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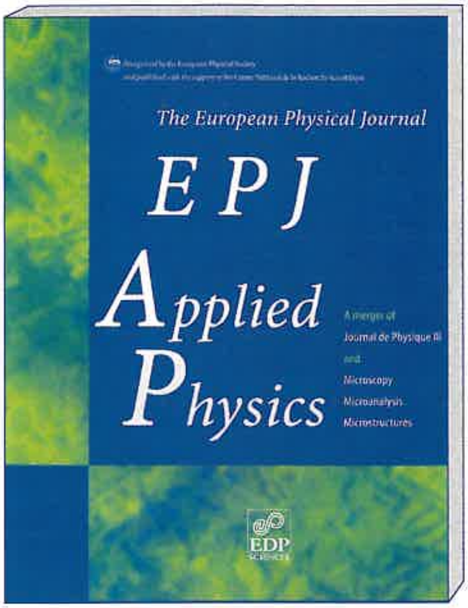

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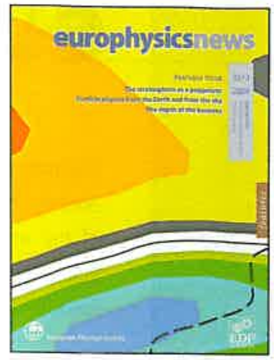

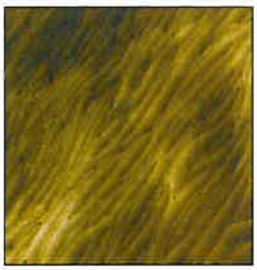

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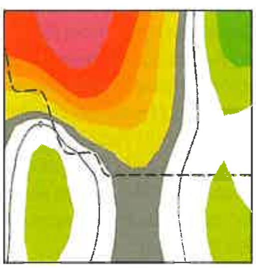

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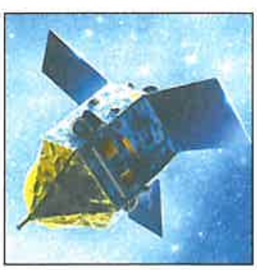

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FEATURES

NEWS, VIEWS AND ACTIVITIES

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Blue lasers on high pressure grown GaN single crystal substrates

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Development of blue and near UV semiconductor light sources has attracted the attention of researchers for several decades. In the sixties, GaN (gallium nitride) and its cousins AlN and InN were already known to be ideal candidates for blue and UV semiconductor light-emitting diodes (LEDs) and laser diodes (LDs). The competitors were zinc selenide based alloys. In the seventies and eighties, the development of ZnSe based LEDs and LDs put that compound much ahead of GaN. In the seventies the development of nitride physics and GaN devices was almost stopped because of two main barriers: the first that the p-type doping method was unknown; and the second that suitable substrates were lacking that would allow the growth of low dislocation-density quantum structures by metal organic vapor-phase epitaxy (MOVPE) and molecular beam epitaxy (MBE).

These barriers were overcome in the early nineties, when Amano, Akasaki [1] and Nakamura [2] discovered p-type GaN doping by Mg and developed the low-temperature buffer layer that lowered the concentration of dislocations in nitride epitaxial layers from 10^{12} to 10^{8} cm^{-2}. The development of the high nitrogen pressure solution growth (HNPSG) method [3] was the important step, which allowed growth of the first dislocation-free GaN epitaxial layers and quantum structures both by MOVPE [4] and MBE [4]. That made it possible to determine many basic physical properties of GaN [5]. These material science achievements and the fact that, in contrast to short lived ZnSe based devices, the nitride based structures remain stable during long laser operation, resolved the ZnSe vs GaN competition. Successful commercialization of blue diodes by Nichia Ltd. and construction of the first blue laser diode by Nakamura in 1996 [6] made GaN based technology the unique solution for blue and UV semiconductor laser diodes of the future.

Despite some progress in reduction of the dislocation density by ELOG (epitaxial lateral overgrowth) technology, the mainstream development effort based on sapphire was slowed down in the late nineties by the lack of progress in reducing the dislocation density below 10^{7} cm^{-2}. The new possibilities were opened by the liftoff technology [7] in which the GaN layer is separated from the sapphire substrate and then is used as a freestanding GaN substrate. This technology is sophisticated and expensive, however it gives GaN substrates with dislocation density about 10^{6} cm^{-2} and reduces thermal stresses in devices. Such two-inch substrates are already available and they serve for construction of blue lasers of a power of hundreds of miliwatts.

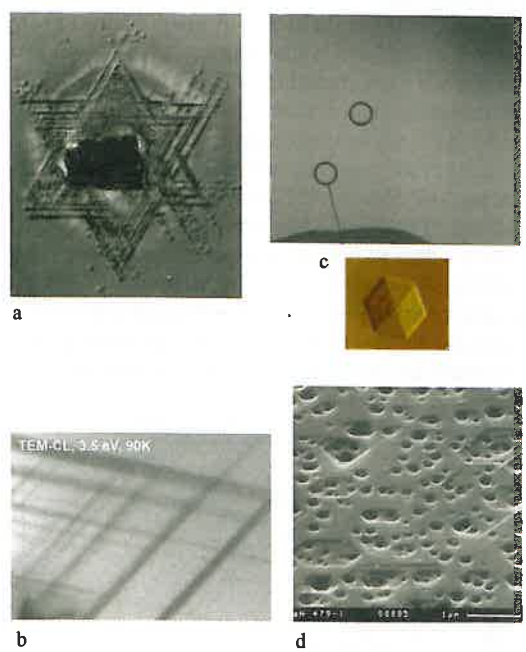
We have chosen the alternative way to construct high power lasers. We use lattice matched GaN substrates of low dislocation density, grown by the HNPSG method. The method provides relatively small substrates, about 1 cm^2 in size but, as will be shown, ultra low dislocation density (below 10^{2} cm^{-2}) allows for easier growth of dislocation-free atomically flat quantum structures, which are crucial for the development of high power UV and blue lasers.

Why dislocations are detrimental to high power semiconductor lasers

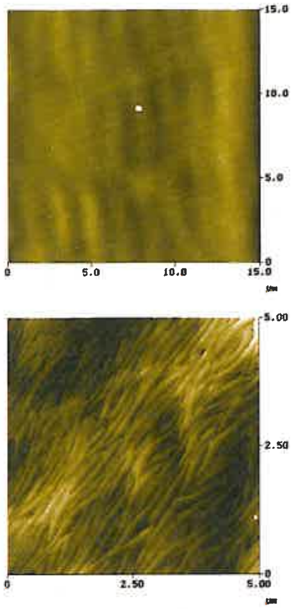
Dislocations can cause deterioration in the operation of quantum-well based optoelectronic devices mainly by three mechanisms:

a) by serving as nonradiative recombination centers for electrons and holes leading to heat generation instead of optical emission
b) by introducing fast diffusion along the dislocation lines, smearing out quantum wells and p-n junctions
c) by disturbing the epitaxial growth, so that atomically flat structures cannot be obtained.

It turned out that GaN based devices are much more tolerant of the presence of dislocations than classical devices based on GaAs. In these new devices, efficient photo- and electro-luminescence was observed even in materials having dislocation densities as high as 10^{8} – 10^{9} cm^{-2} . For GaAs devices nonradiative recombination related to such high densities of dislocations would quench luminescence almost totally. The effective electro-luminescence was observed for GaN devices with quantum wells containing In ($In_xGa_{1-x}N$ with x between few to 30at% of indium). Nakamura explained this effect as the result of potential fluctuations caused by In segregation, which limits the diffusion length of holes and diminishes dislocation-related nonradiative recombination [8]. From the Nakamura model one can draw two conclusions: i) the presence of dislocations can be detrimental to the efficiency of devices working on a very high level of excitation of carriers such



▲ Fig. 1: Dislocations in GaN crystals and layers: a) plastic indentation of high pressure grown GaN single crystal by a diamond pyramid – the dislocations revealed by selective etching surround the hole left by the pyramid [9];
b) cathodoluminescence of this GaN crystal - the black band proving that dislocation related nonradiative recombination quenches the optical emission; c) selective etching of GaN layer grown on a high pressure GaN single crystal; d) selective etching of GaN layer grown on a GaN template deposited on sapphire.

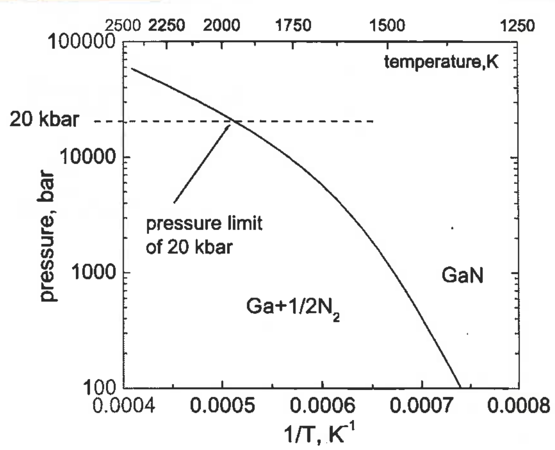


◀ **Fig. 2:** AFM picture of the surface of GaN layer deposited using MOVPE: a) layer grown on high pressure GaN substrate; b) layer grown on GaN template deposited on sapphire substrate.

as high power laser diodes when the kinetic energy of carriers exceeds the potential barriers created by In segregation; ii) nonradiative recombination due to the presence of dislocations may be especially harmful for devices without indium (for example UV devices based on GaN/GaAlN quantum wells). This was the reason why we have concentrated our efforts towards construction of high power blue lasers and UV devices.

As evidence that the dislocations quench almost totally the luminescence in GaN not containing indium, we show the cathodo-luminescence measurements. In Fig 1a we present GaN grown on high-pressure grown substrates where dislocations were induced by plastic deformation using indentation. In Fig 1b, the dark visible lines are caused by nonradiative recombination on dislocations introduced by plastic deformation. [9].

The effects related to mechanisms (b - diffusion along dislocations) and (c - disturbing epitaxial growth) are also important for the reliability of devices. For instance, in both MOVPE and MBE technologies, the most important growth mode is the step flow. Fig. 2 compares the surface morphology of GaN layers deposited on high-pressure GaN substrates and on a GaN/sapphire template,



▲ **Fig. 3:** p-T equilibrium curve for the GaN → Ga(l) +(1/2) N_2(g) reaction [14].

obtained in the same growth process. As is seen, low dislocation density material has regular straight and parallel atomic steps (Fig. 2a) while material on the template with a five order of magnitude higher dislocation density shows irregular steps with visible dislocations at the ends of the steps (Fig. 2b). Regular step-flow is a prerequisite for obtaining atomically flat quantum wells.

As mentioned above, the dislocations in high power LDs should be avoided. Dimensions of the active part of a typical device are 5-20 µ x 500 µ, which correspond to the area 2.5-10 x 10^{-5} cm^2. Thus the dislocation density below 10^4 cm^{-2} is mandatory for manufacturing the dislocation-free devices. As will be demonstrated in the next Section, high-pressure grown GaN crystals have a dislocation density much below this limit and create possibilities to growth epitaxial structures for such devices..

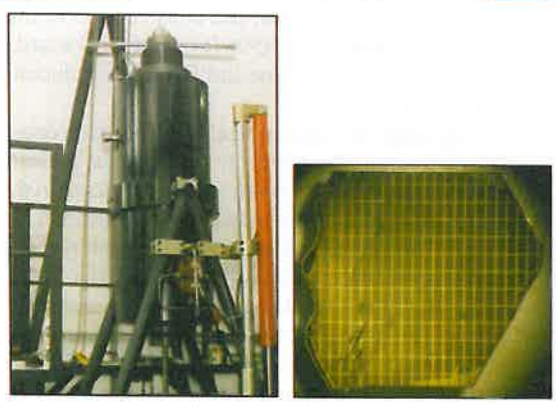
Substrates – thermodynamics and crystal growth

The GaN binding energy, equal to 9.12 eV/atom-pair, is quite high. For comparison GaAs has a binding energy equal to 6.5 eV/atom-pair. Therefore, as shown in Table 1, the GaN melting temperature is much higher than these for typical semiconductors used in electronics, such as Si, GaP or GaAs.

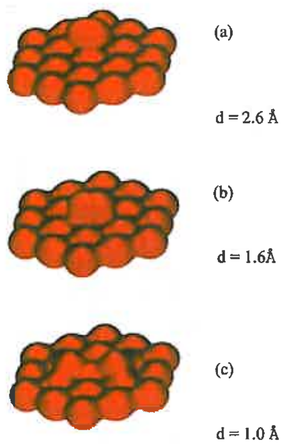
▼ **Table 1:** Melting conditions of some elemental and III-V semiconductors

crystal	T^M, K	p^M, bar.
Si	1685	< 1
GaAs	1510	15
GaP	1750	30
GaN – [10]	**2493**	**~ 60 000**

Even more important is the fact that the binding energy of a N_2 molecule is extremely high, equal to 9.72 eV/molecule, which is the highest binding energy of all diatomic molecules [11]. In addition, the enthalpy of evaporation of liquid gallium is relatively high, equal to 2.81 eV/atom [11]. Despite high bonding energy of GaN, the balance of the GaN synthesis reaction: Ga(l) + (1/2)N_2(g) → GaN(s) is strongly shifted towards the constituents: liquid Ga and gaseous N_2. This fact has extremely important



▲ **Fig. 4:** a) The high-pressure apparatus, constructed in HPRC for crystallization of GaN. The maximum working pressure is 15 kbar, the maximum temperature – 1600°C, the internal diameter – 100 mm; b) GaN crystals grown from solution at high N_2 pressure. The grid size is 1 mm.



◀ Fig. 5: Electronic charge distribution for the N_2 molecule and 19 Ga atom cluster, obtained from quantum mechanical calculations: a) d = 2.6 Å, b) d = 1.6 Å, c) d = 1.0 Å [15]; d – denotes the distance between the molecule and the Ga surface.

consequences for GaN crystallization because GaN becomes unstable at high temperatures at the normal pressure of nitrogen. As shown in Table 1, the equilibrium nitrogen pressure for GaN at its melting temperature is close to 60 kbar [10]. That pressure is inaccessible for large-volume high-pressure apparatus, thereby rendering impossible the growth of GaN from stoichiometric melt as used in standard Czochralski [12] or Bridgman [13] methods. It has to be crystallized by methods allowing lower temperatures and pressures, from which the solution growth seems to be the best choice.

The method known as high-nitrogen-pressure-solution-growth (HNPSG) is a practical realisation of the GaN synthesis reaction [4]. The HNPSG method relies on a high pressure of nitrogen, which allows an increase in the growth temperature of GaN. The pressure-temperature diagram of GaN stability is shown in Figure 3 [14].

At present, GaN single crystals are obtained in high-pressure gas vessels, that allow working nitrogen pressures up to 20 kbar. These vessels have internal diameters up to 10 cm and volumes up to 4500 cm^3. The crystal growth system is equipped with an internal furnace with graphite multi-zone heaters that allow the temperature to be changed in the two-inch crucible. A view of the high-pressure apparatus is presented in Figure 4a [4].

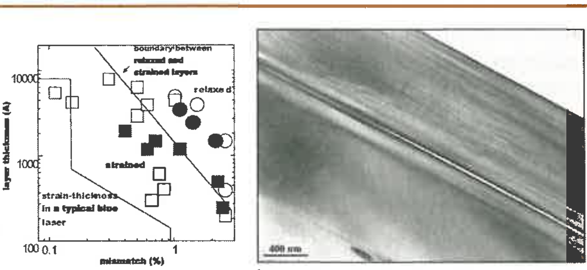
Growth of GaN proceeds via three consecutive stages: dissolution of nitrogen in liquid gallium, transport of nitrogen in the liquid by convection and diffusion and crystallization in the cold zone. The mechanism of the dissolution of the nitrogen in the liquid gallium was investigated using quantum mechanical calculations [15]. As shown in Figure 5 the nitrogen molecule undergoes dissociation at the gallium surface and then single nitrogen atoms are dissolved in gallium. The calculated energy barrier for N_2 dissociation is 3.4 eV. The barrier is much smaller than the N_2 binding energy (9.72 eV/molecule), indicating that the liquid Ga surface exerts a strong catalytic influence that speeds up the N_2 dissociation and dissolution. After dissolution, the atomic nitrogen is transported to the cold end where the GaN crystal grows from nitrogen rich gallium. The growth of large size good quality GaN crystals requires precise pressure and temperature control during the process.

Due to hexagonal symmetry of its crystallographic wurtzite structure, GaN crystals grown by the HNPSG method usually have the form of hexagonal platelets. The large hexagonal surfaces of bulk GaN crystals correspond to {0001} polar crystallographic planes. Conventionally the Ga-side denoted as the {0001} surface is the one that is used for epitaxy. The side faces of the crystals are mainly the polar {10-11} and also non-polar {10-10} planes [4]. The crystals in the form of hexagonal platelets grow slowly, with a rate below 0.1mm/h into {1010} directions (perpendicular to the c-axis). The growth is strongly anisotropic being much slower (about 100 times) in directions parallel to the c-axis. Typical duration of the growth processes is 120 - 200 hours, which gives a crystal with linear size up to 20 mm. These crystals have usually perfect morphology suggesting stable layer-by layer growth. One of these crystals is shown in Fig. 4b.

The high quality of these crystals has been proven by several methods including x-ray diffraction, transmission electron microscopy (TEM), atomic force microscopy (AFM) and selective etching. The typical picture of selective etching of both GaN layers on GaN single crystals and on sapphire is shown in Fig. 1c and d, respectively. Typical high quality high-pressure grown GaN single crystals have a dislocation density not higher than 10^2 cm^{-2} while the best quality GaN layers on sapphire have above 10^7 cm^{-2} [4].

Epitaxy

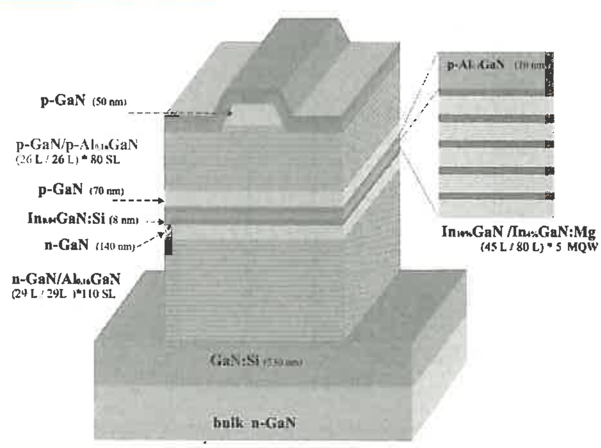
The structure of GaN homoepitaxial layers follows the structure of the GaN substrates provided that the surface preparation technique and the conditions of the epitaxial growth are properly chosen [17]. As shown before in Fig 2, the atomic step flow on the surface of the homoepitaxial layer is not perturbed and new dislocations are not created. However if we continue to grow layers of AlGaN and InGaN, as necessary to obtain a blue laser structure, the lattice mismatch between GaN and those ternary layers can



a

b – courtesy of M. Albrecht

▲ Fig. 6: Critical conditions for lattice relaxation for III-N ternaries: a) X-ray data: open circles - AlGaN relaxed, open squares - AlGaN strained, filled squares – InGaN strained, open squares – InGaN relaxed, b) TEM image of the multilayer structure deposited on GaN substrate by MOCVD, the sequence of layers from the lower left corner: n-GaN, n-$Al_{0.11}Ga_{0.89}N$/n-GaN superlattice, n-GaN, $In_{0.09}Ga_{0.91}N$, p-GaN, p-$Al_{0.14}Ga_{0.86}N$/p-GaN superlattice, p – GaN.



▲ Fig. 7: Structure of GaN laser.

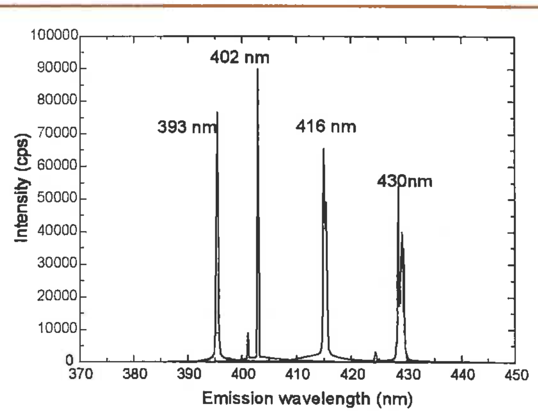
induce misfit dislocations. This phenomenon was analyzed by Domagała et al. [18] by x-ray measurements of lattice parameters for various GaN-based epitaxial layers deposited on GaN substrates as a function of InGaN (AlGaN) composition and thickness. It is shown in Fig 6a that for mismatch and thickness present in a typical blue laser structure, the relaxation of the strain by the generation of dislocations was not observed. In Fig 6b a TEM crossection of the multilayer structure, grown by MOVPE on high-pressure GaN substrate, similar to the blue laser structures is presented. It does not contain dislocations, confirming the results of x-ray measurements.

