg GmbH under the umbrella of the European Physical Society (EPS) SINN02 will focus on how to improve technically the network of independent but cooperating regional Harvest brokers and gatherers of the PhysNet service and how to enlarge the active network of PhysNet-mirrors (www.physics-network.org).

SINN02 will consist of two parts, a Technical Workshop covering topics such as XML-query language and usage: Installation, configuration and operation of Harvest gatherers and brokers. The second part will be a conference on 'Open Distributed Science Information Management', divided into the following thematic sessions: field specific portals for sciences (with distributed content); field specific retrieval; OAI service providers: concepts for services and realisation and long term archiving (in physics) and cooperation with libraries

In addition to all known partners of SINN and PhysNet, we invite representatives of all national physical societies as well as representatives of other fields to take an active part in the conference.

Contributions to the technical part as well as to the conference are welcome. The deadline for contributions related to the conference topics will be September 15th 2002. The deadline for registration will be September 30th 2002, but we would appreciate an earlier registration.

Further information about SINN02 and a registration form can be found at: www.isn-oldenburg.de/projects/SINN/sinn02/

EPS Council report 2002

This years Council meeting took place at the Magnus Haus in Berlin on March 22-23. An overall constructive meeting, it shed new light on many of the recurrent issues facing the society.

Alex Bradshaw welcomed the participants on behalf our hosts, the DPG, and provided an interesting historical overview of the Magnus Haus. Built in the 18th century, the majority of the buildings occupants have been devoted to science, and has housed many of the Europe's best, including the French mathematician Lagrange, and of course, T. Magnus. The building was acquired by the by its current owners, when the physical society of the former GDR and the DPG merged, following the political changes in 1989-1990. The Magnus Haus was restored by Siemens AG, and is now used as a meeting centre in science, art and culture, with a strong physics component.

M. Ducloy, the EPS President opened the meeting, beginning with a résumé of the main activities of the 2001 under his leadership and though the Executive Committee. Meetings were held with most of the EPS Divisions and Interdivisional Groups, to understand how they work, and to convey what the Executive Committee is doing. Meetings of the Executive Committee were also held in connection with meetings of regional groupings of societies, in Minsk with the many societies from Eastern Europe, and in Athens with the representatives of the Balkan Physical Union.

Much of the work in 2001 was carried out to implement the EPS Strategy Plan for Science presented at Council 2000. To ensure that the EPS covers all fields of physics, two new divisions were established. A Division on the Physics of Life Sciences was established thanks to the hard work, enthusiasm and skill of P. A. Lindgard, and a Division of the Environmental Physics was established using the in depth understanding of the field by C. Zerefos.

Two new working groups were also established. To study the Framework 6 programme, M. Allegrini accepted to lead a group that will provide useful information to EPS members on issues such as how to apply for grants, what contacts exist, and act as a conduit for informing Brussels of EPS concerns with regard to FP6. Following the IUPAP conference on women in Physics, the EPS has also established a working group to study issues relating to gender equality on physics, under the competent direction of G. Gehring.

A further working group as established to study the EPS Constitution and By-laws, and adapt them where necessary to changes within the Society and Europe. Issues to be addressed include the formation and representation of divisions, membership for other learned societies, student membership and voting rights.

C. Rossel reported on activities at the Secretariat, the most exciting being the progress concerning the office space for the EPS to be built on the campus of the Université d'Haute Alsace (Mulhouse). Many meetings were held with the University's technical staff, and three local architects were invited to present plans for the building. (Since Council, the jury has selected the drawings of the new EPS building, and they will be published in the next issue of EPN).

