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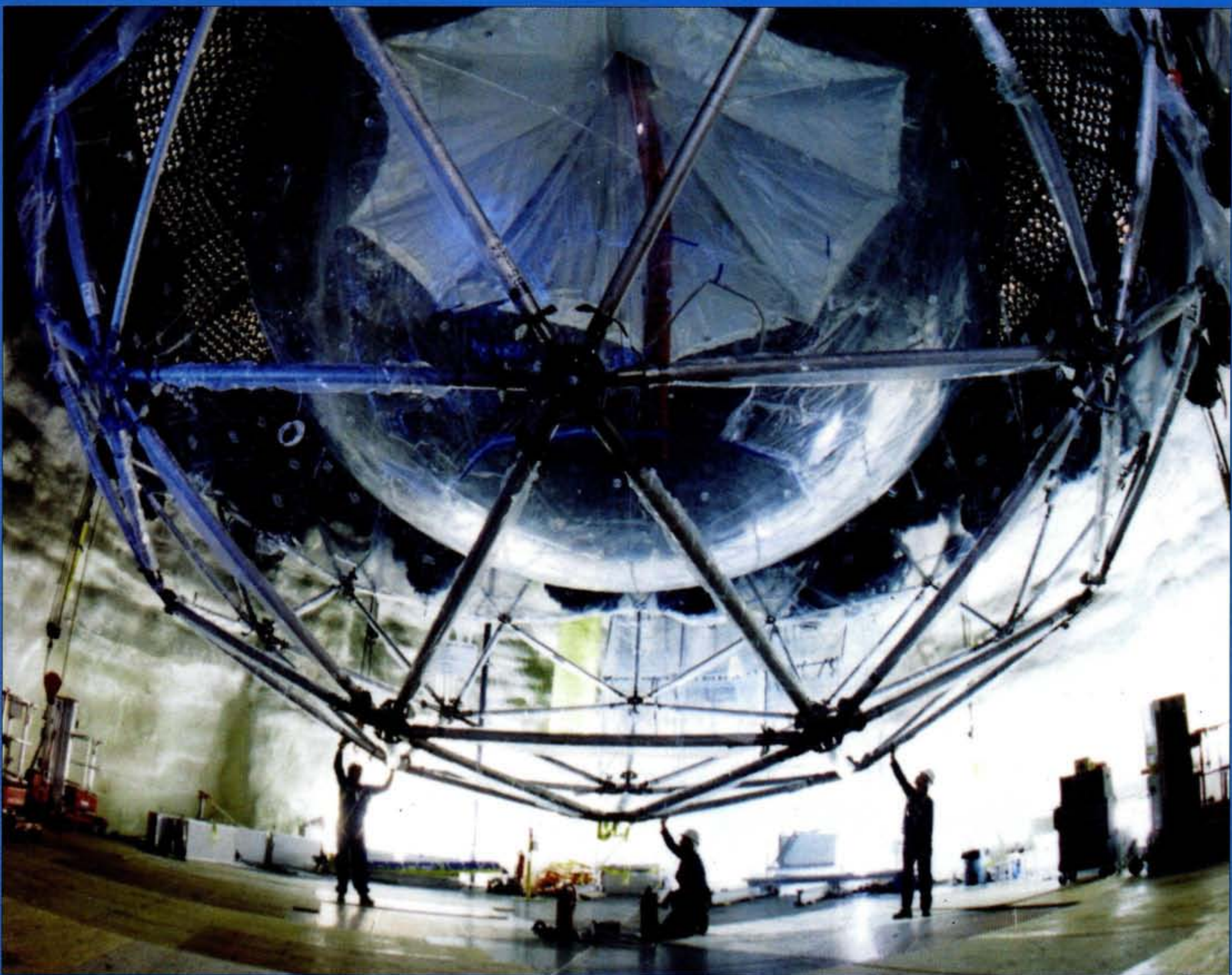

SNO sees solar particles oscillating

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

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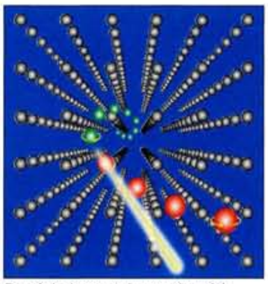

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Cover: The Sudbury Neutrino Detector (SNO) during construction, 2000 m underground in a nickel mine in Ontario, Canada. The detector has produced the first direct evidence for the "oscillation" of electron-type neutrinos from the Sun (see p5).

SOLAR PARTICLES

The Sudbury Neutrino Observatory confirms the oscillation picture

The Sudbury Neutrino Observatory, which started taking data in 1999, has announced its first results on solar neutrinos, which confirm the suspicion that something happens to these particles on their 150 million kilometre journey from the Sun to the Earth.

Experiments have been monitoring solar neutrinos for some 40 years. To see neutrinos at all demands a major effort, so measurements are difficult and reliable results take time to amass. As the work continued, physicists began to suspect that their experiments were not seeing as many solar neutrinos as expected – there was a "solar neutrino problem".

Neutrinos are produced in the nuclear reactions in the Sun's core, which provide the Sun's energy (the radiant light and heat which make life possible is only a by-product of the Sun's nuclear furnace). If physicists think that they understand what happens inside the Sun, they should be able to predict the number of neutrinos which arrive at the Earth. When measurements do not agree with the prediction, there is a dilemma – either we do not understand how the Sun works, or neutrinos are perverse particles that do not behave as expected.

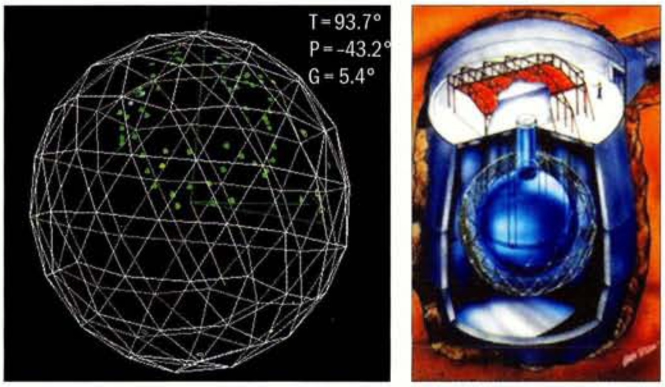
In appraising these two alternatives, it is important to remember that, 100 years ago, physicists could not understand where the Sun got its energy from and why it hadn't yet burned out. Only the advent of nuclear physics in the 1930s showed how nuclear transformations could supply such prodigious and enduring outputs. The neutrino concept was an initially hesitant postscript to this nuclear picture. To understand nuclear beta decay, there had to be a particle that would be very difficult to detect – if it could be detected at all. From the start, neutrinos acquired a reputation for being non conformist.

The new Sudbury results confirm that bizarre neutrino behaviour is the reason for the solar neutrino deficit – the particles are indeed living up to their non conformist reputation.

Neutrinos come in three types – electron, muon and tau – according to their subnuclear parentage. When such distinct neutrino types were first discovered, it was initially believed that each type was immutable – a neutrino born with an electron (as in beta decay or the reactions deep inside the Sun) could continue to show such electron character for ever.

However, the non conformist reputation of these particles led some far-sighted physicists to suspect that perhaps neutrinos were not immutable. Perhaps there was a small chance that a neutrino could change its allegiance in flight. A neutrino that began its journey in electron class could 'oscillate' and upgrade to muon class. Such changed seating arrangements en route could explain an observed deficit of electron-type solar neutrinos.

The Sudbury Neutrino Observatory (SNO) is a vessel containing 1000 tonnes of heavy water, 2000 m underground in an active nickel mine in Ontario, Canada. Particles resulting from neutrino collisions produce flashes of light that are picked up by 9500 photomultiplier tubes. The detector is sensitive to those solar neutrinos produced via the beta decay of boron-8.



Left: when a neutrino from the Sun hits a nucleus in the heavy water of the Sudbury Neutrino Observatory (SNO) detector, a faint cone of light spreads out and is picked up (green points) by the surrounding light sensors. Right: schematic of the SNO detector. The detector cavity, 34 m high by 22 m in diameter, is 2000 m underground in a nickel mine in Ontario, Canada. The 1000 tonne heavy water target is contained in a 12 m diameter acrylic vessel, viewed by 9500 phototubes mounted on an 18 m diameter concentric geodesic sphere.

The heavy water is the key – SNO is the first extraterrestrial neutrino detector to use heavy water. In one heavy water reaction (call it reaction A), an electron-type neutrino can break up a target deuteron, producing two protons and an emergent electron. Electrons can also appear from elastic scattering (reaction B), where an incoming neutrino bounces off an atomic electron, which then recoils. However, reaction B can be produced by any kind of neutrino.

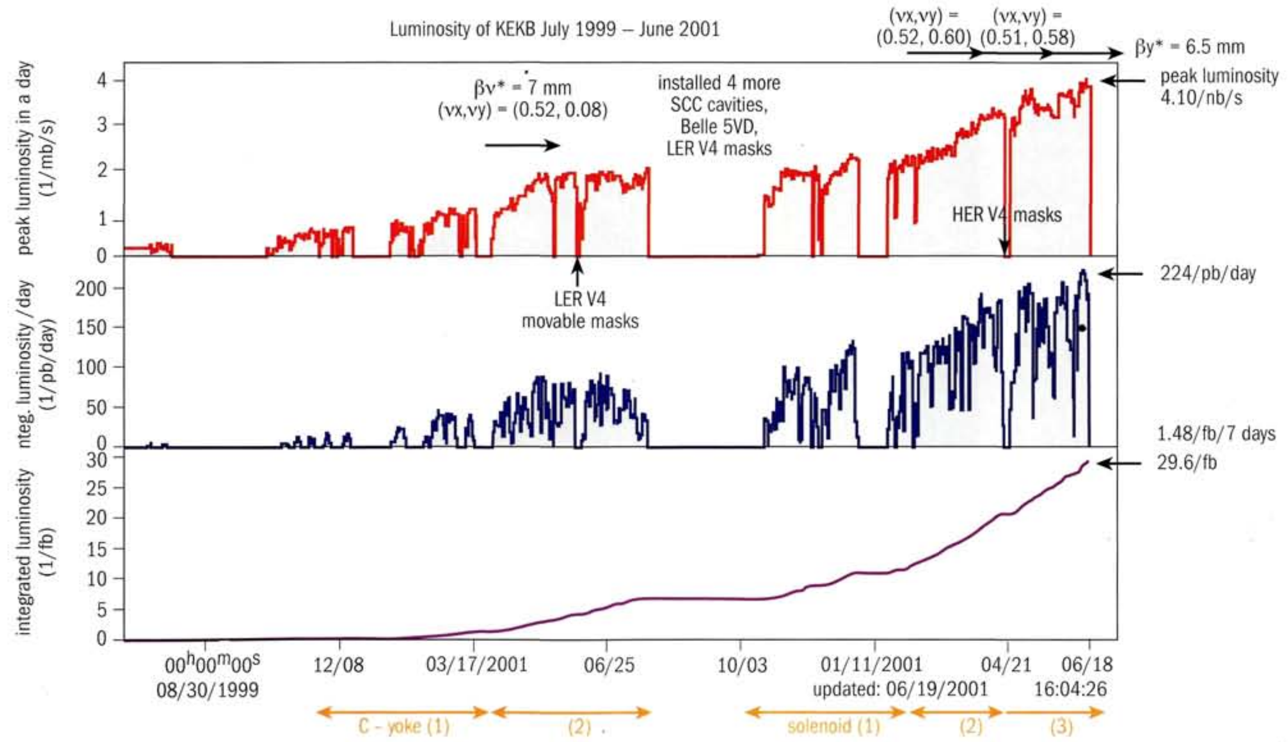
Over 241 days, SNO collected 1169 neutrino events, which were carefully analysed to classify them as being due to reaction A or B.

The apparent flux of solar neutrinos measured via the observed rate for reaction A ($1.75\,0.\pm 07 +0.12 - 0.11 \pm 0.05 \times 10^6\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, where the three sets of errors are respectively statistical, systematic and theoretical) is slightly lower than the precision measurement ($2.32 \pm 0.03 +0.08 - 0.07 \times 10^6\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$) via reaction B, by the Superkamiokande detector in Japan (*CERN Courier* September 2000 p8 – SNO's measurement of the rate for reaction B has not yet attained this precision). The fluxes as measured via the two reactions are different because some of the electron neutrinos produced in the Sun have "oscillated" into other types of neutrino en route, and on arrival at SNO are no longer able to trigger reaction A.

Evidence for neutrino oscillations has been seen in other situations (*CERN Courier* September 2000 p8). The SNO result is the first direct evidence for solar neutrinos oscillating on their journey to Earth. When an experiment makes its debut with such important results, its future looks assured.

JAPAN

Japan's KEKB offers unprecedented



Unprecedented luminosity (a measure of the machine's collision rate) at the KEKB Japanese B-factory electron–positron collider: the top two charts show the increase in peak and daily performance, with the milestones achieved by machine improvements. Integrated luminosity, like age, can only go in one direction, but it has effectively doubled this year at KEKB.

The KEKB Japanese B-factory collider is delivering unprecedented luminosity (a measure of the machine's electron–positron collision rate) to the international collaboration running the Belle experiment. Since the commissioning of the machine in November 1998, the KEK machine team has solved many difficulties and has recently made major progress – it has achieved the highest luminosity in collider history: $4.49 \times 10^{33}\ cm^{-2}\ s^{-1}$.

Integrated luminosities (a measure of the collision "dose" administered) are 232 pb^{-1} per day, 1.50 fb^{-1} per week and 4.83 fb^{-1} per month. These are all numbers recorded by the Belle detector. Total data so far collected by Belle had reached 33.1 fb^{-1} by mid-July.

KEKB luminosity has been nearly doubled this year, as seen in the figure above. This was brought about by several machine improvements. First, 1300 out of 1800 m of field-free region of the arcs in the low-energy ring (LER) has been covered with solenoid windings. This suppressed the vertical blow-up of the beam due to the photoelectron cloud up to about 900 mA. The second improvement came from the installation of new movable masks on the moving chamber in the high-energy ring (HER). This replacement, already verified at LER in the previous year, has raised the HER stored current limit HER 580 to 770 mA.

Third, a state-of-the-art setting was achieved in the betatron tunes – very close to the half-integer resonance. The vertical tunes were raised beyond half-integer resonance lines in both rings to gain stability of the orbits as well as a wider high-luminosity area in the tune spaces. The horizontal tunes, especially in LER, were set even closer to the half-integer resonance to gain the dynamic focusing effect of the beam–beam interaction without sacrificing the machine aperture. Other notable improvements are in the orbit control, betatron tune monitor and control, beam-size control, the beam-abort system, the logging system and the injectors.

Though the peak luminosity and integrated luminosity per month are a little higher than those of PEP-II/BaBar at SLAC, Stanford, KEKB needs further improvements to continue to be competitive with its rival in the long run (even assuming the present luminosity of PEP-II). KEKB has significant obstacles in running more than nine months a year due to the periodic inspection of the refrigeration system required by law, expensive summer electricity, a weak cooling system incapable of handling summer heat and so on.

Several improvements are planned during this summer's shutdown. More solenoid windings are planned in the LER. Currently the electron-cloud effect still looks to be the dominant restriction on the number of bunches circulating in the LER.

Currently, the collision is carried out with four-bucket spacing. A shorter spacing is essential to achieve higher luminosity, because the bunch current is limited in both rings for various reasons.

The replacement of the vacuum chamber is

luminosity

CP-violation parameter

In time for the summer conference season, both of the big experiments measuring the charge-parity (CP) asymmetry in the decays of B-mesons reported impressive results.

The BaBar experiment at the PEP-II electron–positron collider at SLAC, Stanford, based on a sample of 32 million B pairs, reported a value for the sin2ß CP-violation parameter of 0.59 ± 0.14. The BELLE experiment at the KEKB electron–positron collider at the Japanese KEK laboratory, with 31.3 million B pairs, measures the parameter as $0.99 \pm 0.14 \pm 0.06$.

These are the most precise measurements of this parameter so far. For statistical sticklers, the results are now clearly non-zero – physicists can say with confidence that CP violation happens in B decays. Using earlier measurements, the world average becomes 0.79 ± 0.12 compared to the theoretically predicted value of 0.70 ± 0.12.

planned at the interaction region (IR), where a tentative limit of the total current is given by the heating of the IR chambers. A new chamber with a taller aperture will be installed in the HER downstream of the IR, as well as additional cooling systems in LER upstream.

Current movable masks of absorber type are going to be replaced with spoiler-type masks to reduce damage by beam loss.

Damage to the movable masks has been a serious obstacle in beam operation. A solution will be thinner masks to reduce significant heating damage.

Other related improvements planned for this summer are a mask protection system with the beam-loss monitor and the addition of a few more radiofrequency cavities to give a margin for high-current operation.

The Belle detector at the Japanese KEKB is studying the decays of B-mesons (particles containing the fifth "b" quark), in particular the delicate violation of charge-parity (CP) symmetry (see above).

The impact of the machine's performance on this measurement was eagerly awaited.

CERN

New CMS visitor centre proves a star attraction

Top: visitors at the opening of the new CMS visitor centre at CERN. Bottom: the 13 × 6 m, 120 tonne inner cylinder of the vacuum tank that houses the superconducting magnet for the CMS experiment at CERN's LHC collider reaches the Faucille Pass, at the summit of the Jura Mountains, en route to CERN. The 120 km journey from manufacturer Franc-Comptoise Industrie, a subsidiary of the German DWE concern, took five days. The cylinder is the largest single element of the CMS detector.

The Compact Muon Solenoid (CMS) experiment, which is being carried out in preparation for the installation of CERN's forthcoming Large Hadron Collider (LHC), became one of the laboratory's star visitor attractions during the inauguration of a new visitor centre on 14 June.

Until recently, CERN's 20 000 annual visitors were taken on a guided tour of one of the experiments at the Large Electron–Positron collider (LEP), the laboratory's flagship research facility. With the closure of LEP last year, underground visits are no longer possible, and a new series of itineraries has been put in place, including preparations for LHC experiments.

The CMS experiment is particularly well suited for visits, because it will be constructed almost entirely on the surface.

Information about CMS, including animations and live Web-cams, can be found at "http://cmsinfo.cern.ch".

USA

CERN computing wins top award

On 4 June in Washington's National Building Museum, Les Robertson, deputy leader of CERN 's information technology division, accepted a 21st-century Achievement award from the Computerworld Honors Program, on behalf of the laboratory.

This prestigious award was made to CERN for its innovative application of information technology to the benefit of society, and it followed the laboratory's nomination by Lawrence Ellison, chairman and CEO of the Oracle Corporation.

Members of the team that initiated the SHIFT project at CERN. Left to right: Ben Segal, Matthias Schroeder, Gail Hanson (holding the Computerworld trophy), Bernd Panzer, Jean-Philippe Baud, Les Robertson and Fréderic Hemmer.

Ellison nominated CERN in the science category in recognition of "pioneering work in developing a large-scale data warehouse" – an innovative computing architecture that responds precisely to the global particle physics community's needs.

The kind of computing needed to analyse particle physics data is known as high-throughput computing – a field in which CERN has played a pioneering role for over a decade. In the early 1990s a collaboration of computer scientists from the laboratory, led by Les Robertson, and physicists from many of CERN's member states developed a computing architecture called SHIFT, which allowed multiple tape, disc and CPU servers to interact over high-performance network protocols. SHIFT's modular design simultaneously allowed scalability and easy adoption of new technologies. (For an overview of SHIFT and its development, see *CERN Courier* July p19.)

Over the years, CERN has proved these features by evolving SHIFT from the systems of the 1990s, based on RISC (reduced instruction set computer) workstations and specialized networks, to today's massive systems. These include thousands of Linux PC nodes linked by gigabit Ethernet to hundreds of Terabytes of automated tape storage cached by dozens of Terabytes of caches based on commodity disk components.

CERN has since worked on evolving SHIFT in collaboration with physicists and engineers from universities and laboratories around the world. Several collaborations with industrial partners have been formed as successive technologies were integrated into the system. Today, SHIFT is in daily use by the many physics experiments that use CERN's facilities, providing a computing service for more than 7000 researchers worldwide.

For the future, CERN and other particle physics institutes are working on scaling up this innovative architecture to handle tens of thousands of nodes, and incorporating computational grid technology to link the CERN environment with other computing facilities, easing access to the colossal quantities of data that will be produced by experiments at the laboratory's forthcoming particle accelerator, the Large Hadron Collider, which will switch on in 2006.

Welcoming the award, CERN director-general, Luciano Maiani said: "This is an important recognition of CERN's excellence in information technology. In particular, it is a reward for the teams of physicists on CERN's LEP experiments who contributed to the development and implementation of this new architecture. The prize is also an encouragement for the physicists working on the complex challenges of LHC computing."

Hans Hoffmann, CERN's director of scientific computing, commented: "In addition to its major contribution to physics, CERN has been a consistent innovator in information technology, from the Web to its current work on grid computing. We are delighted with this prize; particularly as it demonstrates recognition for CERN's computing initiatives, not from the academic world but from industry's leading computing experts."

Also among the winners this year was Tim Berners-Lee, who received the Cap Gemini Ernst & Young Leadership award for Global Integration in recognition of his pioneering work on the World Wide Web – work carried out while he was at CERN in the early 1990s.

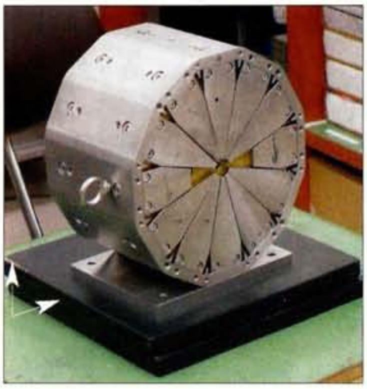
● More information on the Computerworld Honors Programme is available at "http://www.cwheroes.org".

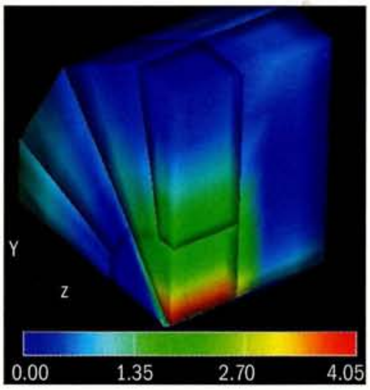
JAPAN

Magnets become more compact

A new development in Japan that enables powerful magnetic fields to be obtained without using expensive electromagnets could open the door to smaller, special-purpose particle accelerator installations.