For laser application we grow GaN/AlGaN/InGaN laser structures in a home-made vertical flow MOVPE reactor and VG Semicon MBE machine. We grow our structure as a separate confinement heterostructure laser, with AlGaN cladding layers and Mg and Si doped GaN waveguides. The active layer of the device is a 5x $In_xGa_{1-x}N/In_{0.024}Ga_{0.976}N$ (QW 0.08<x<0.12) structure consisting of 80Å-thick Si doped barriers and 40Å-thick undoped well layers. The details of the structure are given in the following and are illustrated on Fig. 7.

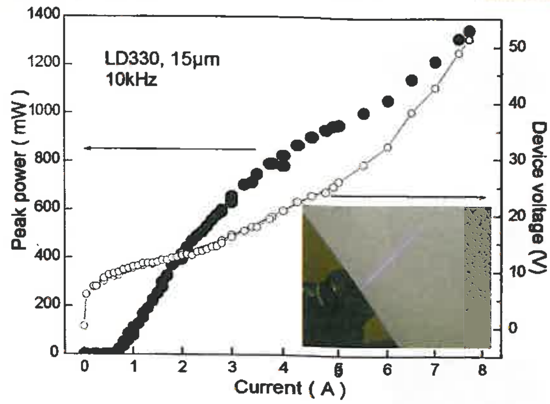
Contacts and processing – laser device

The devices were processed as ridge-waveguide, oxide-isolated lasers. The mesa structure was etched out in the wafer, down to a depth of 0.3 µm (roughly to the middle of the upper cladding layer). The laser structure was then isolated by e-beam deposition of a 0.2 µm layer of SiO_x. The stripe width is 5-20 µm and the resonator length is 500 µm. The reflectivity of the cleaved mirrors was increased to 50% by coating them with two pairs of quarter-wavelength layers of SiO_2/ZrO_2. The Ni/Au ohmic contacts, of a typical contact resistance $1\cdot10^{-4}\ \Omega\cdot cm^2$, were deposited on the top surface of the device, while Ti/Au contacts were deposited on the backside of the highly conducting n-GaN crystal.

The emission wavelengths of the lasers, as presented in Fig. 8, are between 390 and 430 nm. The threshold currents for these lasers are between 380 to 800 mA (for a 15 µm stripe width), while the threshold voltage ranges from 7.5 to 9 V. These values correspond to current densities of 5-10 kA/cm². This current density is still a factor of two higher than for the devices manufactured by Nichia and Sony. We attribute this fact to excessive carrier overflow. The slope efficiency of our devices is in the range of 0.25-0.3 W/A per facet (0.5-0.6 W/A for total emission) for the current range 0-3 A. For higher currents the efficiency slightly decreases. Figure 9 shows the basic electrical and optical characteristics of our lasers, all measured under pulsed current conditions (30 ns pulse length, 10 kHz repetition, room temperature). The maximum optical power per mirror was 1.3 W. Because of the symmetric coating, the total optical power can be stated to exceed 2.5 W, which makes this the largest optical power reported for nitride lasers [20].



▲ Fig. 8: Emission spectra for laser diodes grown on bulk GaN. Pulse operation is at room temperature.



▲ Fig. 9: Current – light and current – voltage characteristics of a high-power, pulsed-current operated laser diode.

The devices were life tested under constant current conditions and variable temperatures in the range of 35-70°C. The lifetime usually is defined as a time after which the optical power of the device (at constant current) decreases down to 50 % of its initial value. Accelerated tests predicts a lifetime approaching 10 000 h have been performed at the following conditions: current 1 A, frequency 100 kHz, pulse length 30 ns. The activation energy of the degradation processes was estimated to be 3.2 eV, similar to the value determined by Sony. No change in electrical properties of the devices was observed during aging. The mechanism of long-term degradation still remains undetermined.

Summary – present status and the future

Despite the big commercial success of blue and green LEDs based on (AlGaInN compound) compounds and an introduction blue and violet LDs to the market, the physical properties of GaN and InGaN and AlGaN systems are still not well understood. Similarly the technology of GaN devices is still far from maturity.

The main problem for technology based on freestanding HVPE grown GaN substrates is the reduction of the density of dislocations. The size of the substrates is already sufficient for many industrial application, however the dislocation densities still remain two orders of magnitude above the magic value $10^4\ cm^{-2}$, necessary for dislocation-free LDs that are especially important for high power LDs. The prospects for this method depend on whether the technology will be able to break this barrier in the near future.

The technology of blue lasers based on HNPSG single crystals has been able to provide dislocation-free laser structures, which has allowed record power to be obtained in the pulse mode operation. It has also brought the devices on the market—at present these devices are the only European devices on offer to customers.

The main areas, in which our blue laser technology should be improved, are:

- processing and heat management
- strain engineering
- p-type doping by magnesium.

But especially the move towards shorter wavelength (UV range) requires further progress in strain engineering to prevent the generation of misfit dislocations and the cracking of AlGaN layers with higher aluminum content.

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References

[1] H. Amano, M. Kito, K. Hiramatsu, I. Akasaki. Jpn. J. Appl. Phys. Part 2-Letters, **28** (1989) L2112

[2] S. Nakamura, T. Mukai, M. Senoh, N. Iwasa, Jpn. J. Appl. Phys. Part 2-Letters .**31** (1992) L139

[3] J. M. Baranowski, in MRS Symposium Proceedings vol. 449, F. A. Ponce, T. D. Moustakas, I. Akasaki, B. A. Monemar, Editors, p. 393, Materials Research Society, Pittsburgh (1996)

[4] I. Grzegory, S. Krukowski, M. Leszczynski, P. Perlin, T. Suski, S. Porowski, Acta Phys. Pol. A Suppl. **100** (2001) 57

[5] Properties, Processing and Applications of Gallium Nitride and Related Semiconductors, ed. by J.H. Edgar, S.T. Strite, I. Akasaki, H. Amano and C. Wetzel, INSPEC-IEE London 1999

[6] S. Nakamura, M. Senoh, S. Nagahama, N. Iwasa, T. Yamada, T. Matsushita, H. Kiyoku, Y. Sugimoto, Jpn. J. Appl. Phys. **35** (1996) L217

[7] S.T. Kim, Y.J. Lee, D.C. Moon, C.H. Hong, T.K. Yoo J. Cryst. Growth **194** (1998) 37

[8] S. Nakamura IEICE Trans. **E83-C** (2000) 529-535

[9] J.L. Weyher, M. Albrecht, T. Wosinski, G. Nowak, H.P. Strunk, S. Porowski, Mater. Sci. Eng. **B80** (2001) 318

[10] W. Utsumi, H. Saitoh, H. Kaneko, T. Watanuki, K. Aoki, and O. Shimomura, Nature materials **2** (2003) 735

[11] I. Barin Thermochemical Data of Pure Substances 3rd edition, VCH Weinheim 1994

[12] E. Monberg, in Handbook of Crystal Growth 2. Bulk Crystal Growth A. Basic techniques ed by D.T.J. Hurle North-Holland Amsterdam 1994, p.51

[13] D.T.J. Hurle and B. Cockayne, in Handbook of Crystal Growth 2. Bulk Crystal Growth A. Basic techniques ed by D.T.J. Hurle North-Holland Amsterdam 1994, p.99

[14] J. Karpinski, J. Jun and S. Porowski, J. Cryst. Growth **66** (1984) 1

[15] Z. Romanowski. S. Krukowski, I. Grzegory, S. Porowski J. Chem. Phys. **114** (1990) 6353

[16] I. Grzegory, M. Boćkowski, B. Łucznik, S. Krukowski, Z.Romanowski, M. Wrtal Growth A. Basic techniques ed by D.T**246** (2002) 177

[17] M. Leszczynski, I. Grzegory, H. Teisseyre, T. Suski, M. Bockowski, J. Jun, J. M. Baranowski, S. Porowski and J. Domagala, J. Cryst. Growth **169** (1996) 235

[18] J. Domagala, M.Leszczynski, P. Prystawko, T. Suski, R. Langer, A Barski, M. Bremser J. Alloys Compounds **286** (1999) 284

[19] P. Prystawko, R. Czernecki, M. Leszczynski, P. Perlin, P. Wisniewski, L. Dmowski, H. Teisseyre, T. Suski, I. Grzegory, M. Bockowski, G. Nowak, S. Porowski, Phys. Status Solidi A **192** (2002) 320

[20] P. Perlin, M. Leszczyński, P. Prystawko, R. Czernetzki, P. Wisniewski, J.L. Weyher, G. Nowak, J. Borysiuk, L. Gorczyca, T, Swietlik, G. Franssen, A. Bering, C. Skierbiszewski, I. Grzegory , T. Suski and S. Porowski, Photonic West Conference Proceeding San Jose 2004

The stratosphere as a puppeteer of European winter climate

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The depletion of the stratospheric ozone layer and the increase of greenhouse gas concentrations have led to changes in the climate of the stratosphere, the atmospheric layer between about 10 and 50 km. Stratospheric climate change currently receives wide attention among environmental physicists, because it will likely influence the speed of recovery of the ozone layer, and it may induce climate change in the troposphere, the atmospheric layer between the earth's surface and the stratosphere. Recent studies indicate that a significant part of the European winter warming observed in the past and predicted for the next decades might be due to changes in the climate of the stratosphere. To some extent the troposphere and the stratosphere might be regarded here as puppet and puppeteer, respectively. Unusually, the puppet's weight is about ten times that of the puppeteer.

Stratospheric ozone depletion

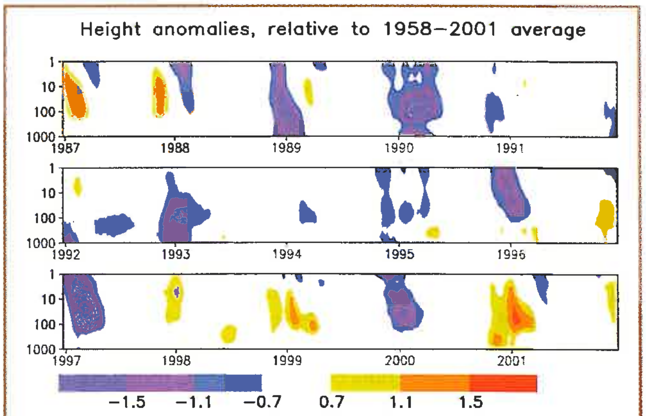
The ozone layer has been depleted due to human emissions of ozone-depleting gases containing chlorine and bromine. The ozone depletion is largest, about 50%, over Antarctica in winter-spring. This annually recurring "ozone hole" is due to special (photo)chemical ozone destruction reactions at very low temperatures that only occur in winter-spring over Antarctica and, to a lesser extent, the Arctic. Over the Arctic the depletion is up to about 20%, and is more variable than over Antarctica. Also at middle latitudes the ozone layer has been depleted, by about 5% between 1980 and 2000. As a result of international regulations, the total abundance of the ozone-depleting gases in the atmosphere has begun to decrease in recent years. Natural chemical and transport processes limit the rate at which these gases can be removed from the stratosphere. Model predictions indicate a recovery of the ozone layer to pre-ozone hole conditions by the middle of the 21st century. For more information about stratospheric ozone depletion see, e.g., Fahey *et al.* (2003).

Stratospheric global cooling

The ozone depletion leads to less absorption of solar radiation in the stratosphere and, consequently, to colder stratospheric temperatures. Also the increased greenhouse gas concentrations lead to colder stratospheric temperatures, which can be understood as follows. Greenhouse gases emit radiation at their local temperature, and absorb radiation that is emitted by the surrounding air, most of which is at lower altitudes. The emission increases with increasing temperature, according to Stefan-Boltzmann's law. Since in the stratosphere the temperature increases with altitude, the cooling by the emission at the local temperature exceeds the warming by the absorption of the radiation that is mainly emitted at the lower temperatures of the altitudes below. Thus in the stratosphere an increase in greenhouse gases will lead to more radiative cooling and, consequently, lower temperatures. In the troposphere, where the temperature decreases with altitude, the emission is less than the absorption, and a greenhouse gas increase will cause higher temperatures. Although the climate change due to increased greenhouse gases is often called 'global warming', for the stratosphere the term 'global cooling' would be more appropriate. Temperature observations in the lower stratosphere (15-20 km) show a cooling trend of ~0.6 °C/decade since 1980. The strongest cooling occurs in the polar lower stratosphere during winter-spring (~3 °C/decade). The observed cooling in the upper stratosphere (30-50 km) is 1-2 °C/decade since ~1970, with the magnitude increasing with altitude. Model simulations of the climate response to ozone depletion and increasing greenhouse gases show an increase of the equator-to-pole temperature gradient and a corresponding increase of the westerly wind in the lower extratropical stratosphere, which are also observed (Ramaswamy *et al.*, 2001; Langematz *et al.*, 2003).

European winter warming

In the past decades the surface temperature has increased almost globally (IPCC, 2001). The warming is largest over the Northern Hemisphere (NH) winter continents. A part of this warming may result from the sharp increase in the positive phase of the wintertime Arctic Oscillation (AO) since about 1970. The AO is the dominant geographical pattern of surface pressure variability in the NH. It is basically a dipole with opposite signs north and south of ~60 °N, representing the latitudinal swings of air mass. In the positive phase of the AO the surface pressure at lower latitudes is larger, and the surface pressure at higher latitudes is smaller than the climatological mean value. Since the climatological mean surface pressure at lower latitudes is larger than that at higher latitudes, a positive phase of the AO also corresponds to an enhanced difference in surface pressure between lower and higher latitudes. This enhanced pressure difference leads to enhanced westerly winds, which, in turn, lead to cold winters downstream of the cold winter continents, e.g. over the north-west Atlantic, and warm winters downstream of the relatively warm oceans, e.g. over Europe and Siberia. Thus, a positive phase of the AO corresponds to relatively warm winters in Europe. The observed increase in the positive phase of the wintertime AO accounts for ~30% of the warming of the NH as a whole, and ~50% of the warming of the Eurasian continent (Thompson *et al.*, 2000).



▲ Fig. 1: Height anomalies at pressure levels (in hectoPascal, hPa) from the surface (1000 hPa) to the top of the stratosphere (1 hPa), for all seasons during the period 1986-2001. The height has been averaged over the area north of 60°N. The anomaly for each day is relative to the 1958-2001-average for that calendar day, and has been scaled by the standard deviation of the anomaly's timeseries for all days of 1958-2001. To put emphasis on seasonal timescales, the daily height data have been low-pass-filtered using a 91-day running average. In clear regions (most of which occur in summer) the absolute value of the height anomaly is less than 0.7 times the standard deviation. Red shading corresponds to high temperatures in the area north of 60°N, weak westerly winds, and a negative phase of the Arctic Ascillation (AO); blue shading corresponds to low temperatures, strong westerly winds, and a positive phase of the AO.

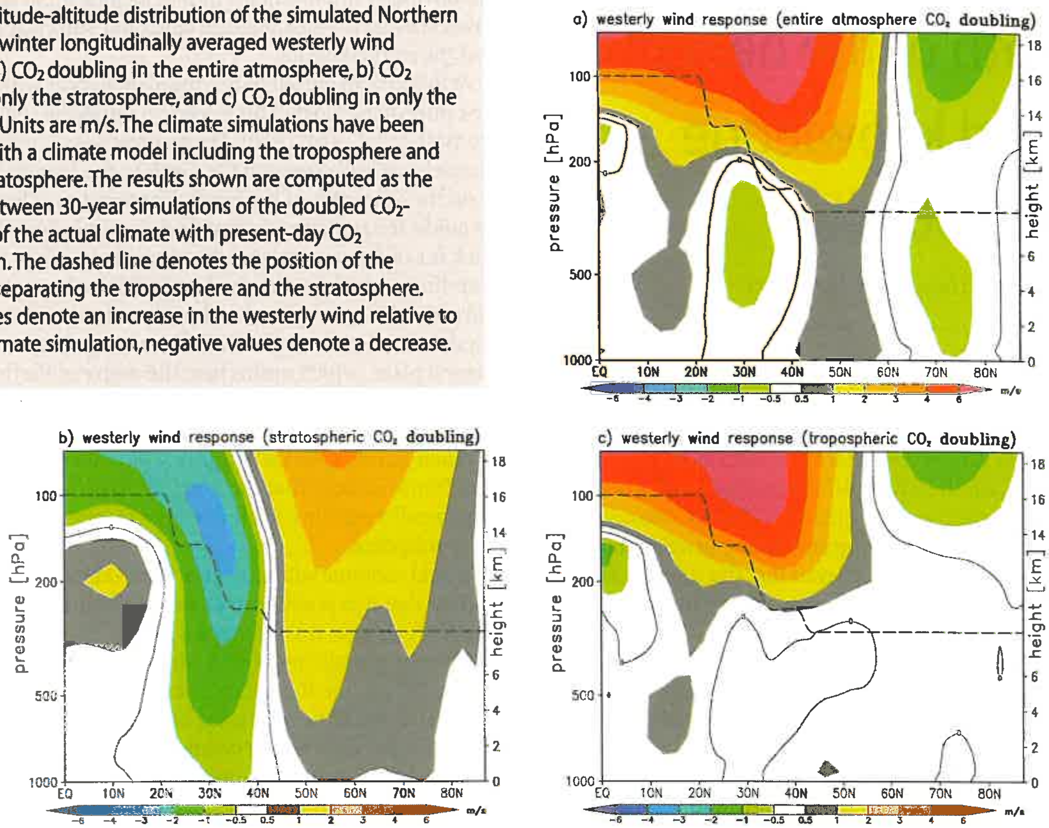
Stratosphere-troposphere coupling

Observations show that there exists at seasonal time-scales a strong relation between the surface pressure pattern and the circulation pattern throughout the troposphere and the stratosphere. In particular, a positive phase of the AO corresponds to enhanced westerly winds in the area north of about 45 °N in both the troposphere and the stratosphere. This is illustrated in Figure 1, which shows anomalies of the height in the polar region at pressure levels from the surface to the top of the stratosphere, for the period 1986-2001 (environmental physicists use height as a function of pressure, rather than pressure as a function of height). We have averaged the height over the area north of 60°N. The anomaly for each day is relative to the 1958-2001-average for that calendar day, and has been scaled by the total time series' standard deviation. This scaled anomaly is a proxy for the strength of the AO. To put emphasis on seasonal timescales, a 90-day low-pass filter has been applied. The data have been obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF) 40-year reanalysis project. A negative height anomaly corresponds to a positive phase of the AO. The anomalies are largest in winter, and comprise both the troposphere and the stratosphere, suggesting a coupling between the stratosphere and the troposphere. An important observation is that anomalies in the stratosphere often precede those in the troposphere, suggesting that variations in the surface AO are often 'driven' by variations in the stratosphere. The anomalies are predominantly negative, i.e. the height values are generally smaller than the 1958-2001-average, which is in line with the observed increase of the positive phase of the AO. In summary, the European winter warming of the last decades can for a large part be explained by an increase in the positive phase of the AO, which in turn might be induced by stratospheric climate change due to ozone depletion and increased greenhouse gas concentrations. More information about the relation between stratosphere-troposphere coupling and climate change is given, e.g., by Hartmann *et al.* (2000). The question whether stratospheric climate change indeed induces an increase in the positive phase of the AO has motivated us to perform idealized experiments with a global climate model comprising both the troposphere and the stratosphere.

A simulation of the separate climate effects of stratospheric and tropospheric CO_2 doubling

Our climate simulations show an increase of the tropospheric westerlies (associated with an increase in the positive phase of the AO) in NH winter middle latitudes in response to uniform CO_2 doubling (Figure 2a). This increase corresponds to an increase in the positive phase of the AO. To address the question to what extent the increase in the positive phase of the AO is caused by stratospheric and by tropospheric climate change, two additional experiments have been performed in which the CO_2 concentration has been separately doubled in the stratosphere and the troposphere. The sum of the separate responses to tropospheric and stratospheric CO_2 doubling is in most regions approximately equal to the uniformly doubled CO_2 response. This implies that the

Fig. 2: Latitude-altitude distribution of the simulated Northern Hemispheric winter longitudinally averaged westerly wind response to a) CO_2 doubling in the entire atmosphere, b) CO_2 doubling in only the stratosphere, and c) CO_2 doubling in only the troposphere. Units are m/s. The climate simulations have been performed with a climate model including the troposphere and the entire stratosphere. The results shown are computed as the difference between 30-year simulations of the doubled CO_2-climate and of the actual climate with present-day CO_2 concentration. The dashed line denotes the position of the tropopause, separating the troposphere and the stratosphere. Positive values denote an increase in the westerly wind relative to the actual climate simulation, negative values denote a decrease.