The financial situation of the Society remains stable. However, it was the opinion of many members present that to expand activities, it is necessary to increase the income of the EPS. How best to accomplish this was the subject of much discussion. The EPS has begun working to increase the number of Associate Members, aware that it is necessary to develop activities and services for physicists working in industry. Most of EPS Associate Members were recruited through personal contacts in the 1970's and 80's. As those contacts retire, and due to changes in the structure of commercial companies, the number of EPS Associate Members has been slowly declining. Many good ideas were expressed to bring new Associate members to the EPS. Personal contacts remain very important and members were urged to use them, or provide names to the EPS Secretariat. Showing who our Associate Members are was also considered and important factor in their recruitment, as was the role of the EPS in training young physicists, who represent the future work force for EPS Associate Members. Other ideas were a forum in Europhysics News, and free or reduced price exhibit space at EPS conferences.

C. Rossel presented the need for a Scientific Communications Officer, to represent the scientific activities of the EPS. A job description and candidate profile were discussed. The Council delegates agreed that a Scientific Communications Officer would be a welcome addition to the EPS. The best candidate would be a physicist, and the position would be suitable for an experienced scientist who understands the European physics community, and any suggestions for suitable candidates would be considered.

During the elections, the Society and gave an overwhelming vote of confidence for the incumbent President, M. Ducloy The Council also elected M. Huber elected as President – elect. He will serve one year as Vice-president, and will become the EPS President at the Council meeting in 2003.

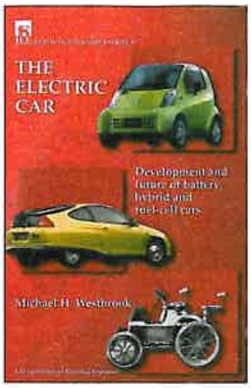
The other members of the Executive Committee that were re-elected are:

- Maria Allegrini (Italy) Vice Treasurer
- David Brown (UK)
- Gerard Delgado Barrio (Spain)
- Karel Gaemers (The Netherlands)
- Dalibor Krupa (Slovakia)
- Peter Reineker (Germany) Treasurer
- Chris Rossel (Switzerland) Secretary
- Cristos Zerefos (Greece)

There were 5 five excellent candidates for the one remaining open position on the Executive Committee. After a very close ballot, Z. Rudzikas (Lithuania) was elected. The Council expressed it heartfelt thanks to the two outgoing members P. A. Lindgard and R. Sosnowsky for their hard work and contributions to the Society over the past five years.

Council in 2003 will be held in Mulhouse on 28 and 29 March. We look forward to seeing you there.

BOOK REVIEWS



The Electric Car:

Development and future of battery, hybrid and fuel-cell cars

Michael H. Westbrook
IEE, 2001
198 pages

This is a very timely little book. The industrialised world has gorged increasingly on fossil fuels, notably crude oil, for half a century and it is widely recognised that this cannot continue indefinitely. The search for alternative automotive fuels and propulsion systems will intensify during the coming decades, and there will be intense competition between vehicle designs as the price of gasoline and environmental concern over emissions increases. "The Electric Car" offers an authoritative overview of the state of the art in novel automotive technologies at the turn of the century.

Written by an electric-car expert involved in the automotive industry for more than 33 years, this book presents a concise discussion of the history of electric cars, propulsion systems and controls, alternative energy sources, and economic aspects, and comments thoughtfully on the outlook for future developments.

When automobiles where first introduced near the turn of the last century, electric vehicles initially dominated – doubtless because of the directness and simplicity of battery-electric motors compared to internal-combustion gasoline engines. However, the Achilles heel of the electric car is its limited energy storage capacity. Since the storage capacity of the conventional lead-acid battery is 35 Wh/kg compared to more than 2000 Wh/kg for gasoline (one of the compelling facts to be found in "The Electric Car" along with a wealth of other technical details), it is not hard to understand why the internal combustion engine was favoured for the private motorcar. However, electric vehicles can operate virtually pollution-free which, along with the rising price and finite supply of gasoline, has brought electric and hybrid cars back into the spotlight.

There are formidable problems to be overcome if electric cars are to see widespread general use. In addition to the problem of increasing the energy density of storage systems so that electric vehicles can have the sort of range to which automobile users have become accustomed, there are thorny problems in re-fuelling and in safety assurance. However, significant progress has been made during recent decades and is well described in this book. The list of references is comprehensive, spanning both professional and general-interest sources. "The Electric Car" can be recommended highly to anyone interested in this topic.

