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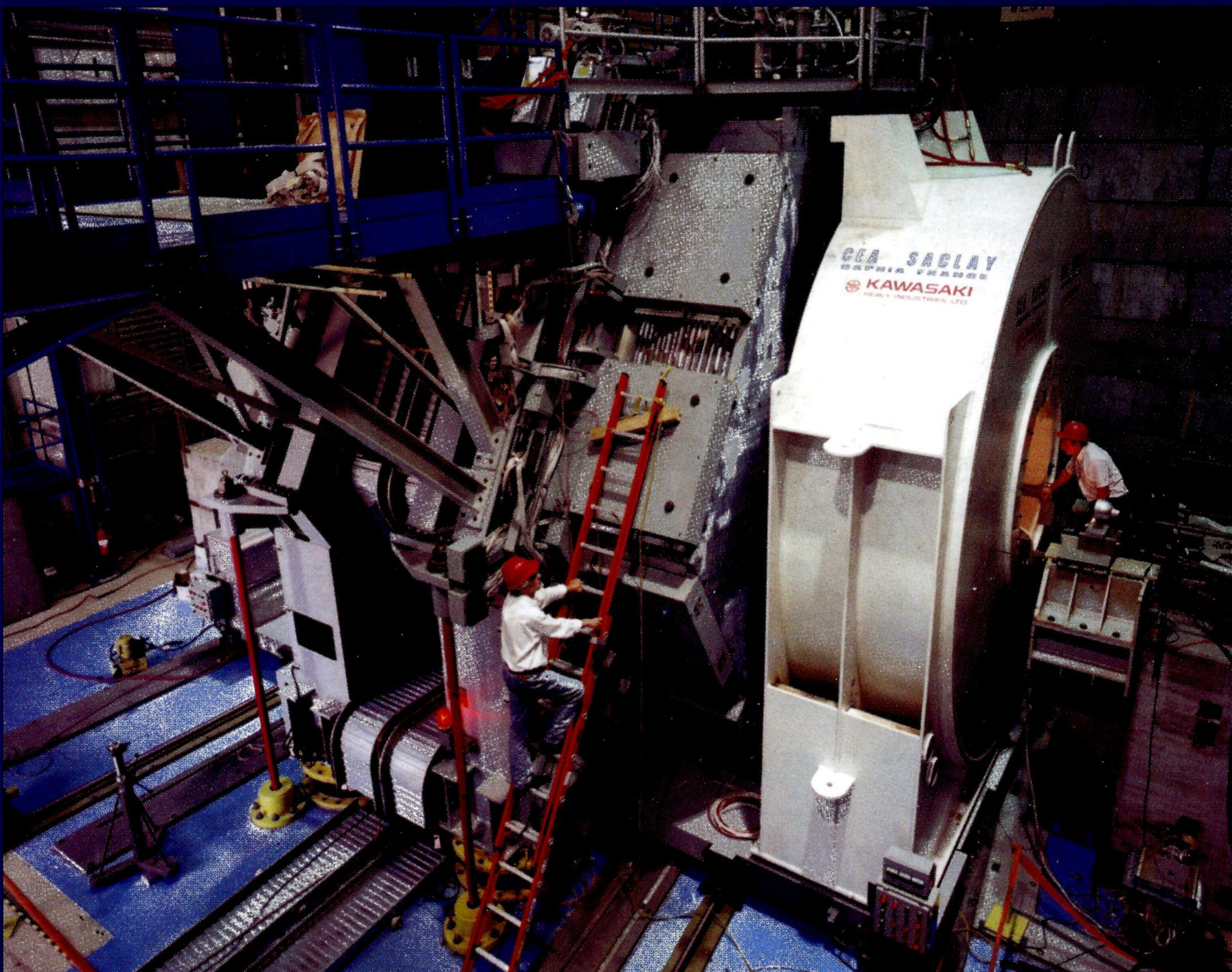

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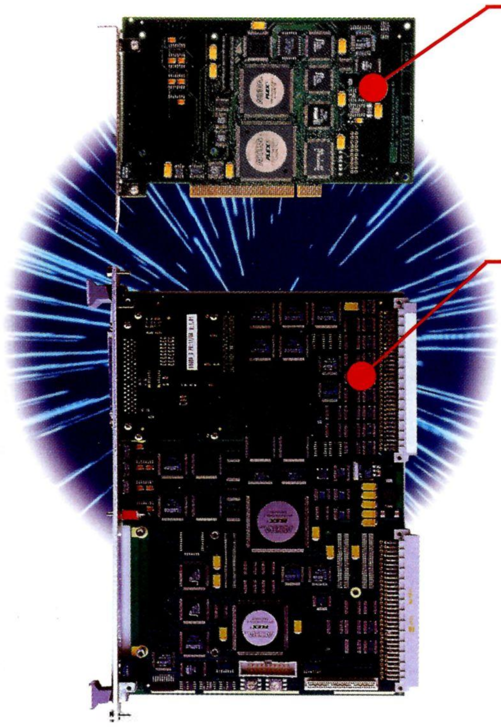

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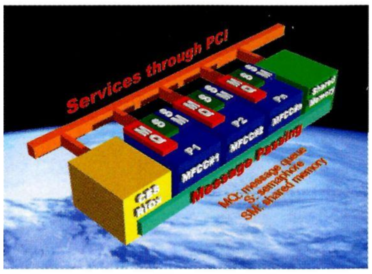

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Covering current developments in high-energy physics and related fields worldwide

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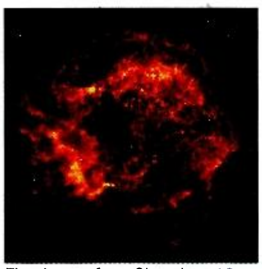

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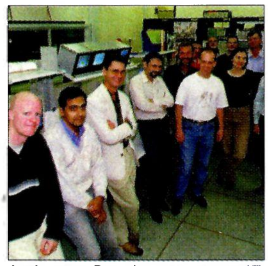

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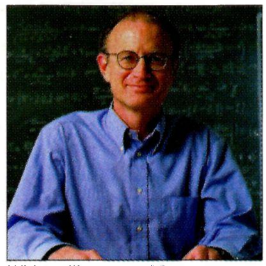