(rather artificial) separation of the climate response into a response to stratospheric and a response to tropospheric CO_2 doubling is physically meaningful. The NH middle latitude tropospheric westerlies strengthen in response to stratospheric CO_2 doubling (Figure 2b), but do not significantly change in response to tropospheric CO_2 doubling (Figure 2c). These results suggest that the increase of tropospheric westerlies in response to uniform CO_2 doubling can be attributed mainly to the stratospheric CO_2 doubling. Since the stronger westerly winds correspond to a stronger positive phase of the AO, the results confirm the suggestion that the observed increase in the positive phase of the wintertime AO is caused by climate change in the stratosphere.

Whereas normally a pupetteer has more than one puppet, the European climate change has probably more than one puppeteer. Recent studies suggest that also changes in tropical sea surface temperatures might have induced an upward trend in the AO. Identifying and understanding the strings between these stratospheric and tropical puppetteers and the European climate change puppet is a major challenge of current studies in environmental physics in the next decade.

References

Fahey, D.W. (Lead Author), *Twenty Questions and Answers About the Ozone Layer: Scientific Assessment of Ozone Depletion 2002*, 42 pp., World Meteorological Organisation, Geneva, 2003. Available via www.wmo.ch/web/arep/ozone.html

Hartmann, D.L., J.M. Wallace, V. Limpasuvan, D.W.J. Thompson, and J.R. Holton, *Can Ozone Depletion and Greenhouse Warming Interact to Produce Rapid Climate Change?* Proc. Nat. Acad. Sci., 97, 1412-1417, 2000. Available via: www.pnas.org/cgi/content/full/97/4/1412

IPCC, *Climate Change 2001: The Scientific Basis.* Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton, J.T. *et al.*, eds., Cambridge University Press, Cambridge, UK, 881pp., 2001. Available via www.ipcc.ch

Langematz, U., M. Kunze, K. Krüger, and K. Labitzke, *Thermal and dynamical changes of the stratosphere since 1979 and their link to ozone and CO_2 changes*, J. Geophys. Res., 108, doi:10.129/2002JD002069, 2003.

Ramaswamy, V., M-L. Chanin, J. Angell, J. Barnett, D. Seidel, M. Gelman, P. Keckhut, Y. Koshlekov, K. Labitzke, J-J. Lin, A. O'Neill, J. Nash, W. Randel, R. Rood, K. Shine, M. Shiotani, and R. Swinbank, *Stratospheric temperature trends: Observations and model simulations*, Rev. Geophys., 39, 71-122, 2001.

Sigmond, M., P.C. Siegmund, H. Kelder, and E. Manzini, *A simulation of the separate climate effects of middle atmospheric and tropospheric CO_2 doubling.* J. Climate, in press, 2004.

Sigmond M., *On the coupling between the stratosphere and the troposphere*, PhD thesis, Technische Universiteit Eindhoven, 111 pp, 2004. Available via www.knmi.nl/~sigmond/

Thompson D. W. J., J.M. Wallace, and G.C. Hegerl, *Annular Modes in the Extratropical Circulation. Part II Trends.* J. Climate 13, 1018-1036, 2000.

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features

The depth of the heavens: Belief and knowledge during 2500 years

Erik Høg, Copenhagen University Observatory

We see the Sun, Moon, and stars in the heavens as if placed on the inside of a sphere. But even early man had ideas about the distances to these heavenly objects. The Greek philosopher Anaxagoras living in Athens 2500 years ago claimed that the Sun is a fiery rock larger than the whole Peloponnesian peninsula. This implies a distance to the Sun larger than 20,000 km. Anaxagoras, however, was accused of blasphemy and had to leave Athens for that reason. His contemporaries believed that the sun god Helios drove his fiery wagon with the Sun across the sky in the day and returned at night sleeping on his ship.

Do we perhaps see this empty golden ship of Helios on the 'Disc of Heavens' from Nebra? This gold plated bronze disc (Figure1) from 1600 B.C. would then be the first known image of cosmos in the history of mankind.

What is in the heavens? Men at all times have seen the Moon, Sun, planets, and stars. Christians in Antiquity and Middle Ages have believed that also God, angels, and saints live in the heavens. Astronomers today do of course find the Moon, Sun, planets, and stars in the heavens, but also star clusters, galaxies, dust, gas, white dwarfs, neutron stars, black holes, and quasars, and furthermore *invisible dark matter* whose true physical nature is a great mystery of astronomy today, since it is not made of atoms or the like.

But we shall be mostly concerned with the belief of mankind over times about the size of the universe with respect to distances to the Moon, Sun, planets, and stars. The recent 100 years with galaxies and the Big Bang shall however be mentioned at last.

The universe of Dante Alighieri

From the present we shall first jump back in time 700 years to Dante's famous Divine Comedy, before returning to the ancient Greeks. A few years ago I began to reread the classics. I said to myself: "it is time since your are in your sixties, read now while still clear in your head". Dante wanders through Hell, Purgatory, and Paradise, and it struck me how often he mentions astronomical subjects. He was well acquainted with the knowledge of his time which he had studied at the universities in Florence and Bologna. It was obviously important for him to include these astronomical or physical aspects—in a poetical cloth, but still clear enough if you read the commentaries.

At the bottom of Hell stands the giant Lucifer with his genitals at the centre of the Earth. This is seen on a drawing (Figure 2) by Sandro Botticelli (1444-1510). Dante must pass Lucifer to enter the channel that leads through the Earth to the mountain of Purgatory on the other side of the Earth. Dante has to ride on the back of his guide, the roman poet Vergil, who courageously clutches to the thick fur of Lucifer and crawls downwards. When he reaches the rounding of the hip near the Earth's centre he must turn around and continue with the head in the other direction. We meet now the physics of Aristotle (384-322 B.C.), saying that bodies seek their 'natural place', which means here the centre of Earth. For Aristotle the attraction of a body towards the centre of Earth was constant, while Newton 400 years later predicts zero gravity at the centre.

When standing on the Purgatory Mountain watching the rising Sun, Dante notices that the Sun will pass over his *left* shoulder. Vergil readily explains that this follows from standing on the southern hemisphere.

I could continue with examples from Dante. His descriptions are so clear that it is possible to draw the picture that Dante and the Middle Ages saw, the universe with the Earth at its centre, surrounded by the spheres of Fire, Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, the fixed stars, the crystal sphere, and uppermost Empyreum with the saints, the angels, and God. This naïve and very popular view of the cosmos in the Middle Ages with the Earth and God at the extremes was not shared by theologians who meant that God is omnipresent at all times.

Dante's picture of the universe with the Earth and God at the extremes is suitable for our table where we give the distances in the visible universe, firstly as given by Ptolemy, secondly the true distances as they have become known during times. Dante has undoubtedly known the distances given by the famous Greek astronomer Ptolemy about AD 150 since his distances were accepted and well known in the whole educated world, the Christian as the Muslim.

▶ Table: Historical and Contemporary Distances

The visible universe is a million billion times larger than Tycho Brahe believed.
(The unit 1 light-year = 1.49 billion Earth radii) Ptolemy is far from being the first to give distances to planets and stars, but his distances gained the status of highest authority during the following 1500 years. He had his values for the Earth radius and distances to Moon and Sun from astronomers working between the years 300 and 100 B.C. Their value for the Sun was 20 times too small, and not even Tycho Brahe knew better. After his time doubts arose, first for Johannes Kepler in 1617. But it took 150 years before the distance to the Sun was safely known from new observations, namely from Venus transits of the solar disc.

Distance to	Ptolemy (~AD 150) Dante and Tycho Brahe	True distance
Centre of Earth	1 Earth radius = ~ 6000 km	1 Earth radius = 6370 km
Moon	33 – 64 Earth radii	60 Earth radii
Sun	1210 Earth radii	25 000 Earth radii since 1770
Stars	20 000 Earth radii = 0.000 014 light-years	Over 10 light-years since 1838
Most distant stars in the Milky Way	—	30 000 light-years in year 1900
Most distant galaxies observable by 1960	—	2 billion light-years in year 1960
Extreme of the visible universe	Stars: 20 000 Earth radii = 0.000 014 light-years	13.7 billion light-years in year 2003
God and the angels	—	—

Speculative ideas

Greek thinking about the system of nature flourished in the regions along the eastern Mediterranean from Archimedes in Syracuse on Sicily to Erathostenes and Ptolemy in Alexandria, and it was active in a very long period of time from about year 600 B.C. to year AD 200 Of course only a narrow part of the societies had time and interest for such matters, but their thoughts were transmitted over times by Romans and Arabs into the Middle Ages.

The Greek philosophers were seeking explanations by *laws of nature* while others in the societies belived in the intervention of events by the sometimes very human gods. This neglect of the gods did usually not lead to political prosecution because of the democratic structure of Greek societies.

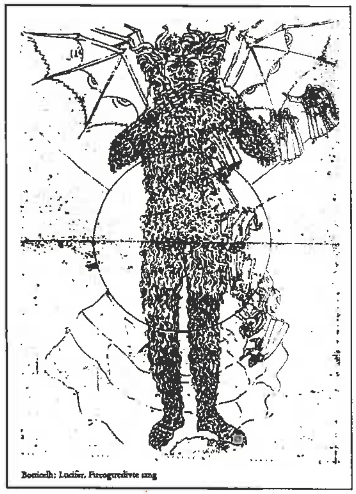
In other societies of the time where the rulers either called themselves gods or claimed to be in close family with gods, such thoughts would be considered as an attack on the social order, resulting in danger of life for those speaking of rational explanations. When Anaxagoras in Athens was blamed for blasphemy it is considered by present-day historians as a result of the political struggle after Perikles who was a close friend of Anaxagoras.

The Greek thinkers wanted to understand the whole universe through rational explanations. About 400 B.C. they formed the opinion that everything consists of four elements: *fire, air, water, and earth* which are themselves not composed of smaller elements. This opinion was the basis for all science until Boyle and Lavoisier about 1700, and we still meet it in TV and popular journals. The Chinese tradition has five elements, the same four as in Europe plus *wood* as a fifth element.

Probably many readers will agree that this opinion is scientifically wrong. It is a speculative idea, not based on thorough physical-chemical observations. *Speculative ideas* shall not mean pure guesswork but, at best, a thinking originating in the deepest imagination the philosopher has about the principles of nature, but which has only a loose connection to experience. We should not merely shake our heads about the old thinkers. We must realize that truth is very difficult to find, so we still live with many erroneous concepts. But in mathematics and science it is possible to gain such a degree of certainty through thinking and experience that very little reason for doubt is left.

We meet speculative ideas with most of the ancient thinkers, which is not said to belittle the historical role of, for instance, Plato and Aristotle, but here Archimedes (~287-212 B.C.) occupies a unique position as the one whose methods and results have eternal validity, for instance the rules of equilibrium and of buoyancy in water, which were derived through experience and mathematical theory. Archimedes deserves to be called the *father of modern science.*

▲ Fig. 1: The Disc of Heavens from Nebra in Germany—This archeological and cultural sensation became known in 2002 and is dated to 1600 B.C., the early bronze age. Anybody can see it has an astronomical subject: Sun, Moon and stars. It is the oldest image of the cosmos.



▲ Fig. 2: Lucifer at the centre of Earth in a drawing by Sandro Botticelli about 1500—Vergil with Dante on his back is crawling down and turns upside down, when he reaches the centre.

All the speculative ideas spring from the irresistible human desire to seek and also to provide an explanation for everything seen and experienced, for instance for the true nature of the Sun and the cycle of day and night, for the creation of the world and man, for life after death, and for the inner motives of politicians. Man adopts these explanations partly through own reasoning, partly by believing in (ancient) authorities or charismatic leaders. Critical sense and hard work can however gradually lead to explanations (theoretical descriptions a physicist would say) which are self-consistent and which agree with the most important observations.

Greek theory and observations

The Greeks introduced *theory* in astronomy in order to predict positions of the planets and eclipses of Sun and Moon. They proposed many possible systems of the universe until Ptolemy's authority overshadowed everything else. Anaximenes of Milet says about 600 B.C. that Earth is a cylinder, three times broader than high, and that it is surrounded by three concentric rings carrying Moon, Sun, and the fixed stars. These rings have diameters of respectively nine, eighteen, and twentyseven times the Earth's diameter. At the same time Pythagoras realizes that the Earth is spherical, partly for the mathematical and speculative reason that he considered the sphere to be the ideal form of a body, partly because he saw the circular shadow of Earth cast on the Moon at lunar eclipse. Philolaus says about 400 B.C. that Earth circles the Sun in the time of one day and night. About the year 350 B.C. Aristotle places the Earth at centre, and it is surrounded by concentric spheres of water, air, and fire, followed by spheres for the heavenly bodies. This system was to become the basis for cosmology and physics for most of the next two thousand years.

A very interesting idea was proposed by Aristarch about 280 B.C., that Earth circles the Sun in one year while it rotates about its own axis in the time of one day and night. But the idea did not get wide acceptance at that time. It took 1800 years before Nicolaus Copernicus (1473-1543) made the same proposal thus moving the centre of the universe from the Earth to the Sun.

The size of the Earth was correctly determined by the ancient Greeks. It was noticed that the Sun stood higher in the sky at noon at a given time of the year when seen from a southern latitude than from a more northern. From the difference in altitude measured in degrees and the distances between the two places on Earth it was easy for Erathostenes about 250 B.C. to compute the circumference of the Earth when he rightly assumed that the Sun was very very far away.

Also the Moon's distance was determined. Hipparchus, *the father of astronomy*, did it about 120 B.C. by means of a solar eclipse that had taken place on 14 March 189 B.C. He knew from reports

▶ Fig. 3: God as the architect, illustration from a Middle Age bible—God has created the universe after geometric and harmonic principles. To seek these principles was therefore to seek and worship God, meant for instance Kepler.

of the event that the Sun covered the whole Moon as seen from Hellespont, but only four fifths of the Sun was covered in Alexandria. He correctly assumed that the Sun was much further away than the Moon and could then easily compute the distance to the Moon.

The angular shift of the Moon with respect to the Sun between observations from two places on the Earth was thus used to measure the distance to the Moon. A similar method of angular shift is applied in our modern times to measure the distances to stars. The angle between a nearby star and one far away changes with time. Considering two observations half a year apart the angle has changed the most, because the Earth after half a year has moved to the other side of the Sun, that means it is shifted by 300 million km. This measurement is complicated by the individual straight motion of the two stars through space. Therefore the separation of the *proper motion* of a star from its distance requires several years of observations.

Music of the spheres

The sequence of the planets and the dimensions of the cosmos were not agreed upon in Antiquity. We find the sequence: Earth, Moon, Sun, planets, and: Earth, Moon, Venus, Mercury, Sun, and: Earth, Moon, Sun, Venus, Mercury. Agreement was only reached with the advent of Copernicus who placed the Sun at the centre: Sun, Mercury, Venus, Earth while the Moon was still closest to the Earth.

Music theory was used to find the size of planetary orbits since the natural intervals of tones were considered fundamental for the system of nature. The *harmony of spheres* was an important concept all the time from Pythagoras to Kepler's *Mysterium Cosmographicum* in 1596. Nowadays we can see that it is completely wrong, without a real connection to the laws of nature in astronomy, and the results obtained by the various ancient scientist were in fact very different.

Music theory as a tool in astronomy became completely meaningless and superfluous with the laws of nature presented in Newton's famous work *Principia Mathematica Philosophiae Naturalis* from 1687, a book on a new physics that came to revolutionize the world.

Newton describes the laws of nature mathematically by means of concepts as velocity, acceleration, force, mass, absolute time, absolute space, and gravity, concepts previously unknown or without a precise meaning.

Newton created his laws on the basis of the laws of planetary motion which Kepler had found on the basis of Tycho Brahe's measurements. But Newton's laws are valid everywhere in the whole world, in the entire universe. They have since been applied to describe all phenomena in nature, the motion of planets, and the structure of atoms. They are applied throughout modern techniques: for construction of bridges, telescopes, motors, rockets etc.

Middle Ages

We must not forget the contribution from the Middle Ages. Christian thinkers were much concerned with the concepts of *time, eternity, and space* because the Christian God is eternal and omnipresent. They created a philosophical language in which they could speak about these matters in a way that made sense. During

Antiquity and Middle Ages the Christian teachers (missionaries and priests) fought astrology and old superstition, which however still have a firm grip in many people of our time. But superstition is quite alien to the Christian belief in an ordered world, a world and a universe ordered in harmony by the eternal God, a God who does not interfere in everyday matters. God as architect of the universe appears, for instance on a illustration in a bible from the Middle Ages. A belief in miracles hardly complies with this concept of God.

In the Christian Europe a broader part of society gradually got a theoretical education than in ancient Greece. It was a rather widely shared opinion in the 16th century that it is permitted to seek the laws of nature for the sole purpose of discovering these laws. Previously, such studies always had to be accompanied by and to end with a praise of the Almighty God. Tycho Brahe and Galilei enjoyed this freedom of research for a while, but they both came to suffer when conservative theologists gained strength again.

The light from the Big Bang

The attentive reader will have noticed that astronomers have often changed opinion about distances, sometimes slowly, sometimes very quickly. They held to the Ptolemaic distances even up to Tycho Brahe. But the visible universe is now one million billion times larger than that of Tycho Brahe, and it has "grown" most quickly during the recent 100 years, by nearly a factor one million according to the table. The reader must ask: *Do we know anything certain at all? Can it continue to grow like this?*

The answers are respectively YES and NO.

Instruments and methods of measurement are fundamental for our knowledge of the universe. But it would require too much space here to describe these matters and the methods to interprete the observations. I must try to gain the reader's confidence through historical information.

I venture to claim that *we know something for certain*, for instance the size of the Earth and the distance to the Moon were nearly right before 100 B.C. The *distance to the Sun* could only be accurately measured after the invention of the telescope and its use in astronomical observations by Galilei in 1610. But astronomers still had to wait for a very seldom event, a passage of Venus across the solar disc, and to send expeditions to exotic places of Earth to get the observations that could provide the much wanted distance to the Sun. That happened for the first time in 1761, and the method worked to satisfaction. In our times some distances in our solar system have been measured directly by reflection of radar signals from Earth to for instance the Moon and Venus.

Progress in measuring the *distance to stars* had to wait for the industrial revolution. One of the preconditions of this revolution was to know the laws of nature as described by Newton in 1687. Since Copernicus in 1543 wrote that the Sun is the centre of Earth's orbit, astronomers had tried to measure the distance to stars through the annual shift of position. But they could only succeed after development of good telescopes, and, not the least, a good mathematical method to treat observations and their errors. The mathematical method of 'least squares' was described by Gauss in 1802. The measurement and the data analysis were mastered by

Bessel for the star No.61 in the constellation of Swan. His careful analysis and its publication in 1838 convinced other astronomers about the reality of the result, contrary to numerous other published 'stellar distances' since Copernicus. The distance of 11.2 light years is a million times larger than Ptolemy's distance to the stars.

The measurement of distances by the annual angular shift has now been possible for stars (see Figure 4) that are within a distance from the Sun of a few per cent of the extent of our Galaxy.

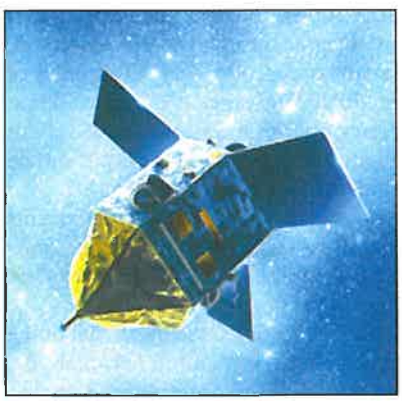
The distance of stars very far away, for instance in other galaxies, can be derived from their observed brightness. The brightness of a star decreases by the square of the distance. This means that a star which is two times further away than a nearby star of the same type is fainter by a factor four. The type of a star can be measured by a study of its spectrum where the colour components of the light are recorded with sufficient detail.

Large telescopes were required to observe the spectra of stars. The interpretation of stellar spectra required a *theory of heat* and an *atomic theory* which were developed in the 19th and 20th centuries. That was possible on the basis of Newton's laws, and later other deep laws were discovered, *quantum theory* and *theory of relativity*.

Through radio techniques and observations from outside the Earth's atmosphere it has been possible during the recent fifty years to study electromagnetic radiation in all wavelengths, not only in the narrow band around the visually visible light which was the basis for all previous astronomy. By 1960 the Palomar 5 meter telescope could record faint galaxies as far away as 2 billion light-years, and nowadays from the Hubble Space Telescope distant galaxies have been observed where the light has been on its way for nearly 13 billion years, almost since the universe began with the Big Bang.