While particle accelerators were invented to supply the high-energy beams needed to pierce through nuclear barriers and see the subnuclear world, most of the accelerators now in use are low-energy machines used for a variety of applications, such as radioisotope production, cancer therapy and ion implantation.





Left: this small prototype permanent magnet designed by a team from Japan's National Institute of Radiological Sciences has exceeded 4 tesla. The inner diameter is 6 mm and the length is 150 mm. Right: field distribution inside the prototype permanent magnet.

In high-energy machines that take beams into the relativistic regime, the magnetic fields have to vary and pulsed electromagnets are the norm.

However, for lower-energy machines and for special-purpose magnets, it can be more economical to use permanent magnets instead, with no requirement for attendant power supplies, cooling or special cryogenics.

This idea was pioneered by Klaus Halbach at Berkeley, who in the late 1970s introduced permanent magnets as "wigglers" and "undulators" to generate synchrotron radiation from a captive high-energy electron beam. The magnetic material of choice was initially a rare-earth/cobalt alloy. Permanent magnets are also used in Fermilab's Antiproton Recycler ring (*CERN Courier* July p16).

Motivated by the need to design compact machines to provide beams for cancer therapy, a team from Japan's National Institute of Radiological Sciences, led by Masayuki Kumada, collaborated with Sumitomo Special Metals to produce a scaled-down, prototype permanent magnet to achieve the required magnetic fields of greater than 4 tesla. So far such fields have only been achievable with large superconducting magnets.

Using suitable magnetic materials such as samarium cobalt, the maximum field that can be attained is about 2 tesla normally. The Halbach-type designs improved on this by using a geometry that effectively amplifies the interior field.

The key innovation in the new idea is to use a saturated iron pole in the magnetic circuit of the permanent magnet to introduce a higher residual field, to compress the magnetic flux, and to weaken the demagnetizing field. Fields of up to 4.45 tesla have been attained when cooled to -25°C (at room temperature the field was 3.9 tesla). With these fields, a machine for handling hadrons (nuclei) for cancer therapy would be less than half the diameter of current machines. The team has begun work on a permanent magnet cyclotron. Another possible application would be high-energy hadron colliders with small beams.

CERN/RUSSIA

Last LHC magnets from Siberia reach CERN

The delivery of Russian magnets to equip transfer lines to feed CERN's new LHC collider is now complete.

Over the past two years, magnets have been steadily arriving at CERN from Novosibirsk's Budker Institute.

Some 360, 6 m dipoles and 180, 1.4 m quadrupoles, now safely at CERN, will be installed in two new underground transfer tunnels, each about 3 km long, connecting the SPS and LHC/LEP tunnels. One of these tunnels recently linked with the 27 km LHC ring (*CERN Courier* July p24).

End of a long road. Left to right: LHC project director Lyn Evans; CERN director-general Luciano Maiani; Budker Institute, Novosibirsk, director Alexander Skrinsky; CERN Accelerator director Kurt Hubner. They are sitting on the last of 360 dipole magnets and 180 quadrupoles from Novosibirsk for the transfer lines to inject protons into the LHC.

Each month some 10 magnet consignments travelled the 6000 km from Siberia, each bearing two dipoles and a quadrupole. Unlike the LHC's main magnets, these are not superconducting. The Budker Institute supplies them under the 1993 Co-operation Agreement, which covers Russian participation in the LHC. Preliminary work on dipole elements is handled by the Efremov Institute, St Petersburg, and on quadrupole elements by the ZVI factory in Moscow. The additional manufacture and the final assembly of the magnets is done at Novosibirsk.

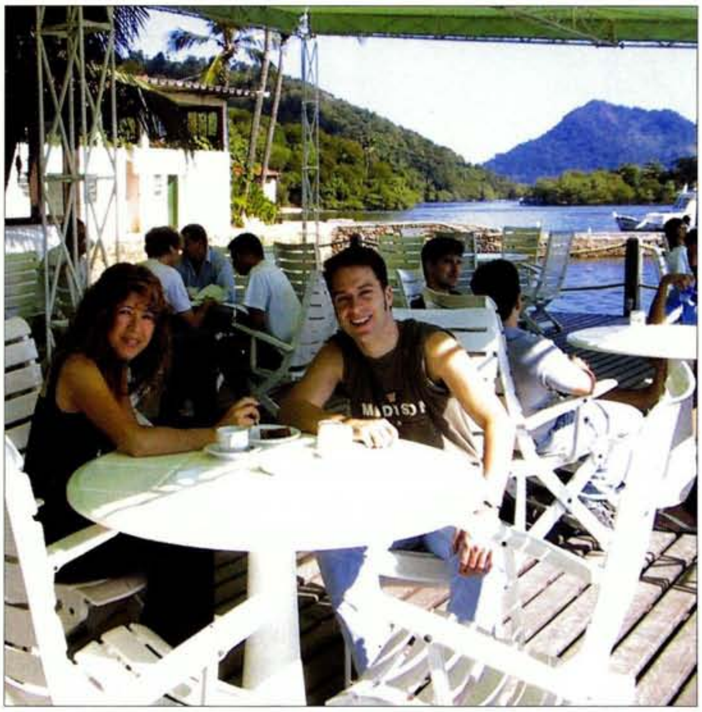
CERN/SOUTH AMERICA

Latin-American school marks start of a new collaboration for CERN

The first school of high-energy physics organized jointly by CERN and CLAF (Centro latinoamericano de física), Rio de Janeiro was held in Itacuruçá, Brazil on 6–19 May and it hopefully marked the opening of a close collaboration between CERN and physicists in Latin America.

This new series of biennial schools is modelled on the school of physics organized by CERN and the Joint Institute for Nuclear Research in Dubna near Moscow, which was, and continues to be, instrumental in fostering relations between CERN and former socialist countries.

Some 71 students attended the inaugural CERN–CLAF school, 56 of them coming from eight Latin-American countries (17 from Mexico, 16 from Brazil, 11 from Argentina and 12 from other countries), 13 from Europe and two from the US.



Time out from physics: Cecilia Uribe of Mexico and Patrick Brockhill of the US, studying in Rio. The school location – Itacuruçá – is an island.

The Latin-American students were centrally funded for all of their travel, board and lodging, while other students were funded by their home institutes. Financial support came from CERN, Spain, France, Portugal and Italy, in addition to Brazil, Mexico and CLAF.

The students were accommodated in twin and triple rooms with students from different countries and regions sharing the same room. This was an important factor contributing to the success of the school.

The 11 lecturers came from Europe, Latin America and the US. The lectures, which were in English, were complemented by daily discussion sessions led by seven physicists from Latin America. The students presented their work in an enthusiastic poster session.

A survey carried out at the end of the school revealed that:

- the school was an undisputed success;
- the level of the students was high, and all profited from the lectures, in spite of minor language problems;
- the mixing of nationalities was important, and students were convinced that contact with other students and with lecturers of international reputation would be significant for their future careers as well as in building up an inter-regional network of young physicists;
- the contacts made at the school were also believed to be important in strengthening the collaboration between individuals and institutions inside Latin America;
- there was a unanimous wish for the school to be continued, and the Mexican physics community and authorities expressed their willingness to host the next event in 2003.

At the conclusion of the school, a meeting with representatives from CERN, several Latin-American countries (Argentina, Brazil and Mexico) and funding agencies discussed strategies for continued and possibly permanent support for the CERN–CLAF School and for strengthening the collaboration between Latin-American countries and CERN. The following actions, mainly in the context of CERN's LHC project, were agreed:

- to continue the biennial CERN–CLAF School;
- to promote the existing and potential collaborations by developing ad hoc protocols between Latin-American funding agencies and CERN, to ensure a stable financial framework for the long timespans of current high-energy physics activities;
- CERN could grant Latin-American groups access to facilities and other services, and give them priority for recuperating surplus equipment;
- CERN will continue to investigate additional funding from the European Union, UNESCO and CERN member states with the aim of increasing the exchange of scientists and to enlarge the duration and number of positions for Latin-American scientists, engineers and trainees at CERN;
- CERN can help by investigating possibilities of scientific, technical, industrial and public education co-operation with Latin America;
- opportunities and conditions under which some Latin-American countries could become CERN observer states would be investigated.

A joint CERN Latin-American steering committee would be set up with the goal of preparing a plan of action. The draft plan will be submitted, for approval, to the authorities of CERN, CLAF and the Latin-American funding agencies. It will also be submitted by CERN's director general to those CERN European member states willing to co-operate, as well as to the European Union and UNESCO. Spain and Portugal have expressed an intention of submitting the plan to the next Ibero-American meeting of presidents and prime ministers which is planned for 2002.

A student's viewpoint

As one of the students at the first school of high-energy physics organized jointly by CERN and CLAF, here are my personal impressions of the school, which I believe represent the feelings of the other students.

The school's structure was basically the same as the traditional European school of high-energy physics: two weeks of excellent courses, discussion sessions and free time for amusement, in physics or other leisure activities.

The European school is designed mainly to teach theoretical physics to experimental physicists. The CERN–CLAF School was wisely adapted to the Latin-American reality – young theorists were also accepted and lectures on experimental physics were added. In addition, students from the US and Europe participated.

The lectures motivated our curiosity and provided material for discussion during the free time and the sessions.

The poster session was a very good occasion to show our work and to learn what others are doing. We had about three hours of stimulating exchange of information and many of us came back during the free time to continue the discussions.

Brazilian students Ana Amelia Machado and Henrique Barbosa prepare their poster contributions at the first CERN–CLAF school of high-energy physics.

The mixture of young theorists and experimentalists was also very fruitful. The students had different physics backgrounds, so the discussions were enriched by different viewpoints.

The students from Europe and the US, with their different culture and experience in high-energy physics, were well integrated. Their participation was also important to encourage discussion in English.

For all of these reasons, the CERN–CLAF school of high-energy physics seems to be mandatory. It will certainly become instrumental in introducing the Latin-American community to the experimental particle physics world.

Erica Ribeiro Polycarpo, *UFRJ Rio de Janeiro*

CRYSTALS

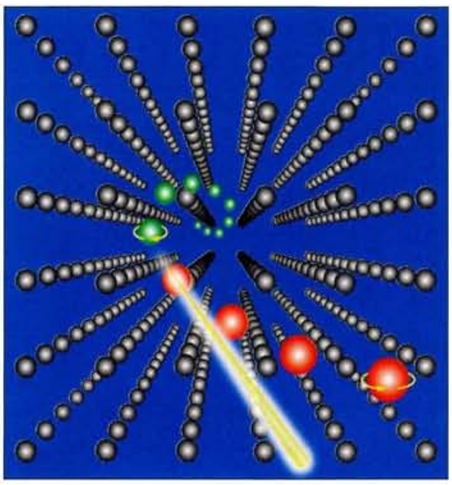
Crystals put spin on particle beam action

New investigations being made into the behaviour of charged particle beams as they pass through crystals suggest that the very high electric fields inside these crystals could be used to orient (polarize) the spins of the particles.

The spin of an electron can be imagined as equivalent to a tiny current-carrying coil. This coil will induce a neighbouring magnetic field, which will interact with any other electromagnetic field.

In the early 1960s it was seen that the interaction of this intrinsic electron magnetism with the magnetic field in a circular accelerator could be used to polarize circulating electrons. This is now routinely used to polarize beams of electrons in storage rings. However, this polarization takes hours to achieve because the fields are very weak.

During the 1990s the NA43 collaboration at CERN made an in-depth study of what happens when a high-energy beam passes through various crystal structures. When such a beam penetrates a crystal, it "sees" a strong coherent electric field due to the nuclear constituents. Moreover, if the charged particles are moving at relativistic speeds, the apparent fields are even higher, attainingthe so-called critical field, 10^{16} V/cm. Under these conditions, the electrons align their spin in the field in about the same time as it takes to traverse the crystal, 1 ps, instead of several hours.



A spin-down electron (green) emits very hard radiation following spin-flip to the spin-up state (red) during the passage of the extremely strong electromagnetic fields in a single crystal.

Under these conditions the photons emitted in the individual electron spin-flips can also be studied. Such effects could be of interest for planned high-energy linear electron–positron colliders, such as CERN's CLIC, and they are probably also found at the surface of neutron stars, where the fields are of a strength comparable to the critical field.

Another well-known crystal-beam effect is "channelling", which is when the charged particle beam is steered through the crystal by its interior electromagnetic fields. Using a bent crystal provides a more economical way of steering a beam than conventional large magnets. Channelling in bent crystals is routinely used in experiments, notably the NA48 CP-violation study at CERN (*CERN Courier* July p5).

Edited by Archana Sharma

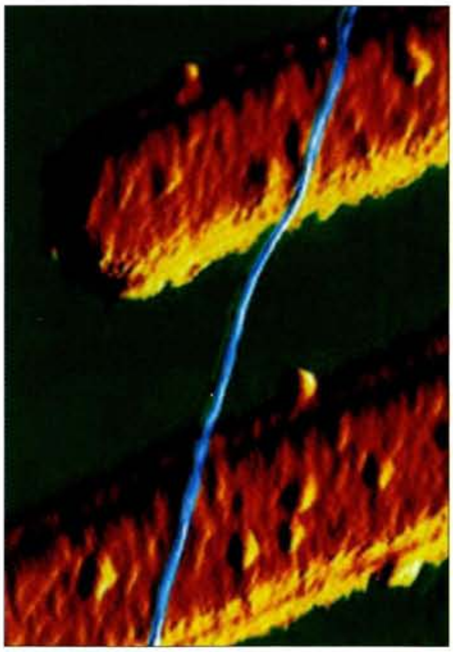
Except where otherwise stated, these news items are taken from the Institute of Physics Publishing's news service, which is available at "http://physicsweb.org".

Carbon nanotube research group takes a step towards a world of nanoelectronics

Could the development of nanoelectronics be just around the corner? The world's smallest wires have been soldered together by a research team at the University of Ulm in Germany. The team used a beam of electrons to link two hollow tubes of carbon, each of which measured just two-millionths of a millimetre across. This achievement demonstrates that size should not present any obstacle to the creation of ultra miniaturized electronic circuits.

While microchip manufacturers struggle to create silicon wires of 10 times the thickness of such carbon nanotubes, the nanotubes themselves are capable of forming components spontaneously from carbon-rich gases. The nanotubes conduct electricity and can act in the same way as transistors and other electronic devices. If they could be connected, such circuit components could immediately shrink microelectronics – and hence boost computer power – by an order of magnitude.

A current can be passed between two wires simply by placing them in contact with one another. Nanotubes, however, are too small to work in this way – electric current is not transmitted between them efficiently when one is placed on top of another. To improve the level of contact between crossing nanotubes, therefore, a beam of electrons was focused onto the point where the tubes crossed one another.



Carbon connections, produced by an electron beam, can connect adjacent carbon nanotubes.

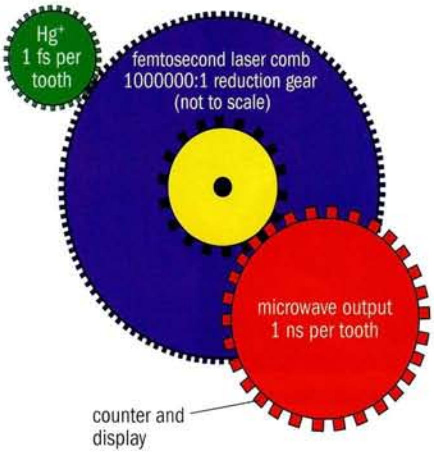
When nanotubes are exposed to the atmosphere, their surfaces pick up carbon-containing contaminants. The debris in between the nanotubes is then converted into electrically-conducting graphite-like carbon, which fixes one tube to the other. The cylindrical channels of the two tubes remain unconnected – much in the same way that subway lines in separate tunnels might run one above the other. Cutting the tubes in two and joining the ends to make a four-way tunnel could have a different effect on the conductivity, which might also be useful in electronics.

Physicists clock up world record on time

Researchers in Colorado have developed a clock that is potentially so precise that, had it started measuring time when the Earth was formed 4.5 billion years ago, it would still be accurate to within a second or so by the present day.

Substantially more reliable than the best existing clocks, this development could enable physicists to measure the fundamental constants of the universe with incredible accuracy. In conventional atomic clocks, atoms rearrange their electron clouds when stimulated by microwaves oscillating at exactly the atoms' resonant frequency. The detection of the excited atoms then retunes the frequency of the microwave generator. The oscillator producing the microwaves becomes locked to the atoms' resonant frequency, which remains extremely stable.

Some of the most crucial effects in physics reveal themselves only under experimental conditions of phenomenal precision. For example, the "fine-structure constant" – which measures how strongly matter interacts with light under ordinary conditions – may not be constant at all, but may vary slowly as the universe gets older. More accurate clocks might enable this idea to be tested.



Mechanical analogy of the optical clock.

Atom-cooling techniques developed during the past decade have transformed atomic timekeeping. The colder an atom is, the less its resonance is blurred by its motion. The Colorado researchers excited the resonance of a single, trapped mercury atom and used a visible-light laser that was boosted into the ultraviolet range.

They solved the tick-counting problem using a second laser that emitted light in pulses just 25 fs long. This laser interacted with the visible light, converting it into an analogous signal, the timing of which was set by the pulse rate. A high-frequency light signal was converted into a lower-frequency microwave signal, the oscillations of which could be monitored – just as mechanical gearing can transform rapid revolutions into slower ones. *Science*

Newly discovered compound is utilized in superconducting wires and thin films

Less than six months after the metallic compound magnesium diboride was found to be a superconductor (April p11), scientists in the US have developed a practical technique for making wires from it. Other researchers have also produced thin films of the compound and have markedly increased the amount of electrical current that it can carry.

In January, researchers in Japan announced their discovery that magnesium diboride can act as a superconductor (a material in which electricity flows with virtually no resistance) at temperatures of less than −234 °C (39K). Magnesium diboride has been a known substance since the 1950s, but it had never been tested for superconductivity.

To make the wires, scientists at Agere Systems in Murray Hill, New Jersey, filled iron tubes with magnesium diboride powder before stretching and flattening the tubes into ribbons approximately 1 cm wide and 1 m long. The wires were then baked at 870 °C, which fused the magnesium diboride powder into a solid.

The technique is similar to that used to make wires out of high-temperature superconductors. Superconducting wires could find uses in power transmission cables, efficient electric motors and magnets for magnetic resonance imaging machines.

Meanwhile, other scientists have looked into ways of improving the compound's remarkable magnetic properties. Specialists at Imperial College in London blasted magnesium diboride with protons, knocking some of the superconductor's atoms out of place. Researchers at the universities of Wisconsin and Princeton diffused oxygen into thin films of magnesium diboride. The oxygen atoms, they believe, displaced some of the boron atoms in magnesium diboride.

Such defects pin down the magnetic fields penetrating a superconductor. Otherwise, forces generated by the electric current push the magnetic fields into the superconductor's atoms. This jostling dissipates energy, just as electrons bumping into atoms in ordinary metals produce electrical resistance.

To produce their thin films, the Wisconsin and Princeton researchers used ultraviolet lasers to vaporize magnesium diboride, which then settled in a layer a fraction of a micron thick. The oxygen-tainted magnesium diboride films were able to work in magnetic fields almost twice as strong as those lacking the oxygen impurities. Thin superconducting films could be used for electronic components and sensitive magnetic sensors. *Nature*

Edited by Emma Sanders

Sky survey produces 14 million new results

In June, two major survey collaborations released their data to the world's astronomy community. The Sloan Digital Sky Survey (SDSS) released observations of some 14 million objects, including spectra of 50 000 galaxies and 5000 quasars. The 2dF galaxy redshift survey released the redshifts of some 100 000 galaxies.

A preliminary analysis of the SDSS data has already revealed two record-breaking quasars at redshifts of 6.0 and 6.2.

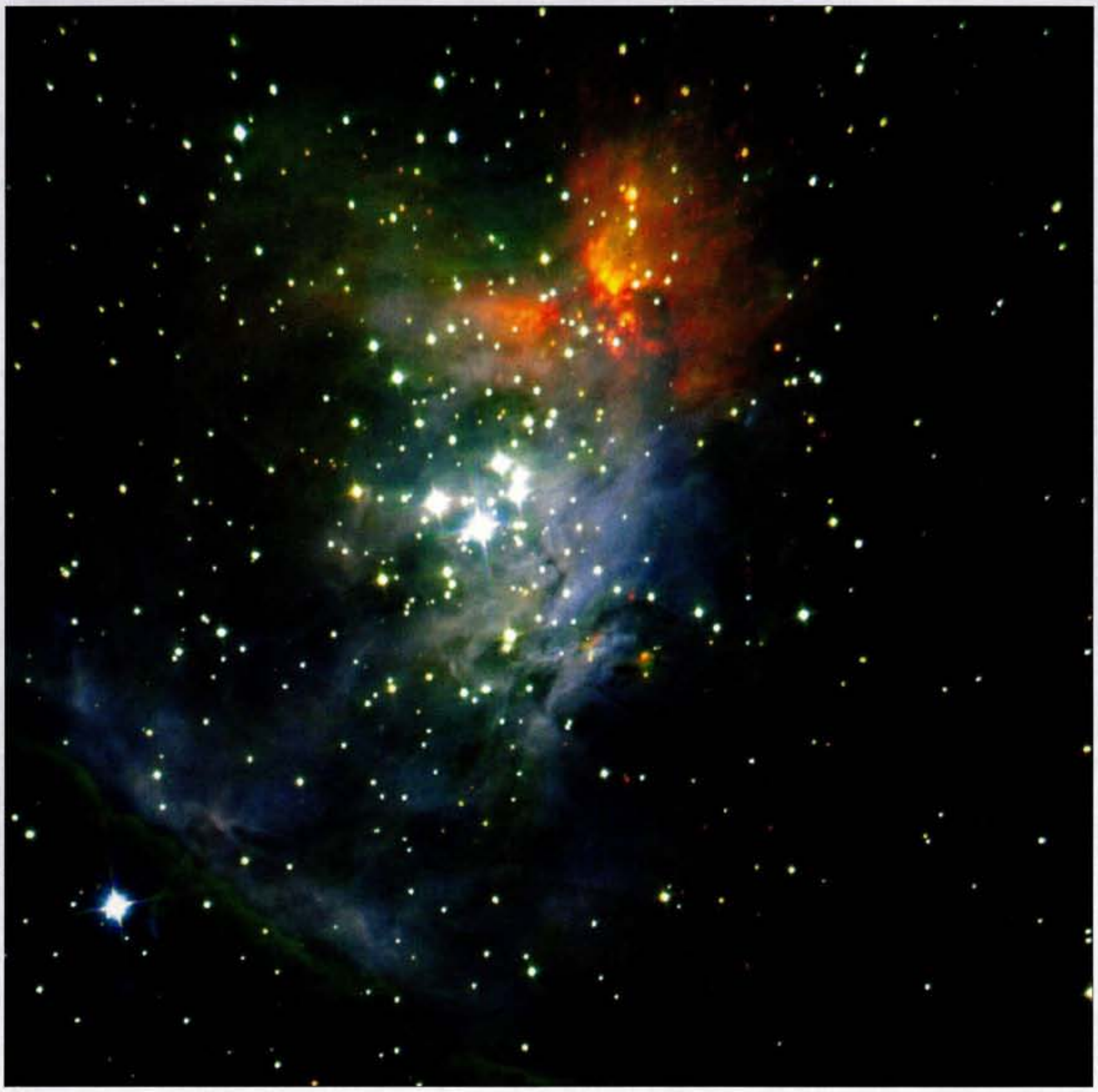
Quasars – short for quasi-stellar objects – are no larger than our solar system, yet they can outshine galaxies containing hundreds of billions of stars.