Bill Tyson

Dr. W.R. Tyson
MTL/CANMET, 568 Booth St., Ottawa, Ont., Canada K1A 0G1
Ph. (613)992-9573
fax (613)992-8735
e-mail btyson@NRCan.gc.ca

Books for review

An Introduction to the Science of Cosmology
D.J. Raine, E.G. Thomas, IOP Publishing, 2001, 220 pages

Brownian Motion:
Fluctuations, Dynamics and Applications
R.M. Mazo, Oxford Science Publications, 2002, 289 pages

Complete Scattering Experiments:
Physics of Atoms and Molecules
U. Becker, A. Crowe, KA/PP, 2001, 279 pages

Cosmic Rays at Earth:
Researcher's Reference Manual and Data Book
Peter K.F. Grieder, Elsevier, 2001, 1093 pages

Exploring Nature's Dynamics (+ disk)
E.A. Jackson, Wiley. Series in nonlinear science, 2001, 303 pages

Great Physicists:
The life and times of leading physicists from Galileo to Hawking
W.H. Cropper, Oxford, 2001, 500 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

Matter & Interactions:
Modern Mechanics (Vol. I)
R. Chabay, B. Sherwood, Wiley, 2002, 432 pages

Modern Cosmology
S. Bonometto, V. Gorini, U. Moschella, IOP Publishing, 2002, 480 pages

The Physics of Alfven Waves
N.F. Cramer, Wiley VCH, 2001, 298 pages

Polarised Light in Science and Nature
D. Pye, IOP Publishing, 2001, 124 pages

Relativity:
Special, General and Cosmological
W. Rindler, Oxford, 2001, 428 pages

Theory of Photon Acceleration
J.T. Mendonça, IOP Publishing. Series in plasma physics, 2001, 222 pages

Thin Film Magnetoresistive Sensors
S. Tumanski, IOP Publishing, 2001, 441 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

Letters

An institute for atomic physics and cosmology

Many attributes have been attached to the last century, but if physicists are asked they would in all probability call it an atomic age. Not only because of the emergence of the physics of atoms and molecules, together with the nuclear and particle physics and technologies, but the invention of Quantum mechanics, arguably the greatest scientific achievements of the last century, if not in the entire history, was initiated by the atomic physics research. So important the concept of the atom in its widest sense has been that Richard Faynman used to emphasize that if one was to transmit to "outer space" our greatest and most important discovery concerning Nature, that would be the inference that the material world is atomic in structure.

Another remarkable signature of our age is the rise of scientific cosmology, based (mainly, but not exclusively) on Einstein's General Relativity. With the advance of observational means, this discipline has passed from the speculative sphere to a truly scientific subject. Modern man has come for the first time in history to the awareness that he is but a part of an infinite whole (with a specific meaning of the latter attribute).

The atomic hypothesis of Leukippus and Democritus from the 5th century B.C. was arguably the most significant idea we have inherited from ancient Greece, whose culture in general and science in particular, have laid the foundation of the present day European and world culture. They have also laid down, the first in history, a truly rational cosmology, based on the atomic hypothesis. Though not much has been preserved of their writing on the subject, it is clear now that they have sown the seeds of all the principal concepts of the present day physical cosmology. These include the idea of an infinity of worlds, not only in number but in their physical nature. The very mechanism of forming particular worlds, by atomic whirls, was later resumed by many European thinkers and cosmologists, from G. Bruno, Decartes, Kant, Laplace, to Alfven etc. The idea of disappearance and generations of new cosmoses sounds familiar to modern ears too. With the later Epicurus' concept of randomness, these ancient cosmologies have found their modern counterparts in many contemporary cosmological paradigms, like that of Linde's stochastic self-reproducing multiverses, etc.

As we know the theoretic-philosophical achievements of the powerful minds of these two "physikoi" from ancient Abdera had an unfortunate fate in subsequent European history, for a number of reasons. (Incidentally, Protagora, who was the first to formulate an anthropic principle by postulating that "The man is a measure of all things", was born in Abdera, too).