We have observed the radiation emitted when the universe was only 380,000 years old when the temperature of the Big Bang 'fire ball' had fallen below 3000 degrees. At this temperature the gas in the universe becomes transparent so that the radiation can travel unhindered, not being absorbed again as when the gas is hotter. This radiation was discovered by Penzias and Wilson in 1964 as microwaves coming from all over the sky. This *cosmic background radiation* has much longer wavelengths now than when its was emitted because of the expansion of the universe during the time since the radiation started its journey 13.7 billion years ago. This age of the universe has been measured with a precision of 1 per cent by a recent satellite, WMAP.

The long wavelengths of the radiation correspond to a radiation temperature of only 2.726 degrees above the absolute zero point of −273.15 degrees Celsius. The temperature of the radiation is very constant over the whole sky, varying by only 40 millionths of a degree.



▲ Fig. 4: HIPPARCOS, the first astrometric satellite, measured accurate distances of stars. It was launched by the European Space Agency in 1989. In 3 years Hipparcos obtained distances for 120,000 stars up to 1000 light-years away. It provided 2.5 million stars for the Tycho-2 Catalogue including positions, proper motions, and colour measurements.

The mathematical analysis of the accurately measured variations has given crucial information about the early development of the universe.

The invisible universe

The light or any radiation we observe from an object in the universe can only have been on its way since the Big Bang 13.7 billion years ago. This very long, but finite time defines *our cosmic horizon* which is a sphere centred on the observer. The distance to objects in the visible universe, that is the universe inside our cosmic horizon, has been our main subject. It must, however, be stressed that the whole universe is much larger, perhaps even infinite in size; but according to observations with the WMAP satellite the universe is probably finite. In any case the whole universe has no centre, it looks approximately the same in its large-scale features for any observer. This is called the *cosmological principle* which is basis for all modern cosmology and which is also in accordance with accurate observations for instance by WMAP.

Some words about time, space, and distances are required. We see a distant galaxy as it looked when light left it several billion years ago which is called the *look-back time* of the galaxy. We define the *look-back distance* to the galaxy as the look-back time multiplied with the speed of light 300,000 km per second.

We may observe the angular size and the brightness of a galaxy at some distance. If the same kind of galaxy is observed at a twice larger distance we expect it to look twice smaller and four times fainter. These laws are accurately valid up to distances of several hundred million light-years, but not for many billion light-years. For such galaxies *other kinds of distances* than the look-back distance are required to describe our observations with the same laws.

Space and time are described as a four-dimensional space-time in the general theory of relativity presented by Einstein in 1915, and this theory has ever since been the preferred mathematical basis for studies of the universe. It describes a universe which has no centre, and it provides new kinds of distances in an expanding universe by which the angular size and brightness of a galaxy can be treated consistently, even at the largest distances.

The theory of relativity does not actually predict that the universe expands, but it allows an expansion or a contraction. The actual expansion was discovered by Edwin Hubble in 1929 when he found that the lines in spectra of distant galaxies were shifted towards red indicating a velocity away from us, with larger velocities for larger distances. Since the velocity is proportional to the distance, an observer at any position in the universe will see similar expansion velocities, in accordance with the cosmological principle.

Modern observations and theory have reached the most distant parts of the visible universe with great succes in obtaining a consistent picture through mathematical descriptions. One of the most astounding results is that the mass of all visible matter (that is atomic matter as stars, dust, and gas) is too small to explain the observed velocities in galaxies and clusters of galaxies. The total gravity required by the observed velocities is ascribed to the visible atomic matter plus some kind of *dark matter* which has been a riddle in astronomy for seventy years. It appears now that there is ten times as much dark matter as atomic matter. In fact the formation of galaxies and galaxy clusters is totally dominated by the gravity of the dark matter, while the atomic matter merely shows us the motion of the dark matter.

A more recently discovered riddle of similar magnitude is based on observation of very distant objects in the universe. It appears that the expansion of the universe is faster now than it was in the past. This effect is ascribed to *dark energy* which accelerates the expansion.

Dark matter and dark energy are just convenient names used by astronomers when speaking of the large velocities seen in the motion of visible matter in the universe. It is the great challenge for present astronomy and physics to understand the *true physical nature* of dark matter and dark energy.

Finally some conclusions. The entire universe has *probably a finite volume*, being slightly curved through the presence of visible and dark matter, and of dark energy. The universe will *probably expand forever* and will do so *faster and faster* because of the presence of dark energy.

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About the author
Erik Høg, Copenhagen University Observatory, has been involved in the European efforts in space astrometry since the earliest studies in the 1970s. In 1999 he received "The Director of Science Medal, *for outstanding contribution to the science programme*" of the European Space Agency

Bibliography
Dreyer, J.L.E. 1953, *A History of Astronomy from Thales to Kepler*, Dover Publications, Inc.

Pedersen, Olaf 1992, *The Book of Nature*, Vatican Observatory Publications

Pedersen, Olaf 1993, *Early Physics and Astronomy, A Historical Introduction*, Cambridge University Press

Stephenson, Bruce 1994, *The Music of the Heavens, Kepler's Harmonic Astronomy*, Princeton University Press

Van Helden, Albert 1985, *Measuring the Universe, Cosmic Dimensions from Aristarchus to Halley*, The University of Chicago Press

WMAP 2003, *Wilkinson Microwave Anisotropy Probe*, http://map.gsfc.nasa.gov

Particle physics from the Earth and from the sky

Daniel Treille, CERN, Geneva, Switzerland

Recent results in particle physics offer a good balance between the news "coming from the Earth", namely results from the various colliders, and news "coming from the sky", concerning solar and atmospheric neutrinos, astroparticle programmes, searches for dark matter, cosmic microwave background (CMB), cosmology, etc.

In the light of this information, gathered in particular from the 2003 Summer Conferences (EPS in Aachen, Lepton-Photon in Fermilab), an account of the status of our field is given. It will appear in two parts, corresponding approximatively to the division between the Earth and the sky. The first one covers the Electroweak Theory, ideas beyond the Standard Model, Quantum Chromodynamics (QCD), Beauty and heavy ion physics.

Electroweak Theory
The Electroweak Theory (EWT), together with Quantum Chromodynamics (QCD), modern version of the strong interaction, builds the Standard Model (SM) of Particle Physics [1]. The EWT is a fully computable theory. All EW measurable quantities, called "observables", as for instance the properties of the various Z^0 decay modes, can be predicted with great accuracy and compared to measurements. Each of them allows in particular to determine the Weak Mixing Angle, i.e. the parameter of the 2×2 unitary matrix which transforms the two abstract neutral bosons of the EWT into the two neutral physical states, photon and Z^0. The internal consistency of the EWT implies that all values of the Weak Mixing Angle obtained should coincide. In terms of the standard Big Bang model, the breaking of the EW symmetry, namely the time at which known elementary particles got their mass, presumably through the Higgs mechanism*, occured at about 10^{-11}s after the Big Bang.

The e^+e^- high-energy colliders LEP at CERN and SLC (SLAC Linear Collider) have delivered their quasi-final results. Their contribution to the validation of the EWT has been invaluable. However, besides celebrating this great success, it is worth considering the few areas of obscurity left and discussing how one can hope to improve the precision measurements in the future.

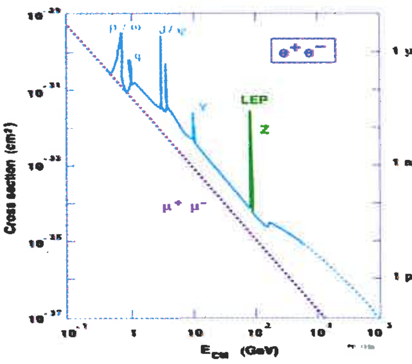
It is amusing to remember what was expected from LEP, for instance at the time of the meeting held in Aachen, in the same place as the 2003 EPS Conference, in 1986. In nearly all domains the quality and accuracy of the final results of Z^0 and $W^\pm$ physics* have been much better than foreseen, in particular due to the progress made during the last decade on detectors (microvertex devices allowing a clean tag of beauty particles, by revealing their long lifetime (flight path) of about 1 picosecond (few mm), luminometers providing a very accurate absolute normalization of the various processes, etc), on methods (such as how to determine the number of neutrinos from the Z^0 properties, ...) and on the mastering of theoretical calculations.

Figure 1 and its legend recall what is the scenery of e^+e^- collisions. Sitting on the huge Z^0 resonance, LEP recorded about 18 millions Z^0 events and SLC about half a million only, but with the strong bonus of a large polarization of the incident electrons and better conditions for beauty tagging. From this large amount of data, many observables were measured, often with an accuracy of one per mil or better. Later, LEP200 measured e^+e^- interactions at higher center-of-mass energies, up to 206 GeV: it recorded about 40K W pair events and set quite strong lower mass limits on the Higgs boson and Supersymmetric Particles.

If one summarizes the whole set of available EW measurements (LEP/SLC and others) by performing a global fit [2], one finds that the SM accounts for the data in a satisfactory but nevertheless imperfect way: the probability of the fit is only 4.5%.

The measurement lying furthest from the average is that of the weak mixing angle by the NuTeV experiment in Fermilab [3], which scatters neutrinos and antineutrinos on target nuclei. Before invoking new physics, the possible "standard" causes of such a disagreement were carefully investigated: unexpected features of the quark distribution inside nucleons are the most likely culprits. If this measurement is excluded from the fit, the probability becomes 27.5%, a reassuring number.

The other noticeable disagreement concerns the two most precise electroweak measurements, namely the spin asymmetry A_{LR} at SLC, i.e. the relative change of rate of Z^0 production in e^+e^- collisions



▲ Fig. 1: The scenery of e^+e^- collisions as a function of energy. LEP1 was "sitting" on the huge Z^0 resonance. Beauty factories exploit the Υ(4S) resonance located in the family of Υ beauty-antibeauty resonances near 10 GeV. The J/ψ is the lowest charm quark-antiquark bound state near 3 GeV. (*Fig. courtesy U. Almaldi.*)

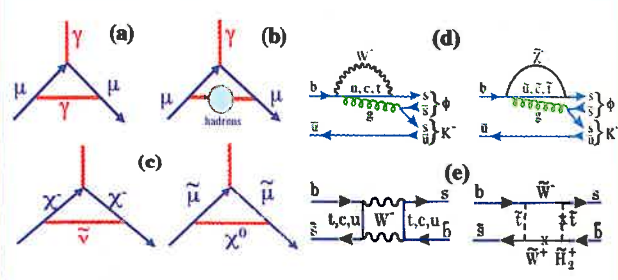
when one flips the electron helicity (i.e. the component of its spin along the direction of motion), and the forward-backward asymmetry of beauty production on the Z^0 at LEP, $A_{FB}{}^b$, i.e. the manifestation of the violation of particle-antiparticle conjugation C (and of parity P) in $e^+e^- \rightarrow Z^0 \rightarrow$beauty-antibeauty, which give values of the weak mixing angle differing by 2.7 standard deviation with no hint of an explanation, neither instrumental nor theoretical.

An ambiguity which is not yet removed concerns the theoretical interpretation of the muon g-2 measurement [4] obtained in Brookhaven with an experimental accuracy of ~ 5 10^{-7}. The slight departure of the muon g factor, relating the magnetic moment to the spin, from its canonical value of 2 (i.e. the value given by the Dirac equation describing pointlike relativistic fermions) is due to the fact that the electromagnetic interaction of a muon and a photon is perturbed by the exchange of one (or more) additional photon(s) (figure 2a). After correction of a small error, the theoretical frame is sound. However, the tiny hadronic contribution (figure 2b) to this quantity expected in the SM, which reflects the probability that the additional photon fluctuates into a light hadronic system, differs, depending on the way it is estimated. To obtain its value one has to resort to subsidiary experimental data. Using for this purpose the hadronic decays of the tau* (plus a set of assumptions) leads to a relatively fair agreement between theory and experiment (the latter larger than the former by 1.4 σ. However using hadronic production in low energy e^+e^- collisions leads to an excess of experiment over expectation which according to the most recent analyses [5] amounts to 2.7 σ. The situation may still change with the advent of data from the B Factories in SLAC and in KEK (Japan) and from KLOE in Frascati. This residual discrepancy is all the more unfortunate given that the g-2 observable is potentially a powerful telltale sign of new physics, in particular Supersymmetry [1], since new particles can contribute to the perturbation as virtual states (figure 2c). While a significant excess of the measured value over theory could point to an appetizing window for the masses of some supersymmetric particles, good agreement could on the contrary eventually turn into a noticeable constraint on the minimal value of their masses.

A low energy measurement which "returned to the ranks" is that of atomic parity violation (APV). APV [6] occurs because in an atom the electrons and the nucleus interact not only by photon exchange but also by Z^0 (and its possible recurrences at higher mass Z^{0}') exchange. Alkali atoms, having a single outer electron, are the only ones that lead to tractable atomic calculations. Due to recent refinements of some theoretical estimates, there is presently a good agreement between the expectation and the 0.6% accurate measurement on cesium made in Boulder in 1997. The APV measurement does not weight much in the EW fit. However, a remarkable result for such a small sized experiment is that the lower mass limit it sets on a potential Z' (600-800 GeV) is quite competitive with those of LEP or Tevatron. However, to stay so in the face of future LHC data, the APV measurement should reach ~ 1‰ or so. The possibility of a programme using francium, the next alkali atom, much more sensitive but radioactive, is sometimes mentioned.

It is worth underlining here the promises of another set of low energy measurements concerning Electric Dipole Moments (EDM), in particular of the neutron. For particles to have a permanent EDM the forces concerned must violate the invariance under time reversal T (and therefore under CP*), and the SM expectations are out of reach, far below existing and foreseeable limits. But various scenarios beyond the SM may lead to strong enhancements. Very sophisticated methods involving ultra cold neutrons are under study and may bring an improvement of two orders of magnitude on the present neutron EDM upper limit. Limits on the muon EDM, as a by-product of the g-2 measurement, and on the electron EDM, through measurements made on various atoms, in particular Hg, are likely to improve as well. If no positive evidence is found, these limits will in particular become a major constraint for Supersymmetry.

Let us finally quote a potential problem concerning the unitarity of the Cabbibo-Kobayashi-Maskawa (CKM) matrix[7], and more precisely its first row. The CKM matrix gives the relationship between the quarks seen as mass and as flavour eigenstates. Unitarity just means that when one "rotates" from one base to the other the probability has to be conserved. The CKM matrix is a 3x3 unitary matrix, entirely defined in terms of four real parameters. It gives a concise description of all that we know at present about the weak interactions of quarks. The first row of the matrix concerns essentially the u⇔d and the u⇔s (Cabbibo angle) transitions and the fact that their moduli squared do not add exactly to unity could indicate that the value of the Cabibbo angle is slightly underestimated. Actually, after including recent results, like the data of E865, at Brookhaven Alternate Gradient Synchrotron, on the decay $K \rightarrow \pi e \nu$, the remaining deficit relative to unity amounts only to ~1.8 σ and is not a big worry



▲ Fig. 2: Examples of loop diagrams
(a) The lowest order diagram contributing to g-2.
(b) The hadronic contribution to g-2.
(c) SUSY particles in the loops as a possible contribution to g-2.
(d) Penguin diagrams (SM and SUSY) contributing to one B decay mode. The ressemblance to a penguin is a matter of taste.
(e) The loop diagrams responsible for beauty-antibeauty oscillation.

The message from LEP

In spite of the few open questions quoted above, the first message of LEP/SLC is therefore the quality of the agreement of the SM, or more exactly of its neutral current (i.e. Z^0) sector with data. Any theory attempting to go beyond the SM (see below) must therefore mimic it closely and offer very similar predictions of the various EW observables. Most interestingly, because of the extreme accuracy of the measurements, the agreement has been demonstrated at the quantum loop-level. Before expanding this last point, let us remark that the situation is less precise for the charged current sector of the SM. As for its scalar (Higgs or equivalent) sector, still largely untested, it will need the CERN Large Hadron Collider (LHC) to be explored.

In a given process, particles, even if they are too heavy to be produced as "real" particles, can nevertheless intervene as "virtual" states and slightly influence the process. Figure 2 presents a variety of such loop diagrams. Accurate measurements on a process can thus yield information on these virtual particles. At LEP the "missing pieces" of the SM were the top quark, too heavy to be pair produced but whose existence was never in doubt, and the Higgs boson, not yet observed directly at present. As G.Altarelli put it, LEP physicists were in the situation of a bush hunter, his ear to the ground, trying to hear the pace of a tiger (the Higgs) while an elephant (the top) was rampaging around.

It is well known that Z^0 physics at LEP gave a rather accurate "indirect" estimate of the top quark mass (presently $171.5^{+11.9}_{-9.4}$ GeV), in very good agreement with the value that later the Tevatron measured "directly" by producing the top, presently 174.3 ± 5.1 GeV (figure 3a). Once the "large" effect of the elephant-top on the relevant electroweak observables was well under control, one could search for the tiny effect expected from the tiger-Higgs boson, which in the SM is assumed to be the only missing piece.

Ignoring the disagreements quoted above, essentially that existing between A_{LR} and A_{FB}^b, and considering only the mean values, one can thus deduce, in the strict frame of the SM, the preferred mass region for the Higgs boson (remembering that the information concerns the logarithm of its mass):

$M_h = 91^{+58}_{-37}$ GeV, and $m_h < 219$ GeV at 95% CL (figure 3b).

Taken alone, the A_{LR} observable would give for the boson mass a range between about 15 and 80 GeV, while the observable A_{FB}^b would give it between about 200 and 700 GeV. The W mass value (the world average is 80.426 ± 0.034 GeV) indicates also a Higgs mass region on the low side.

Let us remark that the SLC measurement seems to contradict the lower limit of 114.2 GeV set on the Higgs mass by the direct Higgs search* at LEP200, as well as the indication for an effect near 115 GeV which is presently at the 1.7 σ level. However the problem would be less acute if the top mass was a few GeV, say one standard deviation, higher than one states presently, a possibility that a reanalysis by the Tevatron [8] experiment D0 of its Run I data might suggest. If it were so the limit on m_h would be raised from 219 to ~280 GeV. For this reason, and many other good ones, a precise determination of the top mass is "devoutly to be wished". The Tevatron will reduce the uncertainty to ~2.5-3 GeV, per experiment and with an integrated luminosity of $2fb^{-1}$ (i.e. providing 2 events for a process having a cross-section of a femtobarn, i.e. 10^{-39} cm^2). The LHC should reach an uncertainty of ~1-2 GeV, while a Linear Collider will do about ten times better.

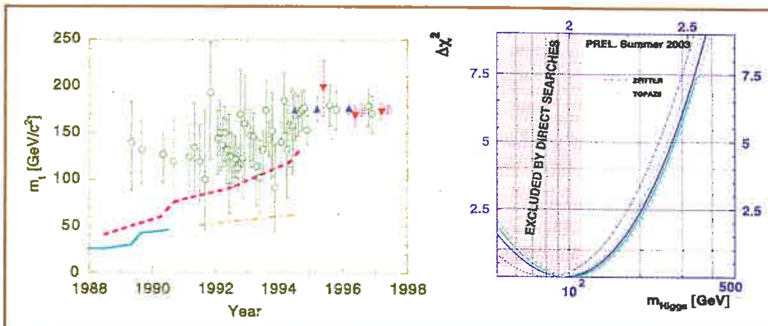
The other key message of LEP/SLC is thus the indication of a light Higgs boson. Is this the truth, or could it be an illusion? Clearly if one quits the frame of the SM by introducing new physics, it is quite possible to invent "conspiracies", i.e. interference of amplitudes of different processes, by which a heavy Higgs boson has its effect on electroweak observables compensated by something else, like new particles or extradimensions of space. However, these solutions are more or less artificial: it is thus reasonable to focus on the simplest scenario and to test in priority the assumption of a light boson by obtaining direct evidence for it.

Beyond the standard model

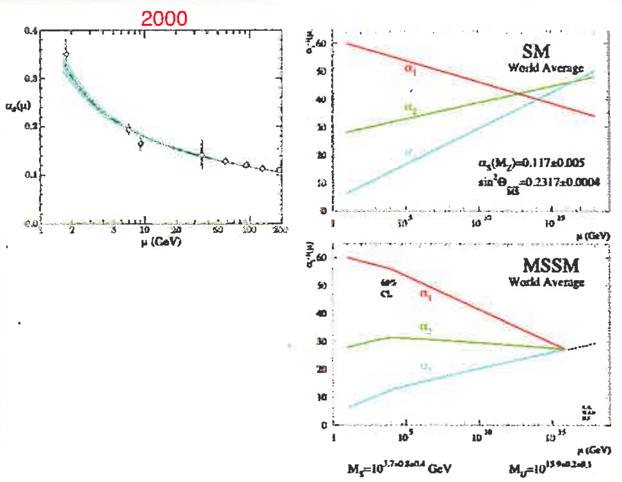
Exhaustive reviews of the direct searches for new physics at colliders, updating the existing limits, have been given. Unfortunately, besides the D_{sJ} particles* found by the Beauty Factories [9] and the Pentaquarks [10]*, no discovery has showed up at the high-energy frontier.