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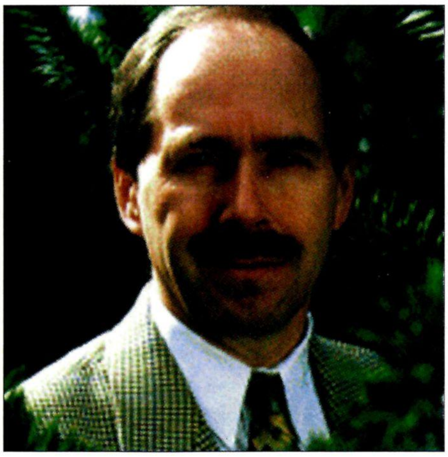
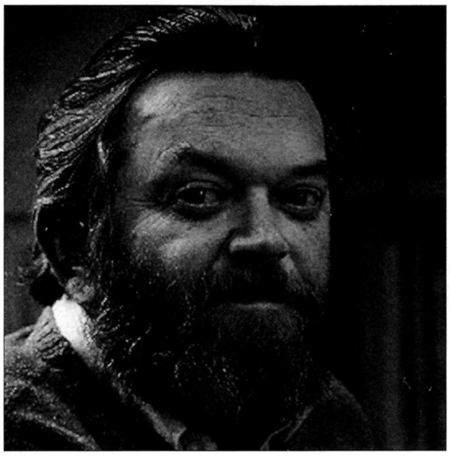
Cover: Construction of the BaBar detector at the PEP-II B factory, SLAC, Stanford. The new generation of B factories will provide new insights into the behaviour of heavy quarks (p29).

Nobel Prize for Physics 1999



Gerardus 't Hooft of Utrecht.



Martinus Veltman of Bilthoven.

The last Nobel Prize for Physics this century goes to Gerardus 't Hooft of Utrecht and Martinus Veltman of Bilthoven in the Netherlands, "for elucidating the quantum structure of electroweak interactions in physics".

Exactly 20 years ago the Nobel prize went to Sheldon Glashow, Steven Weinberg and Abdus Salam for their contributions to the electroweak theory – the unified theory of weak and electromagnetic interactions, which was first published in 1967. It was 't Hooft's and Veltman's work that put this unification on the map, by showing that it was a viable theory that could make predictions possible.

Field theories have a habit of throwing up infinities that at first sight make sensible calculations difficult. This had been a problem with the early forms of quantum electrodynamics and was the despair of a whole generation of physicists. However, its reformulation by Richard Feynman, Julian Schwinger and Sin-Ichiro Tomonaga (Nobel prizewinner 1965) showed how these infinities could be wiped clean by redefining quantities like electric charge.

Each infinity had a clear origin, a specific Feynman diagram, the skeletal legs of which denote the particles involved. However, the new form of quantum electrodynamics showed that the infinities can be made to disappear by including other Feynman diagrams, so that two infinities cancel each other out. This trick, difficult to accept at first, works very well, and renormalization then became a way of life in field theory. Quantum electrodynamics became a powerful calculator.

For such a field theory to be viable, it has to be "renormalizable". The synthesis of weak interactions and electromagnetism, developed by Glashow, Weinberg and Salam, and incorporating the now famous "Higgs" symmetry-breaking mechanism, at first sight did not appear to be renormalizable. With no assurance that meaningful calculations were possible, physicists attached little importance to the development. It had not yet warranted its "electroweak" unification label.

The model was an example of the then unusual "non-Abelian" theory, in which the end result of two field operations depends on the order in which they are applied. Until then, field theories had always been Abelian, where this order does not matter.

In the summer of 1970, 't Hooft, at the time a student of Veltman in Utrecht, went to a physics meeting on the island of Corsica, where specialists were discussing the latest developments in renormalization theory. 't Hooft asked them how these ideas should be applied to the new non-Abelian theories. The answer was: "If you are a student of Veltman, ask him!" The specialists knew that Veltman understood renormalization better than most other mortals, and had even developed a special computer program – Schoonschip – to evaluate all of the necessary complex field theory contributions.

At first 't Hooft's ambition was to develop a renormalized version of non-Abelian gauge theory that would work for the strong interactions that hold subnuclear particles together in the nucleus. However, Veltman believed that the weak interaction, which makes subnuclear particles decay, was a more fertile approach. The result is physics history. The unified picture based on the Higgs mechanism is renormalizable. Physicists sat up and took notice. As Sidney Coleman at Harvard said, this work "turned the Weinberg-Salam frog into an enchanted prince!"

One immediate prediction of the newly viable theory was the "neutral current". Normally the weak interactions involve a shuffling of electric charge, as in nuclear beta decay, where a neutron decays into a proton. With the neutral current, the weak force could also act without switching electric charges. Such a mechanism has to exist to assure the renormalizability of the new theory. In 1973 the neutral current was discovered in the Gargamelle bubble chamber at CERN and the theory took another step forward.

The next milestone on the electroweak route was the discovery of the W and Z carriers, of the charged and neutral components respectively, of the weak force at CERN's proton–antiproton collider. For this, Carlo Rubbia and Simon van der Meer were awarded the 1984 Nobel Prize for Physics.

The electroweak baton was taken up in 1989 by CERN's LEP electron–positron collider, where precision data enabled 't Hooft and Veltman's technique to be put to work to predict the mass of the sixth "top" quark. Although at the time unseen, physicists knew that the top quark had to be contributing indirectly. Corrections involving the top quark have the unusual property of becoming larger as the top mass increases. When the top quark was discovered at Fermilab's Tevatron proton–antiproton collider in 1995, its mass was exactly where the calculations said it would be.

The only missing link in the electroweak picture now is the Higgs mechanism, and, with LEP exploring new energy regimes, the physicists are eagerly scanning the latest LEP data. On the sidelines is CERN's LHC, which will bring Higgs physics to its ultimate conclusion.

Neutron facility to open at CERN

The lead target of the TARC experiment is being resurrected for the new nTOF facility.