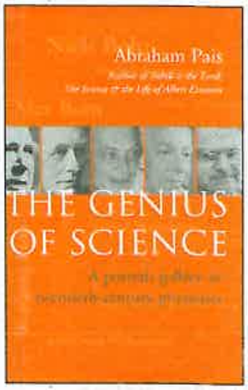
One of the latest developments in modern physics is the merging of our microcosmic and megascopic worldviews (particle physics and cosmology). Taking account of the importance of the atomistic concept and the rise of contemporary cosmology from the one side and the present trend towards scientific unification of the European cultural millieu on the other, I take the liberty to propose the founding of a European centre for Atomic Physics and Cosmology, which would provide opportunities to researchers from Europe and the world to come and stay for a period doing research there. This would be an institution like that at Trieste (ICTP), or better like the Alexandrian Library. The location would be, of course, Abdera (Avdira in modern Greek), where all this started from.

Establishing such a centre would contribute much to the development of atomic physics and cosmology research in the area, that would include South-east Europe, Asia Minor and the East Mediterranean region in general. This would, at the same time, be the best tribute to the Abderian school and ancient Greece in general, whose cultural offspring we all are, not only in Europe. It would be a sort of rehabilitation of the neglected thinkers, first of all Leukippus and Democritus, but also Epicurus, who had inferred the most important feature of the material world without microscopes and colliders, and set up the first rational cosmology without telescopes (and research funds!).

After the rise of the modern natural sciences and accounting the fact that not much of Democritus' written works are extant (except the ethics), this Abderian thinker emerges today as a scientific giant, who should be treated on equal footing with Plato and Aristotle. I consider it our duty to take an initiative that the centre proposed be founded.

As for the financial side, I hope and expect that the world community, not only the scientific, would be cooperative in this respect.

Petar Grujic
Belgrade, Yugoslavia



In Europhysics News 33/1, Dr Muller reports on the Gallery of portraits of physicists due to the late, sadly missed, Professor Pais. I find it surprising that a large section of this report concerns Dr Muller's views on the influence of Jews on twentieth century physics. First of all this is not relevant to A. Pais' book. Second, I find it offending to many great scientists to read a sentence such as "the past century theoretical physics was an almost entirely Jewish enterprise". I refuse to give a list of those who can rightfully feel mistreated by the statement, because I don't want to fall into the pitfall of making such lists. Indeed my main criticism of Dr Muller's article concerns the fact that he proposes to our consideration a list of famous scientists, some belonging to the biographies contained in Pais' book, others which he thinks could or should have been included, all declared to be Jewish. I have no idea on the religious beliefs of those scientists; of course, there is more to the subject than religious beliefs as, unfortunately, the third Reich has evilly demonstrated. But there is no evidence that, if asked, the scientists of Dr Muller's list would have identified themselves simply in those terms. Therefore, if general comments on the Jewish heritage and influence on science, might have been acceptable if done with care and in the right place, I regard the statements and lists of names in Dr Muller's review as totally out of place and unacceptable. Sincerely yours

Edouard Brézin
Professor of Physics, Ecole Normale Supérieure, Paris

Letters

The author replies

The only thing I seem to be guilty of is drawing attention to a remarkable statistically very significant fact, which is very well-known among and sometimes discussed by historians of physics, the late Abraham Pais not excluded. I regard allusions to the third Reich, in this context, as totally out of place and unacceptable. Sincerely yours

F.A. Muller

Letters, opinions, comments... please send them to:
Europhysics News, 34 rue Marc Seguin, BP-2136,
68060 Mulhuose Cedex, France
email: epn@evhr.net

Whenever I see a question like "Will machines start to think like humans?" [Europhysics News 33/2], I remember the words of John Van Neumann at a seminar about computers at the Princeton Institute for Advanced Study in 1948. When asked whether computers will ever learn to think like human, Johnny's answer was:

"It depends upon what you mean by thinking. If you can define precisely what you mean by thinking, I can build a machine that will do it."