Nevertheless the motivations pushing to go beyond the SM are still present and more compelling than ever. The main one is the Hierarchy Problem that can be stated as follows. Gravity exists and defines a very high energy scale, the Planck scale* (~10^{19} GeV) at which the gravitational force becomes strong. In the SM all other masses, in particular the Higgs mass, should be irredeemably pulled towards this high scale by the radiative effects already quoted. Something more is needed to guarantee the stability of low-mass scales. Traditionally the routes leading beyond the SM either call for new levels of structure and/or new forces, as Technicolour (TC) [11] does, or involve more symmetry among the players of the theory, as in the case of Supersymmetry (SUSY) [1,12], in which SM particles and their "superpartners", i.e. the new particles of opposite spin-statistics (a boson as partner of a SM fermion and vice-versa) that SUSY introduces, conspire to solve the Hierarchy Problem.

TC breaks the EW symmetry in an appealing way, very reminiscent of the way the electromagnetic one is broken by supraconductivity (which, crudely speaking, gives a mass to the photon). However TC meets serious problems in passing the tests of electroweak measurements, because it harms too much the predictions. On the other hand SUSY, which has a more discrete effect in this respect, keeps its eminent merits and remains the most frequented and even crowded route. In this context another important result [13] derived from the LEP data is the quasi-perfect convergence near 10^{16} GeV of the electromagnetic, weak and strong coupling "constants" in the frame of SUSY, the so-called Supersymmetric Grand Unification (SGU) (figure 4b). This "running" of coupling constants with the energy scale is another consequence of the quantum nature of the theory: it is due to the effect of virtual particles appearing in the loop diagrams. The presence of



▲ Fig. 3: *Left*: The top mass from indirect LEP measurements (open circles) and from the direct Tevatron measurements (colour triangles).
Right: The preferred region for the SM Higgs mass (near the bottom of the χ^2 curve) deduced from electroweak measurements.



▲ **Fig. 4:** *Left*: The evolution of the strong coupling constant with the energy scale. *Right*: The convergence of the SM coupling constants, approximate in the SM (upper figure), exact in SUSY (lower figure). One should distinguish this smooth running of couplings from the evolution of the intensity of the interaction with the energy scale, depending on the mass of the exchanged boson.

superpartners explains why the "running speed" is different in SUSY and in the SM.

SUSY is certainly a broken symmetry as no partner of known particles with opposite spin-parity exists with the same mass. These partners are assumed to be heavy, but not too much (few hundred GeV to few TeV) as otherwise SUSY would no longer cure the hierarchy problem. Furthermore the convergence of couplings quoted above requires that the superpartners appear at relatively low mass, say 1 to 10 TeV.

With the diversity of the possible SUSY breaking mechanisms*, this theory presents a complex phenomenology with many different possible mass spectra for the supersymmetric particles. Its minimal version however offers a golden test: it predicts a very light Higgs boson, i.e. <130 GeV in full generality (for m_{top}=175 GeV), and <126 GeV once SUSY is broken, as it has to be, and in particular in all versions of Supergravity[14] presently considered as the reference points for future searches. This is a mass window that LEP, with 80 additional (i.e. 30% more) superconducting accelerating cavities and the magnificent performances of the accelerating field finally reached, could have explored and which stays as the first objective of future programmes. If SUSY represents the truth, the LHC, or maybe, with much luck and considerable improvements, the Tevatron, will discover it by observing, besides the light Higgs boson, some supersymmetric particles. But a Linear Collider will be needed to complete its metrology in the mass domain it will give access to.

However, quite interesting new roads have appeared in recent years.

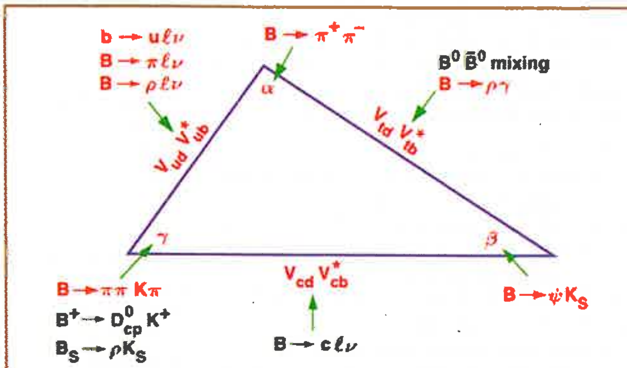
One, the Little Higgs scenario, leaving aside the Big Hierarchy problem (the one we introduced above) for the time being, tackles first the Small Hierarchy one, namely the fact that LEP announces a light Higgs boson while it pushes beyond several TeV the scale of any new physics (except SUSY which can still be "behind the door"): again the Higgs mass should be pulled to this high scale and the fact that it is not calls for efficient cancellation mechanisms to be at work. Keen to do without SUSY, this model, by an algebraic tour de force, manages to realize the compensations needed by inventing new particles, a Z', a W', a new quark, etc., at the mass scale of few TeV. The existing EW measurements put however the model under a severe tension. True or not, this theory has the merit to reinvigorate the LHC phenomenology by introducing new particles into the game and in particular insisting on quantitative tests concerning their decay modes.

The other new route postulates the existence, so far uncontradicted, of extra dimensions of space (ED), large enough to generate visible effects at future experiments. The general idea of an ED, due to Kaluza and Klein, is rather old (around 1919). The Superstring Theory requires EDs since it is consistent only in 9 or 10 spatial dimensions. For long, however, these EDs were thought to be "curled up" (compactified) at the Planck scale, until it was realized that things could be different. Several versions are presently put forward [15]. With substantial differences between them, they all predict Kaluza-Klein recurrences of the graviton or some of the SM particles, i.e. new states which can be produced if their mass is at the TeV scale or below, or that may change the rate of SM processes through their effect as virtual particles.

Such an eventuality, which has to be fully explored, would be an extraordinary chance for LHC and its prospective study also contributes an agreeable diversification of its phenomenology. However, before dreaming too much, it is important to appreciate correctly the existing limits, drawn either from accelerators or from astrophysics. For the ADD scenario, one should also consider the impact of dedicated tests of Newtonian gravity at small scale [16], which, besides micro-mechanical experiments, use sophisticated methods involving Ultra Cold Neutrons and maybe in the future Bose-Einstein Condensates, which build interesting bridges between particle physics and other sectors of physics.

Moreover, it is still a rather natural attitude to assume that extra dimensions, if they play a role, would do so at much higher energy scales, for instance the one of Grand Unification (GU). Many studies follow that path and analyse what one or more extra dimensions bring to the already very successful theories of Supersymmetric GU. This complements the class of studies which, to the symmetry group of GU, add other ones (a new U(1), a new SU(3), etc.) whose role is to deal in particular with the mystery of the triplication of families (i.e. the existence of the electron, muon and tau families).

The hope is that these attempts, performed from "bottom to top", i.e. from low towards high energies, and those, from "top to bottom", of Superstrings [17] will meet one day and guide each other.



▲ **Fig. 5:** The "d-b" Unitary Triangle. Adding to zero three complex numbers like $V_{ud}V_{ub}^*$, etc. naturally lead to draw a triangle. We indicate which B decay modes give access to its angles and sides. V_{ij} is the element of the CKM matrix connecting the flavour eigenstate quark i to the mass eigenstate quark j.

Quantum Chromodynamics (QCD)

QCD is the modern version of the strong interaction. The numerous experimental successes of QCD [18], besides its natural simplicity (a single parameter, the strong coupling "constant", if one forgets the quark masses), make it an exemplary theory. Most of the sectors of particle physics feed QCD and need it. QCD is both turned towards the domain of very high energies, where it exhibits "asymptotic freedom"*, and towards the low energy hadronic world, where its strong coupling at large distance leads to confinement of quarks and gluons. This evolution with the energy scale has been very clearly demonstrated in the past decade (figure 4a). All QCD aspects, from perturbative to non-perturbative, are actively studied and essential to extract correctly the physics of other sectors, EW measurements, beauty physics, heavy ions, etc. Nevertheless it is clear that all of them still need much progress, in particular to meet the requirements of future experimental programmes.

The QCD lattice simulations* built upon the basic principles of the theory, have become fundamental tools, well established and vital to many fields. The progress achieved is greatly due to that of the computing means, but also to the improvements of the algorithms and methods.

One of the few dark points concerning QCD seemed to be an excess of the production of beauty quark-antiquark pairs in various types of collisions compared to the predictions of the theory. However, new data and refined theoretical expectations show that the problem seems to be fading away.

The values of the single parameter of QCD, its coupling constant, extrapolated to the energy scale of the Z^0 mass, $\alpha_S(M_Z)$, obtained from very different sectors, are now well coherent. The uncertainty on this quantity, after having considerably decreased, is now stabilizing. Its absolute value, 0.118 ± 0.003, is in very good agreement with what is required by the most elaborate versions of Supersymmetric Grand Unification, including the effects appearing at the Grand Unification scale.

The nucleon structure and the distributions of the quarks and gluons inside it are better and better known and understood, especially thanks to HERA and in particular at the very small values of the fractional momentum x carried by the constituents, a crucial region since it will govern the production cross-sections at LHC.

However, when the spin intervenes, our understanding of nucleons is still poor. It is not yet clear how the spin of a nucleon is shared between its constituents. One is thus expecting from future polarization programs [19], in particular polarized proton-proton collisions in the RHIC collider at Brookhaven, a number of clarifications, in particular concerning the gluon helicity distribution, by measuring processes at transverse momenta large enough for the perturbative and computable version of QCD to apply.

It is important to underline that much remains to be done in matters of QCD if one wants to enter the CERN Large Hadron Collider (LHC) [20] era in optimal conditions, namely with a good mastery of the SM prediction for the many different topologies that searches will explore. Indeed before claiming for a discovery one

LEXICON

Asymptotic Freedom, Infrared Slavery: picturesque ways to express the consequences of the running of the strong coupling with the energy scale. At large energies (small distances) the coupling goes asymptotically to zero and the quarks inside the nucleon react as free particles when they are hit. But, at large separations (low energy or "infrared" limit) the coupling becomes strong and its effect guarantees the confinement of quarks and gluons.

CKM Matrix: in the SM the quark mass eigenstates are not the same as the weak eigenstates, and the matrix relating these bases was defined for six quarks, and given an explicit parameterization by Kobayashi and Maskawa, generalizing the four quark case described by a single parameter, the Cabibbo angle. The mixing is expressed in terms of a 3×3 unitary matrix operating on the charge −1/3 quark mass eigenstates d, s and b. The elements are the V_{ij} quoted in the text. Their values are determined by the weak decays of the relevant quarks (i.e. V_{cb} from beauty semileptonic decay into charm) and by neutrino scattering.

CP: symmetries represent a crucial aspect of particle physics. The invariance of the physical law under spatial mirror symmetry P is maximally violated by the Weak Interaction. The CP symmetry, product of P and of the charge conjugation C which interchanges particle and antiparticle, is also violated by the Weak Interaction, a fact which is a decisive one concerning our own existence, i.e. the matter-antimatter asymmetry in the Universe. Since the CPT symmetry is a sacred one in our present vision of the physical world (and is experimentally found to be exact), the time reversal symmetry T has to be violated as well by the Weak Interaction (and is indeed found to be so).

D_{sJ} Particles: these are narrow states of masses 2317 and 2460 MeV, discovered at the B-factories. They are likely to be P-wave levels of the D_S meson system (charmed and strange) but the surprise came from their mass, lower than expected.

Higgs Mechanism: the hypothetical mechanism by which the elementary particles and in particular the Z^0 and W get their mass by interacting with a field, the Higgs field. This is analogous to the case of supraconductivity: in a supraconductor one can say that by interacting with the field of Cooper pairs the photon gets a mass m and cannot penetrate the supraconductor by more than m^{-1} (Meissner effect). But this is just an analogy. In the SM the Higgs boson is an elementary Lorentz-scalar field. To fulfil its role, the Higgs field must be a complex doublet in an abstract space called the Weak Isospace.

Higgs Search: the direct search for the Higgs boson at LEP looked for the boson production in association with a Z^0 boson, $e^+e^- \to h^0Z^0$. The mass reach at LEP2 was therefore approximately the ultimate available center-of-mass energy minus the Z mass (i.e. 115 GeV for the 206 GeV of LEP200). A Higgs boson of such masses decays mostly into beauty-antibeauty, hence the vital role of the b-tagging technique in this search.

Lattice QCD: at the scale of the hadronic world, say 1 GeV, the QCD coupling constant is of order unity and perturbative methods fail. Lattice QCD which is QCD formulated on a discrete Euclidian space time grid provides a non-perturbative tool for calculating the hadronic spectrum, etc, from first principles. The discreteness of the grid acts as a non-perturbative regularization scheme.

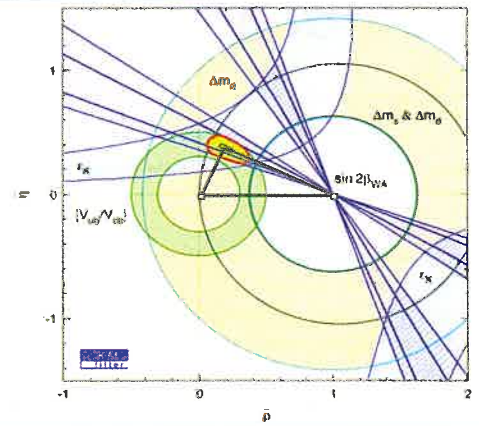
Pentaquarks: the present interpretation of newly discovered light narrow baryon resonances with a manifestly non-standard content of quarks. Diquark states may be involved in building them. This discovery is very interesting and under active study but probably does not call for any revolutionary revision of QCD.

Planck Scale: the energy scale at which the gravitational interaction between individual particles, negligible at present scales, becomes as strong as the other (unified) interactions. At that scale the theory must then incorporate gravitation, neglected in the SM. The problem is that, until the advent of String Theory, the theory of gravity, Einstein's General relativity, and Quantum Theory were not compatible.

SUSY Breaking Mechanisms: one does not know exactly how this occurs, but one can "parameterize this ignorance" within a few scenarios. The general idea is that the breaking occurs at high energy scale in a "hidden sector," and that the breaking is transmitted to the observable world by a "messenger." In the much studied case of SUGRA, the messenger is simply gravity.

Tau: the tau, discovered in 1974, is the charged lepton of the third (and last) family. Its mass is 1.777 GeV and its lifetime 0.291 ps. LEP and other programmes have shown that, besides its heaviness, the tau is "standard" and a mere recurrence of the electron and muon. Being standard it can be considered as a "laboratory": for instance its decay modes into light hadrons are a precious source of information on low energy hadronic physics.

Z^0, $W^\pm$: the neutral and charged quanta of the Weak Interaction. Discovered at CERN in 1983. Studied in detail at LEP 1 and 2, respectively. Masses: 91.1875 (21) and 80.426 (34) GeV, respectively. The Z mass was so accurately measured at LEP ($2.3\ 10^{-5}$) that it became one of the three basic entries of the SM, from which all other quantities are computable at first order. The Z and W decay into fermion-antifermion pairs, with branching ratios accurately predicted by the SM.



▲ Fig. 6: The tip (yellow) of the Unitary Triangle as determined from LEP, K physics, etc. The blue cones give the value of its angle β directly measured at B Factories.

should be confident with the estimate of the SM background. This remark is particularly true for the indispensable Monte Carlo programs needed to simulate the expected observations.

Heavy flavours

We recall that, in the jargon of particle physics, this corresponds to the physics of heavy quarks of the second, strangeness and charm, and especially third (beauty and top) generations. The heaviness of these quarks offers a simplified approach to the spectroscopy of hadrons containing them. Concerning the few symbols used below, B denotes a beauty meson (a beauty quark and a light antiquark, or vice-versa), while B_S is a meson containing beauty and strangeness. We recall that the ϕ is a narrow strange-antistrange bound state, while the J/ψ is the equivalent for charm. K_S (K_L) is the short (long)-lived neutral strange meson.

The progress of heavy flavour physics, especially of beauty physics is impressive. One must first underline the remarkable performances of the e^+e^- Beauty Factories, PEPB (detector BaBaR) at SLAC, and in particular KEKB (detector BELLE) in Japan, the first machine to deliver a luminosity of 10^{34} $cm^{-2}s^{-1}$ (the luminosity, multiplied by the cross-section of a given process, gives the rate of corresponding events). These colliders sit on the Upsilon(4S) resonance shown in figure 1, decaying into beauty meson-antimeson pairs.

In the study of the CKM matrix* defined above, the highlight is the determination of the so-called Unitarity Triangle [7]. In the SM, the unitarity of the CKM matrix, expressed in a graphical way, leads to the figure of a triangle, one for each of its rows and columns. This is because one of its four parameters is a non-zero phase, so that the CKM matrix is complex. Among the 6 unitarity relations, the "d-b" one, $V_{ud}V_{ub}^*+V_{cd}V_{cb}^*+V_{td}V_{tb}^*=0$, is particularly interesting because the three sides of the corresponding triangle (figure 5) have similar sizes. The length of its sides and its angles can be extracted from various measurements in the field of heavy flavour physics, and in particular of beauty physics. With enough of these measurements one can build this triangle in different ways: thus one can check that the result is unique, and, first of all, that one is indeed dealing with a triangle and not a more complicated situation that theories beyond the SM may announce.

It is clear that a very successful first round of experiments has been accomplished [21,7]. The direct measurement at Beauty Factories of one of the angles (called β or ϕ_1, depending on the continent...) via the theoretically very clean mode $B \rightarrow J/\psi K_S$ is in excellent agreement with the determination of the tip of the Triangle through the measurement of its sides made during the past decade at LEP and elsewhere, from B and K physics results (figure 6). This is another major success of the SM. However, revealing new phenomena through B physics calls for a still much better accuracy.

The roadmap, concerning the second round of measurements, defines an ambitious programme, involving many different decay modes of beauty and extremely demanding from the experimental (luminosity needed, control of systematics, etc.) as well as from the theory side: the hadronic uncertainties must be controlled, since the b quark under study is irredeemably confined inside beauty mesons, and one must obtain a reliable estimate of the contribution from loop diagrams complicating the process, the famous "penguins" (figure 2d), which represent both an embarrassing "pollution" and a promise, since it is in their loops that new physics, like Supersymmetry, could appear.

The kaon rare modes [22] also allow one to build another Unitarity Triangle through $K^+ \rightarrow \pi^+\nu\nu$, $K_L \rightarrow \mu\mu$, $K_L \rightarrow \pi^0\nu\nu$, $\pi^0e^+e^-$, etc. Several recent results and the promise offered by future experiments like CKM in Fermilab go in the right direction.

Finally, the muon rare modes are equally promising and the expected performances very impressive indeed: $\mu \rightarrow e\gamma$ with a sensitivity per event of 10^{-14} at PSI, conversion μe in nuclei at 2 10^{-17} in MECO at BNL.

Heavy ions

In the Big Bang model the transition from free quarks to hadrons occurred at a few microseconds. High energy heavy ions collisions are under study, to find evidence for the reverse step, i.e. the fusion of nucleons into a quark–gluon plasma (quagma) [23].

Fresh results are coming from the RHIC collider in Brookhaven, concerning Au-Au collisions up to 200 A GeV and have brought a few "surprises" concerning the properties of the hot and dense medium thus produced. The quote expresses the fact that some of them were actually predicted long ago.

The chemical freeze-out (at which the identity of the particles is fixed) occurs at 175 MeV (the Hagedorn temperature [24]), as at the CERN SPS, but the medium is now nearly baryon-free. The kinetic freeze-out (at which their kinematics is fixed) happens near 100 MeV. The medium undergoes an explosive expansion at a speed of 0.6 c, and shows a strong anisotropy of transverse flux, suggesting a hydrodynamic expansion due to very strong pressure gradients developing early in the history of the collision. Remarkably, the collision zone is opaque to fast quarks and gluons and this has a strong impact on hard phenomena: suppression of hadrons produced at large p_T, jet "quenching", i.e. the decrease of their rate of production, phenomena which are not observed in control collisions D-Au. Several questions concerning the Hanbury-Brown-Twiss (HBT) correlations (a concept borrowed from astronomy), e.g. the size of the collision zone, or the fate of charm in this opaque medium, etc. have still to be clarified.