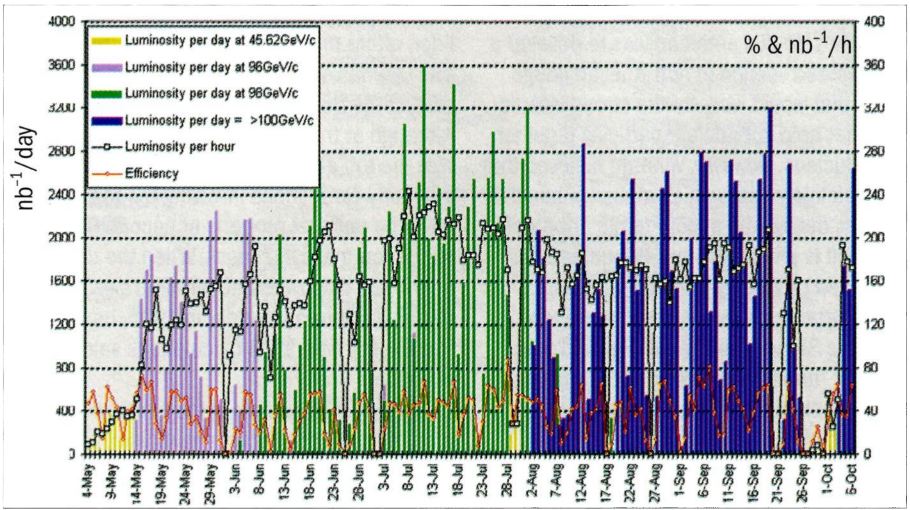
A new facility is set to join the CERN experimental programme from April 2000. The neutron time-of-flight (nTOF) system will support a range of experiments that study neutron-induced reactions. They will cover subjects as diverse as stellar nucleosynthesis and basic nuclear physics, and they will be complementary to experiments already under way at the laboratory's ISOLDE radioactive beam facility.

Taking its cue from the recent TARC experiment at CERN, which studied the transmutation of elements using neutrons moderated in lead, the facility will also study the neutron-induced transmutation of radioactive isotopes found in nuclear waste.

The nTOF facility's strong point is its extremely high resolution for neutron capture cross-sections over the 1 eV to 250 MeV energy range. Neutrons, produced by spallation in a lead target that was recycled from TARC, will travel to an experimental area 200 m downstream. It is this distance that gives nTOF its unprecedented neutron energy resolution, which is expected to be of the order 10^{-4} over the entire energy range.

The facility is currently under construction and, when it starts up next year, it will have been commissioned in record time. One reason for this is the extensive use made of the existing infrastructure. The facility will be installed in an existing tunnel leading from the Proton Synchrotron accelerator, which will provide the protons driving the spallation process in the lead target, to CERN's west experimental area. Moreover, this tunnel passes 7 m below another that formerly housed the Intersecting Storage Rings collider. The experimental target will be situated below this tunnel, which will be adapted to provide target-handling facilities.

The first experiments at the nTOF will be designed to test its performance. Known neutron capture cross-sections will be evaluated before the nTOF programme moves on to a range of new measurements.



The integrated luminosity per hour and per day of the 1999 operation of CERN's LEP collider. The blue lines illustrate operation at 100 GeV per beam and above.

An even greater step for LEP

On 24 September 1999 the French authorities gave their formal permission for CERN's LEP electron–positron collider to run at beam energies of up to 105 GeV. Immediately following the receipt of the letter, two fills were running at 101 GeV. However, the machine then had cryogenics problems.

LEP had been running impressively at 100 GeV per beam (a collision energy of 200 GeV) since early August.

Assembly of CMS magnet begins

The first ring for the barrel yoke of the superconducting solenoid magnet that will be used in the CMS experiment at CERN.

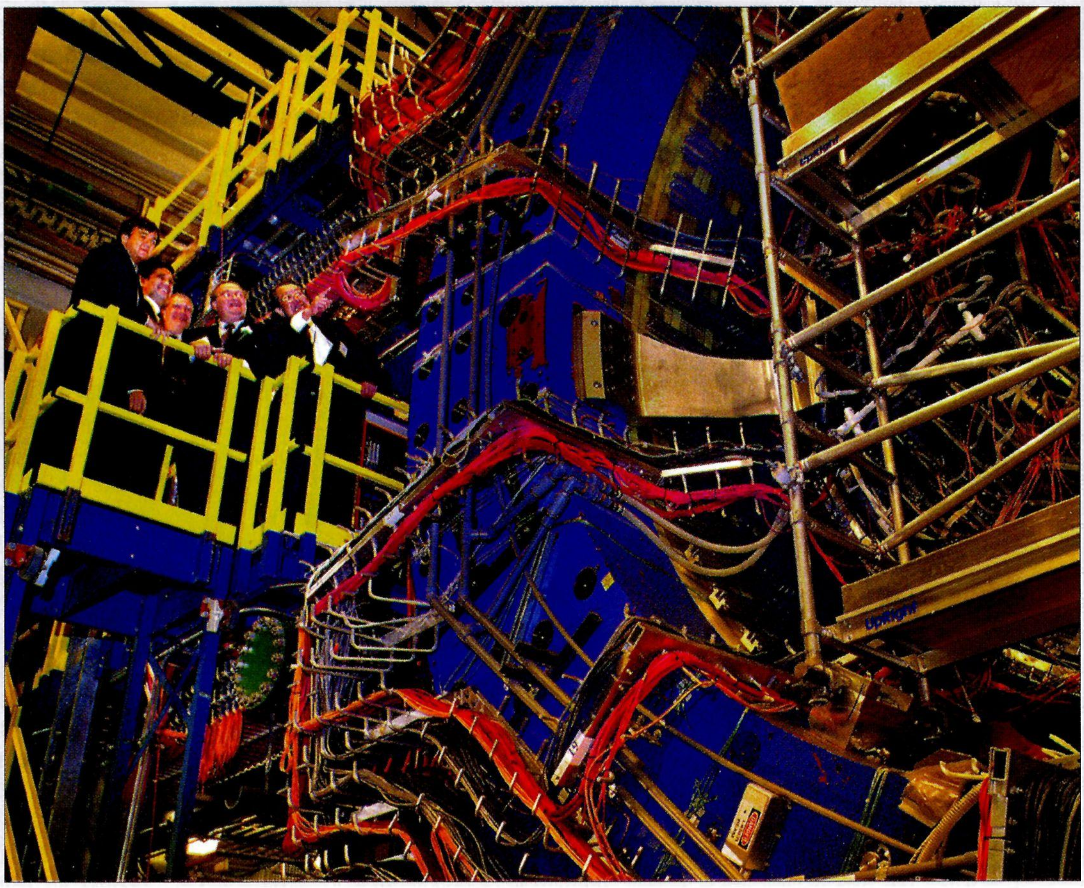
The world's largest superconducting solenoid magnet – for the CMS experiment at CERN's LHC collider – recently took an important step towards completion when the first ring of its barrel yoke was assembled near Munich. The order for the manufacture of the yoke was given to Germany's Deggendorfer Werft und Eisenbau GmbH (DWE) in the largest individual contract for a high-energy physics experiment ever placed. The contract was worth some 23 million Swiss francs. Following a worldwide call for tender, the order for the CMS barrel iron yoke and vacuum tank was signed on behalf of the CMS collaboration between DWE and the Swiss Federal Technical Institute ETH Zürich in April of last year.