The survey employs the 2.5 m telescope at the Apache Point Observatory, New Mexico. Over the next four years, astronomers will measure the distance to more than a million galaxies, and these distances will be combined to produce the largest three-dimensional map of the universe ever.

The 2dF survey uses the Anglo-Australian telescope on Mount Stromlo. The goal of the collaboration is to measure 250 000 redshifts by the end of the year. Preliminary results include the measurement of irregularities in matter distribution, corresponding to fluctuations in the microwave background (*CERN Courier* July/August p15).

Just one of 50 000 galaxies: NGC 3521. (SDSS.)

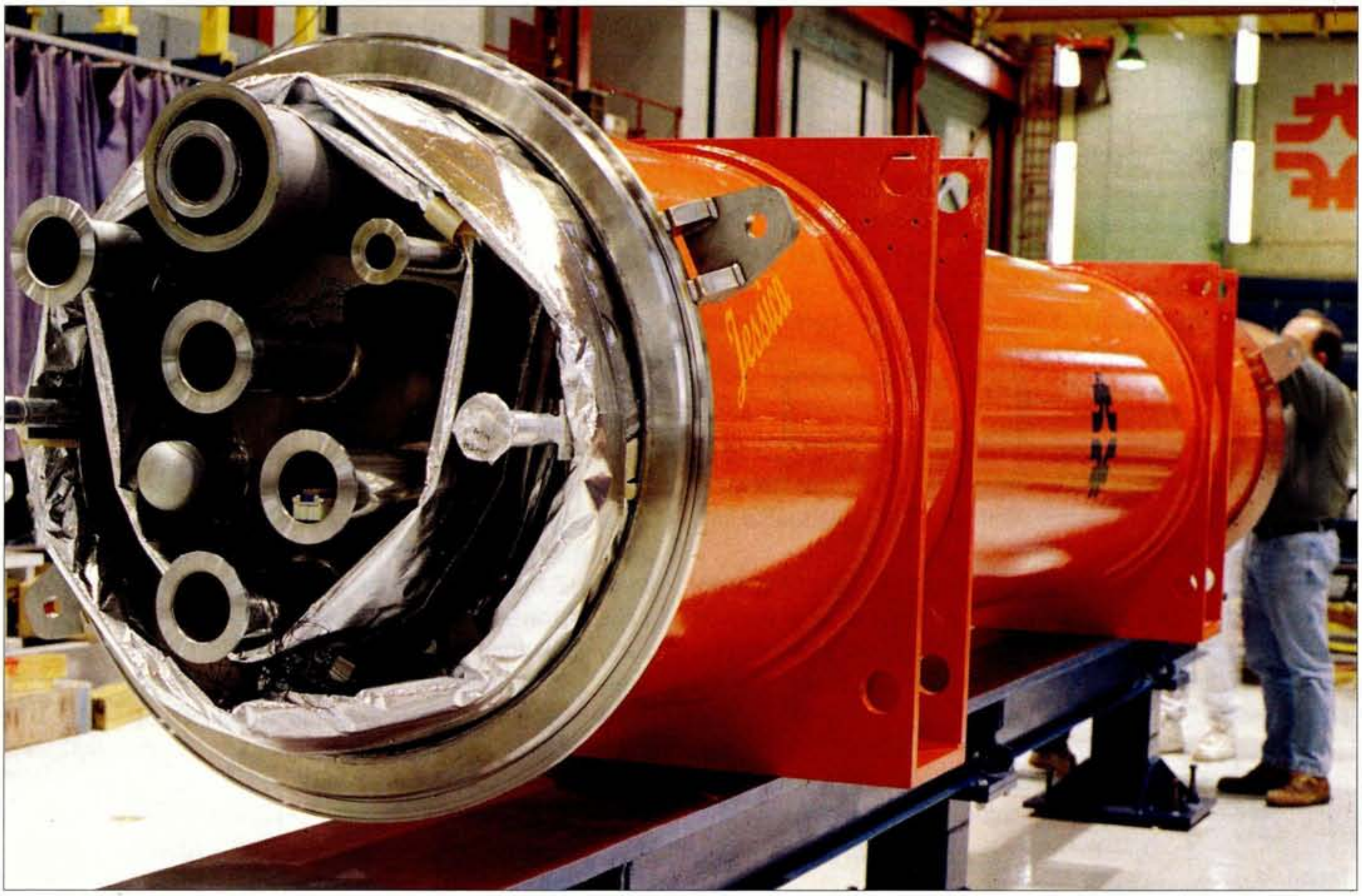
Picture of the month



The largest population of brown dwarf objects yet discovered has been identified using the European Southern Observatory's Very Large Telescope. Brown dwarfs weigh less than around 7% of the mass of the Sun and are unable to generate their own energy for any substantial period of time. Indeed, many of their properties are similar to those of the giant gas planets in our solar system. However, the ESO study has revealed a high incidence of disks around the 100 new brown dwarfs discovered in the Trapezium cluster (left). This supports the theory that the objects are more similar in nature to stars than to planets. Brown dwarfs make up a small part of the dark, non-luminous matter in the universe. (European Southern Observatory.)

The international jigsaw puzzle

As well as the 20 nations of the CERN family, several other nations further afield are making major contributions to the laboratory's flagship Large Hadron Collider.



A prototype superconducting quadrupole magnet under assembly at Fermilab. Magnets like these will squeeze the LHC beams and boost the collision rate. Such insertion magnets for the LHC are also being supplied by Japan.

The Large Hadron Collider, which is now under construction in CERN's 27 km ring tunnel, attracts significant contributions from several major nations outside the CERN member state community, making it truly a world machine.

In addition to these important contributions from Canada, India, Japan, Russia and the US, CERN host states France and Switzerland also contribute significant additional resources to the Large Hadron Collider (LHC) above and beyond their natural involvement as part of the 20-nation European CERN community.

Canada

The contribution to the LHC from Canada is valued at C$40 million, much of which is used for hardware to help to upgrade the injector chain, particularly the Booster and the PS synchrotron. This ▷

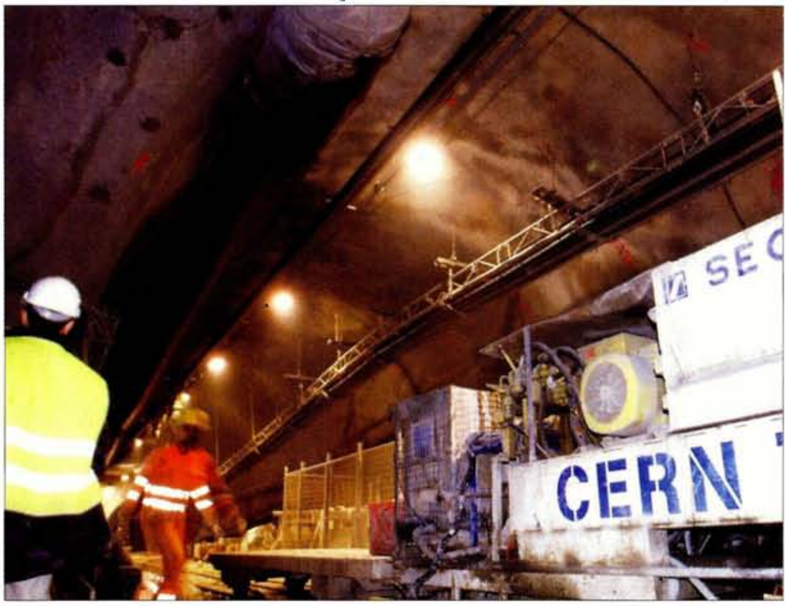
involvement goes back to 1995 and is coordinated by the Canadian TRIUMF laboratory.

Equipment includes ferrite rings and the tuning and high-voltage power supplies for four new radiofrequency cavities for the Booster, which was upgraded from 1 to 1.4 GeV specifically for its new role in the LHC injector chain.

Canadian contributions also include most of the magnets and power supplies for the transfer line between the Booster and the PS, major equipment for the Booster main magnet power supply, and a reactive power compensator to reduce Booster-induced transients on CERN's electrical supply system.

A second wave of Canadian contribution is mainly for the LHC ring, including 52 twin-aperture quadrupole magnets for "beam cleaning" insertions, together with power suplies for kicker magnets, pulse-forming networks and switches.

Canada will also develop beam-position monitor electronics and carry out some beam optics studies.



As a special contribution, Switzerland is underwriting the cost of one of the tunnels through which protons will be fed to the 27 km LHC ring.

India

The initial CERN-India co-operation agreement was signed in 1991 and is renewed every five years. The value of equipment covered is \$25 million, of which half is transferred by CERN into a special fund to underwrite further joint ventures.

The main Indian hardware contribution is superconducting sextupole and decapole spool pieces amounting to half of the total LHC requirement for such corrector magnet equipment. In addition, India will supply LHC magnet support jacks and quench heater power supplies.

Circuit breakers are being supplied by Russia, but India remains responsible for the necessary electronics. In addition, India is carrying out several programming and documentation projects.

Japan

Japan's early entry into the LHC arena in 1995 provided a memorable boost for the project. Japanese contributions currently total approximately ¥13 850 million (some SFr160 million). Of this sum, some SFr25 million was earmarked for constructing of the solenoid magnet for the ATLAS experiment (May p8).

The KEK national laboratory acts as a major coordinator for all of this work. Japan is the source of much of the basic material (steel and superconducting cable) for the LHC.

A further significant Japanese contribution to the LHC is the 16 quadrupoles used to squeeze the colliding beams and boost the interaction rate. Also on the list of equipment are compressors for cooling superfluid helium.

Russia

The contribution of the Russian Federation to the LHC machine is valued at SFr 100 million. One-third is channelled into a special fund for CERN-Russian collaboration.

The largest and most visible part of this contribution is the thousands of tonnes of magnets and equipment for the beamlines to link the SPS synchrotron to the LHC. The supply of this equipment from Novosibirsk will soon be complete. Novosibirsk is also supplying insertion magnets for the LHC ring.

The Protvino laboratory is responsible for 18 extraction magnets and the circuit breakers that will receive the electronics from India. The Joint Institute for Nuclear Research, Dubna, is contributing a damping system, and a number of other Russian research centres will furnish a range of items and equipment, including design work, radiation studies, survey targets, ceramic components, busbars and shielding.

USA

Work in the US for the LHC centres on interaction regions 1, 2, 5 and 8, together with some radiofrequency equipment for Point 4. The work is shared between the Brookhaven, Fermilab and Lawrence Berkeley National laboratories.

The impressive list of contributed hardware includes superconducting quadrupoles and their cryostats for beam intersections (Fermilab), superconducting dipoles for beam separation (Brookhaven) and cryogenic feed boxes (Berkeley).

The beam insertion hardware overlaps with that from Japan, and there has been excellent co-operation on LHC contributions between these two industrial giant nations.

Host nations

France and Switzerland, as CERN host nations, make special contributions to the LHC. For France, this includes 218 person-years of work, spread over four major technical agreements, covering the cold mass for LHC short straight sections (handled by the CEA Atomic Energy Commission), the short straight section cryostats and assembly (by the CNRS national research agency), calibration of 8000 thermometers for the LHC (by the Orsay laboratory), and design and series fabrication work for the superfluid helium refrigeration system (CEA).

In addition to this national involvement, the local Rhone-Alpes

The Budker Laboratory in Novosibirsk is supplying thousands of tons of magnets for the transfer lines linking CERN's beam-supply system with the LHC tunnel, as part of the Russian contribution to the LHC (see p9).

regional government and the *départements* of Ain and Haute-Savoie also contribute.

Under the regional government plan, about 90 person-years of assistance will be supplied by young graduates of technical and engineering universities. Haute-Savoie contributes design work on the integration of microelectronics for the LHC cryogenic system.

In addition, the LAPP laboratory at Annecy is developing ultrasonic equipment to monitor superconducting dipole interconnections, and it is doing design work for the vacuum chambers of the major LHC experiments. Ain has contributed the land to build a major new construction and assembly hall next to the CERN site.

The Swiss contribution comes from the federal government and the canton of Geneva, and it covers the cost of a 2.5 km tunnel through which protons will be fed from the SPS to the LHC in the anticlockwise direction.

For the major physics detectors, scientists are used to seeing major equipment being built piecewise in an international jigsaw puzzle, but the LHC machine, too, is taking on such a character.

For the major physics detectors, scientists are used to seeing major equipment being built piecewise in an international jigsaw puzzle, but the LHC machine, too, is taking on such a character.

A path to international contributions was pioneered by the HERA electron–proton collider at DESY, Hamburg, in the 1980s.

For HERA, Canada, France, Italy and the Netherlands supplied components, Israel and the US contributed technological development, and person power came from China, Poland and the UK. □

Fifty years of the renormalization group

Renormalization was the breakthrough that made quantum field theory respectable in the late 1940s. Since then, renormalization procedures, particularly the renormalization group method, have remained a touchstone for new theoretical developments. Distinguished theorist *Dmitry Shirkov*, who worked at the cutting edge of the field with colleague Nikolai Bogoliubov, relates the history of the renormalization group.

Quantum field theory is the calculus of the microworld. It consists principally of a combination of quantum mechanics and special relativity, and its main physical ingredient – the quantum field – brings together two fundamental notions of classical (and non-relativistic quantum) physics – particles and fields.

For instance, the quantum electromagnetic field, within appropriate limits, can be reduced to particle-like photons (quanta of light), or to a wave process described by a classical Lorentz field. The same is true for the quantum Dirac field.

Quantum field theory (QFT), as the theory of interacting quantum fields, includes the remarkable phenomenon of virtual particles, which are related to virtual transitions in quantum mechanics. For example, a photon propagating through empty space (the classical vacuum) undergoes a virtual transition into an electron–positron pair. Usually, this pair undergoes the reverse transformation: annihilation back into a photon. This sequence of two transitions is known as the process of vacuum polarization (figure 1(a)). Hence the vacuum in QFT is not an empty space; it is filled by virtual particle–antiparticle pairs.

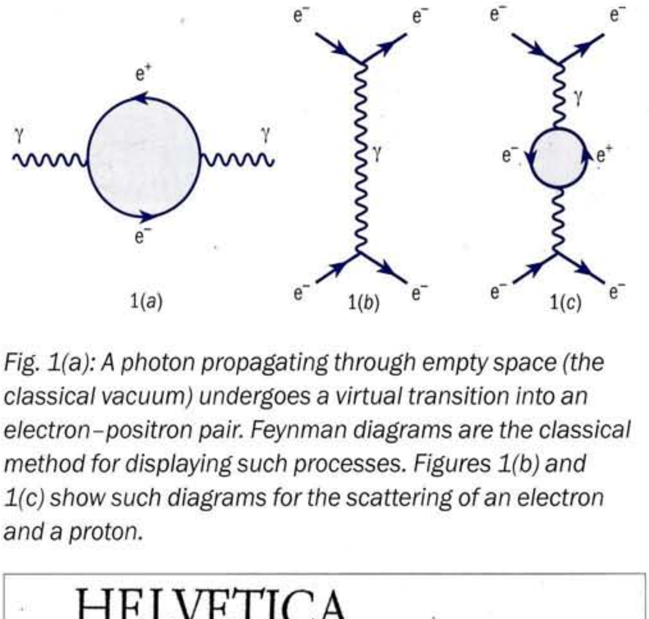
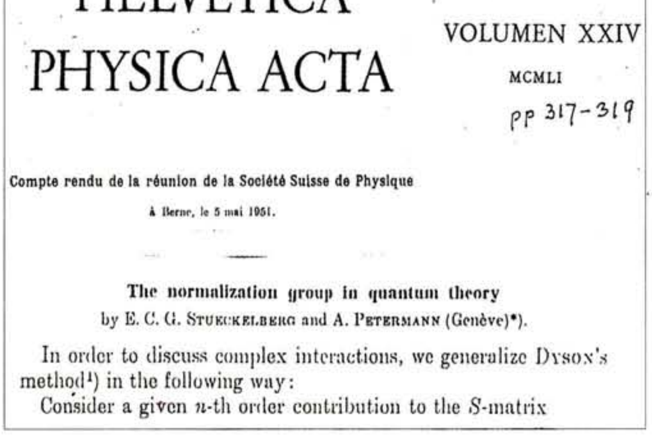


Fig. 1(a): A photon propagating through empty space (the classical vacuum) undergoes a virtual transition into an electron–positron pair. Feynman diagrams are the classical method for displaying such processes. Figures 1(b) and 1(c) show such diagrams for the scattering of an electron and a proton.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Compte rendu de la réunion de la Société Suisse de Physique

à Berne, le 5 mai 1951.

The normalization group in quantum theory

by E. C. G. Stueckelberg and A. Petermann (Genève)*).

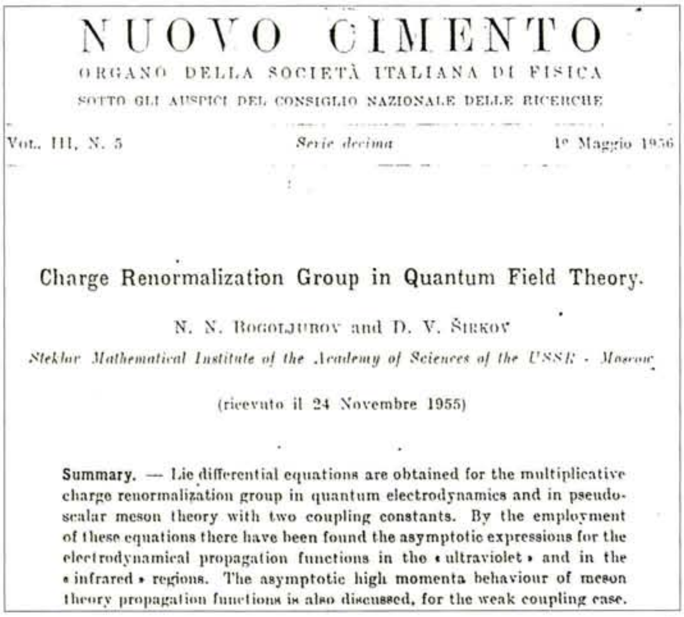
In order to discuss complex interactions, we generalize Dyson's method[1]) in the following way:

Consider a given n-th order contribution to the S-matrix

Fig. 2: This groundbreaking two-page note by Ernest Stückelberg and André Petermann in 1951, entitled "The normalization group in quantum theory", went unnoticed.

Another example of vacuum polarization is the electromagnetic interaction between two electric charges (e.g. between two electrons, or between a proton and an electron). In QFT, rather than a Coulomb force described by a potential, the interaction corresponds to an exchange of virtual photons, which, in turn, propagate in space-time accompanied by virtual electron–positron pairs (figure 1(c)). The theory of the interaction of quantum fields of radiation (photons) and of quantum Dirac fields (electrons and positrons) formulated in the early 1930s is known as quantum electrodynamics.

QFT calculation usually results in a series of terms, each of which represents the contribution of different vacuum-polarization mechanisms (illustrated by Feynman diagrams). Unfortunately, most of these terms turn out to be infinite. For example, electron–proton scattering, as well as Feynman diagram 1(b) (Møller scattering), also includes radiative corrections (figure 1(c)). This last contribution is infinite, owing to a divergence ▷



NUOVO CIMENTO

ORGANO DELLA SOCIETÀ ITALIANA DI FISICA

SOTTO GLI AUSPICI DEL CONSIGLIO NAZIONALE DELLE RICERCHE

Vol. III, N. 5 — *Serie decima* — 1° Maggio 1956

Charge Renormalization Group in Quantum Field Theory.

N. N. Bogoljubov and D. V. Širkov

Steklov Mathematical Institute of the Academy of Sciences of the USSR - Moscow

(ricevuto il 24 Novembre 1955)

Summary. — Lie differential equations are obtained for the multiplicative charge renormalization group in quantum electrodynamics and in pseudo-scalar meson theory with two coupling constants. By the employment of these equations there have been found the asymptotic expressions for the electrodynamical propagation functions in the « ultraviolet » and in the « infrared » regions. The asymptotic high momenta behaviour of meson theory propagation functions is also discussed, for the weak coupling case.

Fig. 3: The term "Renormalization Group" was first introducedIn pioneering papers by Nicolai Bogoliubov and Dmitry Shirkov in the mid-1950s.

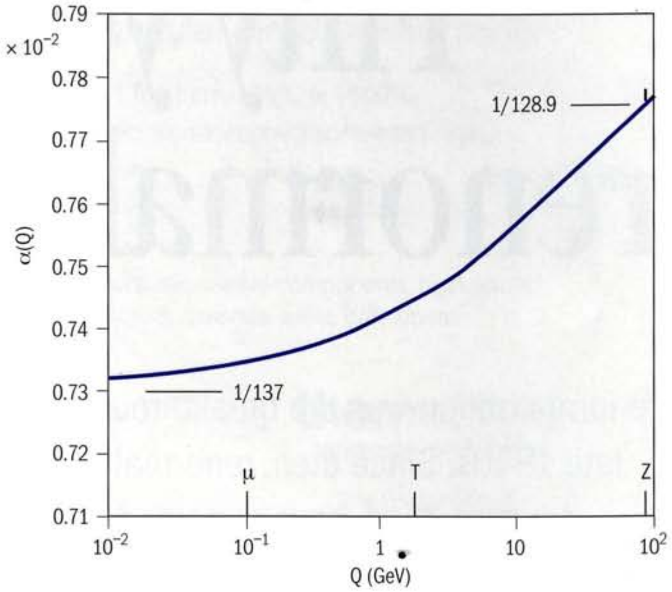


Fig. 4: Momentum transfer evolution of QED effective electron charge squared. The monotonically rising theoretical curve is confronted with precise measurements at the Z mass at CERN's LEP electron–positron collider.

of the integral in the low wavelength/high-energy region of possible momentum values of the virtual electron–positron pair. One such infinity is the analogue of the well known infinite self-energy of the electron in classical electrodynamics.