Harry J. Lipkin
Weizmann Institute of Science, Rehovot, Israel

Physics on Stage 2

Physics on Stage 2 a festival for physics teachers, took place at the European Space Agency's Space Research and Technical Centre (ESTEC) in the Netherlands from 2 to 6 April.

Four hundred teachers and educational experts from 22 European countries were present to show to their collegues the most innovative projects for teaching physics. Physics on Stage 2 was an ideal forum to exchange ideas, discuss teaching aids and make recommendations for ways to inject more excitement and motivation into today's physics education.

Physics on Stage 2 follows up the success of the first Physics on Stage, held at CERN in Geneva in November 2000. It is being hosted by ESA and supported by five other European research organisations: CERN, ESO, EFDA-JET, EMBL and ESRF. It also benefits from the contacts and input of the EPS and the EAAE. Many distinguished visitors also visited the festival, including Gerard t'Hooft, winner of the 1999 Nobel Prize for Physics, His Excellency Dr Louis Hermans, Minister for Research, Culture and Science in the Netherlands, and Philipe Busquin, the Commissioner of DG Research of the European Commission.

A group of German physics students during their performance "The Secret of Bubbles"

The week-long festival consisted of four main elements: special performances, presentations by delegates, workshops on topical themes, and a fair at which exhibitors will showcase their projects and learn about those of their European colleagues — a lively forum for information exchange, cross-fertilisation and inspiration.

The Swedish delegation attracted large crowds with many exciting simple physics experiments

One very positive development from the members of the European Research Organisations Forum (EIROFORUM) was a proposal to establish a Teachers' Programme Office. This office would ensure that all of the hard work and good ideas going into Physics on Stage events would be available in following years. The Teachers Programme Office would also serve as a source for teaching material for all science teachers in Europe.

The EPS has offered to assist the EIROFORUM in many different areas including providing contacts for establishing a network for the Teachers' Programme Office by which the teachers can be reached in their countries, i.e., where they are located and working. Moreover, EPS has offered to provide much useful support by professionally guided work such as, to give a small example, developing a template, through which teachers could submit their experiments for Physics on Stage 3 in a standard form.

europhysics news recruitment

Contact **Susan Mackie** ¥ EDP Sciences ¥ 250, rue Saint Jacques ¥ F-75005 Paris ¥ France
Phone +33 (0)1 55 42 80 51 ¥ fax +33 (0)1 46 33 21 06 ¥ e-mail mackie@edpsciences.org

INTERNATIONAL AUTHORITY IN NUCLEAR SAFETY, TECHNOLOGY AND VERIFICATION SEEKS

PLASMA PHYSICIST

The International Atomic Energy Agency (IAEA), an independent United Nations organization headquartered in Vienna, Austria, with 133 Member States and a staff of 2200, serving as the global focal point for international co-operation in the safe and peaceful use of nuclear energy, is seeking a Plasma Physicist for its Physics Section. **This individual will be responsible for co-ordinating and planning the Agency's scientific programme regarding nuclear fusion and plasma physics.**

Education and experience required: Ph.D. or equivalent in physics or nuclear engineering in fusion related subjects. At least 10 years relevant professional experience.

Knowledge, skills and abilities required. Strong record of research publications in the field of nuclear fusion. International experience in performing technical projects. Demonstrated capability in preparation of technical and management documents. Fluency in English. Knowledge of French, Russian or Spanish desirable.

Benefits: The IAEA offers a stimulating multicultural working environment in the beautiful and culturally rich city of Vienna, Austria, with easy access to Europe-wide attractions. The post offers: **tax free remuneration; rental subsidy; 6 weeks annual vacation**; medical insurance coverage; a staff retirement plan; full coverage of removal expenses for staff member, family, and personal effects; additional allowance for installation expenses; assistance with finding housing and schools in Vienna; financial assistance with the education of dependent children; and paid travel to the home country for the staff member and family every other year.