The CMS solenoid coil will measure 6 m in diameter and 12.5 m in length. At 4 T it will have the highest field of any magnet of its kind and it will be able to store some 2.5 GJ of energy. Its return yoke will weigh 11 000 tons and will consist of two endcaps, each of which will have three disks, and a barrel yoke that is made up of five rings.

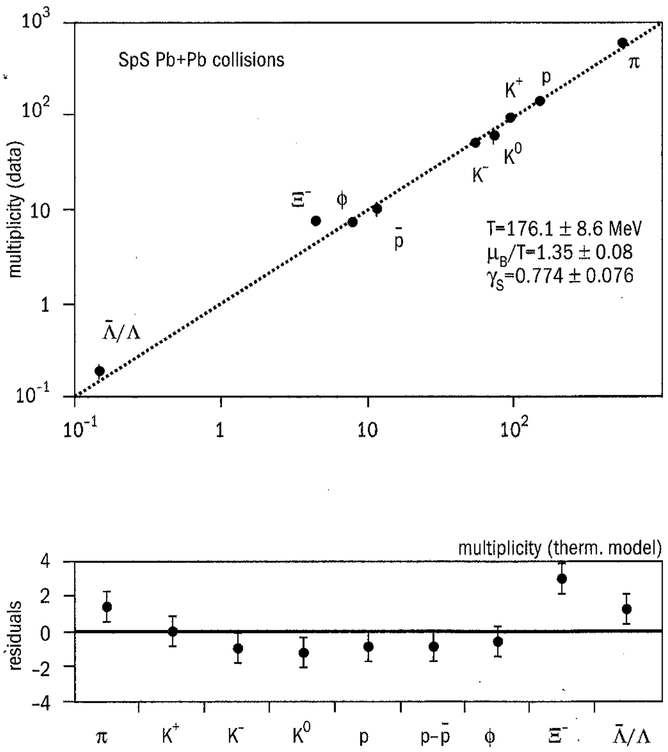
The magnet system was designed by a CMS team and was financed by a consortium of CMS funding agencies in Switzerland, the US, Germany, Cyprus, Russia and the CMS Common Fund. DWE is coordinating the magnet's construction with subcontractors in the Czech Republic, France, Germany, Italy, and the Russian Federation.

Eight of the ten feet for the yoke are being provided as an in-kind contribution by Pakistan, where they are being manufactured by the company Scientific Engineering Systems. China will be donating the supports for the endcaps. They are being manufactured in China by the Hudong Heavy Machinery Company. The final assembly of the yoke will commence in July 2000 at CERN. After being tested on the surface, the magnet will be lowered, ring by ring, to the CMS experimental hall some time towards the end of 2003.

After the formal dedication of Brookhaven's relativistic heavy-ion collider (RHIC) on 4 October (left to right) US Energy Secretary Bill Richardson, Congressmen Rick Lazio, Gary Ackerman, Brookhaven director John Marburger and RHIC project head Satoshi Ozaki, inspected the STAR detector at RHIC. RHIC handled its first beams of gold ions this summer and will soon commence its research programme.



Experiments rechart the Big Bang



These diagrams compare the total production rate of various subnuclear particles (hadrons – from pions to hyperons) as seen by the NA49 experiment at CERN (which is studying central high-energy lead ion collisions), with a statistical Hagedorn-type model (developed by F Becattini). The model shows that the transition temperature, T_0, above which quarks no longer stick together to form hadrons, is about 180 MeV.

In the beginning there were quarks and gluons – the "quark–gluon plasma". Density and temperature decreased as the universe expanded and cooled. The quarks and gluons began to freeze, forming subnuclear particles (protons and neutrons). These in turn stuck together to form nuclei. So goes the dogma.

To check whether or not this is true, experiments at CERN hurl beams of high-energy nuclei at targets to create hot, dense fireballs of protons and neutrons. These may be hot and dense enough for the protons and neutrons to melt and their component quarks and gluons to be released from their nuclear habitat.

Experiments using beams of lead ions at CERN's SPS synchrotron have recently polished their results. Included is the NA50 study, which is looking at the production of J/psi particles. These particles are composed of a heavy (charmed) quark and an antiquark, which are bound together. They are more difficult to form when quarks and antiquarks are less likely to stick together. A clear signal of J/psi suppression (*CERN Courier* May p8) was, therefore, greeted as the first resynthesis of the quark–gluon plasma since the Big Bang. However, some physicists are pointing out that this is not the whole story.

In any plasma (a gas of charged particles) the charge carried by any one particle is screened by those surrounding it. This is called Debye shielding. Quarks and gluons interact via the tripartite colour charge rather than the familiar dual (positive/negative) electrical charge.

It is this screening mechanism that prevents quarks from sticking together above a certain critical temperature, T_0, and beyond a certain energy density, E_0. Subnuclear particles melt under these conditions.

However, the J/psi, as the lightest particle containing charmed quarks, is very small and tightly bound. Therefore it melts at a slightly higher temperature, about $1.3T_0$. This apparently small temperature shift is amplified for the energy density, which behaves as the fourth power of temperature. Thus J/psis melt at energies of around $3E_0$, which is much later than most subnuclear particles.

Furthermore, J/psis are special because their constituent charm quark–antiquark pair will never recombine once the plasma fireball expands and cools. They lose contact with each other and adhere instead to other, lighter quarks to form D mesons. Light quarks in the plasma will recombine into protons, kaons, pions, etc.

NA50 sees the onset of J/psi disappearance in the most violent "head-on" collisions of lead ions (and only lead ions) at maximum SPS energy (158 GeV per nucleon). The energy density, therefore, must have reached about $3E_0$ in these collisions. Other experiments using lead ion beams, such as NA49, estimate from calorimetric measurements that the energy density achieved in these collisions is about 3 GeV per cubic fermi (1 fermi = 10^{-13} cm, which is the "diameter" of a proton). Tentatively combining these observations leads to the conclusion that the critical density, E_0, is about 1 GeV per cubic fermi, which is in agreement with quark–gluon field theory calculations.