When theorists met this problem in the 1930s, they were puzzled – the first QED approximation (e.g. for Compton scattering) produces a reasonable result (the Klein–Nishina–Tamm formula), while the second, involving more intricate vacuum-polarization effects, yields an infinite contribution.

Renormalization is discovered

The puzzle was resolved in the late 1940s, mainly by Bethe, Feynman, Schwinger and Dyson. These famous theoreticians were able to show that all infinite contributions can be grouped into a few mathematical combinations, Z_i (in QED, $i = 1,2$), that correspond to a change of normalization of quantum fields, ultimately resulting in a redefinition ("renormalization") of masses and coupling constants. Physically, this effect is a close analogue of a classical "dressing process" for a particle interacting with a surrounding medium.

The most important feature of renormalization is that the calculation of physical quantities gives finite functions of new "renormalized" couplings (such as electron charge) and masses, all infinities being swallowed by the Z factors of the renormalization redefinition. The "bare" values of mass and electric charge do not appear in the physical expression. At the same time the renormalized parameters should be related to the physical ones, measured experimentally.

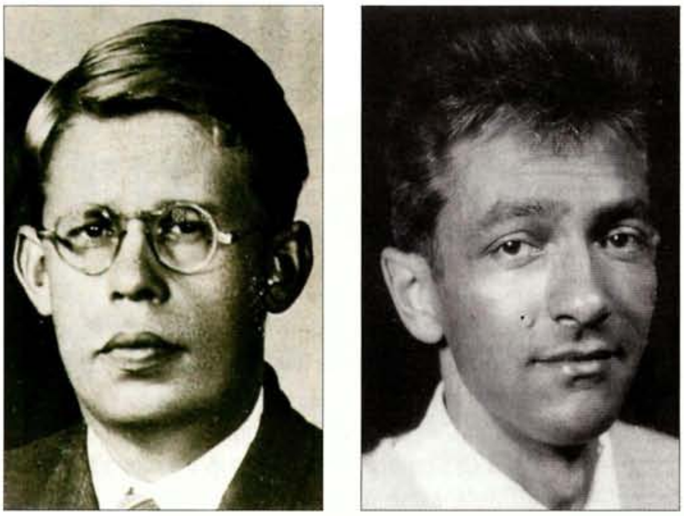
When suitable renormalized quantum electrodynamics calculations gave results that were in precise agreement with experiment (e.g. the anomalous magnetic moment of the electron, where agreement is of the order of 1 part in 10 billion), it was clear that renormalization is a key prerequisite for a theory to give useful results.

Once the field theory infinities have been suitably excluded, the resultant finite parameters have the arbitrariness that corresponds to the possibility of various experimental measurements. For example, the electric charge of the electron measured at the Z mass (at CERN's LEP electron–positron collider) yields the fine structure constant α as 1/128.9 (the value used in the theoretical analysis of LEP events), rather than the famous Millikan value 1/137. However, the theoretical expressions for physical quantities, like observed cross-sections, should be the same, invariant with respect to renormalization transformations equivalent to the transition from one α value to the other. In the hands of astute researchers, this invariance with respect to arbitrariness has been developed into one of the most powerful techniques of mathematical physics. (For a more technically detailed historical overview, see Shirkov 1993.)

The impressive story of an elegant mathematical method that is now widely used in various fields of theoretical and mathematical physics started just half a century ago. The first published "signal" – a two-page note by Ernest Stückelberg and André Petermann (1951), entitled "The normalization group in quantum theory" (figure 2), remained unnoticed, even by QFT experts.

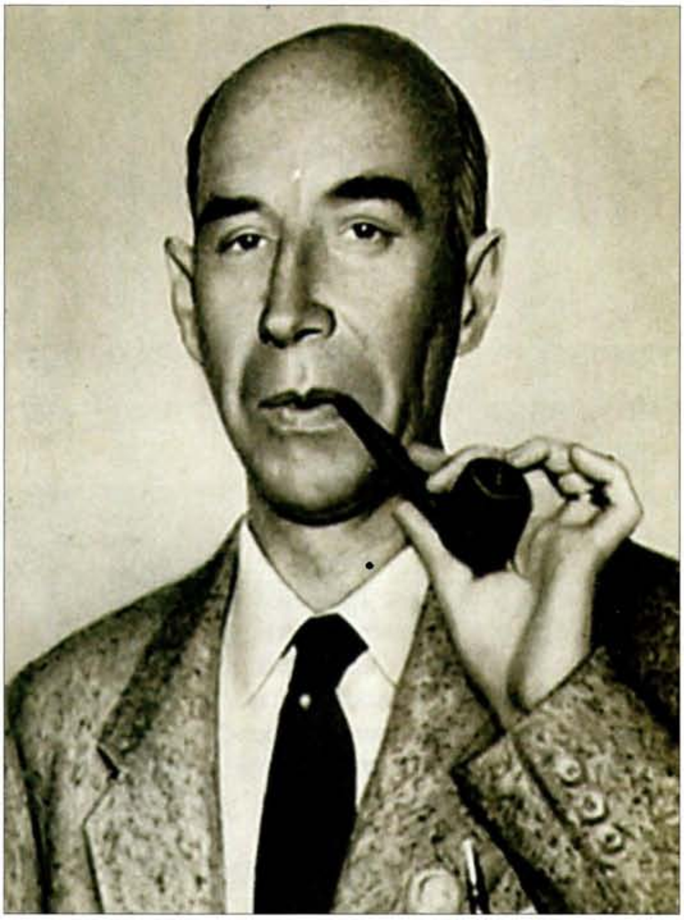
When renormalized, quantum electrodynamics calculations gave results in precision agreement with experiment, it was clear that renormalization is a vital prerequisite for a theory to give useful results.

However, from the mid-1950s the Renormalization Group Method to improve approximate solutions to QFT equations became a powerful tool for investigating singular behaviour in both the ultraviolet (higher



Nicolai Bolgoliubov (left) and André Petermann (right).

Group photo at the 1959 high-energy physics "Rochester" conference in Kiev. Left to right: Stanley Mandelstam (half obscured); Murray Gell-Mann; Francis Low; Harry Lehmann; and Dimitry Shirkov.



Ernest C G Stückelberg.

energy) and infrared (lower energy) limits.

Later, this method was transferred from QFT to quantum statistics for the analysis of phase transitions and then to other fields of theoretical and mathematical physics.

In their next major article (Stückelberg & Petermann1953), the same authors gave a clearer formulation of their discovery. They distinctly stated that, in QFT, finite renormalization transformations form a continuous group – the Lie group – for which differential Lie equations hold. Unfortunately, the paper was published in French, a language not very popular among theorists at that time. In any case, it was not mentioned in Murray Gell-Mann and Francis Low's important paper of 1954.

A more complete and transparent picture appeared in 1955–1956 with papers by Nicolai Bogoliubov and Dmitry Shirkov. In two short Russian-language notes (Bogoliubov & Shirkov 1955a), these authors established a connection between the work of Stückelberg and Petermann and that of Gell-Mann and Low, and they devised a simple algorithm, the Renormalization Group Method (RGM – using differential group equations and the famous beta-function) for practical analysis of ultraviolet and infrared asymptotics. These results were soon published in English (Bogoliubov & Shirkov 1956a, 1956b) and then included in a special chapter of a monograph (Bogoliubov & Shirkov 1959), and from that time the RGM became an indispensable tool in the QFT analysis of asymptotic behaviour.

It was in these papers that the term "Renormalization Group" was first introduced (figure 3), as well as the central notion of the RGM algorithm – an invariant (or effective, or running) coupling. In QED, this function is just a Fourier transform of the effective electron charge squared, $e^2(r)$, first introduced by Dirac (1934).

The physical picture qualitatively corresponds to the classical electric charge, Q, inserted into polarizable media, such as electrolytes. At a distance r from the charge, due to polarization of the medium, its Coulomb field will depend on a function Q(r) – the effective charge – instead of a fixed quantity, Q. In QED, polarization is produced by vacuum quantum fluctuations. Figure 4 shows the momentum transfer evolution of QED effective coupling ($\alpha = e^2/hc$).

Applications in QFT

The very first applications of the RGM included the infrared and ultraviolet asymptotic analysis as well as the resolution (Bogoliubov & Shirkov 1955b) of the "ghost-problem" for renormalizable local QFT models.

The most important physical result obtained via RGM was the theoretical discovery (Gross & Wilczek 1973; Politzer 1973) of the "asymptotic freedom" of non-Abelian vector models. In contradistinction with QED, here the vacuum polarization effect has an opposite sign owing to fluctuations of non-Abelian vector mesons, such as gluons. This explained quantitatively why quarks interacted less ▷

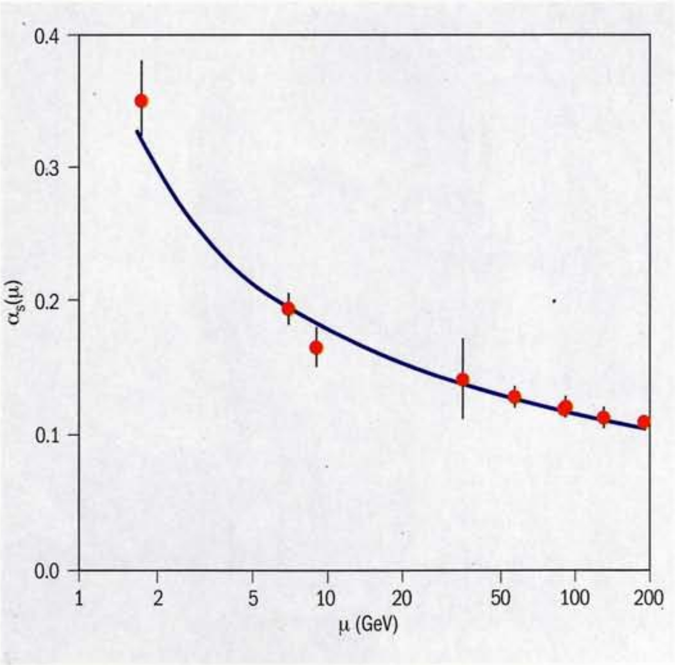


Fig. 5: Renormalization in action – the quantitative correspondence between theoretical curves for effective QCD coupling squared, $\alpha_s(Q^2)$, and data (taken from the recent Particle Data Group review).

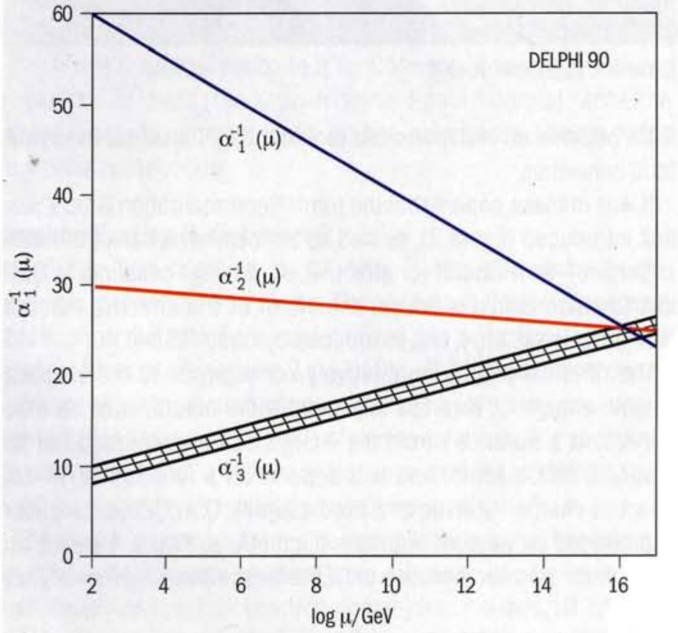


Fig. 6: Early results from CERN's LEP electron–positron collider showed how varying (running) coupling constants support the idea of the Grand Unification of strong and electromagnetic and weak interactions.

at smaller distances, and it became a cornerstone of the theoretical QFT now known as Quantum Chromodynamics (QCD; figure 5).

Another illustration, this time more speculative, is the so-called "chart of interaction" (figure 6) that gave rise to the idea of the Grand Unification of strong and electroweak interactions.

At the beginning of the 1970s, Kenneth Wilson (1971) devised a specific version of the RG formalism for statistical systems. It was based on Kadanoff's idea of "blocking"; more specifically, averaging over a small part of a big system. Mathematically, the set of blocking operations forms a discrete semigroup, different from that of QFT. The Wilson group was then used for the calculation of critical indices in phase transitions. As well as critical phenomena (in the 1970s and 1980s), it was applied to polymers, percolation, non-coherent radiation transfer, dynamical chaos and some other problems. A rather transparent motivation of Wilson's RG facilitated this expansion. Kenneth Wilson was awarded the 1982 Nobel Prize for this work.

On the other hand, in the 1980s a more simple and general formulation of the QFT renormalization group was found (Shirkov 1982, 1984). This relates the RG symmetry to a widely known notion of mathematical physics – self-similarity. Here, the RG symmetry appears in the role of symmetry of a particular solution with respect to its reparameterization transformation. It can be treated as a functional generalization of self-similarity – functional similarity.

Later, this formulation was successfully applied to some boundary value problems of mathematical physics, such as to the problem of a self-focusing laser beam in nonlinear media (Kovalev & Shirkov 1997). Here, the RG-type symmetry solution is described by a multiparametric group, and it enables the two-dimensional structure of the solution singularity to be studied.

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D V Shirkov, *honorary director of the Bogoliubov Laboratory of Theoretical Physics, JINR, Dubna.*

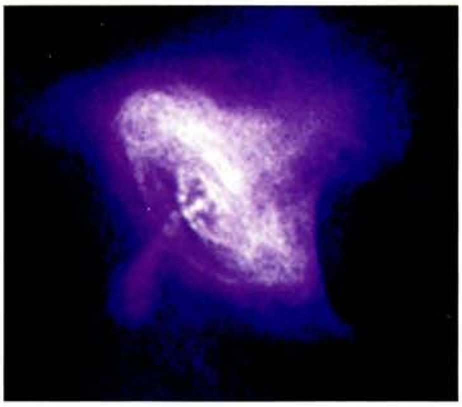
Astronomers benefit from particle physics detectors

A new kind of X-ray polarimeter giving greatly improved sensitivity and based on methods developed for particle physics gives astronomers a new handle on X-ray measurement.

In astronomy there are basically four types of observation that can be made using electromagnetic radiation (photons): measuring the photon direction (imaging), measuring their energy and frequency (spectroscopy), measuring their polarization (polarimetry) and counting the numbers of photons (photometry). These techniques provide complementary information and so are vital for exploring different wavelengths of radiation.

So far, astronomers have not been able to detect efficiently the polarization of photons at X-ray wavelengths, but this should be changed with a new polarimeter for space-borne observations that has been developed in Rome CNR and Pisa INFN by two teams led by Enrico Costa and Ronaldo Bellazzini respectively (Cash 2001).

X-ray astronomy has revealed some of the most violent and compact spots in the universe, such as the surfaces of pulsars, close orbits around giant black holes and the blast waves of supernova explosions. The current flagship of X-ray astronomy is NASA's Chandra observatory (see "http://chandra.harvard.edu").



An X-ray image of the centre of the Crab nebula taken by the Chandra X-ray Observatory in space. In the centre of the nebula is a bubble of highly intense, polarized synchrotron radiation formed by high-energy particles flung from the pulsar and trapped in the surrounding magnetic field. Wrapped round the central pulsar is a torus of synchrotron radiation, and jets of radiation appear to emerge from the poles of the pulsar.

By making efficient use of the few photons emitted by discs around black holes and other objects, X-ray astronomers have successfully applied photometry, imaging and spectroscopy to these hot, energetic and often variable sources. Polarimetry has been largely ignored at X-ray wavelengths because of the inefficiency of existing instruments. Yet such a technique could provide a direct picture of the state of matter in extreme magnetic and gravitational fields, and it has the potential to resolve the internal structures of compact sources that would otherwise remain inaccessible. The new X-ray polarimeter, which was developed by the teams in Rome and Pisa, promises to revolutionize space-based observations.

Classic measurements

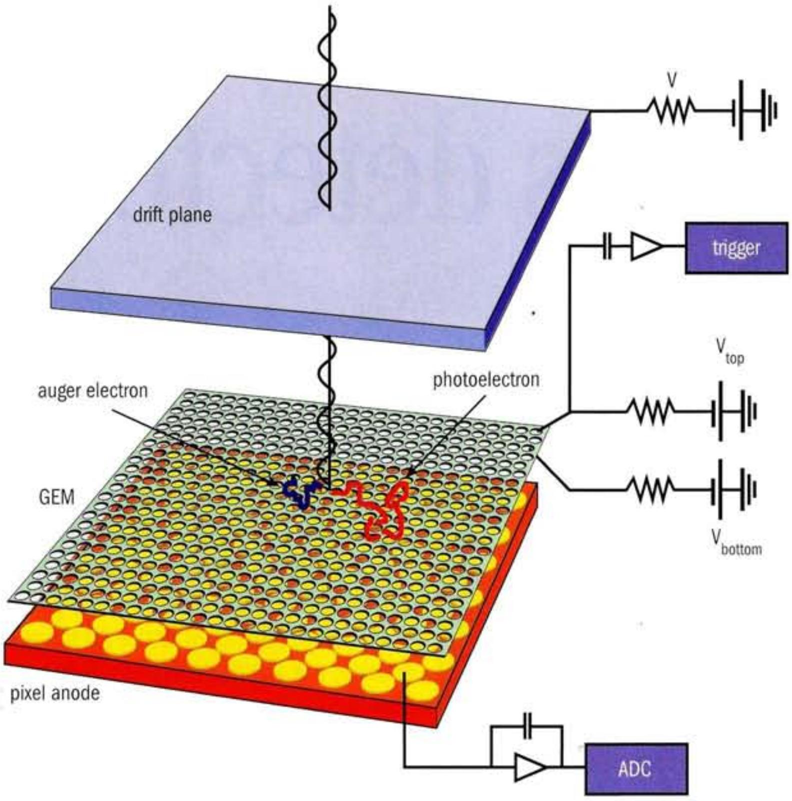
The first and only generally-accepted measurement of polarized X-rays from an astronomical object dates from more than a quarter of a century ago when a Bragg crystal polarimeter in orbit around the Earth was used to observe the Crab nebula (Weisskopf *et al.* 1976). This is a remnant of a supernova and is unusual because it has a bright pulsar owing to a neutron star at its core. Spinning at about 30 times per second, the intense magnetic field of this star leaves an indelible imprint on high-energy particles and X-rays.

High-energy electrons that are forced to follow a curved path by a magnetic field emit synchrotron radiation as they change direction. The vibrating electric and magnetic fields of the X-rays are characterized by a polarization angle, which describes the extent to which the fields in the individual photons line up. Synchrotron emission is the source of the polarization detected in the Crab nebula. Being able to measure the polarization as a function of its position across the Crab nebula would reveal a much better picture of the geometry of the magnetic field in the nebula and its central pulsar.

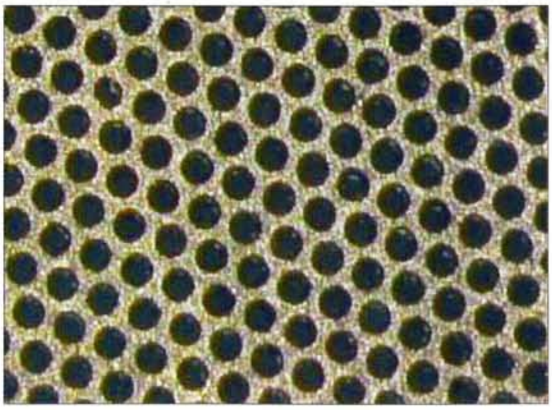
There has been no unambiguous detection of X-ray polarization from a celestial source since the Crab discovery – all other sources are too faint and/or not sufficiently polarized. To capture the polarization of these faint sources requires a device capable of measuring the polarization angle of every photon collected by an X-ray telescope.

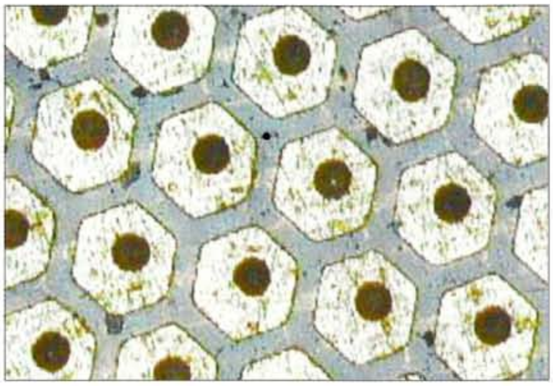
Italian device

The new instrument developed by the Italian teams functions mainly as a photon-counting detector, its overall architecture being similar to a radiation Geiger counter or a proportional counter used in particle physics. The main difference is that traditional position-sensitive X-ray gas detectors typically see only the centroid of the charge cloud produced by the photoelectron, the extent of which is the ultimate limit of the space resolution – a sort of noise to be kept as small as possible. The new concept reverses this approach, trying to resolve the track to measure the interaction point and the prime direction of the photoelectron. ▷



The micropattern gas detector for an X-ray polarimeter. The photon is absorbed at some point in the drift gap. The photoelectron track is drifted by the electric field to the gas electron multiplier (GEM). This device is made of a thin (50 μm) polyimide foil perforated by many microscopic holes, where a large electric field provides charge amplification. Finally the charge is collected by the 200 μm read-out pixels, each connected to an independent electronic chain. On receiving a trigger from the GEM, all of the signals are converted from analogue to digital, so that the image of the track is projected onto the detector plane.





Microscope picture (top) of the the gas electron multiplier (GEM) microstructure used in an X-ray polarimeter and its pixelized read-out (bottom).

The direction of emission of the photoelectron is a very sensitive indicator of the polarization of the parent photon. The motion of the electron is driven by the direction of the electromagnetic field in the original photon, thereby recording the linear polarization of the X-ray. The polarimeter then has to measure not only the presence of the electron, but also the microscopic path that it has taken.

For the first time, photoelectrons of only a few kilo-electronvolts (2–10) are reconstructed not as an indistinct blob of charge but as real tracks. From the detailed study of their momenta it is possible to determine with high efficiency the direction of emission of the photoelectron, which represents the "memory" of the polarization of the incident photon.