However the most prominent signatures which could reveal a quark-gluon plasma are not yet available from RHIC and it is from the CERN Super Proton Synchrotron that results are still coming. In particular, the experiment NA45 confirms that the excess of low mass e^+e^- pairs, $m_{ee}>0.2$ GeV, implies a modification of the ρ resonance in the dense medium, probably linked to its baryonic density. The suppression of the production of the J/ψ, the lowest bound state of charm and anticharm, which could signal its fusion in the quagma [25], is confirmed by the analyses of NA50 and keeps all its interest. Unfortunately no unique prediction of this effect exists for RHIC and LHC. Data are needed: the next ones should come from PHENIX at RHIC and from NA60 at the CERN SPS.

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About the author

Daniel Treille is a senior physicist at CERN and a former spokesman of the DELPHI experiment.

References

[1] G. Kane, in *Scientific American*, June 2003, for a brief reminder of the SM and Supersymmetry Basics can be found in H. Georgi, *Scientific American*, April 80, p 104, G. t'Hooft, ibid., June 80, p 104

[2] All EW results are those provided by the LEP EW Group

[3] *CERN Courier*, Jan-Feb 02, article 6, p7

[4] F.J.M. Farley, *Europhysics News*, (2001) Vol. 32 No.5, *CERN Courier* Jan-Feb. 2004, article 2. The last g-2 result is from hep-ex/0401008

[5] M. Davier *et al.*, *Eur.Phys.J.*C 31, 503 (2003), S. Ghozzi and F. Jegerlehner, hep-ex/0310181

[6] M.A. Bouchiat, L. Pottier, *Scientific American*, June 1984

[7] Y. Karyotakis, G. Hamel de Monchenault, *Europhysics News*, (2002) Vol. 33 No.3

[8] J.F. Grivaz, *Europhysics News*, (2003) Vol. 34, No. 1

[9] *CERN Courier*, June 03, article 2, p6, July-Aug 03, article 6, p8, Sept 03, article 6, p9

[10] *CERN Courier*, Sept 03, article 1, p5, and a review by R. Jaffe and F. Wilczek, hep-ph/0401034

[11] K. Lane, Two lectures on Technicolour, hep-ph/0202255

[12] *CERN Courier*, Dec. 2000, article 19 *CERN Courier*, Jan-Feb. 2002, article 15

[13] *CERN Courier*, March 1991, article 1

[14] *CERN Courier*, Sept 02, article 17, ibid. Sept 03, article 17

[15] P. Binetruy, *Europhysics News*, (2002) Vol.33 No.2 *Scientific American*, August 2000, *CERN Courier*, March 2000, article 6

[16] *CERN Courier*, vol.43, n06, article 15 by I.Antoniadis

[17] B. Greene, The elegant Universe, H. Haber and G. Kane, Scientific American, April 83, p56, M. Green, *Scientific American*, Sept. 86, page 44, *CERN Courier*, April 99, article 11

[18] F. Wilczek, QCD made simple, *Physics Today*, Aug. 2000, *CERN Courier*, April 03, article 15

[19] *CERN Courier*, Jan-Feb. 2002, article 16, HERA with polarized e: *CERN Courier*, April 03, article 1, p5, HERMES: *CERN Courier*, Nov 01, article 18, COMPASS: *CERN Courier*, Sept. 99, article 19, RHIC: *CERN Courier*, April 02, p8, Jan-Feb 03

[20] *CERN Courier*, Jan-Feb 03, article 1, July-Aug 03, article 2

[21] *CERN Courier*, April 01, article 15, may 2002, article 2, see also reference 7

[22] KTeV: *CERN Courier*, April 99, article 2, July-Aug. 2001, article 1, E787: *CERN Courier*, March 2002, article 2, p4 KLOE: *CERN Courier*, Sept. 99, article 23 NA48: *CERN Courier*, Sept. 99, article 2, July-Aug. 2001, article 1

[23] *Europhysics News*, (2000) Vol. 31, No. 3, *CERN Courier*, Oct. 2002, article 13

[24] *CERN Courier*, Sept. 03, article 18

[25] *CERN Courier*, May 1999, article 7

Physics in daily life: Hear, hear...

L.J.F. Hermans, Leiden University, The Netherlands

Even a tiny cricket can make a lot of noise, without having to "refuel" every other minute. It illustrates what we physicists have known all along: Audible sound waves carry very little energy. Or, if you wish: the human ear is pretty sensitive—if the sound waves are in the right frequency range, of course.

How exactly our ears respond to sound waves has been sorted out by our biophysical and medical colleagues, and is illustrated by the familiar isophone plots that many of us remember from the textbooks. They are reproduced here for convenience. Each isophone curve represents sound that seems to be equally loud for the average person.

The figure reminds us that the human ear is not only rather sensitive, but that it also has an astonishingly large range: 12 orders of magnitude around 1 kHz. This is, in a way, a crazy result, if we think of noise pollution. It means that if we experience noise loud enough to reach the threshold of pain, and we assume a $1/r^2$ decay of the sound intensity, we would have to increase the distance from the source by a factor of 10^6 to get rid of the noise. Or, if we stand at 10 m from the source, we would have to walk away some 10 000 km.

All this assumes that the attenuation can be neglected, since we have been taught that sound wave propagation is an adiabatic process. Obviously, real life isn't that simple. There are several dissipative terms. For example, think of the irreversible heat leaks between the compressed and the expanded areas: the classical absorption coefficient is proportional to the frequency squared, which makes distant thunder rumble. Then there is attenuation by obstacles. There is the curvature of the earth. There is the curvature of the sound waves themselves, usually away from the earth due to the vertical temperature gradient. Without loss terms like these, forget a solid sleep.

Illustration by Wiebke Drenckhan

A second feature worth noticing is the shape of the curves. Whereas the pain threshold is relatively flat, the threshold of hearing increases steeply with decreasing frequency. If we turn our audio amplifier from a high to a low volume, we tend to loose the lowest frequencies. The "loudness" control is supposed to compensate for this.

Finally, it is interesting to notice the magnitude of the sound intensity. How much sound energy do we produce when we speak? Let us assume that the listener hears us speak at an average sound level of 60 dB, which corresponds to 10^{-6} W/m^2 as seen from the right-hand vertical scale. Assuming that the listener is at 2 m, the sound energy is smeared out over some 10 m^2. This means that we produce, typically, 10^{-5} W of sound energy when we talk. That is very little indeed. During our whole life, even if we talk day and night and we get to live 100 years, we will not talk more than 10^6 hours. With the above 10^{-5} W, this means a total of 10 Wh. Even with a relatively high price of 50 Eurocents/kWh, this boils down to less than one cent for life-long speaking. Cheap talk, so to speak.

Council approves a new Constitution and unit fee

Martin C.E. Huber, EPS President

In its 2004 meeting, held in Mulhouse on March 26 and 27, the Council of the European Physical Society concluded the long-standing discussion of two substantial items: Council approved a thoroughly revised Constitution with new By-laws, and Council also adopted a revised unit fee. These votes are bound to have major, positive consequences for the further development of our Society.

Here I want to highlight just a few features of the new EPS Constitution and By-laws. First of all: they are more easily readable. Some of the arcane terminology of the previous versions has disappeared. The former "Ordinary Members according to Art. 4b", for example, which actually were the National Physical Societies that had joined the EPS, are now called Member Societies and the "Individual Ordinary Members" have become Individual Members. At the same time, the annual fee for Individual Members has been noticeably reduced from the previous amount of 36.4 Euros: those who belong to a Member Society pay now 20 € (or 15 €, if they are below age 30, or are retired). Students and teachers may now also join the EPS as Individual Members; they pay 15 €, and need not belong to a Member Society.

Individual EPS membership becomes more attractive

On the other hand, individuals who are currently enrolled in EPS Divisions and Groups as "National Society Members" will be able to maintain that kind of membership only until the end of this year. This will have no negative financial impact; rather the contrary, because "National Society Members" paid no extra fee, yet, keeping track of such members was a difficult task and considerable administrative burden.

The new By-laws define the privileges of Individual Members as follows:

- the right to vote at General Meetings,
- the right to elect Council Delegates representing the Individual Members,
- the right to hold office in the Executive Committee,
- the right to hold office in Divisions and Groups,
- Europhysics News are sent directly to their specified address,
- reduced registration fees at conferences organised by the EPS and its Divisions and Groups,
- benefits based on agreements with Collaborating Societies, and
- inclusion in the EPS Directory.

Moreover, Council may elect Individual Members, whose achievements in physics or whose commitment to the EPS warrants specific recognition, to be EPS Fellows. This will be a distinguished title—it may be awarded only to 5% of all Individual Members.

To streamline the administrative process, a straightforward procedure guaranteeing payment as well as updated information for Individual Members is now being introduced: in future, Individual Members will pay their fee to the EPS via their National Physical Society. In practice, the forms for the annual renewal of membership in the National Physical Societies will have an extra 'box', where individuals can express their wish to become an Individual Member of the EPS.

It is hoped that the clearly defined privileges of Individual Members and the much-reduced fee will attract more Individual Members to the EPS, so that the loss of income through the lower fee will be compensated by a larger number of Individual Members. It is generally thought that the younger generation believes more strongly in European ideals than the older generation, where certain scepticism against matters European may still prevail. The number of "Individual Ordinary Members" has, in fact, grown over the past few years, in spite of the rather high fee. This lends credence to the expectation that the number of Individual Members will increase with the new conditions.

As mentioned, Council also concluded the long debate about the unit fee, which is the basis for financial contributions to the EPS. In an Annex, the Constitution now contains the provision for a 'stepped unit fee'. This new instrument had to be introduced, because the two large Member Societies of the EPS, i.e., the 'Deutsche Physikalische Gesellschaft' (DPG) and the 'Institute of Physics' (IoP) in the United Kingdom, had mounted highly successful membership drives so that the size of their combined membership grew to nearly 80% of the membership of all the EPS Member Societies. Accordingly, contributions that were strictly proportional to the actual number of their members would have led to an undesirable dominance of financial contributions from these two large Member Societies.

A corollary of the successful membership drives of the DPG and the IoP is that the medium-sized and smaller Member Societies of the EPS should now also try to attract more members—this is the only way to restore a certain balance vis-à-vis the larger societies. The 'World Year of Physics 2005' is a wonderful opportunity to start such efforts.

I am very grateful to the members of Council that they adopted the new unit fee. This will make it possible for the EPS to improve its services, especially in the field of communications. I am sure that under the guidance of the Executive Committee the Secretariats in Mulhouse and Budapest will do this as efficiently and economically as possible. ■

Adopting the Constitution

The text reproduced on pages 88–95 was approved by the EPS Council on 27 March 2004. It will come into effect 40 days after the date of the appearance of Europhysics News, Volume 35 no. 3, unless one eighth of the Ordinary Members request that the decision by Council to amend the Constitution and By-laws be submitted to a ballot of a General Meeting. The members of the Society would then be requested in a ballot by mail to adopt the Constitution and By-laws as amended.

Constitution of the European Physical Society

Based on the version of Geneva, September 26, 1968
Including all amendments until March 1998
and modified as a draft proposal (16 December 2003)

CONTENTS

I. GENERAL RULES

Article1
Name, Duration, Seat, Communication

1. Under the name of "European Physical Society" (hereinafter the SOCIETY), an association has been organised and incorporated; it is governed by the Art. 21 and the following of the Local Civil Code (Alsace/Moselle) and by the present constitution. It is registered at the Tribunal d'Instance, Mulhouse.

2. Its duration shall be perpetual.

3. Its seat is at F-68100 Mulhouse, France.

4. All communications of the SOCIETY to its members may be made through its Official Magazine. The By-laws determine which publication of the SOCIETY is considered as the Official Magazine as well as the details for communication with and information to the members.

5. All communication required to be in writing may be made in paper or electronic form.

Article 2
Object of the Society

1. The object of the SOCIETY is and shall be to contribute to and promote the advancement of physics, in Europe and in neighbouring countries, by all suitable means and in particular:
a) by providing a forum for the discussion of subjects of common interest;
b) by providing means whereby action can be taken on those matters which appear desirable to handle on the international level.

2. In order to fulfil its object, the SOCIETY shall act either directly or through its members or through Divisions and Groups created by its members or through corresponding or affiliated societies or similar bodies.

II. MEMBERSHIP

Article 3
Types of Members - Definition

1. The membership of the SOCIETY shall consist of Member Societies, Individual Members, Honorary Members and Associate Members. All members of the SOCIETY shall have the rights and responsibilities as defined by this Constitution and by the By-laws. The procedure for the admission of members is regulated by the By-laws.

2. Member Societies
International and national physics-related societies organised or existing under the laws of the state of their incorporation or of their seat and which, in the SOCIETY's opinion, make a significant contribution to science in Europe may become Member Societies.

3. Individual Members
The following individuals may become Individual Members of the SOCIETY:
a) individuals who are a member of a Member Society;
b) individuals who are a member of a society which is not a Member Society but has been approved by the SOCIETY as a Collaborating Society;
c) individuals who have shown by their contribution to science, by their professional activity or otherwise to the SOCIETY's satisfaction, that they can further the object of the SOCIETY;
d) students enrolled in physics or physics-related degree courses;
e) teachers of pre-university physics and physics-related subjects.

3.1 The SOCIETY may elect as EPS Fellows Individual Members whose achievements in physics or commitment to the SOCIETY warrants specific recognition.

4. Honorary Members
The SOCIETY may elect individuals who have made an outstanding contribution to the advancement of physics by independent, original research or have rendered significant services towards the progress of physics to Honorary Members of the SOCIETY.

5. Associate Members
The SOCIETY may admit national or international organisations, research institutes, industrial companies, publishers, universities, similar organisations and individual donors as Associate Members.

Article 4
Obligations and Liability

1. Membership of the SOCIETY implies strict adherence to the Constitution, to the By-laws and to any lawful decision made or to be made by the organs or officers of the SOCIETY.

2. Members of the SOCIETY are not personally liable for the debts and liabilities of the SOCIETY.

3. The SOCIETY is only liable to the extent of its assets.

Article 5
Termination of Membership

1. Membership terminates:
a) on withdrawal;
b) on death;
c) on failure to pay membership fees;
d) on expulsion.

2. The procedure for the termination of membership is regulated by this Constitution and by the By-laws.

III. ORGANISATION & STRUCTURE

Article 6
Organs of the Society

1. The organs of the Society are:
a) the General Meeting;
b) the Council;
c) the Executive Committee;
d) the Secretariat;
e) the Auditors.

2. The competence and structure of the organs are defined in the provisions of this Constitution.

Article 7
Other Bodies of the Society

1. The SOCIETY may establish Divisions that normally focus on specific disciplines of physics.

2. The SOCIETY may establish Groups that normally focus on general issues in physics.

3. Individual Members may become members of Divisions or Groups.

4. The competence, rights, privileges and structure of Divisions and Groups are defined by the provisions of this Constitution and the By-laws.

5. Organisational provisions in Divisions and Groups shall be fixed in By-laws of the relevant Division or Group. To the extent where no such provisions are made and adopted by the Division or Group, the provisions of this Constitution are considered as applicable to the internal organisation of a Division or Group. In this case, each member of a Division or Group shall have one vote.

IV. THE GENERAL MEETING

Article 8
Structure of the General Meeting

The General Meeting consists of all Members of the SOCIETY.

Article 9
Competence of the General Meeting

1. The General Meeting is the supreme authority of the SOCIETY.

2. The General Meeting has all such powers as have not been conferred upon the Council or upon another organ under the present Constitution.

3. The General Meeting may be called to take decisions and resolutions in matters relating to modification of the Constitution and By-laws in accordance with Art. 11.

4. The General Meeting has exclusive authority to dissolve, wind-up or merge the SOCIETY.

Article 10
Meetings of the General Meeting

1. General Meetings
a) An Ordinary General Meeting shall be held at least every three years.
b) Extraordinary General Meetings shall be held: (i) on the discretion of the Executive Committee; (ii) if demanded by the Council; (iii) at the request of at least 20 % of the Individual Members by written notice served on the Secretary General and containing the precise items to be discussed; (iv) if requested by at least 12.5% of Members in accordance with the provisions of this Constitution for amendments to the Constitution proposed by Council.

2. Call for a Meeting
a) General Meetings shall be called by the Secretary General.
b) General Meetings also may be called by the Executive Committee if the Secretary General fails to send the call immediately after the request by the Executive Committee.
c) Summoning of a General Meeting shall be effected in writing to each member or by publishing in the Official Magazine of the SOCIETY stating the place, date, time and agenda of the meeting. All supporting information shall be attached, especially reports of the Executive Committee or Secretary General, annual accounts or draft resolutions. The Secretary General must submit the proposals of the Executive Committee.
d) Members shall receive six months' notice of the date, venue and preliminary agenda for General Meetings. The final agenda for such General Meeting and all supporting information shall be communicated with three months' notice.

3. Place of the Meeting
a) The Executive Committee shall determine the venue for General Meetings.

4. Attendance and representation
a) Individual Members and Honorary Members shall attend in person. Member Societies and Associate Members shall be represented by the person named in writing from time to time to the SOCIETY as its representative.
b) At the opening of a General Meeting a register of attendance shall be completed.
c) Members present or represented are mentioned in this Constitution jointly as "represented".

5. Chair
The meeting is chaired by the President of the SOCIETY, in his/her absence by another member of the Executive Committee. In the event that the President has not named the chairman in his/her absence, the Executive Committee shall appoint the chairman from amongst its members. The chairman of the meeting shall appoint the secretary for the meeting.

6. Quorum and formal requirements
a) The General Meeting has a quorum to pass resolutions if at least 50 Members are represented. In the event of less than 50 Members being represented, another General Meeting with the same agenda shall be convened immediately and be held within three months after the second call. This new General Meeting will have a quorum, irrespective of the number of Members represented.

7. Voting
a) Voting in general shall follow the rules set out below under Art. 11.
b) Votes in a General Meeting shall be taken by show of hands unless a secret ballot vote is requested by simple majority. All votes concerning the election of persons shall be by secret ballot unless a vote by a show of hands is requested by unanimous decision of the represented Members.

8. Records
a) The course of the General Meeting shall be recorded in minutes, stating the place and date of the meeting, attendees, subjects of the meeting, the nature of the discussion and the resolutions. The minutes shall be signed by the chairman of the meeting and the secretary and be filed together with the register of attendance and powers in the General Meetings Register of the SOCIETY. Copies and extracts shall be certified by the Secretary General. Each Member shall receive a copy of the minutes.
b) The minutes can be contested only in accordance with the rules of the Constitution for the contest of a resolution as set out below under Art. 11.

Article 11
Resolutions of the General Meeting

1. Decision making process and resolutions
a) A decision of the General Meeting shall be made as a resolution of the members.
b) As a matter of principle resolutions shall be taken during a General Meeting.
c) Resolutions may also be adopted by proceedings in writing if no statutory provisions require a specific form.
The quorum for resolutions in writing requires at least 20% of the Members entitled to vote in the General Meeting returning valid ballot papers.
Notwithstanding the above, any resolution brought by Members according to Art. 16 requires a vote in which at least 50% of the members participate.
Any decision about the dissolution of the SOCIETY is not allowed in proceedings in writing but requires attendance at a General Meeting.
d) The term "General Meeting" used in the Constitution or in the By-laws refers equally to a meeting of members or to a consultation or voting in writing.

2. Votes and Majority Requirements
a) Each Member present shall have one vote.
b) Decisions to dissolve, wind-up or merge the Society require a 2/3 majority.
c) Resolutions relating to changes to the Constitution require a 2/3 majority, except for modifications to the membership fees, which follow the rules set out in Art. 15.
d) All other resolutions require a simple majority.

3. Contesting of Resolutions or Minutes
Resolutions or minutes can be contested by a Member within a period of one month after receipt of minutes in writing. If no contestation is received within this period, resolutions or minutes shall be deemed to be accepted.

V. THE COUNCIL

Article 12
Structure of the Council

1. The Council shall be composed of delegates of the members as follows:

	Type of member or body	Delegates
a)	Member Societies	1 (one) per MemberSociety
b)	Individual Members	5 (five) in total
c)	Divisions and Groups	1 (one) per Division or Group
d)	Associate Members	5 (five) in total

2. Normally the nomination of a delegate shall be made for a term of four years.

3. A former delegate who has served for a total period of four years normally shall not serve again before three years after the end of his/her term as delegate.

4. In case a delegate is unable to execute his/her office for an interim period he/she shall be represented by a substitute to be nominated by the relevant member or body. If the relevant member or body deems necessary, it is free to replace its delegate.

5. The Council shall take office in accordance with the rules set forth in the By-laws.

6. The proceedings for the nomination of the delegates of the different types of members and bodies shall be defined in the By-laws.