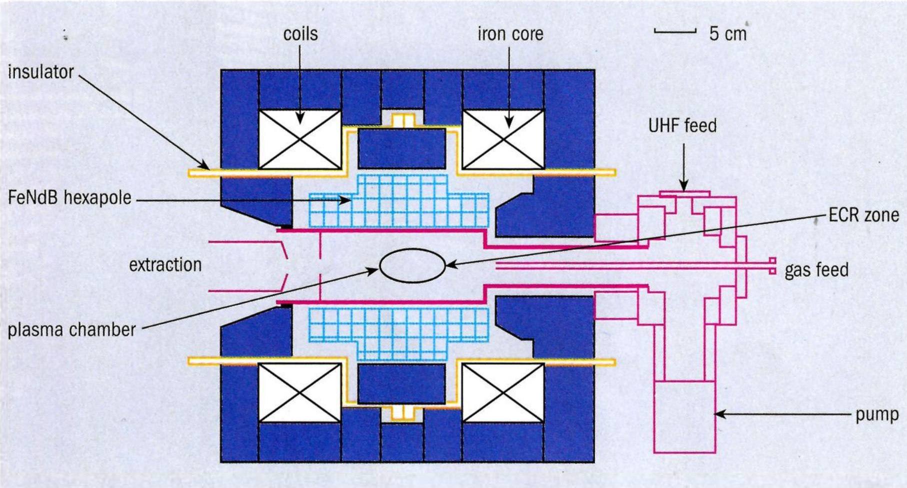
This can now be tested by the experiments using lead beams (NA44, NA49, WA89 and WA97). Reinhard Stock of Frankfurt points out that hadron production in these reactions can be reconciled with quarks and gluons combining at T_0, which is near 180 MeV, and E_0, which is near 1 GeV per cubic fermi.

Previous theoretical studies of the transition from a quark–gluon fireball to a subnuclear fireball by John Ellis of CERN and Klaus Kinder-Geiger (who died in last year's Swissair plane crash) had set the stage. Their model set out to explain how different subnuclear particles containing quarks and gluons emerged from electron–positron annhilations.

They showed that the transition probability depends on statistical mechanics, so that the relative production levels of different subnuclear particles infers the temperature prevailing at their birth. This happens as the initial high-energy density quark–gluon fireball expands and cools towards the critical temperature at which the particles crystallize.

Thus, experiments with high-energy nuclear beams are recharting the Big Bang.

ECRIS feeds transuranic nuclei experiments



Typical 14 GHz ECRIS. Schematic of an electron cyclotron resonance ion source (ECRIS).

The recent discovery of new superheavy transuranic nuclei (*CERN Courier* September p18) has reawakened interest in the possibility of an "island of stability" inhabited by quasi-stable nuclei. These exotica are produced by bombarding a suitable nuclear target with a high-energy beam of specially prepared nuclei and studying the resulting decay chains in a suitable detector.

The discovery of these nuclei is a major accomplishment for the accelerators that handle the beams and is a tribute to the expertise of the scientists at the three traditional world centres for this work – Dubna near Moscow, the GSI heavy-ion Laboratory in Darmstadt and the US Lawrence Berkeley Laboratory, where transuranic nuclei were first discovered by McMillan and Abelson 60 years ago. The detectors (the SHIP velocity filter at Darmstadt and gas-filled separators at Dubna and Berkeley) also play a vital role.

However, given the minuscule production rates of the new nuclei (roughly one every two weeks), a prerequisite for achieving anything at all is to be able to supply enormous doses (10^{18}) of ions to feed the accelerators in a reasonable time. Moreover, the ions required are highly charged: krypton-19^+ at Berkeley, calcium-5^+ at Dubna and nickel-9^+ at Darmstadt. The supplied beams also have to be well defined so that no precious particles are lost downstream in the acceleration and transport stages. The standard source that meets all of these demanding criteria is the electron cyclotron resonance ion source (ECRIS), which is capable of supplying adequate doses nonstop over several weeks.

ECRIS uses neither cathodes nor arc discharges. The cavity is filled with vapour and subjected to microwave oscillations in a magnetic field. Ionization electrons in the vapour see the source as a miniature cyclotron, whirling round and acquiring energy. These high-energy electrons trigger a plasma breakdown and in turn rip out more electrons, thus ionizing the vapour to high charge states.

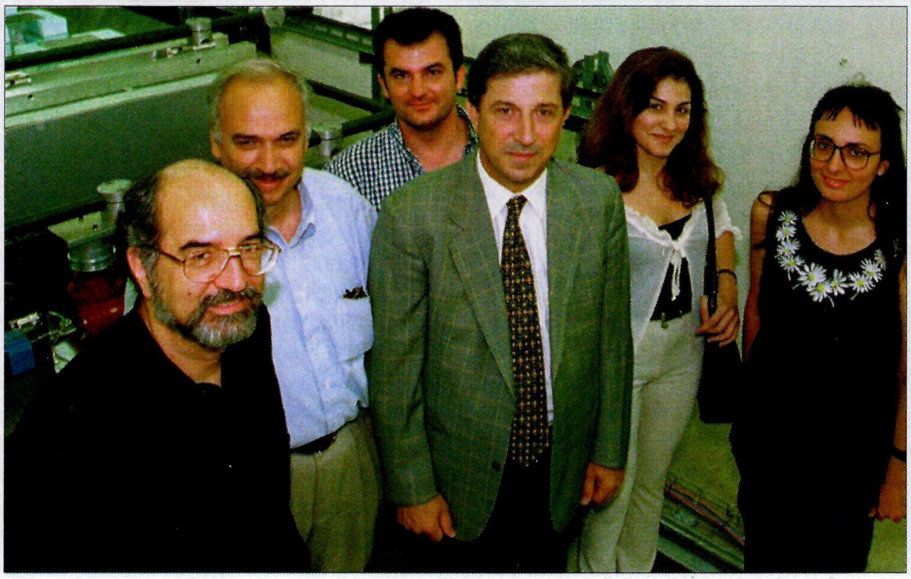
Owing to the absence of electrodes, these sources are very reliable and can provide virtually unlimited amounts of ions. Darmstadt is now equipped with its CAPRICE ECR source, Dubna with ECR4M and Berkeley with ECR-U, all of which are operating at 14 GHz.