When enough events have been detected, the polarization of the emitting source will have been measured. This device makes maximal use of the available information and, when placed at the focus of a large X-ray telescope in orbit, will be able to detect as little as 1% polarization in sources a thousandth of the intensity of the Crab nebula. This will open a new window on the geometry of X-ray-emitting sources.

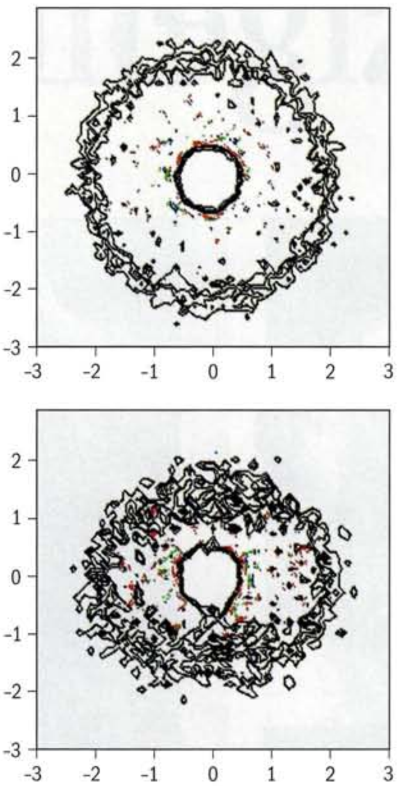
The instrument used to measure the photoelectron distribution uses micropattern electrode structures of the type developed for particle physics studies (*CERN Courier* March p14). Specifically, the techniques used are the gas electron multiplier (GEM) introduced by Fabio Sauli at CERN in 1996, in which micropores in a thin foil provide a strong field for electron amplification, and a pixel read-out structure using advanced multilayer PCB technology as a collecting anode. The new instrument, being truly two-dimensional (pixel), reveals any polarization direction without having to rotate the detector. The thin GEM foils and the thick film pixel boards used are manufactured at CERN.

Polarizing mechanisms

Synchrotron radiation is not the only polarizing phenomenon in space; equally important is X-ray scattering. When an X-ray bounces off an electron, as well as losing (or gaining) energy and thereby changing its wavelength, the emerging radiation is also linearly polarized, with its electric field perpendicular to the plane that contains both the incident and the scattered photons. The degree of polarization depends on the angle through which the X-ray scattered, reaching 100% for a deflection of 90°.

This effect can be used to determine the basic geometry of a number of compact X-ray sources.

For a start, the X-ray-emitting regions of active galactic nuclei and quasars demand a closer look. The hot gas swirling into the giant black hole that powers these sources emits copious X-rays through both thermal and non-thermal processes. Narrow jets of particles travelling very close to the speed of light can form by means that are



Distributions of the centres of gravity of photoelectron tracks relative to the reconstructed impact points for unpolarized (top) and 100% polarized (bottom) X-rays. No preference in the track direction results in a circular symmetric distribution for unpolarized radiation. Preferential emission in the direction of polarization results in a strongly asymmetric distribution for fully polarized radiation.

only partially understood. The X-ray spectrum that emerges is complex, featuring emission from several parts of the source (Mushotzky, Done, & Pounds 1993). Radiation passing close to the black hole will be curved and its polarization direction twisted. Furthermore, radiation from one part of the source can scatter off another, creating more features in the spectrum.

The measurement of polarization as a function of the energy of the X-rays could reveal the history of the scattered radiation and provide a unique test of the physics of these fascinating objects. Significant improvements in observing power usually lead to important new discoveries.

These new precision polarimeters could detect polarization in unexpected places – maybe from the surfaces of thermal neutron stars, or even from interstellar shocks that arise when high-speed plasma collides with quieter regions of cooler gas.

Ronaldo Bellazzini, *INFN Pisa*

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Enrico Fermi: genius

This year marks the centenary of the birth of Enrico Fermi, one of the giants of 20th-century science, and one of the last physicists to be both an accomplished experimentalist and an influential theorist. Here, *Gianni Battimelli* of the University of Rome "La Sapienza" traces the life of a genius.

Enrico Fermi was born on 29 September 1901 in Rome to a family with no scientific traditions. His passion for natural sciences, and in particular for physics, was stimulated and guided in his school years by an engineer and family friend, Adolph Amidei, who recognized Fermi's exceptional intellectual abilities and suggested admission to Pisa's Scuola Normale Superiore.

After finishing high-school studies in Rome, in 1918 Fermi progressed to the prestigious Pisa Institute, after producing for the admission exam an essay on the characteristics of the propagation of sound, the authenticity of which the commissioners initially refused to believe.

Studies at Pisa did not pose any particular difficulties for the young Fermi, despite his having to be largely self-taught using material in foreign languages because nothing existed at the time in Italian on the new physics emerging around relativity and quantum theory. In those years in Italy, these new theories were absent from university teaching, and only mathematicians like Tullio Levi-Civita had the knowledge and insight to see their implications.

Working alone, between 1919 and 1922, Fermi built up a solid competence in relativity, statistical mechanics and the applications of quantum theory to such a degree that by 1920 the institute director, Luigi Puccianti, invited him to establish a series of seminars on quantum physics.

First published work

Even before taking any formal examinations, Fermi published his first important scientific work – a contribution to the theory of general relativity in which he introduced a particular system of coordinates that went on to become standard as Fermi coordinates – the beginning of a long series of scientific contributions and concepts associated with his name.

At Pisa, Fermi strengthened a friendship with Franco Rasetti and maintained scientific contact with his former high-school companion, Enrico Persico. In parallel with his outstanding ability in theoretical physics, Fermi developed a genuine feeling for experimental investigation, acquiring with Rasetti in the institute's laboratory, which was put at their disposition by Puccianti, an excellent acquaintance with the techniques of X-ray diffraction. It was on this subject that Fermi carried out work for his bachelor dissertation, which he eventually presented in July 1922.

Fermi's group discovered the radioactivity induced by neutrons, instead of the alpha particles used in the Paris experiments.

Above left: the young Enrico Fermi. ... 1931 Nuclear Physics Congress. (A... Sapienza.) Above right: In front of t... Oscar D'Agostino, Emilio Segrè, Ed... taken by Bruno Pontecorvo. (Archiv... Below right: Enrico Fermi (left and...

After his bachelor's work, Fermi returned to Rome where he came in contact with Physics Institute director Orso Mario Corbino. Corbino succeeded in obtaining a scholarship for Fermi, which Fermi then used to finance a six-month stay in 1923 at Max Born's school in Göttingen. Although this school probably had at the time the most progressive ideas towards the final formulation of quantum mechanics, Fermi did not find his stay particularly comfortable. The school's excessive formal theoretical hypotheses, devoid of physical meaning, around which Born, Heisenberg, Jordan and Pauli were work-

s and giant of science

Centenary programme

In Italy the Fermi centenary is being marked by a series of meetings and events:
20 March – 28 April: exhibition on Fermi and Italian physics in Rome at the Ministry for the University and Research
2 July: Fermi, Master and Teacher, organized by the Italian Physical Society, for the opening of the 2001 courses of the Scuola Internazionale di Fisica "Enrico Fermi", Varenna (Como)
29 September: opening of an exhibition, Enrico Fermi e l,universo della Fisica, in Rome's Teatro dei Dioscuri
29 September – 2 October: an international meeting, Enrico Fermi and the Universe of Physics, in Rome
3–6 October: an international meeting, Fermi and Astrophysics, at the International Center for Relativistic Astrophysics (ICRA), Pescara
18–20 October: an international meeting, Enrico Fermi and Modern Physics, organized by the Scuola Normale Superiore, Pisa, and Instituto Nazionale di Fisica Nucleare, Pisa
18–28 October: an exhibition, Enrico Fermi. Immagini e documenti inediti, organized by the Associazione per la diffusione della cultura scientifica "La Limonaia", Pisa University's Department of Physics, the town and local authorities, at the Limonaia di Palazzo Ruschi
22–23 October: a meeting, Enrico Fermi e l'energia nucleare, organized by Pisa University
In November: a meeting, Fermi e la meccanica statistica, organized by Pisa University's Department of Physics.
In the US:
29 September: a Fermi centenary symposium at the University of Chicago.

o Fermi. Centre: Niels Bohr and Enrico Fermi on Rome's via Appia during the gress. (Archivio Amaldi, Dipartimento di Fisica, Università di Roma La ront of the Institute of Physics in Rome's via Panisperna in 1934 (left to right), egrè, Edoardo Amaldi, Franco Rasetti and Enrico Fermi . This photograph was . (Archivio Amaldi, Dipartimento di Fisica, Università di Roma La Sapienza.) eft and Arnold Sommerfeld.

ing, were not to his taste, and he preferred to work alone on some problems of analytical mechanics and statistical mechanics.

More intellectually stimulating, and fertile for scientific results, was Fermi's second foreign visit one year later, thanks to a Rockefeller Foundation scholarship. From September to December 1924, Fermi worked at Leiden, at the institute directed by Paul Ehrenfest, where he found a much more congenial scientific atmosphere.

Between 1923 and 1925, Fermi published important contributions to quantum theory that culminated at the beginning of 1926 in the formulation of the antisymmetric statistics that are now universally known under the name Fermi-Dirac. In this fundamental work, Fermi took to their conclusion ideas that he had began to develop in Leiden on the statistical mechanics of an identical particle system, introducing the selection rule (Exclusion Principle) introduced by Pauli at the beginning of 1925, so as to construct a satisfactory theory of the behaviour of particles henceforth called fermions.

The far-sighted initiatives of Orso Mario Corbino for developing Italian physics bore their first fruits. In 1926 Corbino established a competitive chair of theoretical physics in Rome (the first of its kind in Italy), as a result of which Fermi gained a professorship at the institute in the via Panisperna at the age of 25.

The following September a major international physics convention took place in Como for a Volta commemoration.

It was during this convention that a demonstration, which was ▷

carried out by Sommerfeld and others, of the effectiveness of the new quantum statistics for the understanding of hitherto insoluble problems, ensured Fermi's international reputation.

At the institute on the via Panisperna, a new collaboration began to take shape around Fermi and Rasetti at the beginning of 1927, as Corbino selected a group of promising young people. These included Edoardo Amaldi and Emilio Segrè.

By the end of the 1920s the "via Panisperna boys" switched from studying atomic and molecular spectroscopy to investigating the properties of the atomic nucleus - described by Corbino in a celebrated 1929 speech as the new frontier of physics.

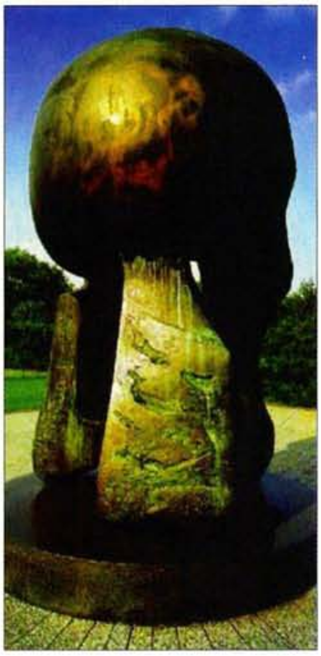
This new line of research reflected Fermi's growing scientific stature. In 1929 he was the only physicist designated to join the new Royal Academy of Italy. With this, and being secretary of the national physics research committee, he was able to steer funding and resources towards the new fields of research.

Honouring a name

On 16 November 1954, on hearing that Enrico Fermi's health had deteriorated, President Eisenhower and the US Atomic Energy Commission gave him a special award for a lifetime of accomplishments in physics and, in particular, for his role in the development of atomic energy. Fermi died soon after, on 29 November.

The Enrico Fermi US Presidential Award was subsequently established in 1956 to perpetuate the memory of Fermi's brilliance as a scientist and to recognize others of his kind – inspiring others by his example.

Fermi's memory is also perpetuated in the US through the Enrico Fermi Institute, as the department of the University of Chicago where he used to work is now known, and the Fermi National Accelerator Laboratory (Fermilab), which was named in his honour in 1974.



Henry Moore's sculpture Nuclear Energy *(left) bears the caption: "On December 2, 1942, man achieved here the first self-sustaining chain reaction and thereby initiated the controlled release of nuclear energy." Under the leadership of Enrico Fermi, Chicago Pile No. 1 (CP-1) was constructed in a makeshift laboratory under the grandstands of Stagg Field Stadium at The University of Chicago. The sculpture was unveiled at 3.36 p.m. on 2 December 1967, precisely a quarter of a century after the event that it commemorates.*

Nuclear summer

An important turning point was the first International Conference on Nuclear Physics, which was held in Rome in September 1931, and of which Fermi was both major organizer and scientific inspiration. Here, the main ongoing problems of nuclear physics were examined, which soon went on to be solved, notably in the "anno mirabile" of 1932 with the discovery of the neutron.

In the autumn of 1933, Fermi then added what is possibly his biggest contribution to physics - namely his milestone formulation of the theory of beta decay. In this formulation he took over the hypothesis of the neutrino, which had been postulated several years earlier by Pauli to maintain the validity of energy conservation in beta decay, and he used the idea that the proton and neutron are two different states of the same "fundamental object", adding the radically new hypothesis that the electron does not pre-exist in the expelled nucleus but is liberated, with the neutrino, in the decay process, in an analogous way to the emission of a quantum of light resulting from an atomic quantum jump.

The theory also fitted in with the new formalism developed by Dirac in his quantum theory of radiation. It is interesting to note that Fermi's work, which was initially sent to the *Nature* and was turned down because it was "too abstract and far from the physical reality", was published elsewhere.

In 1934, nuclear physics research at via Panisperna capitalized on Frederic Joliot and Irene Curie's discovery of artificial radioactivity. Fermi's group discovered the radioactivity that is induced by neutrons, instead of the alpha particles of the Paris experiments, and soon they revealed the special properties of slow neutrons.

Sudden departure

Meanwhile the political situation in Italy began to give worrying signs of deterioration. While the major foreign laboratories began to invest in the new accelerators - fundamental machines to produce sources of controlled and intense subnuclear "bullets" to bombard the nuclei - Fermi's attempts to obtain the necessary resources for an appropriately equipped national laboratory were not successful.

For a number of years, Fermi resisted numerous offers of posts in US universities. Then, in 1938, the promulgation of new racial laws threatened the Fermi family directly (Fermi's wife, Laura Capon, was Jewish), so he took the decision to leave the country.

The opportunity to emigrate came with Fermi being awarded the Nobel Prize for Physics for his work on artificial radioactivity and slow neutrons. In December 1938 he received the prize in Stockholm and from there embarked with his family for the US and Columbia University in New York. Officially, he went to the US to deliver a series of lectures, but his friends knew that he had no intention of returning.

Wartime involvement

The discovery of nuclear fission and the outbreak of war dramatically highlighted the possible use of nuclear energy for military purposes. With his experience in neutron physics, Fermi was the natural leader for a group to carry out the first phase of a plan that would eventually lead to the atomic bomb - the achievement of a sustained and controlled chain reaction.

The work, which was classified as a military secret, was carried out in the University of Chicago's Metallurgical Laboratory. In December 1942 the first controlled fission chain reaction was achieved in the reactor constructed under Fermi's direction. This led in turn to the Manhattan Project, in which Fermi had prominent roles, such as general adviser on theoretical issues, and finally as a member of the small group of scientists (with J Robert Oppenheimer, Ernest Lawrence and Arthur Compton) that was charged with expressing technical opinions on the use of the new nuclear weapon.

In August 1944, Fermi moved to the village-laboratory of Los Alamos for the final development of the bomb, and in July 1945 he was among those who witnessed the first nuclear explosion in the Alamogordo desert.

Return to the laboratory

At the end of the Second World War, Fermi returned to Chicago and resumed his research in fundamental physics, at a time when new subnuclear particles were being discovered and when the new quantum electrodynamics was soon to appear.

In those years he led an influential research group, and a good number of the students associated with the group later went on to win Nobel prizes. The group continues to provide scientific advice for the US government.

Fermi, as a member of the General Advisory Committee, was against development work for a thermonuclear device, but this line met considerable resistance from Edward Teller, who went on, with mathematician Stan Ulam, to carry out much of the necessary theoretical work.

In those years Fermi led an influential research group, and a good number of the students associated with the group later went on to win Nobel prizes.

In this new context, Fermi developed an interest in possibilities that were being opened up by electronic computers, and in the early 1950s, in collaboration with Ulam, he carried out fundamental and pioneering work in the computer simulation of nonlinear dynamics.

Fermi returned twice to Italy. In 1949 he participated in a conference on cosmic rays in Como, which was the continuation of a series held earlier in Rome and Milan. Five years later, at the 1954 summer school of the Italian Physical Society in Varenna, he gave a memorable course on pion and nucleon physics.

On return to Chicago from this trip, he underwent surgery for a malignant tumour of the stomach, but he survived only a few weeks, dying on 29 November 1954.

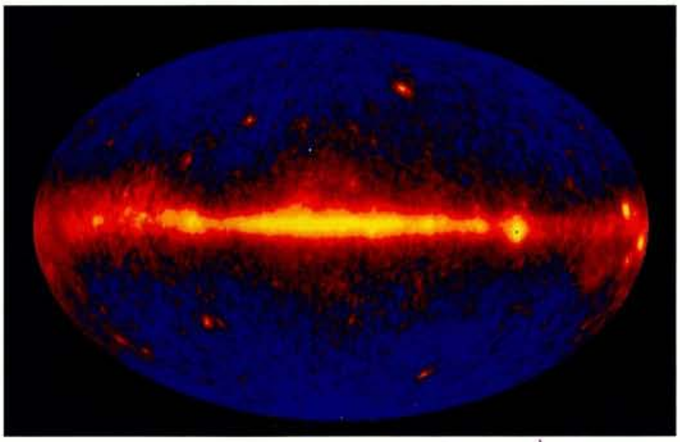
● This article was originally published in *INFN Notizie*, April 2001.

Gianni Battimelli, *Rome, "La Sapienza"*.

Gamma-ray telescopes take shape

Turning to unusual wavelengths, astronomers reveal new pictures of the universe. This article describes a major new gamma-ray window opening up soon in Southern Africa.

Now looming on the Namibian skyline is the High Energy Stereoscopic System (HESS) – a next-generation system of imaging atmospheric Cherenkov telescopes that is aimed at the study of cosmic gamma rays in the energy range from about 100 GeV to several TeV, with the goal of identifying the sources of the cosmic rays in our galaxy in particular, and of studying non-thermal particle populations in the universe in general.



Map of the gamma-ray sky in the 100 MeV energy range, produced by the EGRET detector aboard NASA's Compton Gamma Ray Observatory. The bright band coincides with the galactic plane.

Cosmic rays have played an important role in early particle physics, and they continue to provide the highest-energy particles available to physicists. Even after decades of cosmic-ray research, the sources and acceleration mechanisms of cosmic rays are still the subject of intense discussion. The dominant component of the cosmic radiation – charged atomic nuclei – cannot be used to pinpoint the accelerator sites directly, because, except for ultrahigh energies, the nuclei are deflected in the interstellar and intergalactic magnetic fields and their propagation resembles diffusion.

However, in almost all scenarios for cosmic-ray acceleration, reactions at or near the source result in the production of neutral secondary particles – gamma rays and neutrinos – which can be used to generate a genuine image of the sky at highest energies, and which can also be used to study the propagation of cosmic rays.

A brief history of gamma-ray astronomy

High-energy gamma-ray astronomy from space has a long history, via NASA's SAS 2 satellite, which was launched in November 1972, and the European COS-B satellite, which was launched in August 1975, culminating in results such as the gamma-ray sky map (see above) produced by the EGRET instrument on NASA's big Compton Gamma Ray Observatory.

This map illustrates the key features mentioned above – the bright gamma-ray continuum tracing the Milky Way results from cosmic rays interacting with interstellar gas. As the distribution of gamma rays follows the column density of gas closely, one concludes that cosmic rays pervade the Milky Way more or less uniformly.

Superimposed onto the continuum are well over 200 point sources, which is indicative of cosmic particle accelerators. About a third of these sources can be identified with known galactic and extragalactic objects, such as pulsars or quasars. The character of the remaining ones is open.

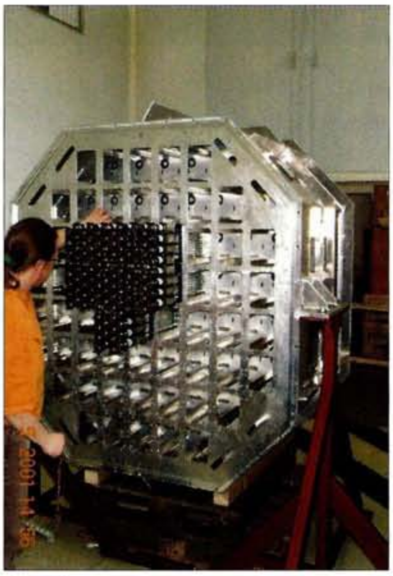
Owing to their small (less than a square metre) detection areas, combined with the steeply falling energy spectrum of gamma rays, satellite instruments are, however, limited in their energy range and cannot reach the TeV (10^{12} eV) or PeV (10^{15} eV) energy range relevant for the study of very-high-energy cosmic-ray sources. Only ground-based instruments can currently provide the required large detection areas.

Ground-based detectors

Many attempts to detect high-energy gamma rays with air shower arrays failed to provide convincing results. The breakthrough finally came with the imaging atmospheric Cherenkov telescopes, which were pioneered with the Whipple telescope in Arizona. These instruments see the air showers initialized by high-energy gamma rays using the Cherenkov radiation generated by the shower particles in the air. The intensity of the shower image provides a measure for the energy of the primary; the orientation of the image is used to determine the direction of the primary; and the shape of the image can be used to separate gamma-induced showers from the showers generated by nucleonic cosmic rays.

In 1989 the Whipple group succeeded in establishing the Crab ▷

nebula as a strong galactic source of TeV gamma rays, and then discovered two extragalactic sources – the active galactic nuclei Markarian 421 and 501. More recently, high-energy gamma-ray astronomy has attracted additional interest because it both permits novel investigations in observational cosmology and provides a means with which to search, via their annihilation radiation, for neutralino dark matter candidates accumulating in the centres of galaxies.