Applicants should send their curriculum vitae before 6 June 2002, quoting the vacancy notice no. 2002/035, to: Division of Personnel - International Atomic Energy Agency - Wagramerstrasse 5 - P.O. Box 100 - A-1400 Vienna, Austria. (see details on *http://www.iaea.org/worldatom/Jobs*)

INTERNATIONAL ATOMIC ENERGY AGENCY

Our Goal: *to facilitate the safe contribution of nuclear technologies to peace, health and prosperity throughout the world, while ensuring that no technology or material under our oversight or provided with our assistance is used to further any military purpose.*

Deutsches Elektronen-Synchrotron

HASYLAB-Research

DESY

First experiments using the new free-electron laser at the TESLA Test Facility have been performed. Wavelengths around 100 nm with pulse lengths of 30-100 fs and peak powers of around 1 GW have been reached.

The final goal is to provide beams of wavelengths down to 6 nm at a new VUV FEL user facility at DESY.

CALL FOR FEL PROPOSALS

Reseachers are invited to submit proposals for experiments at the extended FEL starting in the year 2004.
Proposals for this first experiments must reach HASYLAB before **July 1, 2002**. Proposals for subsequent experiments are also welcome at a later date.

An independent peer project review panel reviews the FEL proposals on the basis of scientific merit, their feasibility at HASYLAB, and their position in the general program. Access is provided free of charge for all non-proprietary research.

Detailed information about the VUV FEL User Facility and guidelines for the submission of proposals are available on the web: http://www-hasylab.desy.de/facility/fel/main.htm or contact Dr. Josef Feldhaus (ext -3901, josef.feldhaus@desy.de).

Hamburger Synchrotronstrahlungslabor HASYLAB at
Deutsches Elektronen-Synchrotron DESY
Notkestrasse 95 • D-22603 Hamburg • Germany
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The European Organization for Nuclear Research, CERN

The European Laboratory for Particle Physics

CERN is the leading international laboratory for fundamental research in particle physics. It is an intergovernmental organization with its seat in Geneva, Switzerland, and has 2500 staff members and more than 6000 scientific users from 80 countries. The annual budget, currently about 1 billion Swiss francs, is funded by 20 Member States. At present, CERN is constructing the Large Hadron Collider, LHC, the world's most powerful particle accelerator that will provide new insights into the origin and the structure of matter and into the forces governing the Universe.

The Director-General is the Chief Executive Officer and legal representative of the Organization, and is directly responsible to the CERN Council, the Organization's governing and decision-making body composed of the representatives of the Member States. The term of office of the present Director-General, Professor Luciano Maiani, ends on 31st December 2003. The Council is therefore inviting applications for the appointment of a

DIRECTOR-GENERAL

for a five-year term of office starting on 1st January 2004. The Council is scheduled to make the appointment in December 2002. To allow the Director-General Designate sufficient time for consultation and familiarization with CERN, a position within the Organization can be arranged for the year 2003. An appropriate remuneration and benefits package will be offered.

The successful candidate will: provide scientific and managerial leadership to the Organization; prepare and execute the decisions of the CERN Council and its Committees; lead the implementation of the approved scientific programme, with emphasis on the completion of the LHC construction and the initial LHC research programme; develop strategic options for the long-term scientific programme of the Organization; and maintain and develop close relations with Member States and non-Member States and with the world-wide scientific user community of CERN.

Candidates should have: proven capacity for providing scientific and managerial leadership for CERN, for representing the Organization in dealings with governments and other bodies in and outside the Member States and for effective building of consensus within the Organization, the Member States and internationally; outstanding expertise and a high reputation in particle physics and/or related fields; and communication and negotiation skills in accordance with the level of the position.

Additional information may be obtained from the Chairman of the Search Committee, Dr J. Feltesse, by calling +33 1 69 08 13 99.

Applicants are requested to address a letter of interest, with a detailed curriculum vitae, to: The Chairman of the Search Committee, Dr J. Feltesse, c/o Mrs B. Beauseroy, CERN Council Secretariat, CH-1211 Geneva 23, Switzerland before 31st May 2002.