Incidently, CERN's new heavy-ion linac, commissioned in 1994, also uses a 14 GHz ECR ion source (supplied by France) and produces lead-27^+ ions at 2.5 KeV per nucleon to feed CERN's programme of research using beams of heavy ions.

The Greek delegate to CERN Council, Prof. Floratos (centre), welcomed the arrival at CERN of the first muon detector for the ATLAS experiment to come off the production line. Produced by a collaboration between three Greek universities, the chamber is the first of 1200 that will be built for the experiment at the LHC over the coming years.

The ATLAS muon detection system will cover 17 000 m^3. Its production is being shared between 46 institutions around the world, with strict quality control procedures at each. Chambers will be arriving at CERN over the next four years, with the full detector being ready for installation by early 2004.

Prof. Floratos is accompanied by members of the team that established the Greek production line, which began in August.



The Gigabyte System Network is demonstrated at CERN

Arie Van Praag (left) and Tzvetomir Anguelov from the Institute for Nuclear Research and Nuclear Energy, Sofia, at work on the GSN to Gigabit Ethernet Bridge at CERN.

To mark the major international Telecom '99 exhibition in Geneva, CERN staged a demonstration of the world's fastest computer networking standard, the Gigabyte System Network. This is a new networking standard developed by the High Performance Networking Forum, which is a worldwide collaboration between industry and academia. Telecom '99 delegates came to CERN to see the new standard in action.

The academic scientific community has been at the forefront of networking for nearly three decades. In the pioneering days of the late 1960s and early 1970s, it was computer scientists working on the US ARPANET, the British National Physical Laboratory network and the French Cyclades that got networking off the ground. Later, the US NSFNET and British JANET brought networking to the academic community as a whole. At CERN, the pioneering CERNET of the 1970s was a network of networks before the Internet was born. Then, when the ARPANET became the Internet and jumped the Atlantic into Europe, high-energy physics was, for a long time, its most important user.

Today, networking has entered the industrial mainstream, but laboratories like CERN still play an important role. CERN's contribution to the Gigabyte System Network (GSN) has been the development of a bridge to connect the new standard with the increasingly popular Gigabit Ethernet local networking architecture. The CERN set-up, currently the largest GSN network in the world, is a valuable proving ground for the new technology.

GSN is the first networking standard capable of handling the enormous data rates expected from CERN's forthcoming Large Hadron Collider (LHC) experiments. It has a capacity of 800 Mbyte/s (that's getting on for a full-length feature film), making it attractive beyond the realms of scientific research. Internet service providers, for example, expect to require these data rates to supply high-quality multimedia across the Internet within a few years. Today, however, most home network users have to be content with 5 kbyte/s, or about a single frame. Even CERN, one of Europe's largest networking centres, currently has a total external capacity of only 22 Mbyte/s.

Edited by Alison Wright

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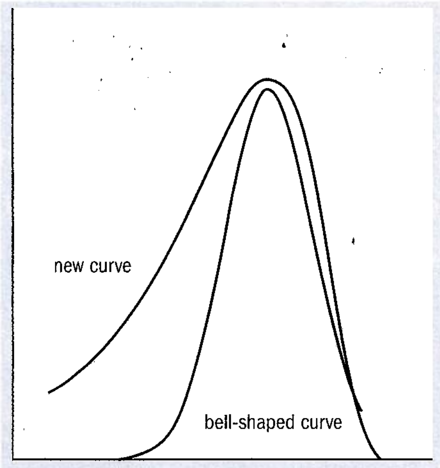
Understanding gained from chaos

A new mathematical curve is challenging the traditional bell-shaped Gaussian distribution as a description of random fluctuations. Why it applies so widely to many different systems can be explained by chaos theory.

The curve first came to light in studies by two scientists at University College London and Ecole Normale Superieure (ENS), Lyon, who simulated the ordering of spin vectors in a ferromagnet at a critical temperature. They plotted the probability spectrum (the "probability density function") to see if the overall magnetization of the sample would fluctuate by a certain amount from its normal behaviour, or equilibrium.

Fluctuations about such a mean value are expected to follow a symmetric Gaussian distribution, with a high probability for small fluctuations from the mean. Large fluctuations are rarer but are equally distributed on either side. The plot, while matching a Gaussian shape at the high end, had a distinctive, exponential lower tail. This gives a higher probability for fluctuations below the mean (for example, this curve gives the probability of a low fluctuation, of more than six standard deviations from the mean value, as 2×10^{-4} compared with 1×10^{-9} for the Gaussian).



The traditional bell-shaped Gaussian distribution says that a random effect is just as likely to go over the top as it is to fall short. However, new studies show that, in some cases, the distribution is skewed, so that the latter becomes much more likely.

Then, almost by accident, they discovered the same curve on the desk of an ENS colleague who had been studying turbulence in a closed system. He had also plotted probabilities of fluctuations – found in the power consumption of turbulent flow produced when air is trapped between two counter-rotating discs.

To explain such similar behaviour in two different systems, the scientists reached for one of the central concepts of chaos theory: self-similarity. If a system is self-similar, it looks the same when viewed from far away and close up. A fractal is a good example. The magnet at critical temperature and the turbulence in the closed air system are both self-similar and hence are governed by the same statistics.

The same curve has since been plotted by US scientists looking at the distribution of species in ecosystems. The system is self-similar, so the distribution of species in 1 km^2 of a certain habitat ought to be the same as that in 1 m^2.

Another US study showed that the incidences of severe floods, forest fires, earthquakes and avalanches also follow the curve, with the "worst" incidents occurring more often than was indicated by predictions based on bell-shaped curves.

Condescending to condense

In 1995, Colorado physicists achieved a world first by cooling rubidium atoms to such low temperatures that the atoms condensed into a single quantum state – a ground state – to form a Bose–Einstein condensate. A second team has turned its attention to fermionic atoms, which have a half-integer spin.

Pauli's Exclusion Principle says that it is impossible to make a fermionic condensate because no two fermions can exist in identical quantum states. However, fermions can be cooled in such a way that they fill up quantum levels systematically from the bottom up. This is called a "degenerate" state.