7. Members of the Executive Committee cannot be members of the Council except that the President of the Executive Committee shall be the Chairman of meetings of Council, and shall have a casting vote in accordance with Art. 15, para. 2e).

Article 13
Competence of the Council

1. The Council has all such powers as are generally exercised by the General Meeting. In particular, it has the delegated powers to:

a) Adopt and Modify the Constitution and By-laws;
b) Adopt, Modify and Annul By-laws for Divisions and Groups;
c) Elect members to the Executive Committee;
d) Appoint the auditors;
e) Accept new Members and elect EPS Fellows and Honorary Members; Individual Members category 3(a) and 3(b) shall be accepted upon nomination by the corresponding Member Society or Collaborating Society;
f) Accept Collaborating Societies;
g) Expel Members;
h) Determine the annual Member contributions;
i) Accept reports of the Executive Committee;
j) Approve the annual accounts;
k) Accept gifts to the SOCIETY;
l) Establish or adopt Divisions and Groups.

Article 14
Meetings of the Council

1. The Council shall meet not less than once a year.

2. A Meeting of the Council shall be held upon the request of 20% of its delegates or upon request of the Executive Committee.

3. In a meeting a quorum of the Council shall be the first whole number equal to or greater than 50% of the total number of Delegates in the Council.

4. A member may be represented by another member. A member may not represent more than two other members. The power of representation has to be submitted to the General Secretary in writing.

5. Additional provisions on the structure and the organisation of the Council may also be defined in By-laws.

Article 15
Resolutions of the Council

1. Decision making process and resolutions
a) A decision of the Council shall be made as a resolution of the Delegates.
b) As a matter of principle resolutions of the Council shall be taken during a meeting.
c) Resolutions of the Council may also be adopted by proceedings in writing if no statutory provisions require another specific form. No decision concerning an amendment of the Constitution may be made by the Council in writing.
d) The quorum for resolutions in writing requires at least 75% of the Delegates to return valid ballot papers; the number of votes allocated to those members is irrelevant for purposes of determining the quorum.

2. General Votes
For all matters other than determining membership fees, Delegates have votes as follows:

Delegates		Votes per Delegate
a) Delegates of Member Societies corresponding to a total membership of		
	1 – 1 000	1
	1 001 – 2 000	2
	2 001 – 5 000	3
	5 001 – 10 000	4
	10 001 – 20 000	5
	20 001 – 30 000	6
	30 001 – 40 000	7
	Greater than 40 000	8
b) Delegates of Individual Members		2
c) Delegates of Divisions or Groups in total corresponding to a total membership of (Members in the relevant Division or Group)		
	50 – 200	1
	201 – 400	2
	401 – 750	3
	Greater than 750	4
d) Delegates of Associate Members		2

e) The President of the Society shall have a casting vote in case of a tie.

3. Votes in Decisions on financial contributions of members
a) In decisions on membership fees for Individual Members and Member Societies, the Delegates of these members have votes equal to the total units assessed according to the By-laws. The votes attributed to Individual Members in this paragraph will be distributed equally among the Individual Member Delegates. Delegates of Divisions and Groups and Delegates of Associate Members have no vote in decisions on fees of Individual Members and Member Societies.
b) In decisions on fees of Associate Members the voting rules as under Art. 15, para. 4. shall apply.

4. Majority Requirements
a) All decisions of the Council require simple majority unless specifically stated in the Constitution to be otherwise.
b) Resolutions on the amendment of the Constitution or the By-laws require a qualified majority of at least 2/3 of the votes cast in accordance with Art. 15, para. 2.
c) Resolutions on membership fees for Individual Members and Member Societies require a qualified majority of at least 3/4 of the votes cast in accordance with Art. 15, para. 3a).

Article 16
Special Proceedings on Constitution

1. Any proposal of amendment of the Constitution shall be sent to all members of the SOCIETY through the Secretary General, at least three months before the meeting of the Council, which shall decide upon such a proposal.

2. The Secretary General shall communicate such decision without delay by mail to all members of the SOCIETY or in the Official Magazine or by such other methods of communication satisfying the principle of wide dissemination as the Council may decide.

3. If within 40 days of such communication the Executive Committee or 15% of the existing Members of the SOCIETY request the relevant decision be submitted to a decision of the General Meeting the Secretary General must organise such a consultation.

4. The ballot in this case of the General Meeting shall be made in writing.

VI. THE EXECUTIVE COMMITTEE

Article 17
Structure of the Executive Committee

1. The Executive Committee shall be elected by the Council, normally from the Council's own members; it shall consist of eleven members:

- a President who shall also be the President of the SOCIETY and the Chairman of the Council;
- a Vice-President, or President-elect;
- a SOCIETY Secretary;
- a SOCIETY Vice-Secretary;
- a Treasurer;
- a Vice-Treasurer;
- five other members.

2. The President shall be in office for a term of two years. He/she shall serve as President-elect for one year prior to taking up the office of President. He/she may also serve for one further year as Vice-President following completion of the term as President. No person may serve more than one term as President.

3. Members of the Executive Committee shall be elected for a term of two years, for a maximum of two terms.

4. Any break in continuity of service in the Executive Committee shall be for a minimum period of four years. This provision does not apply to any member of the Executive Committee nominated as President-elect.

5. Members of the Executive Committee shall take part, ex officio, in the meeting of the Council. They shall have no voting right (except the President who shall have a casting vote in accordance with Art. 15 para. 3.)

Article 18
Competence of the Executive Committee

1. The Executive Committee governs and represents the SOCIETY and shall have general charge of all matters of interest to the SOCIETY.
2. The Executive Committee is empowered to:
a) fulfil the object of the SOCIETY as it is defined in Art. 2;
b) administer the assets and property of the SOCIETY;
c) summon the meetings of the Council and of the General Meeting;
d) organise ballots and consultations as necessary;
e) appoint committees entrusted with special tasks within the general framework of the SOCIETY;
f) sponsor and supervise divisions and groups organised within the SOCIETY by its members in accordance with the By-laws;
g) appoint delegates or representatives of the SOCIETY to scientific Conferences or meetings;
h) carry out decisions of the Council and of the General Meeting;
i) present to the Council or to the General Meeting as necessary annual and other reports and a financial report together with the auditor's report;
j) appoint the Secretary General;
k) negotiate terms and conditions with physics related societies for the purpose of conferring Collaborating Society status;
l) fulfil any other tasks which may be delegated to it by the General Meeting.

Article 19
Representation of the SOCIETY

1. The SOCIETY is bound by the signature of its President or, should the President be prevented from signing, of the Vice-President or President-elect together with the signature of another member of the Executive Committee.

2. Should the President of the Society be unable to fulfil his/her obligations as President, or should the SOCIETY find itself without a President, the Executive Committee shall have the right to elect an Acting president from among its members who shall remain in office until the next Council meeting.

Article 20
Organisation of the Executive Committee

The details of the organisation of the Executive Committee are set forth in the By-laws.

VII. SECRETARIAT

Article 21
Administration of the SOCIETY

1. The Secretariat is the administrative body of the SOCIETY.

2. The Secretariat is directed by the Secretary General who shall be responsible for the administrative matters of the SOCIETY. The Secretary General establishes the minutes containing the deliberations and decisions of the General Meeting, the Council and the Executive Committee.

3. The details of the organisation of the Secretariat are set forth in the By-laws.

Article 22
Appointment and Responsibility

1. The Council appoints from time to time a firm of statutory auditors, who shall report on the accounts of the SOCIETY. The Council may also appoint at its discretion two individuals from among its members to act as auditors. These auditors may at all times require that the books and all relevant documents or reports be presented to them and they may examine the cash and financial situation.

2. The statutory auditors may be re-elected.

IX. RESOURCES

Article 23
Resources, Funds, Bodies

1. The resources of the SOCIETY consist of:
a) dues paid by members;
b) possible gifts, bequests and legacies;
c) subsidies or grants which may be awarded to it by public or private bodies;
d) any other resources which may derive from its own activities.

2. In order to fulfil its purpose and to secure its functioning, the SOCIETY may at all times constitute or organise separate or independent funds or bodies and give them an appropriate legal structure.

3. The details of the annual dues and the units are set forth in the By-laws.

Article 24
Financial Year

The financial period shall be the calendar year.

X. WINDING-UP OF THE SOCIETY

Article 25
Procedure and Assets

1. The winding-up or merger of the SOCIETY may be decided only by an extraordinary General Meeting, formally summoned for this special occasion.

2. In the event of the SOCIETY being wound up, the assets remaining after discharge of all debts shall be transferred to a body or bodies having aims similar to those of the SOCIETY.

By-laws of the European Physical Society

Based on the versions of Vienna, 14 July 1969 (initial version)
Leiden, 28 March 1998 (revised version)
and modified as a draft proposal (16 December 2003)

I. COMMUNICATIONS

RULE 1

1. The Official Magazine of the SOCIETY is "Europhysics News".

2. All communications to the membership defined as "in writing" in the Constitution and By-laws may be replaced by publication in a special section of Europhysics News.

3. The special section in Europhysics News is published under the responsibility of the Executive Committee.

4. The Secretariat shall distribute Europhysics News individually to the Individual Members, Honorary Members and Associate Members.

5. Member Societies shall receive and distribute Europhysics News. Each Member Society will receive one copy of Europhysics News per Effective Member and per student. If for technical reasons they cannot distribute Europhysics News, the Secretariat of the SOCIETY will provide distribution service upon payment. Member Societies with a significant national bulletin distributed at least 10 times a year which do not wish to receive Europhysics News shall publish the special section on news of the SOCIETY as provided by the Secretariat in their own membership journal.

II. MEMBERSHIP

RULE 2

1. Individuals applying for membership shall do so on the standard application form, which shall be signed by two Individual Members, or by two members of the governing body of the relevant Member Society or the relevant Collaborating Society.

2. Teachers and students applying for Individual Membership, who are neither member of a Member Society nor of a Collaborating Society and do not have access to Individual Members are required to submit a statement from their educational institution attesting to their quality as a teacher or student as the case may be.

3. Individual Members shall have the following privileges:
- The right to vote at General Meetings;
- The right to elect Individual Member Council delegates;
- The right to hold office in the Executive Committee;
- The right to hold office in Divisions and Groups;
- Europhysics News sent directly to their specified address;
- Reduced registration fees at conferences organised by the SOCIETY and its Divisions and Groups;
- Benefit from agreements with Collaborating Societies;
- Inclusion in the SOCIETY's directory.

RULE 3

1. Societies eligible for membership as Member Societies shall accompany their application with copies of their constitution and By-laws and of such additional documents as the Council may require.

2. Member Societies shall have the following privileges:
- The right to vote at General Meetings;
- The right to be represented and vote at Council;
- The right to receive a number of copies of Europhysics News as described in Rule 1.5;
- Members of Member Societies may participate in Divisional and Group activities of the SOCIETY.

3. Member Societies shall have the following responsibilities:
- Disseminate information received from the SOCIETY of interest to the European Physics Community to their members using normal communication channels;
- Advertise on membership forms that Individual Membership of the SOCIETY is possible;
- Collect and pay to the SOCIETY fees received from its members for membership in the SOCIETY according to Art. 3.3(a) on an annual basis;
- Transmit in a predefined format contact coordinates for members who have become members of the SOCIETY according to Art. 3.3a).

RULE 4

Council shall elect Fellows of the SOCIETY. Fellows of the SOCIETY shall have the same rights and duties as Individual members. The total number of Fellows at any one time should not exceed 5% of the total of Individual Members of the SOCIETY.

RULE 5

Council shall elect Honorary Members. Honorary Members shall have the same rights as Individual Members of the SOCIETY. The total number of Honorary Members at any one time shall not exceed thirty.

RULE 6

Council shall admit Associate Members. Associate Members shall have the right to send employees to scientific meetings and take out one subscription to the publications of the SOCIETY at a reduced rate. Associate Members shall be represented in the Council according to Article 15.2d) of the Constitution.

RULE 7

All new Members who are elected or admitted shall be informed by the Secretariat of their election or admission and shall receive from the Secretariat copies of the relevant documents.

RULE 8

No election or admission of Members shall become effective until the relevant fees have been paid.

RULE 9

In the event of non-payment of the fee, membership will terminate six months after the end of the year for which payment has not been received.

RULE 10

Expulsion of a member shall be by decision of the Council. The Executive Committee shall present to the Council a full report on the reasons for the proposed expulsion before the matter is considered by the Council.

RULE 11

All matters of doubt or difficulty relating to membership shall be decided by the Council.

III. ORGANISATION

A. The Council

RULE 12

The Council Delegates shall normally take office on 1 April of each year.

RULE 13

1. Member Societies and Divisions and Groups shall have freedom to nominate their representative on the Council, subject only to the Constitution and these By-laws.

2. Representatives on the Council of the Individual Members shall be elected by ballot from a list, provided by the Secretariat, of all nominations signed by at least three Individual Members and received by the Secretariat before 1 January of the year of the election. Only Individual Members shall participate in the vote. The ballot returns with candidates are arranged in order of decreasing number of votes obtained. This then provides the names of that category of Council members, in the number required by Art. 12.1b) of the Constitution. The names for

those who may be needed later on to fill casual vacancies for an un-expired term – always counting down the list, in the direction of decreasing strength of ballot votes received – are also provided.

3. Representatives on the Council of Associate Members shall be elected by ballot from a list, provided by the Secretariat, of all nominations of individual candidates received from the Associate Members before 1 January of the year of the election. Only Associate Members shall participate in the vote. The ballot returns with candidates are arranged in order of decreasing number of votes obtained. This then provides the names of that category of Council members, in the number required by Art. 12.1d) of the Constitution. The names for those who may be needed later on to fill casual vacancies for an unexpired term – always counting down the list, in the direction of decreasing strength of ballot votes received – are also provided.

B. The Executive Committee

RULE 14

1. The Executive Committee shall establish a list of candidates for the replacement of outgoing members of the Executive Committee as positions become vacant. For establishing this list the Executive Committee may consult all relevant bodies of the SOCIETY, i.e. Members Societies, Divisions, Groups, Associate Members and Individual Members (e.g. via their delegates in Council).

2. This list of candidates, which normally should exceed the number of vacancies, shall be presented to the Council accompanied by a CV and an election campaign statement. Candidates who have been designated to stand for a position, i.e. Vice-President (but not the President-elect in those years he/she has to be elected), SOCIETY Secretary and SOCIETY Treasurer shall be indicated. Candidates for President-elect shall be presented on a separate list.

3. Staff members or professionals that are paid employees of another learned Society or similar Organization with potential conflict of interest with EPS cannot stand as a candidate for the Executive Committee.

4. Nothing above precludes nominations from Council Members at the Council Meeting. Such nominations require five supporting Council Member signatures and must be received by the Secretariat of the Council Meeting prior to 18:00 h on the first day of Council.

5. The sequence of voting in the Council shall be as follows:

a) in years where a President-elect is to be elected:
   1st ballot for the President
   2nd ballot for the President-elect
   3rd ballot for the other vacant positions

b) in years where no President-elect is to be elected:
   1st ballot for the President
   2nd ballot for the other vacant positions

6. A candidate for President-elect must receive the absolute majority of votes cast, disregarding abstentions. In the event that there are more than 2 candidates for President-elect and no candidate receives an absolute majority, then the name of the person receiving the lowest number of votes is removed from the ballot and additional ballots shall be organised as necessary.

7. Members of the Executive Committee other than the President and President-elect are elected from a ballot list prepared by the Secretariat. The ballot returns with candidates are arranged in order of decreasing number of votes obtained. This then provides the names of the required number of Members of the Executive Committee to fill the open positions. In case of a tie among candidates, which would lead to one or more supernumerary Members of the Executive Committee, additional ballots for all remaining candidates will be organised as necessary.

RULE 15

All decisions of the Executive Committee shall be by simple majority of those present and voting. In case the vote is a tie, the President shall decide. A quorum of the Executive Committee shall be six.

RULE 16

The Executive Committee shall meet not less than twice a year.

C. The Secretariat

RULE 17

The Secretary General shall be responsible to the SOCIETY Secretary for general administrative matters and to the Treasurer of the SOCIETY for financial matters. The Secretary General shall take part ex-officio, but without voting power, in the meetings of the Council and the Executive Committee.

RULE 18

Besides the Secretary General, the Secretariat shall have employees appointed by the Secretary General as authorised by the Executive Committee.

RULE 19

The Executive Committee may establish supplementary secretariats, subject to approval by the Council.

IV. DIVISIONS AND GROUPS

RULE 20

1. The formation of a Division or a Group may be approved by the Council on receipt of a formal request, including a programme of activities by not less than five Members of the SOCIETY.

2. In order for a Division or Group to have voting rights at Council, it must fulfil the following criteria:
- A minimum of 50 identified members;
- A regularly constituted Board;
- An annual report made to Council, including a programme of activities.

3. In the event of a Division or Group failing to meet the above criteria, Council, upon recommendation of the Executive Committee, may decide to abolish the Division or Group concerned.

RULE 21

Rules and regulations governing Divisions and Groups shall be approved by the Council.

V. MEETINGS, VOTING RULES

RULE 22

The venue of meetings shall be so chosen that there is no restriction on the attendance of members from anywhere.

RULE 23

1. Total units assessed as used in Art. 15.3a) for Individual Members is equal to the total fees paid by Individual Members divided by the unit as defined in Rule 25.

2. Total units assessed as used in Art. 15.3a) for a given Member Society is equal to the membership fee paid by the Member Society in question divided by the unit as defined in Rule 25.

RULE 24

As a general rule abstentions are considered as non-votes.

V. MEMBERSHIP FEES

RULE 25

The annual membership fees for Member Societies and Individual Members shall be expressed in Euro, fixed by the Council for any one year, and calculated in terms of units. The annual membership fees are contained in the annex to the By-laws.

RULE 26

1. When calculating membership fees, the total membership of Member Societies shall be taken into account. For Member Societies each full member shall count as one unit. However, Council may, when establishing fees from Member Societies, take into account any reduced fees applied by them for special membership categories (teachers, students, etc.) and allow amounts less than one unit to be ascribed to such categories of member. The total number of units so calculated for the Member Society is the Effective Number of Units and shall determine the votes for the purposes of Art. 15.3a and the annual dues and units in Art. 23.3 of the Constitution.

2. The membership fee per unit paid by the Member Society may be modulated in steps corresponding to increments in the Effective Number of Units in Member Societies.

RULE 27

1. Council shall set the fees for Individual Members with differential fees according to the membership categories in Constitution Art. 3.3a), 3.3b), 3.3c), 3.3d) and 3.3e). The number of units to be paid by Individual Members are set out in Annex 1. The fee to be paid per unit by Individual Members shall be equal to the average fee per unit paid by the Member Societies collectively.

2. In category 3.3a), Student Members, Teachers, Individual Members below 30 years of age and Individual Members certifying their retirement from professional activities shall pay the number of units in annex 1.

3. For categories 3.3b) and 3.3c), Student members, Teachers, Individual Members below 30 years of age and Individual Members certifying their retirement from professional activities shall pay the number of units in annex 1.

4. In categories 3.3d) and 3.3e), students and teachers shall pay the number of units in annex 1.

5. In cases where the amount to be paid in category 3.3a) would exceed 30% of the fee paid to the National Society for membership therein, special arrangements can be made.

RULE 28

Any proposal by the Executive Committee to increase the membership fee per unit for Member Societies and Individual Members shall be submitted in writing to Individual Members and Member Societies at least three months before the Council is to meet to decide the matter.

RULE 29

Associate Members shall pay annual fees to be set by the Council.

RULE 30

Honorary Members shall not be required to pay any fees.

RULE 31

Membership of a Division or Group shall not involve any additional fee to the SOCIETY from Individual Members.

RULE 32

The Executive Committee shall have power to arrange for payment of fees in local currency where problems of restricted convertibility exist, or to set reduced fees for Members.

RULE 33

Membership fees shall be due on 1 January of every financial year, Members adopted by the SOCIETY during a financial year shall pay fees for the current year proportionally.

Annex 1
Calculation of Membership Fees

As approved by Council 27 March 2004 and applicable as of 1 January 2005 through 31 December 2006

§1 Introduction

For Member Societies the annual membership fee is calculated in a step model. The step model is based on an effective number of members $N_{eff,s}$ for each Member Society *s*. The effective number of members ('units') $N_{eff,s}$ takes into account that the Member Society s may charge for the members N_{si} in a certain category *i* a fraction C_{si} of the full national membership fee.

The fees per effective member that apply in the step model are given in TABLE 1. From the effective number of members, for the first 1000 the fee is 11 €/effective member, for those between 1001 and 2000 it is 10,5 €/effective member, for those between 2001 and 5000 it is 10 €/effective member and for those above 5000 the fee is 8,5 €/effective member.