For general information about CERN, please see http://www.cern.ch

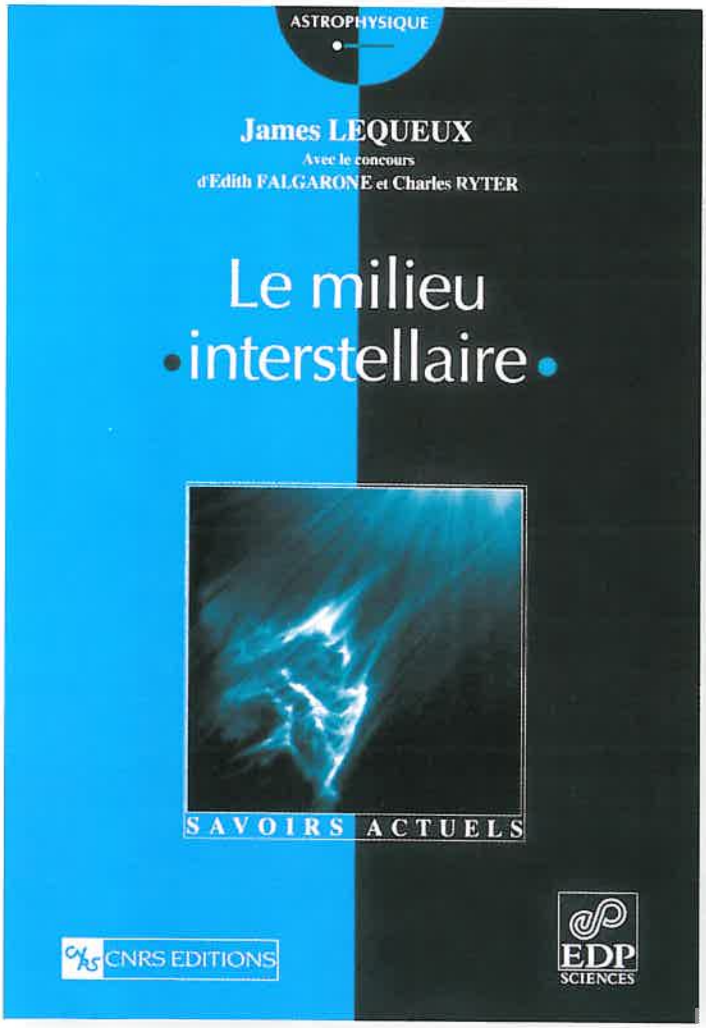
EDP SCIENCES

Astronomie et Astrophysique

Le milieu interstellaire

James Lequeux,

avec le concours d'Édith Falgarone et Charles Ryter



Bien que sa densité soit faible, le milieu interstellaire joue un grand rôle dans l'Univers. C'est à partir de la matière qu'il contient que se forment les étoiles. D'où l'intérêt, pour comprendre l'évolution des galaxies, et notamment de la nôtre, de savoir caractériser les échanges continuels de masse entre les étoiles et le milieu qui les baigne. Cet ouvrage traite par ailleurs de la physique et de la chimie du milieu interstellaire.

- *Collection Savoirs Actuels*
  Coéditée avec CNRS ÉDITIONS
- *Série dirigée par Michèle Leduc*
- *2002*
- *504 pages*
- *2-86883-533-3*
- ***53 €***