Bose–Einstein condensates (BECs) are made using evaporative cooling, where energy is transferred by atom collisions to reduce the temperature of the gas. For fermions this is more difficult, because fermions in similar states repel each other. To get round this, the team used a mixture of potassium-40 atoms in two different spin states and cooling to 290 nK was achieved. This is the lowest temperature ever measured for a fermion gas.

They saw that the degenerate gas had more energy and a wider momentum distribution than predicted by classical physics – evidence that the exclusion principle had forced the atoms to occupy higher quantum states. This sets the stage for further studies of superconductivity and superfluidity.

Meanwhile, other US groups have seen quantized vortices in a BEC of rubidium atoms. Excitations moving through a BEC of sodium atoms lost little or no energy if the velocity was below a critical value. Such a critical velocity for frictionless motion is a hallmark of superfluidity. AIP

Laser light source sings the blues

A group of Japanese, German and Italian researchers has made the first blue vertical cavity surface-emitting laser (VCSEL), which operates at room temperature. By exploiting recent progress in crystal growth technology, an active region of InGaN quantum wells and mirror surfaces of gallium and aluminium nitrides were grown on a sapphire substrate to make disc-shaped cavities. Each one was only 18 μm in diameter. When the cavities were illuminated by a HeCd laser, light was emitted at a wavelength of 399 nm.

Two-dimensional arrays of blue VCSELs could drastically reduce the read-out time in high-density optical data storage (for example, in CDs and DVDs) and increase the scan speed in laser printing technology.

Edited by Emma Sanders

Latest news from the early universe

This month the first elements of the Very Small Array will be installed on Mount Teide in Tenerife. This is one of a number of new projects studying the cosmic microwave background.

Observations of the cosmic microwave background (CMB) are the closest that astronomers can get to the beginning of the universe. It dates from 300 000 years after the Big Bang, when radiation decoupled from matter. Fluctuations in the CMB are evidence for the first clumping of matter particles – the seeds of the galaxies we see today.

The 14 antennae of the Very Small Array (VSA) will map small areas of the sky from 26 to 36 GHz with a sensitivity of 5–10 μK. The VSA will be capable of the two-dimensional mapping of real features and it is expected to be up and running by next summer.

By then, results from the Boomerang balloon experiment will be out. This experiment uses the polar wind to stay aloft and enables the balloon to circle the South Pole for more than 10 days. Thus it avoids the fate of other balloon experiments, which only have a short observation time. The VSA, with its greater resolution, will be able to follow up in more detail any areas of interest identified by the balloon. Balloon observations have different systematic errors than ground-based telescopes, so results are complementary.

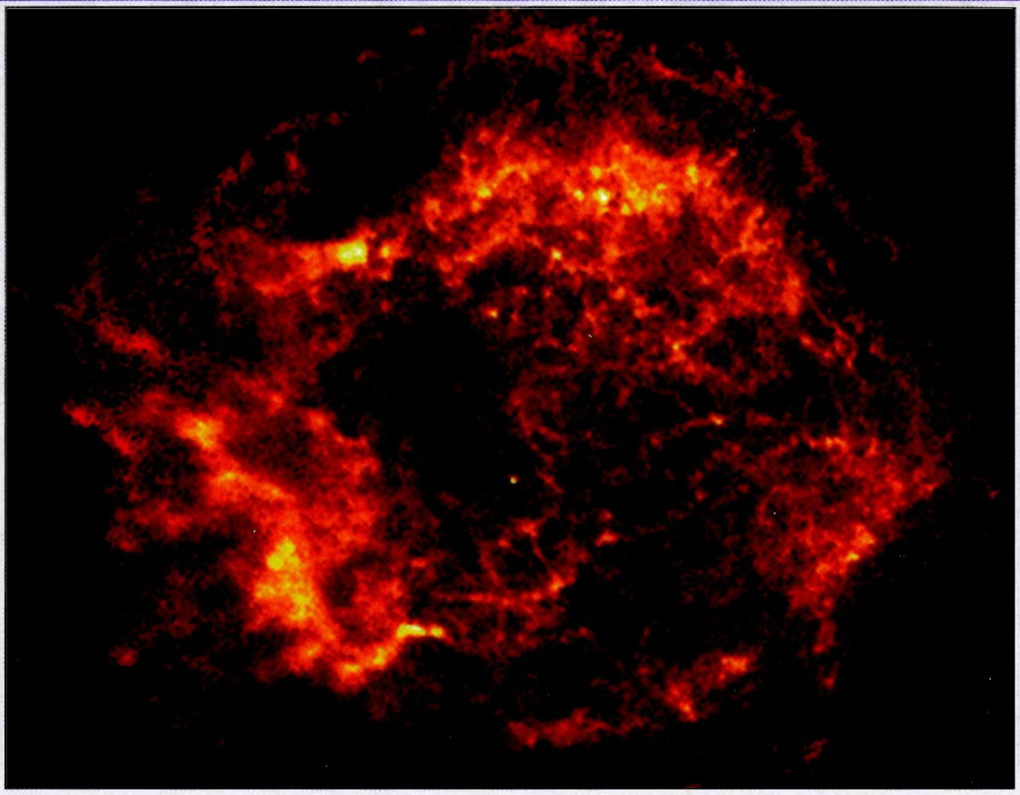
Future projects include the US Cosmic Background Imager, to be installed in the Atacama desert, Chile, and the Degree Angular Scale Interferometer at the South Pole.

It is an interesting time for CMB observations. Following the great leap forward made by the COBE satellite in 1992, which measured the background fluctuations for the first time, years of data analysis and new ground-based experiments are providing fuller and more detailed results. A recent analysis of CMB data has even cast doubt on inflation – the most stalwart theory of the early evolution of the universe. However, other investigations suggest that the discrepancy may be due to instrumental error. The VSA and Boomerang experiments will be in a position to find out.

The study of foreground microwave radiation has also progressed. New sources of microwave emission have been discovered, such as spinning dust grains in our galaxy. When this is better understood, it will make for more accurate CMB results. NASA's Microwave Anisotropy Probe, which is scheduled for launch late next year, will perform the next all-sky survey as a follow up to COBE. At the other end of the spectrum, NASA's X-ray satellite, Chandra, may provide crucial data with its observations of galaxy clusters, the largest scale clumping seen in the universe today. Cosmologists are hoping for some real advances. At worst, they will have to wait for the launch of ESA's Planck satellite some time after 2007 (*CERN Courier* July p14).