Top left: photomontage showing how the new HESS telescopes will look on their site in Namibia. Visible in the background is the Gamsberg, a table mountain about 130 km from Windhoek. Owing to its excellent observing conditions, the Gamsberg was once a candidate site for the European Southern Observatory telescopes. The HESS telescopes are located in the surrounding Khomas Highland, about 30 km from the mountain. Above left: the dish of the first HESS telescope under construction at Okahandja, about 100 km north of Windhoek. Above right: the body of the HESS camera, which will house 60 "drawers", each containing 16 photomultiplier tubes and the associated electronics. The back part of the camera contains the power supplies, the trigger logic and the processor for the data read-out. The camera has a diameter of about 1.6 m and an active field of view of 5°. It weighs about 800 kg and dissipates 4 kW.

Imaging techniques

The imaging atmospheric Cherenkov technique has progressed significantly since the days of the first Whipple telescope.

Stereoscopic observation of air showers by multiple telescopes, as was implemented in the five-telescope HEGRA system (the High Energy Gamma Ray Astronomy telescope in La Palma built by a German-Spanish-Armenian collaboration) and the fine-grained imaging achieved by the CAT telescope camera (Cherenkov Array at Themis, in the French Pyrenees), provide improved shower reconstruction and sensitivity.

The next-generation HESS telescopes build on these developments. They are designed and constructed by an international collaboration of Armenian, Czech, English, French, German, Irish, Namibian and South African researchers. The telescope system combines the stereoscopic imaging of air showers pioneered by the HEGRA telescope system, the fast trigger electronics used in the CAT telescope, and monitoring techniques developed for the Durham and Potchefstroom telescopes to provide an overall ten-fold increase in sensitivity over current instruments.

In Namibia

The HESS telescopes are located in the Khomas Highland of Namibia, near the Gamsberg, which was once considered as a site for the ESO optical telescopes and is renowned among astronomers for its excellent observing conditions. The location near the tropic of Capricorn provides an optimal view of sources in the central part of our galaxy and of the galactic centre region, in addition to the many extragalactic sources that should be discovered.

The mild climate allows the telescopes to be operated without protective enclosures. At 100 km from the capital of Namibia, Windhoek, access to the site is easy. In a vast plain, the site provides ample space for the future expansion of the system.

In its first stage, HESS will comprise four telescopes of the 12 m diameter class. These have a mirror area of 105 m^2 with a focal length of 15 m. The mirror is composed of 382 round mirror elements of 60 cm diameter. An alt-az (horizon-based co-ordinate system) mount allows objects to be tracked across the sky. Cherenkov shower images are viewed by a camera of 960 photomultiplier tubes, each subtending an angle of 0.16°.

The large field of view of the camera (5°) is optimal for the investigation of extended sources such as supernova remnants and allows extensive sky surveys. The photomultipler signals are sampled at a rate of 1 GHz, and they are digitized and read out if a minimum number of photomultipliers (three to five) show coincident signals of several photoelectrons.

The effective detection area of the HESS instrument is determined by the diameter of the Cherenkov light pool, and it varies between 70 000 m^2 at 100 GeV, up to almost 300 000 m^2 at TeV energies, to be compared with less than a square metre of satellite instruments. The directions of individual gamma rays can be reconstructed with 0.1° precision. One expects that strong gamma-ray point sources can be located with an error of a few arc-seconds.

Construction on the site began in August 2000 with the telescope foundations. The steel structures for the telescopes are built in Namibia. The mount of the first telescope was assembled in May, and work on the next telescope is in progress. In Europe, the cameras and the mirrors for the telescopes are being prepared for installation. The first telescope is expected to go into operation late in 2001, the next three up to 2003.

Together with major new Cherenkov telescope projects under construction in the US (VERITAS), in Australia (CANGAROO) and on the Canary Island of La Palma (MAGIC), HESS will provide excellent sky coverage at TeV energies.

It is a fitting acronym – Viktor Hess received the 1936 Nobel Prize for his discovery of cosmic rays.

Werner Hofmann, *MPI Heidelberg*.

STACEE in New Mexico

A novel gamma-ray telescope has recently been commissioned and is observing powerful sources of GeV/TeV gamma rays, such as active galactic nuclei. The Solar Tower Atmospheric Cherenkov Effect Experiment (STACEE) uses an array of heliostats (solar mirrors) at the National Solar Thermal Test Facility of Sandia National Laboratories in Albuquerque, New Mexico.

Aerial view of the New Mexico facility. The Cherenkov light collected by 64 heliostats in the array of 200 is concentrated onto photomultiplier tubes in the tower.

The heliostats are used to collect Cherenkov light from the shower of secondary particles produced by a high-energy gamma ray of galactic or extragalactic origin as it enters the atmosphere. The Cherenkov light collected by the heliostats is concentrated onto an array of photomultiplier tubes. STACEE uses many experimental techniques first developed for subatomic physics experiments. Observations in the gamma-ray energy range from 50 to 250 GeV are important for understanding many high-energy astrophysical objects, especially pulsars, supernova remnants and gamma-ray bursts.

STACEE is designed to study astrophysical sources of gamma radiation in this energy range, which has not yet been explored by previous imaging Cherenkov telescopes on the ground or by previous satellite experiments in space.

The STACEE collaboration consists of 16 scientists from seven institutes in Canada and the US.

The experiment has been built in stages, with each stage using more heliostats, and improved optics and electronics. In 1999, with half of the 64 heliostats and two cameras, STACEE observed the Crab nebula at an energy threshold unprecedented by other sampling detectors.

This year, with two-thirds of the heliostats, STACEE pointed to two BL Lacertae blazars, Markarian 421 and 501. During the period January to May, enhanced X-ray and TeV gamma-ray emission from Markarian 421 was reported. A significant signal from Markarian 421 has been observed and analysis of the Markarian 501 data is ongoing. The low-energy threshold allows extension of the gamma-ray spectrum of Markarian 421, thereby placing additional constraints on emission models during outburst.

AWARDS

European Physical Society awards

The High Energy Physics Board of the European Physical Society awarded the following prizes at the EPS High Energy Physics Conference in Budapest on 16 July:

The Gribov medal goes to **Steven Gubser** (Caltech) for "his outstanding work that has revealed a deep connection between gauge theories and gravitational interactions in the framework of string theories. This made it possible to compute and understand properties of a gauge theory in 3+1 dimensions from a gravitational theory in 4+1 dimensions."

The Young Physicist prize goes to **Arnulf Quadt** (Bonn) for "his outstanding contribution to the measurement of the F_2 structure function in deep inelastic scattering and extending its measurement to low values of momentum transfer and fractional momentum x".

The Outreach prize goes to **Christine Sutton** (Oxford) and **Erik Johansson** (Stockholm) for "their innovative use of electronic and printed media to bring high-energy physics to a wider public, including professional colleagues, students and schools, and in particular their collaboration developing computer interactive packages for educational master classes".

The distinguished HEP-EPS prize 2001 goes to **Donald Perkins** (Oxford) for "his outstanding contributions to neutrino physics and for implementing the use of neutrinos as a tool to elucidate the quark structure of the nucleon".

Jean Tran Thanh Van of Orsay has received a doctorate honoris causa from the Russian Academy of Sciences for his theoretical contributions, particularly his role in the development of the dual parton model, for his unique leadership in the organization of such series of international meetings as the Rencontres de Moriond (since 1966), Rencontres de Blois (since 1989) and Rencontres du Vietnam (since 1993), for his active role in editing and publishing science monographs, especially in the well known series "Basics of ...", and for his persistent efforts to establish close co-operation and good relations between scientists worldwide. The official ceremony was held in Moscow on 29 May following a conference, From the Smallest to Largest Distances, at Moscow's Institute for Theoretical and Experimental Physics (ITEP) on 24–26 May, which paid tribute to Tran Thanh Van.

Maiani recieves honorary doctorate

CERN director-general Luciano Maiani (centre) receives his honorary doctorate diploma from the President of the Slovak Academy of Sciences, Stefan Luby (right). The Italian Ambassador in Slovakia, Luca Del Balzo di Presenzano, is looking on (left).

As briefly mentioned in the July issue of CERN Courier (p 31), CERN director-general Luciano Maiani has been awarded an honorary doctorate by the Slovak Academy of Sciences in recognition of his outstanding contribution to the theory of elementary particles and for important contributions to the development of international scientific co-operation. Also at the award ceremony in Bratislava on 10 May was the Italian Ambassador in Slovakia, Luca Del Balzo di Presenzano, and representives of the Ministry of Foreign Affairs, the Ministry of Education, the Slovak-CERN Committee and the national scientific community. An audience with Slovakian President Rudolf Schuster completed the director-general's programme in Slovakia.

US President George W Bush has announced his intention to nominate **John H Marburger** as director of the Office of Science and Technology. Marburger is currently director of the US Department of Energy's Brookhaven National Laboratory and president of Brookhaven Science Associates. The position traditionally includes the directorship of the Office of Science and Technology Policy – a post that requires Senate confirmation.

SLAC professor **Charles Prescott** has been nominated as a member of the US National Academy of Sciences, the nation's most distinguished body of scientists. Prescott is known round the world for his leadership in electron-scattering experiments involving polarized beams of electrons.

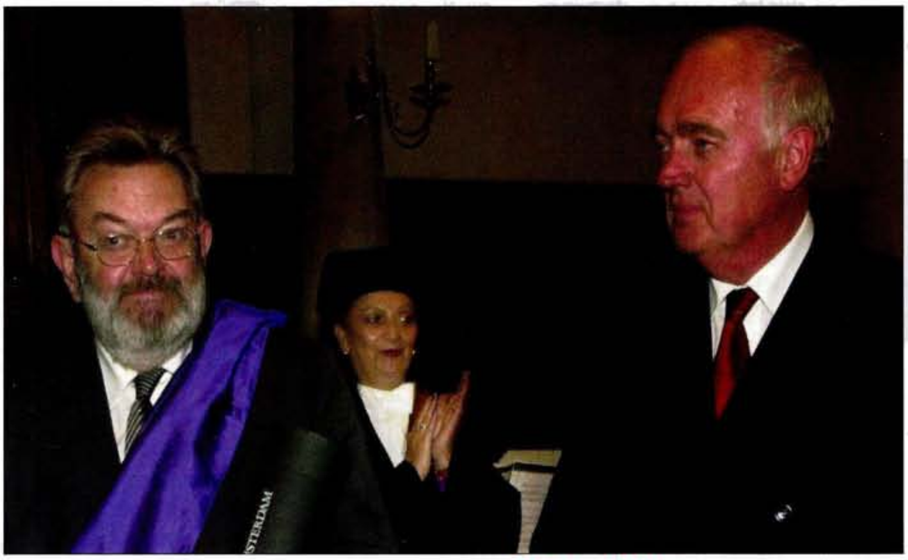
The Particle Accelerator Science and Technology Award of the Nuclear and Plasma Sciences Society of the Institute of Electrical and Electronics Engineers is shared between **John T Seeman** of the Stanford Linear Accelerator Center (SLAC) for his outstanding leadership of the accelerator physics of the design, construction and commissioning of the highly successful PEP II positron–electron asymmetric collider and **Lloyd M Young** of Los Alamos for his invention, development, and beamline operation of the resonantly coupled (radiofrequency quadrupole) structure and the methods used to tune it and other structures.

At the meeting of CERN's governing body, CERN Council, on 15 June, **Hermann Schunck** of Germany was elected vice-president of the Council for one year from 1 July.

Peter Kalmus of London's Queen Mary College was recently made a fellow of London's University College by the college provost, former CERN director-general Sir Chris Llewellyn Smith, and has been awarded a national UK OBE for "services to physics".

AWARDS

Steve Myers (left) and Albert Hofmann of CERN have been awarded the title of Doctor Honoris Causa by the University of Geneva in recognition of their services to accelerator physics and their essential contributions to the success of CERN's LEP electron-positron collider, which closed last year. After they supervised LEP commissioning in 1989, Steve turned to overall machine performance and operation, including the push to increase luminosity and energy. Albert is assured of a place in science history for the legendary precision measurements which showed how the operation of a storage ring could be influenced even by the Moon, rainfall and express trains. Both came to CERN in the early 1970s to join the team working on the pioneering Intersecting Storage Rings (ISR). They received their awards on 8 June from University of Geneva rector Maurice Bourquin, who is also President of CERN Council.



On 21 May this year, 1999 Physics Nobel prizewinner **Martinus Veltman** (left) was appointed honorary professor at the University of Amsterdam. Veltman is seen here with **Jaap Franse**, Rector Magnificus of the university. Veltman shared the 1999 prize with Gerard 't Hooft of Utrecht. (Photo Henk Thomas.)

Pomeranchuk prize

The Pomeranchuk prize for 2001 is awarded to **Lev Nikolaevich Lipatov** (St Petersburg) and **Tullio Regge** (Politecnico Torino).

The prize is awarded to Lipatov for outstanding contributions to theoretical physics, especially to strong interactions at high energy. Head of Theory at St Petersburg's Nuclear Physical Institute, Gatchina, Lipatov is a member of the Russian Academy of Science and for many years worked with V N Gribov. Their famous 1972 papers created the basis of a field-theory description of deep inelastic scattering and electron–positron annihilation – the Gribov–Lipatov evolution equations, – which led to the Gribov–Lipatov–Dokshitzer–Altarelli–Parisi equations.

Lipatov's seminal 1977 papers on the Pomeranchuk singularity in quantum chromodynamics opened the way to a quantitative understanding of strong interactions at high energy. He also contributed to the study of critical phenomena (the semiclassical Lipatov's approximation), the theory of tunnelling and the renormalon contribution to effective couplings.

The prize is awarded to Tullio Regge for outstanding contributions to particle physics and to classical and quantum gravity. In 1959–1960 he showed how an extension of ▷

Among the recipients of the prestigious 2001 American Physical Society Awards (December 2000, p41) was Richard Geller of Grenoble for his work on electron cyclotron resonance ion sources. He is seen here (right) with Director of Grenoble's Institute of Nuclear Sciences Joel Chauvin during an official municipal reception in Grenoble in his honour.

the partial wave decomposition of the scattering amplitude to complex momentum has a simple analytical structure. The results were extended by Gribov, Chew and Frautschi to relativistic quantum field theory. In 1958, I Ya Pomeranchuk formulated his theorem on the asymptotic equality of total cross-sections for particles and antiparticles at high energy. The exchange of a Regge pole with the quantum numbers of the vacuum was found to be in agreement with this theorem. Later, this vacuum-like Regge pole was called the Pomeron. Regge trajectories have become a standard tool in high-energy physics. Regge also suggested and developed an original and fruitful approach to general relativity, the Regge calculus. This considers a special lattice formulation of the theory (with the curvature concentrated on two-dimensional subspaces) instead of continuous space-time. It reveals an unexpected relation between the theory of gravity and the formalism of angular momentum. With De Alfaro, he wrote a monograph, *Potential Scattering*, which for decades was used by graduate students worldwide.

2002 nominations should reach pomeron @heron.itep.ru before 1 February 2002. For more information, see "http://face.itep.ru/ pomeranchuk.html".

Ralf Flaig (right) receives the 2000 Thesis prize of the DESY laboratory, Hamburg, for his work on new experimental methods for charge density determination from **Erich Lohrmann**, Chairman of the Board of Directors of the Association of Friends and Sponsors of DESY.

CERN legal counsel **Jean-Marie Dufour** (right) becomes a Chevalier of the French Légion d'Honneur. He is seen here receiving the esteemed award from French ambassador to the UN in Geneva and delegate to CERN Council **Philippe Petit**.

Achim Richter (left) of Darmstadt's Technical University has been awarded the Stern–Gerlach medal of the German Physical Society, its highest award for experimental physics, for his outstanding achievements in nuclear physics, including the discovery of "scissors mode" excitation. He is seen here with society president Dirk Basting at the prize ceremony.

MEETINGS

A major meeting, **Astronomy, Cosmology and Fundamental Physics**, will be held in Garching, Germany, on 4-7 March, 2002.

The well known connections between astronomy, cosmology and fundamental fhysics draw closer every day. Recent developments include the structures in the cosmic background radiation, evidence for an accelerating universe, searches for dark matter, evidence for neutrino oscillations, space experiments on fundamental physics and discoveries of extrasolar planets. The three European international organizations – the European Southern Observatory, CERN and the European Space Agency) – are thus involved in scientific endeavours and technologies that overlap considerably, and the importance of close communication and co-operation between them is clear.

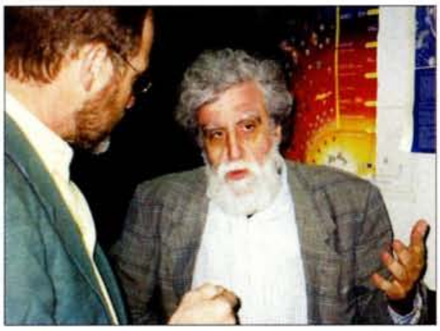
This joint symposium is the first to be co-organized and co-sponsored by all three. Topics will include scientific areas of interest to the communities of the three organizations: astronomy from ground and space; cosmology and astroparticle physics; and fundamental physics in a wider context. The event is meant to give a broad overview, and to highlight the contributions of the three organizations, their plans and the synergies between them. The programme will consist largely of invited reviews and discussion, but there will be some shorter contributed papers and posters.

More details and a registration form will be available at "http://www.eso.org/gen-fac/meetings/symp2002" or you can contact Christina Stoffer and Britt Sjoeberg, European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748, Garching bei Muenchen, Germany; e-mail "symp2002@eso.org"; fax +49 89 32006 480.

NuPECC has decided to update its December 1994 report, "Impact and applications of nuclear science". Three groups of experts have been formed to review the three selected topics: life science, energy, and atomic and materials science. Their reports will be presented and discussed at a workshop, **Nuclear Science: Impact, Applications, Interactions**, to be held in Dourdan near Paris, France, on 21–23 November. All information and the registration form can be found at "http://www.nupecc.org/iai2001".

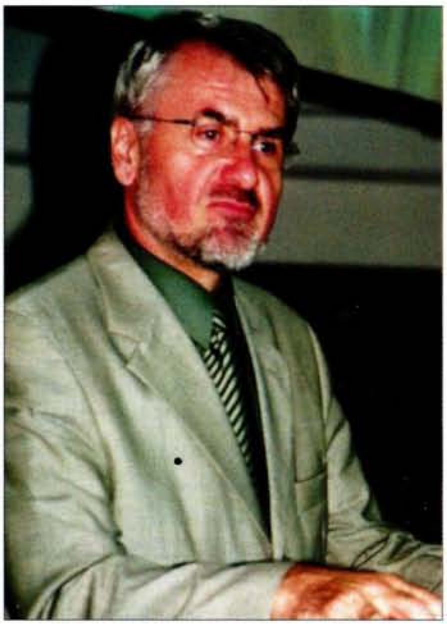
At the opening of the France at CERN trade expo at CERN in June. Left to right: industrial liaison officer **Jean-Claude Brisson**; **Florence Cousquer** of CFME ACTIM; French ambassador to the UN in Geneva and delegate to CERN Council **Philippe Petit**; CERN research director **Claude Détraz**; Research Ministry technical counsellor **Alexandre Defay**; director of the Department of Energy, Transport, Environment and Natural Resources of the Technology Directorate of the Ministry of Research **Bernard Frois**; and IN2P3 director and delegate to CERN Council **Jean-Jacques Aubert**.

At the inauguration of CERN's travelling exhibition, When Energy Becomes Matter, at Vienna's Technischesmuseum in May. CERN accelerator director **Kurt Hübner** (left) and museum director **Gabriele Zuna-Kratky**. (Photo Peter Sedlaczek.)



An interdisciplinary look at the Sun. **Amelio Grillo** of the Italian Gran Sasso laboratory (right) talks about solar neutrino detection with **Jan Kuipers**, chair of the Solar Physics Section of the Joint Astrophysics Division of the European Physical Society and the European Astronomical Society, during a divisional board meeting, which was held at Gran Sasso.

At the opening of this year's International Europhysics Conference on High Energy Physics (HEP2001), which was held in Budapest on 12–18 July, participants were welcomed by the newly appointed Hungarian Minister for Science, **József Pálinkás**, who is a former member of the OPAL experiment collaboration at CERN's LEP collider and Hungarian representative on the European Committee for Future Accelerators. Pálinkás remarked that opening HEP2001 was his very first action on his first day in office. He was pleased that his country's science budget has increased by 61% this year, and he pointed out that the "not so easy" subject of particle physics is good for exercising the minds of bright young men and women, not just for physics, but also in preparation for work in other sectors of society.

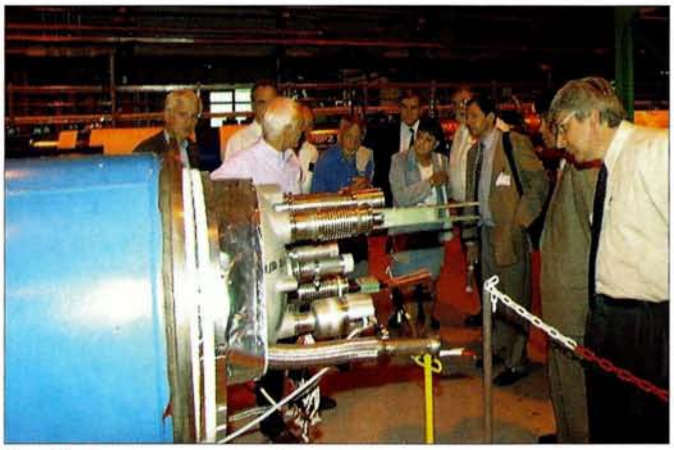


Serbian Science, Technology and Development Minister **Dragan Domazet** signs CERN's VIP visitors' book on 8 June.

Distinguished physicist and former Brookhaven director **Maurice Goldhaber** spent his 90th birthday at a meeting of the proposed UNO neutrino/nucleon decay experiment. Born in Austria, Goldhaber began his research career at Cambridge's Cavendish Laboratory in the 1930s, working with James Chadwick to measure the mass of the newly discovered neutron.

On 5 July, Iranian Minister for Science, Research and Technology, **Mostafa Moin** (right), and CERN director-general, **Luciano Maiani**, signed a draft memorandum of understanding covering the participation of Iranian universities in CERN's scientific programme. Under this agreement, one Iranian researcher and three students will come to CERN to participate in the CMS experiment at CERN's LHC collider, with Iranian industry contributing to the experiment's construction. The memorandum also paves the way for possible further Iranian involvement with experiments at CERN.