The membership fee F_s for each society is calculated as in TABLE 2.

The sum of the fees F_s over all societies gives the total membership fee F_{tot} of the Member Societies. The sum of the effective members $N_{eff,s}$ over all societies gives the total effective number of members N_{eff}. Dividing the total membership fee F_{tot} by N_{eff} and rounding this number to the first decimal gives the average unit fee M_{av}. This number is the basis for the calculation of the membership fee for the individual members as given in TABLE 3.

Summary of the Symbols

N_{si}	number of members in the category *i* of the society *s*
C_{si}	fraction of the full fee charged to the member category *i* of the society *s*
$N_{eff,s}$	effective number of members of society *s*
N_{eff}	total effective number of members
F_s	membership fee of society *s*
F_{tot}	membership fee of all societies
M_{av}	average unit fee

§2 Effective number of members of society *s*

The effective number of members of society *s* is calculated according to the following formula with the summation *i* running over the various member categories of society *s*:

$$N_{eff,s} = \sum_i C_{si} N_{si}$$

The total effective number of members is:

$$N_{eff} = \sum_s N_{eff,s}$$

§3 Step model

$N_{eff,s}$	€/effective member
1 - 1000	11
1001 - 2000	10,5
2001 - 5000	10
5001 - ...	8,5

TABLE 1: $N_{eff,s}$ and fee steps in the step model.

From the effective number of members, for the first 1000 the fee is 11 €/effective member, for those between 1001 and 2000 it is 10,5 €/effective member, for those between 2001 and 5000 it is 10 €/effective member and for those above 5000 the fee is 8,5 €/effective member.

§4 Calculation of the membership fee for society *s*

$N_{eff,s}$	Fee for Member Society *s*
1-1000	$F_s=11\times N_{eff,s}$
1001-2000	$F_s=11\times1000+10{,}5\times(N_{eff,s}-1000)$
2001-5000	$F_s=11\times1000+10{,}5\times1000+10\times(N_{eff,s}-2000)$
5001-...	$F_s=11\times1000+10{,}5\times1000+10\times3000+8{,}5\times(N_{eff,s}-5000)$

TABLE 2: Formulas for the calculation of the membership fee of Member Society *s*

For a Member Society with an effective number of members as given in the left column, the membership fee is calculated using the expression in the corresponding right column.

§5 Total membership fee and average unit fee

The total member fee from all Member Societies is given by:

$$F_{tot} = \sum_s F_s$$

The average unit fee (with respect to the effective number of members) is given by rounded to the first decimal digit:

$$M_{av} = \frac{F_{tot}}{N_{eff}} \Big| \text{rounded to the first decimal digit}$$

Rounded off, the average unit fee is:

$$M_{av} = 9{,}8\ €$$

§6 Membership fee of Individual Members

The membership fee for members according to Art.3 a) ... e) is calculated as the average unit fee multiplied by the number of units given in TABLE 3:

Category	Member	Units

3.3 a)	Full	2
	Below 30 years of age	1,5
	Retired	1,5
	Teachers/Students	1,5
3.3 b)	Full	4
	Below 30 years of age	2
	Retired	2
	Teachers/Students	1,5
3.3 c)	Full	6
	Below 30 years of age	3
	Retired	3
3.3 d)	Student	1,5
3.3 e)	Teacher	1,5

TABLE 3: Units for the various Individual Member categories

Annex 1 Calculation of Membership Fees

As approved by Council 27 March 2004 and applicable as of 1 January 2007

§1 Introduction

For Member Societies the annual membership fee is calculated in a step model. The step model is based on an effective number of members $N_{eff,s}$ for each Member Society s. The effective number of members ('units') $N_{eff,s}$ takes into account that the Member Society s may charge for the members N_{si} in a certain category i a fraction C_{si} of the full national membership fee.

The fees per effective member that apply in the step model are given in TABLE 1. From the effective number of members, for the first 1000 the fee is 11,5 €/effective member, for those between 1001 and 2000 it is 11,0 €/effective member, for those between 2001 and 5000 it is 10,5 €/effective member and for those above 5000 the fee is 8,4 €/effective member.

The membership fee F_s for each society is calculated as in TABLE 2.

The sum of the fees F_s over all societies gives the total membership fee F_{tot} of the Member Societies. The sum of the effective members $N_{eff,s}$ over all societies gives the total effective number of members N_{eff}. Dividing the total membership fee Ftot by N_{eff} and rounding this number to the first decimal gives the average unit fee M_{av}. This number is the basis for the calculation of the membership fee for the individual members as given in TABLE 3.

Summary of the Symbols

N_{si}	number of members in the category i of the society s
C_{si}	fraction of the full fee charged to the member category i of the society s
$N_{eff,s}$	effective number of members of society s
N_{eff}	total effective number of members
F_s	membership fee of society s
F_{tot}	membership fee of all societies
M_{av}	average unit fee

§2 Effective number of members of society s

The effective number of members of society s is calculated according to the following formula with the summation i running over the various member categories of society s:

$$N_{eff,s} = \sum_i C_{si}\, N_{si}$$

The total effective number of members is:

$$N_{eff} = \sum_s N_{eff,s}$$

§3 Step model

$N_{eff,s}$	€/effective member
1 - 1000	11,5
1001 - 2000	11
2001 - 5000	10,5
5001 - ...	8,4

TABLE 1: $N_{eff,s}$ and fee steps in the step model.

From the effective number of members, for the first 1000 the fee is 11,5 €/effective member, for those between 1001 and 2000 it is 11,0 €/effective member, for those between 2001 and 5000 it is 10,5 €/effective member and for those above 5000 the fee is 8,4 €/effective member.

§4 Calculation of the membership fee for society s

$N_{eff,s}$	Fee for Member Society s
1-1000	$F_s=11{,}5\times N_{eff,s}$
1001-2000	$F_s=11{,}5\times 1000+11\times(N_{eff,s}-1000)$
2001-5000	$F_s=11{,}5\times 1000+11\times 1000+10{,}5\times(N_{eff,s}-2000)$
5001-...	$F_s=11{,}5\times 1000+11\times 1000+10{,}5\times 3000+8{,}4\times(N_{eff,s}-5000)$

TABLE 2: Formulas for the calculation of the membership fee of Member Society *s*

For a Member Society with an effective number of members as given in the left column, the membership fee is calculated using the expression in the corresponding right column.

§5 Total membership fee and average unit fee

The total member fee from all Member Societies is given by:

$$F_{tot} = \sum_s F_s$$

The average unit fee (with respect to the effective number of members) is given by rounded to the first decimal digit:

$$M_{av} = \frac{F_{tot}}{N_{eff}} \quad \text{| rounded to the first decimal digit}$$

Rounded off, the average unit fee is:

$$M_{av} = 10{,}0\,€$$

§6 Membership fee of Individual Members

The membership fee for members according to Art.3 a) ... e) is calculated as the average unit fee multiplied by the number of units given in TABLE 3:

Category	Member	Units
3.3 a)	Full	2
	Below 30 years of age	1,5
	Retired	1,5
	Teachers/Students	1,5
3.3 b)	Full	4
	Below 30 years of age	2
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	Teachers/Students	1,5
3.3 c)	Full	6
	Below 30 years of age	3
	Retired	3
3.3 d)	Student	1,5
3.3 e)	Teacher	1,5

TABLE 3: Units for the various Individual Member categories

World Year of Physics 2005: the countdown has started!

C. Rossel

The Second Preparatory Conference for the World Year of Physics 'WYP2005' took place in Montreal on March 20-21, 2004 immediately preceding the March meeting of the American Physical Society (APS). Thanks to the excellent organization by the APS the conference was a great success.

About 70 participants from 30 nations met at the Fairmont Queen Elizabeth Hotel in a friendly and productive atmosphere. After the welcome address of Martin Huber, President of the EPS, and a talk by Béla Joós, President of the Canadian Association of Physicists, the first round of discussions started. The different national and international projects were presented, outlining the great progress accomplished since the first Preparatory Conference that was held in Graz in July 2003. Particularly striking was the variety and originality of the proposed projects including a set of commemorative WYP postage stamps, a range of educational and promotional web sites, poster contests, exhibitions, conferences and science festivals.

Raising public awareness, communicating the beauty and relevance of physics to the public was addressed in the workshop called 'Physics on the Road and Publicizing your WYP2005 Event.' Several examples of outreach projects with live presentations, static displays or other classroom activities were presented in an enthusiastic, yet highly professional manner. The American Association of Physics Teachers (AAPT) unveiled its programme for the WYP2005 and demonstrated the strength of a large society in planning nationwide activities. The state of preparation in countries such as Brazil, China, France, India, Japan, Poland and the USA, just to mention a few, was very impressive.

Several exciting international projects were presented and generated active discussions. Among them, "Light around the World" and "Physics Talent Search" were judged to have a high potential impact on the media. Another project that attracted much attention is the project Einstein@home that consists in establishing a distributed computing network of private PCs worldwide to analyze the huge amount of data generated by LIGO, the US Gravitational-wave Observatory.

The search for gravitational waves was also part of an outstanding, educational talk delivered by Clifford Will of Washington University in St Louis, MO. Will raised the question—after 100 years: 'Was Einstein right?' In his lecture he showed how a revolution in astronomy and technology led to a renaissance of general relativity in the sixties and to a systematic program to try to verify its predictions.

▲ **Photo:** A live demonstration for the 'Physics on the road' workshop, in Montreal, Canada.

Finally, with his project "Stories in Physics," Fred Hartline from Argonne National Laboratory, convinced all the participants that collecting and publishing original personal stories about physics or famous physicists could spark the interest of young students.

All details about this 2nd Preparatory Conference can be found on the WYP2005 web site: www.wyp2005.org. A general consensus among the participants was that EPS13, the 13th General Meeting of EPS in Bern (July 11-15, 2005) will be one of the high points—if not the high point—of the WYP2005. Prizes of several international contests will be awarded during special ceremonies at this meeting. M. Ducloy, president of the WYP International Steering Committee announced also the Conference on "Physics for Tomorrow" planned in January 2005 at the Paris Headquarter of UNESCO. This event promises to become the official launch event for the World Year of Physics 2005. ■

▲ **Photo:** EPS President Martin Huber discusses the WYP2005 with Renato Ricci.

Agilent Technologies Europhysics Prize

The 2004 Agilent Technologies Europhysics Prize is awarded to Michel Devoret, Daniel Esteve, J.E. Hans Mooij and Yasunobu Nakamura for the realisation and demonstration of the quantum bit concept based on superconducting circuits.

Computation based on quantum bits, so-called qubits, promises an enormous gain in calculating difficult problems such as the optimization of the route of a travelling salesman or the factorization of large numbers. Whereas classical bits are based on two state systems represented by the numbers 0 and 1 qubits make use of the quantum concept of superposition of states of a two level systems thus representing a continuous manifold of states varying between 0 and 1. Though the concepts of superposition and entanglement underlying quantum computation have been experimentally demonstrated with a few qubits defined in microscopic quantum systems such as trapped ions or nuclear spins within a suitable molecules, practical implementations of a quantum computer require a sufficiently large number of coherent qubit operations, roughly more than at least 10.000. Here the realisation of qubits in solid states circuits is believed to be a most promising approach to scalable quantum computation.

Employing superconducting circuits as macroscopic quantum systems this year's awardees have contributed substantially to the realisation of solid state qubits and have recently demonstrated coherent control of qubits using resonant microwave pulses. The Saclay group lead by Michel Devoret and Daniel Esteve and the Delft group lead by Hans Mooij have envisioned and verified that superconducting circuits can be used for the realization of qubits either dominated by the quantization of charge - the charge qubit- or the quantization of magnetic flux- the flux qubit. In such circuits control of discrete excess charge or flux can be used to define either a qubit 0 or 1. In 1999 an important breakthrough was achieved by Yasunobu Nakamura and his collaborators in Japan with the demonstration that similar to atomic systems one can coherently control such superconducting circuits with radio frequency pulses to create a superposition state and observe coherent oscillations of the superconducting quantum system. With a modified circuit design the Saclay group was able in 2001 to substantially increase the originally short coherence times and the Delft group demonstrated jointly with Yasunobu Nakamura the long coherent manipulation with Rabi and Ramsey oscillations. With the presently achieved control of decoherence solid state qubit circuits that are scalable and allow for the implementation of error correction schemes which are needed for any practical quantum computation appear to be no longer beyond reach.

These breakthrough experiments have not only increased our understanding of precisely defining and controlling quantum states in macroscopic devices but have now established that the implementation and coherent control of qubits in solid state circuits can be achieved and opens the way to create more complex circuits for, at first simple, qubit operations. Though at present it is still a long way to any practical quantum computer the awardees have convincingly demonstrated that the concept of superconducting qubits is a feasible and promising one.■

EPS-IGA 2004 Prize

Following the meeting of the EPS-IGA 2004 Prize Selection Committee chaired by Dr. Steve Myers of CERN on 20 February 2004, the 2004 Accelerator Prizes are awarded as follows.

The prizes will be awarded and the award winners will make oral presentations of their work during the 9th European Particle Accelerator Conference, EPAC'04, on Thursday 8 July 2004 at the Lucerne Congress Centre (KKL), Lucerne, Switzerland.

The Prize for an individual in the early part of his or her career, having made a recent significant, original contribution to the accelerator field, is awarded to Vladimir Shiltsev (FNAL, Batavia) "For many important contributions to accelerator physics which include theory, beam simulations, hardware development, hardware commissioning and beam studies. In particular for his pioneering work on electron-lens beam-beam compensation."

The prize for an individual for outstanding work in the accelerator field is awarded to Igor Meshkov (JINR, Dubna) "For seminal contributions to numerous advances in accelerator science over the past 40 years. In particular for his development and implementation of the techniques which allowed the original brilliant idea of electron cooling to become a hardware reality and an accelerator tool. In addition for his devotion to and promotion of international collaboration in accelerator physics."

Joint Accelerator Conferences Website Collaboration

Further to the above, the EPAC and PAC conference series have decided to acknowledge the work of the JACoW collaboration. John Poole and Christine Petit-Jean-Genaz, CERN will represent the Collaboration and make a brief presentation during the Prize Ceremony during EPAC'04. The acknowledgement is made in the following citation:

From tiny acorns mighty oak trees grow. An idea from Ilan Ben-Zvi in 1996, nurtured by others, has finally spread its branches as the JACoW collaboration reaches maturity in 2004.

The vision of a Joint Accelerator Conferences Website, maintaining a central database of information of all main participants in the accelerator community and holding electronic copies of all the papers published at the conferences under its umbrella, has taken eight years to reach fruition.

Seven conference series are now involved (PAC, EPAC, APAC, CYCLOTRONS, DIPAC, ICALEPCS, LINAC). The Russian PAC, RUPAC, is about to join, as are several other conference series. A recent decision has confirmed funding to complete the electronic scanning of all PAC and EPAC proceedings back to 1967 and 1988 respectively. The papers will be available to all on the central JACoW site (http://www.jacow.org).

At this conference, EPAC'04, the Scientific Programme Management System (SPMS) is being used for the first time. The central database will allow standardised procedures for submission and publication of papers, and will be of immeasurable benefit to those who work so hard behind the scenes to ensure every conference is a success. Delegates will also see improvements, with developments such as the inclusion of facilities for registration, expected to follow.

While many individuals have played a part, none would begrudge recognition to the two people whose foresight and enthusiasm have served to blend so many varied ideas together: John Poole, the Chairman of JACoW, and Christine Petit-Jean-Genaz, the EPAC Conferences Coordinator.

The Organising Committees of the EPAC and PAC conference series would like to acknowledge their achievement and thank them, and all those involved in JACoW, for their efforts to further the dissemination of scientific knowledge throughout the accelerator community.■

EPS IBA Prize

The EPS Europhysics Prize for Applied Nuclear Science and Nuclear methods in Medicine was awarded to Professor Prof. Guy Demortier, for outstanding and innovative research in many and varied fields of applied nuclear physics, namely in new materials, catalysts, biological material, archaeology and nuclear medicine and, most notably, resulting in ways to improve PET-scans.■

2004 Lise Meitner Prize

The 2004 Lise Meitner Prize for Nuclear Science is awarded to Professor Bent Herskind and Professor Peter Twin for their pioneering development of experimental tools, methods of analysis and experimental discoveries concerning rapidly spinning nuclei, in particular the discovery of superdeformed bands in wide regions of the periodic table.■

Errata

In Europhysics News 35/2, page 47, the article "The quest for brilliance: light sources from the third to the fourth generation" should have been accredited solely to M. Altarelli.

Alterelli's correct affiliations are: Sincrotrone Trieste, Area Science Park, 34012 Basovizza-Trieste (Italy) and Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, 34100 Trieste (Italy).■

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ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Assistant / Full Professor in Experimental Condensed Matter Physics

The Physics Department of ETH Zurich has two openings for professorial positions in experimental condensed matter physics. One of the positions is intended to be filled at a senior level, the other at the assistant professor level (tenure track).

The laboratory for solid state physics has active groups in the fields of magnetism, superconductivity, semiconductor nanostructures, and the physics of new materials. For further details, see www.solid.phys.ethz.ch. The department invites applications from outstanding candidates with expertise in any area of modern condensed matter physics. Areas that are of particular interest include (but are not limited to) nanostructured solid state systems, the development and characterization of new materials, the manipulation of quantum systems in a solid state environment, and biologically inspired solid state physics.

The Physics Department of ETH Zurich offers an international and stimulating research environment. The scientific operations are supported by a first class technical infrastructure. The nearby Paul-Scherrer-Institute (www.psi.ch) operates a synchrotron light source and a spallation neutron source, both equipped with advanced instruments. The FIRST lab at ETH Zurich (www.first.ethz.ch) offers a state-of-the-art cleanroom and equipment for nano-fabrication. The successful candidates will be encouraged to use these facilities.

Teaching duties will include conducting physics courses at all levels, including introductory courses for non-specialists. Courses at Master level may be taught in English.

Applications should be submitted, together with a curriculum vitae, a list of publications, a list of research activities, and a research statement **to the President of ETH Zurich, Prof. Dr. O. Kübler, ETH Zentrum, CH-8092 Zurich, no later than August 31, 2004.** ETH Zurich specifically encourages female candidates to apply with a view towards increasing the proportion of female professors.

UNIVERSITAS BERNENSIS

The Faculty of Science of the University of Bern invites applications for a position of

Full Professor of Experimental High Energy Physics and Head of the Laboratory for High Energy Physics

opening March 1, 2006 at the Laboratory of High Energy Physics of the Physics Institute, University of Bern, Switzerland. Current research activities of the Laboratory include work at CERN especially on the ATLAS experiment at LHC, as well as the physics of neutrino oscillations (OPERA) and dark matter (ORPHEUS).

Candidates should have a proven first rate research record in experimental high energy physics. This may include participation in large experiments and the development of novel experimental techniques. She/he should also be prepared to participate actively in the teaching of physics at both the undergraduate and graduate level. As Head of the Laboratory, the successful candidate has overall responsibility for about 30 collaborators and will be a member of the Board of Directors of the Physics Institute.

The University of Bern especially encourages women to apply for this position. Letters of application, including curriculum vitae, a list of publications, copies of the most important publications, and an outline of past and future research (all in English) should be sent before September 15, 2004 to Prof. G. Jaeger, Dean of the Faculty of Science, Sidlerstrasse 5, CH-3012 Bern, Switzerland.

Further information about the Laboratory can be found at http://www.lhep.unibe.ch and enquiries about this position can be made by contacting Prof. W. Benz, Physikalisches Institut, Sidlerstrasse 5, CH-3012 Bern, Switzerland. Tel: +41 31 631-4403, Fax: +41 31 631-4405, e-mail: wbenz@phim.unibe.ch

LIP

Applications are invited for a post-doctoral position at LIP-Lisbon (www.lip.pt). The position is funded by the European Research Training Network 'Physics Reconstruction and Selection at the Large Hadron Collider' (http://cern.ch/sphicas/PRSATLHC/). The main purpose of the proposed network is to study, design and implement the physics event selection of the CMS experiment in the LHC environment.

The position will be given for 2 years with a highly competitive salary determined according to qualification. Qualifications required include a PhD or equivalent in High Energy Physics, and a clear demonstration of the ability to carry out a research program. Knowledge of modern programming techniques, Object-Oriented software and C++ will be an asset.

Applicants must satisfy the EU RTN eligibility criteria (http://www.cordis.lu/improving/networks/faq.htm#q5).

The position will remain open until suitable candidates are found.

Applications, including CV and reference letters, should be sent to:

Laboratory for Instrumentation and Experimental Particle Physics
Research Training Network-PRSATLHC
Av.Elias Garcia, nº 14 –1º , 1000-149 LISBON, PORTUGAL
e-mail: joao.varela@cern.ch