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- European Physical Journal B (The)
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- European Physical Journal E (The)
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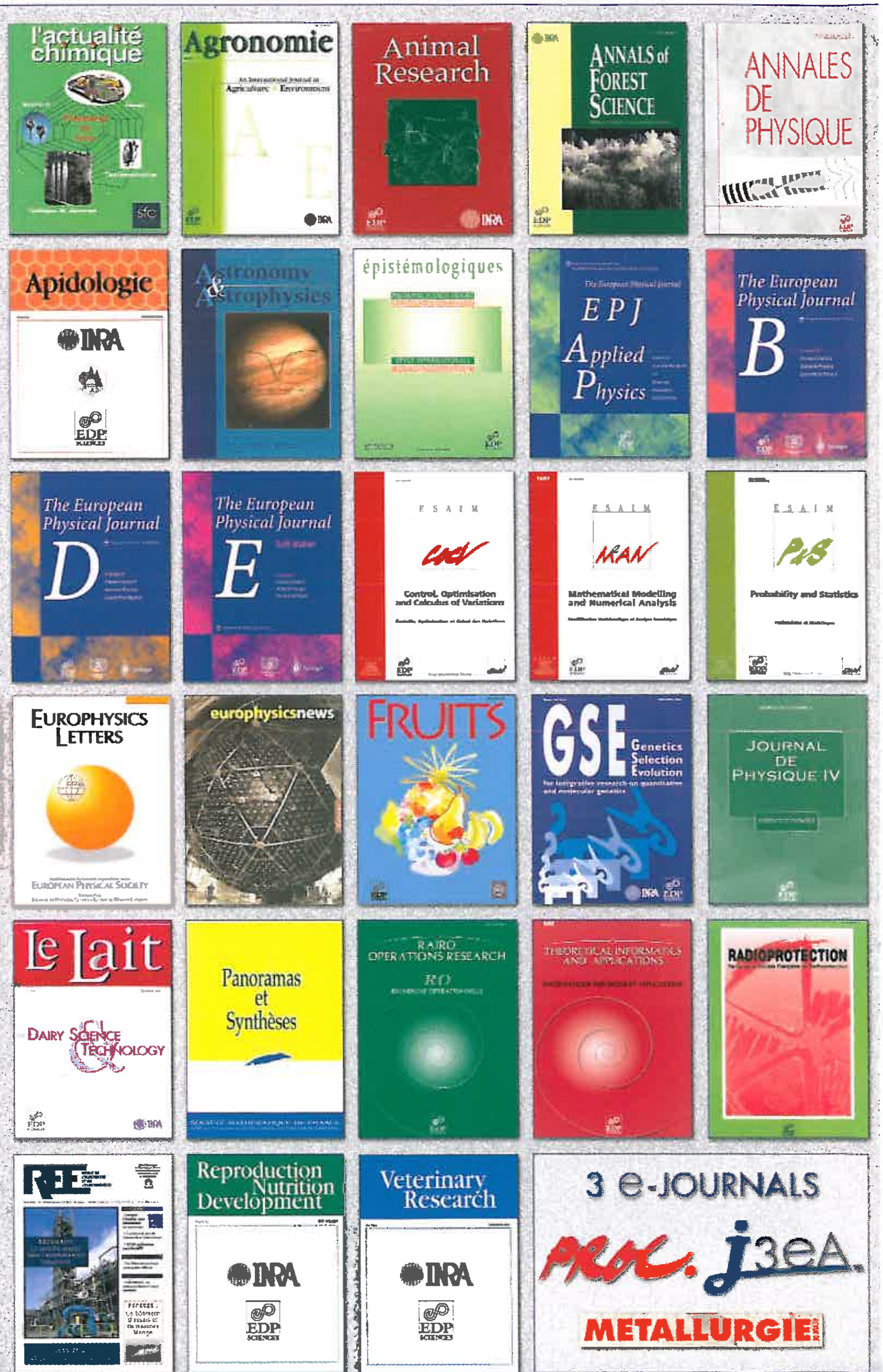
- ESAIM: M^{2}AN
- ESAIM: P&S
- ESAIM: Proceedings
- Europhysics Letters
- Europhysics News
- Fruits
- Genetics Selection Evolution
- Journal de l'Enseignement des Sciences de l'Information et des Systèmes
- JP IV - Proceedings
- Lait (Le)
- Panoramas et Synthèses
- RAIRO: Operations Research
- RAIRO: Theoretical Informatics and Applications
- Radioprotection
- Revue de l'Électricité et de l'Électronique
- Reproduction Nutrition Development
- Revue de Métallurgie
- Veterinary Research



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