Visiting CERN in June was **Mike Lazaridis** (second from left), president and co-chief executive of research in Motion of Canada, a leading designer and manufacturer of wireless communications equipment. A great believer in the importance of fundamental physics for society, Lazaridis is funding the Perimeter Institute in Southwestern Ontario, which is dedicated to theoretical physics. "Theoretical physics gave rise to virtually all of the technological advances of present-day society," said Lazaridis. "From lasers to computers, from cell phones to magnetic resonance imaging, the road to today's technological developments was based on yesterday's ground-breaking theoretical physics." With him are (left to right) CERN member state affairs coordinator and Perimeter Institute scientific advisor **Cecilia Jarlskog**, CERN's Tile Calorimeter Group leader for the ATLAS experiment **Ana Maria Henriques Correia**, and CERN's VIP visit coordinator **Wendy Korda**.



Tom Taylor, deputy leader of CERN's LHC Division, explains superconducting magnet technology for the LHC collider to a delegation from the Organization for Economic Cooperation and Development's Global Science Forum on High Energy Physics.

On 27–29 June, a symposium at Les Houches in the French Alps marked he 50th anniversary of the Summer School founded by **Cécile de Witt** (right) in 1951, which went on to boost the revival of Continental European physics. First focusing on teaching quantum mechanics and quantum field theory, the meeting later turned to in-depth reviews of topical subjects. De Witt is seen here with 1997 Nobel laureate **Claude Cohen-Tannoudji**, who was a Les Houches student in 1955, a session organizer in 1964 and later a lecturer.

Back at school at Les Houches. Left to right: 1991 Nobel laureate **Pierre-Gilles de Gennes**, 1989 Nobel laureate **Normal Ramsey** and **Bryce de Witt**.

FREE LITERATURE

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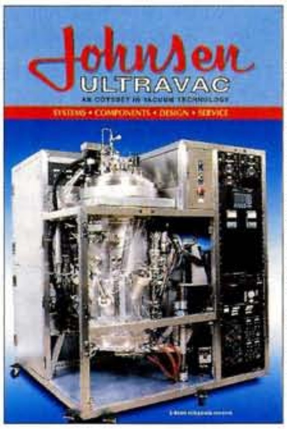

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André Rousset 1930-2001

André Rousset, who played a major role in heavy-liquid bubble chamber physics at CERN, died on 1 July.

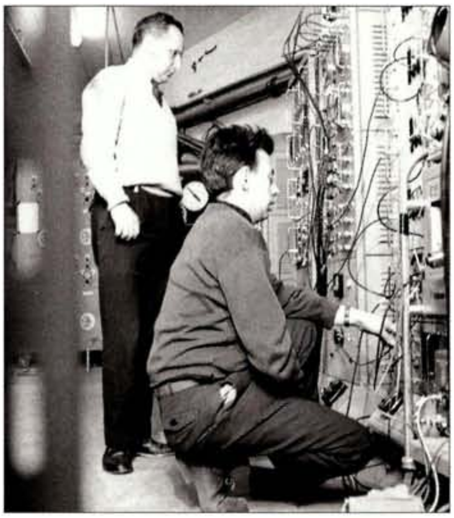
After studying at the Ecole Polytechnique, Rousset joined Louis Leprince-Ringuet's research laboratory in 1954, collaborating in pioneer cosmic-ray studies at the Pic du Midi de Bigorre. In 1960 he became professor at the Ecole des Mines, Paris, and was nominated a director of Leprince-Ringuet's laboratory from 1964 to 1969 before moving to CERN to lead work on heavy-liquid bubble chambers. There he managed the arrival of the big Gargamelle chamber, of which he had been one of the major constructors under the direction of André Lagarrigue, and its subsequent use for experiments in CERN's neutrino beam.

At Gargamelle the weak neutral current was discovered in 1973, signalling the unification of electromagnetic and weak interactions, which merited a Nobel Prize for the theoreticians who had made the prediction. André Rousset was one of the major players in this discovery, along with other physicists of the international Gargamelle collaboration, including André Lagarrigue and Paul Musset. He served as a member of CERN's Scientific Policy Committee from 1974 to 1980.

Returning to Paris in 1974, Rousset became a governmental scientific advisor, before moving to Aérospatiale in 1985, where he was to remain the chairman's scientific advisor until 1995. He retained his physics teaching post at the Ecole des Mines until he retired in 1968.

André Rousset was an enthusiastic and dynamic physicist who was gifted with keen intuition and a strong critical sense. His collaborators will remember a warm and cheerful man, full of spirit and humour, with whom it was always very pleasant to work.

Violette Brisson, LAL.Orsay and Ung Nguyen Khac, Ecole Polytechnique.



Heavy-liquid bubble chamber pioneers – André Rousset (1930–2001, right) with André Lagarrigue (1924–1975) at the BP3 heavy-liquid bubble chamber at CERN in 1962, one of the precursors of the famous Gargamelle chamber.

Christoph Schmelzer 1908–2001

Christoph Schmelzer, one of the pioneers of German particle accelerators and of CERN, a founding father of the GSI Darmstadt laboratory and from 1969 to 1979 its first scientific director, died on 10 June in Heidelberg at the age of 92.

Christoph Schmelzer 1908–2001.

Born in Lichtentanne, Saxony, and schooled in Zwickau, Schmelzer began his university studies at Munich's Technische Hochschule, initially in chemistry, before switching subject and university to study physics at Jena, where he submitted his thesis on high-frequency measurements in 1935.

After a short time at Jena as assistant to Max Wien, Schmelzer went to the US, but had to return in 1939, working until 1945 with Georg Goubeau in Jena on 10 cm wavelength physics and technology. In 1948 he became Walther Bothe's assistant in Heidelberg. In 1952 he turned his attention to particle accelerators at the time when the idea of CERN as a major European laboratory was being launched, becoming a key member of the group designing – and eventually building – the Proton Synchrotron (PS), which was then one of the world's two highest-energy accelerators.

From 1954 to the end of construction, Schmelzer served as deputy to PS Division leader John Adams. However, he is best remembered as the creator and inspiring leader of the group responsible for the PS radiofrequency acceleration system.

The construction of the world's first large alternating gradient accelerator, controlled by beam feedback, was new scientific territory, calling for imaginative new radiofrequency techniques, and many experts doubted that the result would be successful. The accelerating frequency had to follow a nonlinear function of the magnetic guide field with a precision that could not possibly be achieved by external programming. Moreover, a potentially fatal transition energy in mid-acceleration, at which the synchronous phase jumps from one side of the accelerating wave to the other, had to be overcome. Finally, precision frequency tracking of the ferrite-tuned accelerating cavities was required. All of these problems were solved by the first application of multiple feedback systems, deriving their input from the beam itself. Schmelzer was one of the inventors of this new technology.

The 1959 commissioning of the PS was described by Robert Jungk in his book *The Big Machine* (1968 Scribners, New York). After documenting a series of headaches, Jungk continued: "hardly had this [latest] disorder been cured when an extremely complicated radiofrequency system, geared to high-speed switching within ten-thousandths of a second, acted up. The method of beam control, invented in Heidelberg, in which the acceleration of the proton beam is regulated by its own feedback signals, would not listen to reason, and its master, Christoph Schmelzer, ordinarily easygoing, for the first time showed a nervousness that not even his beloved beer could control."

However, soon afterwards, everything ▷

Vladimir L Solovianov 1940–2001

Outstanding high-energy experimental physicist Vladimir L Solovianov died suddenly on 26 June at the age of 60 as a result of a tragic accident.

Born on 17 December 1940 in Dnepropetrovsk in the Ukraine, Solovianov received his diploma degree in physics at Moscow State University in 1964. That year he began his 37 year career at the Institute for High Energy Physics in Protvino, where he earned his candidate (PhD) and doctorate degrees in high-energy spin physics.

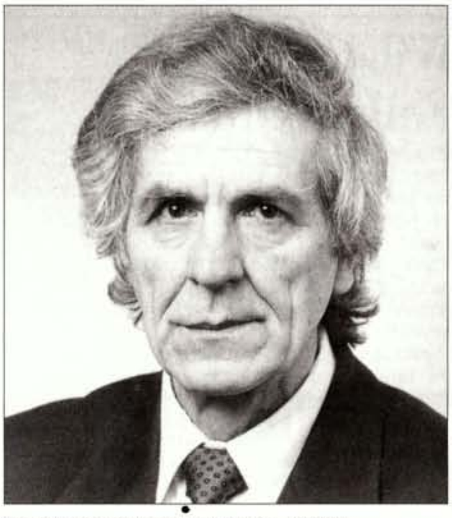
Early in his career, Solovianov helped to create the hodoscope detectors for one of the first elastic scattering experiment at the 70 GeV U-70 accelerator. He then made important contributions to the IHEP-SEN (Saclay) experiment, which made precision measurements of Coulomb-nuclear-interference cross-sections, inclusive cross-sections and spin-polarization effects. He was also a co-author of the key discovery at U-70 in the late 1960s for evidence of an increase in the proton's radius in high-energy strong interactions.

During the past 15 years, Solovianov was a leader in developing three spin-polarization experiments: NEPTUN at the 400 GeV - 3 TeV UNK, and RAMPEX and SPIN@U-70 at the 70 GeV U-70. These experiments form a major part of the Russia-US Physics Collaboration Program in Russia and a major part of IHEP-Protvino's large Polarization Program.

Solovianov was an unusually active and talented physicist. He also made significant contributions to several other CERN-Russia and US-Russia experiments, such as the SPS high-energy elastic polarization experiment at CERN and the E-704 lambda-decay polarized-proton experiment at Fermilab.

His death occurred while he was, as usual, working too many hours each day to ensure that his new and well loved SPIN@U-70 polarized high-momentum-transfer elastic proton-proton scattering experiment would be fully installed and ready to take data in the 70 GeV extracted beam in March 2002. His many colleagues in Russia and around the world will remember him as an outstanding scientist and a wise and loyal friend.

N E Tyurin, M N Oukhanov, A D Krisch.



Vladimir L Solovianov 1940–2001.

came together, and on 24 November 1959 the PS protons sailed through the critical transition energy barrier without difficulty and reached 24 GeV with a transmission factor of 90%.

In 1959, Schmelzer became professor of applied physics at Heidelberg. He pushed the establishment of the GSI heavy-ion laboratory, equipped with the UNILAC linear accelerator, which was formally founded in December 1969 with him as its first scientific director. He furthered the development of the laboratory's installations with a ring accelerator to reach higher energies. Thanks to his vision and wisdom, the GSI laboratory went on to become a world player in heavy-ion research.

Christoph Schmelzer was an honorary professor at Heidelberg and a member of the Heidelberg Academy of Science. In 1978 he was awarded the German Bundesverdeinstkreuz. He is remembered as a warm-hearted and modest man, and his death represents the loss of a leading figure in scientific research.

- Jefferson Laboratory chief scientist and eminent theorist Nathan Isgur died on 23 July, aged 54. A tribute will follow in the next edition.

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Electron Tubes' P25A and P30A ranges of analogue detector packages comprise a photomultiplier tube, a transimpedance amplifier and a negative high-voltage supply, all encapsulated within a compact assembly. The devices provide the ideal interface between photomultiplier tube and amplifier and are simple to use, requiring only low voltage supplies. The frequency response ranges from DC up to 100 MHz, which makes these packages ideal for measuring fast transient light sources ranging from weak to relatively high intensity. Aimed at the instrumentation market, they will be particularly useful in applications such as laser scanning and electron microscopy

For further information, contact Electron Tubes Ltd, Bury Street, Ruislip, Middlesex HA4 7TA; tel. +44 (0)1895 630771; fax 44 (0)1895 635953; e-mail: info@electron-tubes.co.uk; Web www.electrontubes.com.

Light detector package from Electron Tubes.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
Tel. +44 (0)117 930 1026. Fax +44 (0)117 930 1178.
Rates per single column centimetre: mono £36, single colour £38, full colour £40. Please contact us for more information on publication dates and deadlines.

Wilson Fellowships

Fermilab supports particle physicists early in their careers by providing unique opportunities for self-directed research in experimental particle physics. The fellowships are awarded on a competitive basis to Ph.D. physicists of exceptional talent as evidenced by their contributions to the field in their postdoctoral work. Fellows will work at Fermilab in areas of experimental particle physics of their choice. Wilson Fellowships are tenure track positions with an initial term appointment of three years.

Each candidate should submit a curriculum vitae and a detailed statement of research interests and proposed activities, and should arrange to have four letters of reference sent to the address below. Application materials and letters of reference should be received by October 31, 2001.

Materials, letters and requests for information should be sent to:

Patricia L. McBride
Chairman, Wilson Fellows Committee
Fermi National Accelerator Laboratory MS234
P.O. Box 500
Batavia, IL 60510-0500

E-mail: mcbride@fnal.gov

More information can be found at our web site:
http://www.fnal.gov/pub/forphysicists/fellowships/wilson.html

Fermilab

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icalepcs 2001

International Conference on Accelerator & Large Experimental Physics Control Systems

November 27-30, 2001 • San Jose, California, USA

Invited Talks: Edward Moses, *National Ignition Facility (NIF)*
Rolf Bork, *Laser Interferometer Gravitational Wave Observatory (LIGO)*
Marc Ross, *Overview of Accelerator Timing Systems (SLAC)*
Ferdinand Willeke, *Global Accelerator Network*
Mark Plesko, *Java Beans for Acelerator Application Development*

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http://icalepcs2001.slac.stanford.edu

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Candidates should meet the following requirements:

- have a university degree in one of the relevant fields. Some years of professional experience, MSc or PhD, would be an advantage.
- have a good knowledge of English, French and German, the working languages of the EPO
- be a national of one of the Contracting States of the European Patent Organization

Please send your detailed CV to:
European Patent Office, Recruitment Officer,
Postbus 5818, NL-2280 HV Rijswijk
or Fax: **+31 70 3403678**
or recruitment.thehague@epo.org
More information can be found on the WEB :
www.european-patent-office.org/epo/jobs.htm

LIP

LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

RESEARCH ASSOCIATE IN EXPERIMENTAL PARTICLE PHYSICS

Applications are invited for a Research Associate position at LIP-Lisbon to work in the CMS experiment at CERN.

The successful applicant will participate in the LIP activities in the CMS Electromagnetic Calorimeter Trigger and Data Acquisition. The work will involve the development of control software, the test of hardware prototypes and the development of electron and photon reconstruction algorithms.

The successful applicant will be based in the Geneva area integrating a LIP team of physicists and engineers on the CERN site.

Applicants should have a PhD in particle physics and expertise in modern software techniques. The position is for a duration of three years, with a possible extension of three years, and is available from July 2001. A later starting date is possible.

Applications, comprising a curriculum vitae, a list of publications and three letters of reference, should be sent to Joao Varela, CERN/EP, 1211 Geneva 23.

Further information can be requested from joao.varela@cern.ch or obtained at the LIP web site, http://www.lip.pt

PSI PAUL SCHERRER INSTITUT

research for the future

Experimental Physicist

Proton Therapy

Since 1997, PSI is operating a novel proton therapy facility for cancer treatments, using a dynamic beam delivery technique applied on a very compact proton gantry. The positive experience with the present system at PSI is now bringing a further expansion of the facility, with the installation of a dedicated medical accelerator and of a new, second generation, proton gantry.

Your tasks

You assist the project leader on developments for the 2nd gantry, i.e. computational work during the conceptual design, followed by the preparation and the experimental work with the beam during commissioning.

Your profile

You have recently graduated (PhD) in physics and have some practical experience in working with particle beams in an accelerator environment. The requirements include programming skills for the simulation work of the new advanced beam scanning methods and for the analysis of the experimental results. Furthermore, you are a good team player and have a good knowledge in English and German.

For more information please contact Dr. E. Pedroni, tel. +41 56 310 35 18, email eros.pedroni@psi.ch.

Please send your application to: PAUL SCHERRER INSTITUT, Human Resources, ref.code 2100-03, CH-5232 Villigen PSI, Switzerland.

Further job opportunities: www.psi.ch

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success starts with a good education

The University of New Mexico

The neutrino group at the University of New Mexico invites applications for the position of Postdoctoral Research Associate.

Currently, this group consists of two faculty and several students involved in the KAMLAND experiment. The group also has interests in a next generation neutrino/proton decay experiment. The successful applicant is expected to take a leading role in the calibration system as well as data analysis. A Ph.D. in particle or nuclear physics is required. Residency in either New Mexico or Japan is negotiable, but the applicant must be willing to spend significant amounts of time in both locations.

Please send your resume and the names of at least three references to:

Professor B. Dieterle, Department of Physics and Astronomy
University of New Mexico, Albuquerque, NM 87131
(dieter@unm.edu)

POSTDOCTORAL POSITION

Theoretical Heavy Ion Physics
Helsinki Institute of Physics

The Helsinki Institute of Physics invites applications for a postdoctoral position in the theory of ultrarelativistic heavy ion collisions. One to two positions for 1+1 years will be opened, starting Spring 2002 or later. The location can be either the Helsinki Institute of Physics, University of Helsinki, or the Department of Physics, University of Jyväskylä.

Applicants should send their curriculum vitae, list of publications and a research plan, and have two letters of recommendation sent to:

Kari J. Eskola, Department of Physics, University of Jyväskylä,
P.O. Box 35, FIN-40351 Jyväskylä, Finland.

Applications should arrive before September 30, 2001, but later applications may also be considered.

Jefferson Lab Distinguished Fellowship in Beam Physics

(Position #AT2124)

Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia, USA, is an internationally recognized laboratory engaged in fundamental scientific research in nuclear and particle physics based on the Continuous Electron Beam Accelerator Facility (CEBAF). The laboratory is operated for the US Department of Energy under management of the Southeastern Universities Research Association (SURA). In addition to operating CEBAF, the laboratory also operates a Free Electron Laser (FEL) facility. As a result of its core strength and competency in RF superconductivity, the laboratory is a major partner in many national and international projects such as the SNS, CEBAF 12 GeV Upgrade, RIA, and TESLA.

In addition to the operating facilities and projects, the laboratory embodies its key theoretical and experimental expertise in particle and light beams and RF superconductivity in two centers of excellence: the Center for Advanced Studies of Accelerators and the Institute for SRF Science and Technology, with associated computer and laboratory facilities. The laboratory also has a highly specialized world-class particle source/injector group.

In order to further enhance its core competencies in the physics and technology of accelerators, lasers, particle beams, and synchrotron radiation, Jefferson Lab is creating a Jefferson Lab Distinguished Fellowship in Beam Physics Program.

Approximately one award will be made each year on a competitive basis.

The candidates are expected to propose a research project within the Jefferson Lab core competencies in accelerator/laser physics & technology (superconducting RF science & technology, recirculating or energy-recovering linacs, free electron lasers, etc).

Eligibility: These fellowships are targeted to entry-level physicists of exceptional talents. As such, it is restricted to individuals having received a doctoral degree within three years of application. A previous postdoctoral position is not a requirement.

Term of appointment: The initial term of appointment is for three years. The appointment could be extended to another term or converted to a permanent position if justified.

Application: All interested candidates are encouraged to apply by submitting an application to: Employment Administrator, SURA/Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606. Fax: 757-269-7559, E-mail: **jobline@jlab.org**. Please specify position number and job title when applying. The deadline for application is 31 October 2001. The application should include a curriculum vitae, a list of publications, a research proposal, and a list of at least three references. For more information, contact Drs. Jean Delayen (**delayen@jlab.org**) or Swapan Chattopadhyay (**swapan@jlab.org**).

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Jefferson Lab

Mechanical Engineer – Staff Member

Science Serving Society

Summary: Senior Level Mechanical Engineer to work as a member of the Accelerator Physics and Engineering Group in the Los Alamos Neutron Science (LANSCE) Division to provide engineering support for the design, fabrication, procurement, and testing of normal and superconducting linear accelerators, storage rings, normal and superconducting magnets, beam transport systems, beam diagnostics, and associated equipment for the acceleration and transport of electron and ion beams. Carry out finite element thermal and structural analyses of normal and superconducting accelerator cavities. Interact with linac and beam transport physicists, mechanical engineers, mechanical designers, fabrication technicians, and test technicians to define the technical requirements and carry out the mechanical engineering design for linear accelerators and related hardware. Provide technical direction to designers, technicians, and subcontractors for the development and production of linear accelerator hardware. Create technical specifications for in-house and subcontract development and production of linear accelerator hardware.

Required Skills: Significant experience in the design, fabrication, procurement, and testing of mechanical hardware systems including structural, hydraulic, and vacuum systems. Experience in the technical direction of mechanical designers, fabrication and test technicians. Extensive experience in the use of commercial finite element thermal and structural analysis codes. Experience creating applications code in FORTRAN and/or C. Experience in the use of Mechanical CAD systems. Demonstrated oral and written communication skills. Ability to obtain a DOE Q clearance, which normally requires U.S. citizenship.

Desired Skills: Experience in the mechanical engineering design, analysis, fabrication, and testing of normal and superconducting linear accelerator cavities, storage rings, normal and superconducting magnets, beam diagnostic devices, beam transport systems, and related hardware. Experience in the use of CFD codes. Experience with CNC manufacturing and inspection.

Education: Masters Degree in Mechanical Engineering plus ten years relevant experience or equivalent combination of education and experience. Registration as a professional engineer is desirable.

Notes to Applicants: For specific questions about the status of this job, call (505) 667-0763.

To Apply: Submit a comprehensive resume and cover letter that addresses the specific required criteria, referencing "CERN017537", via email to jobs@lanl.gov, or via postal service to Los Alamos National Laboratory, Resume Service Center, Mailstop P286, Los Alamos, NM 87545.

Los Alamos
NATIONAL LABORATORY

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www.lanl.gov/jobs

Project Leader, Linear Collider R&D at Fermilab

Fermilab seeks an experienced scientist to lead its linear collider R&D program. This expanding program is currently pursuing R&D on room temperature structures and rf distribution systems, and studying technology options for a second generation electron-positron linear collider. Responsibilities will include providing management and technical direction for a program aimed at developing cost effective approaches to an electron-positron linear collider over the next several years, and for coordinating the Fermilab effort with national and international partners. The Project Leader will report to the Fermilab Associate Director for Accelerators. This position requires previous experience with linear accelerators or high power rf systems, and demonstrated organizational/leadership abilities. Applicants or interested parties requiring more information should contact:

Steve Holmes
Fermilab Associate Director for Accelerators
Fermilab, MS105
P.O. Box 500
Batavia, IL 60510, USA
E-mail: holmes@fnal.gov
Ph: 630-840-3211

Applications should include a curriculum vitae, publication list, and the names of at least three references.

Fermilab

A U.S. Department of Energy laboratory. Fermilab is an equal opportunity/Affirmative Action Employer

Associate Scientist Position D0 Experiment Fermilab Computing Division

The Computing Division at Fermilab has an opening for an Associate Scientist on the D0 Experiment. The Associate Scientist position offers the opportunity to participate in the research program at the D0 Experiment, a particularly exciting prospect with data from Run II at the Tevatron now being collected. The successful candidate should actively participate in the D0 Experiment and have particular responsibility in the development and maintenance of the computing and analysis infrastructure for D0. The candidate will have the tasks of developing and exploiting expertise in one or more of the following areas: sophisticated distributed data handling systems, database design, reconstruction and triggering algorithms, the C++ infrastructure packages for the experiment, and the design and integration of computing systems of offline analysis. The successful candidate will take a major responsibility for one or more aspects of computing and software for D0. The details of the assignment will be worked out with the head of the D0 Computing and Analysis group. As a member of the laboratory, the candidate is expected to also take a major role in the research program at D0. The candidate must have a Ph.D. in Particle Physics and postdoctoral experience in experimental particle physics, physics analysis and computing. Computing skills including C++ programming and/or scripting language skills are desirable. Good communication skills and the ability to function as part of a team are important. Candidates for this position (Reference #010123) should submit a curriculum vitae, a list of publications, and 3 letters of reference, by September 30, 2001, to **Dr. Matthias Kasemann, Fermi National Accelerator Laboratory, P.O. Box 500, MS 370, Batavia, IL 60510, USA.** A U.S. Department of Energy Laboratory. EOE/AA Employer M/F/D/V

Fermilab

Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)

We invite applications from recent Ph.D. graduates for two post-doctoral positions in

Experimental High Energy Physics

The appointments are made for two years and the positions are available now.

With this year's upgrade of the HERA collider, with prospects for a five-fold increase in luminosity as well as running with a polarized lepton beam, and the upgrade of the H1-Experiment, we are entering a new and exciting phase of physics with *ep*-collisions.

Our group has been engaged in the H1-Experiment at HERA and is actively participating in upgrading the detector for data taking with HERA II. Our main new projects are the liquid argon calorimeter jet trigger, a fast first level trigger delivering jet-like energy clusters, and new sophisticated preprocessing of the input data for the existing second level neural network trigger.

Our group is involved in various aspects of H1 Physics analysis such as structure functions, heavy quark and jet production, heavy vector meson production and search for instantons in QCD. The substantial increase in luminosity will emphasize the physics at high Q^2. We expect the successful candidates to become engaged in one of our upgrade projects and to participate in one of our physics programs.

Our Institute is seeking to increase the number of women in high energy physics. Therefore qualified women are especially encouraged to apply. Applicants with a physical handicap will be given preference, if equally well qualified.

Applications with full CV, statement of research interests, publication list, and names and addresses of three referees, or any inquiries should be made as soon as possible to:

Prof. G. Buschhorn,
Max-Planck-Institut für Physik (Werner-Heisenberg-Institut)
Föhringer Ring 6, D-80805 München
(email: gwb@mppmu.mpg.de)

INFN Istituto Nazionale di Fisica Nucleare

Post-Doctoral Fellowships

for non-Italian citizens in the following research areas:

Theoretical Physics (N.10)
Experimental Physics (N.20)

The INFN Fellowship Programme 2001-2002 offers 30 (thirty) positions for non Italian citizens for research activity in theoretical or experimental physics.

Fellowships are intended for young post-graduates who have not attained 35 years as of October 30, 2001.

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

The annual gross salary is EURO 24,800 for candidates coming from E.U. or U.S.A. and EURO 21,700 for candidates coming from other countries.

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

Candidates should submit their application form, a statement of their research interests and enclose three reference letters.

Candidates should choose one of the following INFN Laboratories:

Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali del Sud (Catania) e Laboratori Nazionali di Frascati (Roma)

Or INFN Sections in the Universities of:

Torino, Milano, Padova, Genova, Bologna, Pisa, Napoli, Catania, Trieste, Firenze, Bari, Pavia, Cagliari, Ferrara, Lecce, Perugia, or one of the 3 universities in Rome "La Sapienza", "Tor Vergata" or "Roma3".

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

Applications must be sent to the INFN no later than *October 30, 2001*.

Candidates will be informed by February 2002 about the decisions taken by the INFN selection committee.

Fellowships must start within three months of the communication to the grantees. Requests of deferment excepted.

Information, requests for application forms, and applications should be addressed to Istituto Nazionale di Fisica Nucleare, Direzione Affari del Personale Ufficio Borse di Studio Casella Postale 56 00044 Frascati (Roma) Italia.

ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
(Prof. Enzo Iarocci)

THE UNIVERSITY *of* LIVERPOOL

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Department of Physics

Initial salaries within the range £20,267 - £32,215 pa

The Department is a leading international research centre. Two lectureships are available from 1 October 2001 for outstanding candidates with research interests in Experimental Particle Physics to lead a research area in the current and future programme. The current programme includes ATLAS and LHCb at CERN, H1 at DESY, BaBar at SLAC and CDF at Fermilab. Detector R&D underpins this and future programmes. Facilities include the new Liverpool Semi-Conductor Centre, powerful computing farms and modern mechanical workshop. You will contribute in an innovative way to departmental teaching.

Informal enquiries to Professor P J Nolan on 0151 794 3377, fax: 0151 794 3362, email: nolan@ns.ph.liv.ac.uk
Visit http://hep.ph.liv.ac.uk/

Quote Ref: B/634/CC *Closing Date: 30 September 2001*

Further particulars and details of the application procedure should be requested from the Director of Personnel, The University of Liverpool, Liverpool L69 3BX on 0151 794 2210 (24 hr answerphone) or via email: jobs@liv.ac.uk

Web site at http://www.liv.ac.uk

COMMITTED TO EQUAL OPPORTUNITIES

SOLEIL

the French third Generation Synchrotron Radiation Facility

SOLEIL is a funded project for the construction and operation of a third generation synchrotron radiation facility in France, on the plateau de Saclay, near Paris. The project consists in building a 2.5 GeV low emittance Storage Ring which will deliver its very high brilliance photon beams to 24 beamlines. The first phase of the construction will start in 2002 and last 4 years, at the end of which the radiation Source and 10 beamlines will become operational. SOLEIL will support scientists in the implementation of fundamental and applied research on the structure of condensed matter in fields such as Physics, Chemistry, Crystallography, Earth Science, Biology and Medicine, Surface and Materials Science.

The Machine Division is responsible for the original design, assembly, commissioning and eventually the operation and development of the electron accelerator complex of the facility (a 350m circumference Storage Ring, a 2.5 GeV Booster and a 100 MeV linear accelerator), of the insertion devices and the photon beam front-ends. The Machine Division is now seeking to recruit the:

HEAD OF THE RF GROUP

Job description

Within the Machine Division, the head of the RF group is responsible for the design, construction, installation and commissioning of the high frequency accelerating systems for the Booster and the Storage Ring. He/she defines and sets up the associated R&D programme. He/she supervises the RF group composed of about 12 engineers and technicians and he/she stimulates its activities. The field of responsibility of the RF group encompasses the super-conducting accelerating cavities of the Storage Ring, the copper cavity of the Booster, together with their associated pieces of equipment (transmitters, HV power supplies, diagnostics, low level electronics and control, ...). It may be extended to the feedback systems required to keep the beam instabilities due to collective effects under control. The SOLEIL RF systems must be designed to provide for a very high reliability and a very low mean time between failures.

As a senior physicist, the head of the RF group contributes to the optimisation of the Machine performances and participates in the Machine physics studies.

Qualifications and experience

You are a graduate from an engineering school and/or you have a PhD in physics. You have at least 10 years of experience or activities in the RF field and you have a thorough knowledge of the accelerating RF systems for particle accelerators. You have a good understanding of accelerator beam dynamics and more specifically of beam instabilities. You are familiar with the computing codes used in the design of accelerating cavities. Some knowledge of super-conducting systems would be desirable. You will have to demonstrate clear skills in managing a group.

General Conditions

SOLEIL offers you an interesting opportunity in a high technology environment. This permanent position is to be filled as soon as possible. The SOLEIL project team is temporarily located on the Orsay University Campus, the final location being 5km away on the Plateau de Saclay (30km South West of Paris). Salary conditions will depend on the experience and qualifications.

Applications and CV should be sent to
Jean-Marc FILHOL, SOLEIL Deputy Project Director, SOLEIL/LURE,
BP 34, F-91898, Orsay (France)
or by email to filhol@soleil.u-psud.fr .

For more information contact filhol@soleil.u-psud.fr or level@soleil.u-psud.fr
or visit the SOLEIL website: http://www.soleil.u-psud.fr/

RESEARCH ASSOCIATE POSITION
EXPERIMENTAL SUBATOMIC PHYSICS
THE UNIVERSITY OF BRITISH COLUMBIA

Applications are invited for a postdoctoral Research Associate position in experimental High Energy Physics at the University of British Columbia. The successful candidate will work on the BaBar experiment and is expected to play a leading role in BaBar data analysis and to contribute significantly to our group's responsibility in the maintenance and operation of the drift chamber and in the development of its related software.

The UBC BaBar group presently has three faculty members: Hearty, Mattison and McKenna. Information on the UBC Physics and Astronomy Department may be found on the web at http://www.physics.ubc.ca .

Candidates must have a Ph.D. degree. Applicants should submit a curriculum vitae and arrange for three letters of reference to be sent by November 15, 2001 to:

BaBar Group , c/o Professor J. McKenna
Department of Physics and Astronomy
6224 Agricultural Road
University of British Columbia,
Vancouver, B.C. V6T 1Z1, CANADA

Salary will depend on experience and will be supplemented with a cost of living allowance while at SLAC. The appointment may be renewed annually, subject to budgetary confirmation and mutual agreement, to a maximum period of 3 years. In accordance with Canadian immigration requirements, priority will be given to Canadian Citizens and permanent residents of Canada.

UBC hires on the basis of merit and is committed to employment equity. We encourage all qualified persons to apply.

E-mail inquiries: hearty@physics.ubc.ca , mattison@physics.ubc.ca or janis@physics.ubc.ca

Applications WILL NOT be accepted by email, hardcopy only please.

DESY

The **Deutsche Elektronen-Synchrotron DESY** in Hamburg, member of the association of national research centers Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren, is a national center of basic research in physics with app. 1,400 employees and more than 3,000 scientific guests from Germany and foreign countries per year. The accelerators in operation are dedicated to particle physics and research with synchrotron radiation.

Within the group – FLC– „Experiments with Lepton Colliders" we are looking for an

Experimental Particle Physicist

for the participation in the ongoing preparatory work for the next generation of particle physics experiments at DESY, in particular in the context of the TESLA program; development of both the physics case and the novel instrumentation and software techniques for experiments at future electron-positron colliders.

Applicants should have a PhD in physics and several years of experience in experimental particle physics. The candidate should have an established record in the field. Excellent communication skills and the ability to work in a large collaborative effort are essential.

Payment and social benefits correspond to those in public services (BAT Ib; according to German Civil Service).

Deadline for application: 30.09.2001 Job No.: 59/2001

Handicapped applicants will be given preference to other applicants with the same qualifications.

DESY supports the careers of women and encourages especially women to apply.

DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY
Notkestraße 85, D-22603 Hamburg, Tel.+49 (0) 40 8998 4918
www.desy.de

INDEX TO DISPLAY ADVERTISERS

The index is provided as a service and, while every effort is made to ensure its accuracy, *CERN Courier* accepts no liability for error

Associate Scientist Beams Division

Fermi National Accelerator Laboratory currently seeks an Associate Scientist to work in one of the Beams Division systems groups (Tevatron, Main Injector, Antiproton Source, Proton Source), contributing to machine operation, improvements, and diagnostics. Additional duties will include writing application programs in C, performing shift work during machine commissioning periods and conducting beam studies, coupled with advanced accelerator calculations aimed at improving machine performance and versatility. This role will also entail making accesses into beam enclosures and working in radiation and ODH areas. Some shift work is required during commissioning.

Qualified candidates will possess a PhD in Physics, with a minimum of three years of postdoctoral work and prior experience in experimental beam physics. Exact title and level will depend on the qualifications of the selected candidate.

Qualified applicants should submit a curriculum vitae, publication list and the names of three references to: **John Marriner, Head, Beams Division, Fermilab, MS 306, P.O. Box 500, Batavia, IL 60510, USA.**

Fermilab

A U.S. Department of Energy National Laboratory
We are an EEO/AA Employer M/F/D/V

RWTH RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

The Deutsche Forschungsgemeinschaft (DFG) has installed a new graduate college at Aachen Technical University (RWTH). The college starting in october 2001 has the title Elementary Particle Physics at the TeV Scale

Several grants are offered to students working on their doctoral thesis in experimental or theoretical particle physics. The monthly stipend is 2000 DM (approx .1000 Euro). Where applicable a family supplement of DM 300 will be paid. In addition one postdoc position is available with a monthly stipend of DM 2970-3270.

More information concerning the research topics and the research groups can be found in in the web using the adress

http://www.physik.rwth-aachen.de/phys1b/Kolleg

The new college will not only offer interesting research topics but also additional courses serving the further qualification of the students. Please send your application with curriculum vitae and a statement of research interest as soon as possible to the spokesmen of the college:

Prof. Ch. Berger
I.Physikalisches Institut der RWTH-Aachen
D 52056 Aachen

Email: berger@rwth-aachen.de

CERN COURIER RECRUITMENT BOOKING DEADLINE

October issue: 14 September

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during the IUVSTA 15th International Vacuum Congress, the AVS 48th International Symposium, and the 11th International Congress on Solid Surfaces

- *Diversification for Vacuum Equipment Manufacturers*
- *Vacuum Equipment Challenges for XHV*
- *Forecasting the Semiconductor Market*
- *Japanese Vacuum Industry Trends*
- *Semiconductor Capital Equipment Trends and Outlook*
- *Cathodic Arc Plasma Vapor Deposition Principles and Trends*

For more information, contact:
Association of Vacuum Equipment Manufacturers International
505/856-6924 • Fax 505/856-6716
E-mail <aveminfo@avem.org> • Web Site <www.avem.org>

AVEM International
Association of Vacuum Equipment Manufacturers International

BOOKSHELF

The Supersymmetric World: The Beginnings of the Theory edited by G Kane and M Shifman, World Scientific, ISBN 981024522X.

It is notoriously difficult to write with perspective about the history of science of very recent events. This is particularly true in the case of supersymmetry. Actually, supersymmetry is not at all a recent idea; it is about 30 years old and, when compared with the pace of recent progress in science, it seems to come from another geological era.

Nevertheless, the role of supersymmetry in the description of the physical laws and its destiny in the history of scientific ideas are not yet settled.

Physicists are struck by its mathematical beauty, its trustworthy promises to merge general relativity with the principles of quantum mechanics, and its symmetry properties that allow a coherent description of the vastly hierarchical structure of the relevant size scales of the microworld. Nevertheless, we still lack definite experimental evidence for its existence.

This book does not attempt to present a chronological history of the events that led to the theoretical discovery of supersymmetry and its successive developments. Instead it collects personal reminiscences of the pioneers and founders of supersymmetry. In this way it gives the reader all of the elements necessary to reconstruct his/her own favourite history.

Supersymmetry is by now a familiar concept among both theoretical and experimental particle physicists. Entering an auditorium during a conference or a seminar on high-energy physics and listening to a speaker expounding on the production rates of gluinos and squarks, you certainly get the impression that these particles are real entities with well measured properties. In fact they are just a theoretical conjecture, the confirmation or disproof of which is waiting for the Large Hadron Collider to operate at CERN. But how many people in that auditorium know why supersymmetry was first introduced in particle physics, or how superstrings were invented (by Ramond, Neveu and Schwarz) before supersymmetry was even known, or, in a more anectodal vein, how the name developed from the super-gauge symmetry' of Wess and Zumino to super-symmetry' (with the hyphen) of Salam and Strathdee? This book is excellent reading for all of those (in that auditorium or not) who do not know the answers or just want to know more.

In the beginning, supersymmetry was a solution in search of a problem. The first proponents did not have in mind the hierarchy puzzle or quantum gravity, which are the main arguments used now to motivate supersymmetry and which did not appear in scientific literature until the early 1980s. Golfand and Likhtman invented supersymmetry when trying to understand parity-violation in weak interactions (before the Standard Model of electroweak interactions emerged). Volkov and Akulov introduced non linear supersymmetric transformations to explain massless neutrinos (interpreted as Goldstone fermions). Then Wess and Zumino rediscovered supersymmetry on the other side of the Iron Curtain and, with formidable theoretical developments, opened the gate to the superworld.

There is a lot to be learned from the early developments of supersymmetry and this book provides the necessary material in an unusual form – through personal recollections. It has to be said that many of the contributions contain technical discussions of the theoretical progress that require a good scientific knowledge on the part of the reader. However, these are mixed with reminiscences, personal remarks and anecdotes that make the reading more suggestive and captivating.

The book also contains an essay by R Di Stefano that attempts a systematic study of the historical developments of supersymmetry. I found this essay, written in 1988, too dated to have sufficient vision of the field. On the other hand, most contributions from the original founders of supersymmetry are full of interesting remarks, both from scientific and historical points of view. Particularly vivid is the chapter written by Yuri Golfand's wife, with an intense and passionate portrait of her husband and of the sufferings, injustices and intellectual humiliations borne by the Jews in the Soviet Union.

Gianfrancesco Giudice, CERN.

Books received

ICHEP 2000: Proceedings of the 30th International Conference on High-Energy Physics edited by C S Lim and Taku Yamanaka, World Scientific, ISBN 9810245335, two-volume set £179.

The record of the symposium held in Osaka on 27 July – 2 August 2000.

Sixty Years of Double Beta Decay: from Nuclear Physics to Beyond Standard Model Particle Physics by H V Klapdor-Kleingrothaus, World Scientific, ISBN 9810237790, £147.

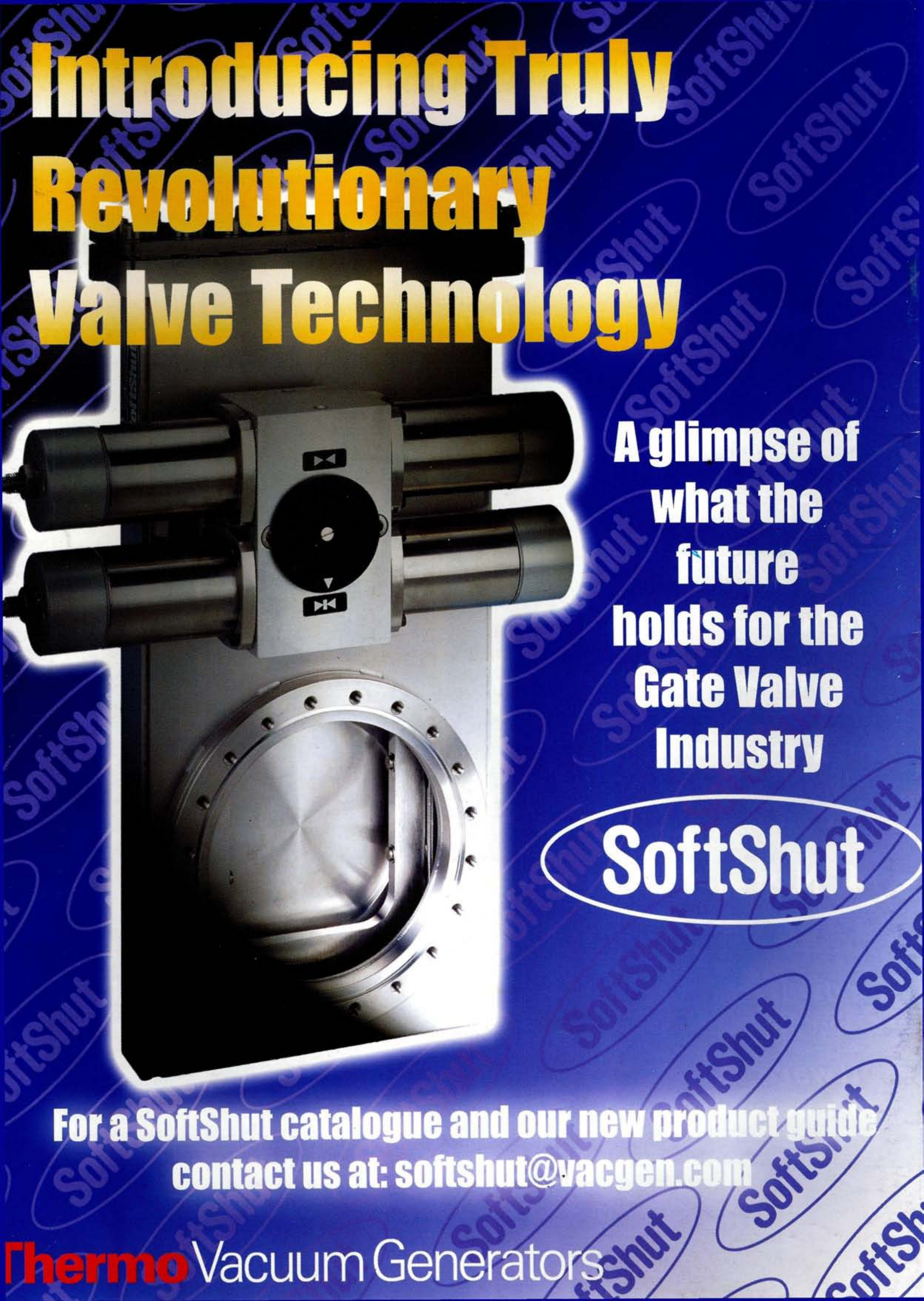
A useful review (62 pages) and bibliography (33 pages), with 1200 pages of reprinted papers, including pioneer neutrino papers (at the front) and extracts from *CERN Courier* (at the back).

Particle Physics and the Universe: Proceedings of the Nobel Symposium, 20–25 August 1998 edited by L Bergström, P Carlson and C Fransson, World Scientific, ISBN 9810244592, £55.

This includes a tribute to David Schramm (who died on 19 December 1997) by Michael Turner, and many contributions, then topical, on cosmology and astrophysics, by distinguished people.

Basics and Highlights in Fundamental Physics, Proceedings of the International School of Sunbnuclear Physics edited by Antonino Zichichi, World Scientific, ISBN 981024536X, £121.

The record of a school held in Erice, Sicily, in August/September 1999. It is prefaced by tributes to Bjorn Wiik, who died on 26 February 1999, by Kjell Johnsen, Horst Wenninger and Günter Wolf, and it goes on to cover basics, theoretical and experimental highlights, and a special session for new talents. Gerard 't Hooft gave the opening lecture on the Holographic Principle.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