The VSA is a collaboration between Cambridge University, Jodrell Bank and the Canary Islands Institute for Astrophysics. The Boomerang partners are the US and Italy, with contributions from the UK and CERN.

Picture of the month

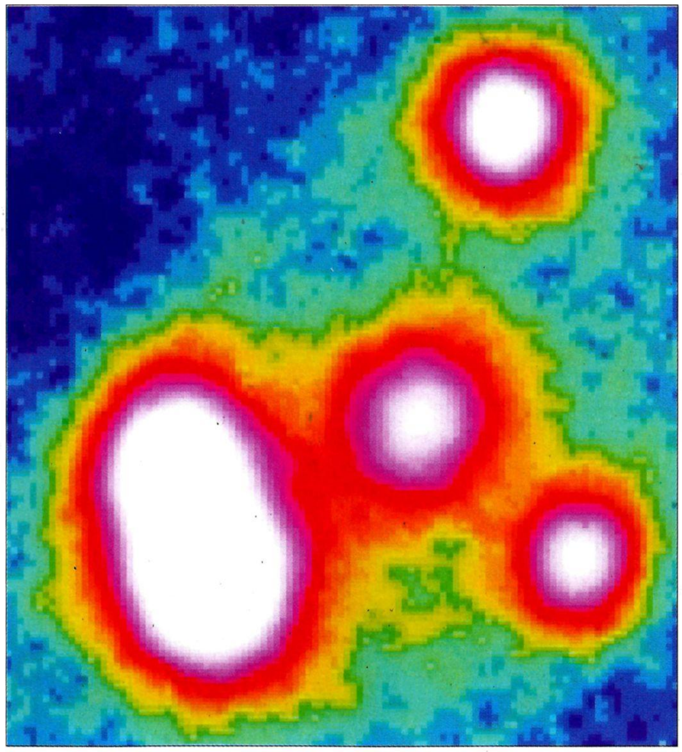


This image of the Cassiopeia A supernova remnant is the first from the new Chandra X-ray satellite, which was launched this summer (*CERN Courier* September p15). Cassiopeia A is an expanding shell of gas, of about 10 light-years in diameter with a temperature of about 50 million degrees centigrade. It is the remnant of a star that exploded about 300 years ago. (NASA/CXC/SAO.)

New study of distant quasars

Subaru, Japan's new 8.3 m telescope on Mauna Kea in Hawaii (*CERN Courier* March p9), is being used for a new study of gravitationally lensed quasars. A luminosity of more than 100 galaxies is emitted from a quasar, which has a volume no larger than our solar system.

Einstein's theory of General Relativity shows that the gravitational pull from massive objects is able to deflect rays of light like a lens. For example, astronomers see four bright images of the quasar PG1115+080 more than 10 billion light years away. The four lensed images appear around a much nearer, massive galaxy in the centre, which acts as the lens. The relative brightness and position of the individual images gives a measure of how rapidly the universe is expanding.



Gravitationally lensed image of a distant quasar (PG1115+080) viewed through the Japanese Subaru telescope. (National Astronomy Observatory of Japan.)

LEP pursues Higgs boson and greater W precision

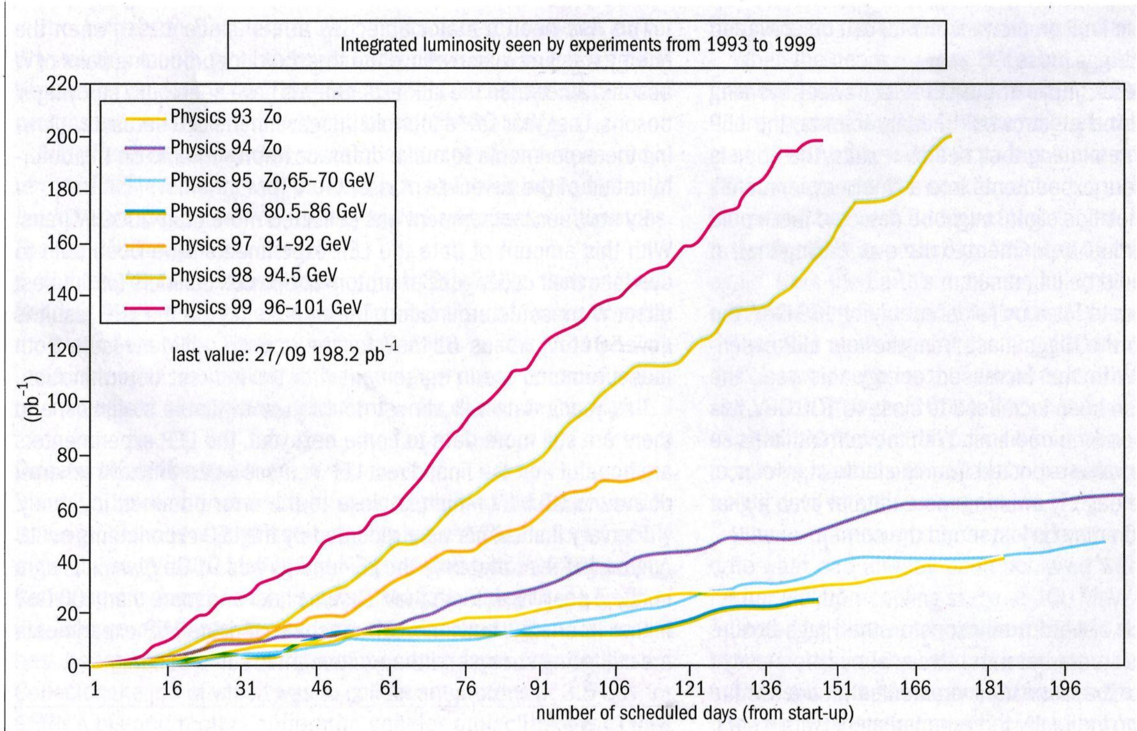
While we wait for a definitive sighting of the enigmatic Higgs particle, there is no lack of careful precision work for the experiments at CERN's LEP electron–positron collider. *Bob Clare* of MIT looks at the latest in LEP physics.

For the past two years, CERN's LEP electron–positron collider has been performing better than ever (*CERN Courier* October p14). Each year sees new increases in collision energy and, just as important, new records in luminosity (a measure of the collision rate). Last year, LEP delivered about 200 inverse picobarns of luminosity to each of the four experiments and, as a result, almost quadrupled the collected data on W bosons (produced as oppositely charged pairs).

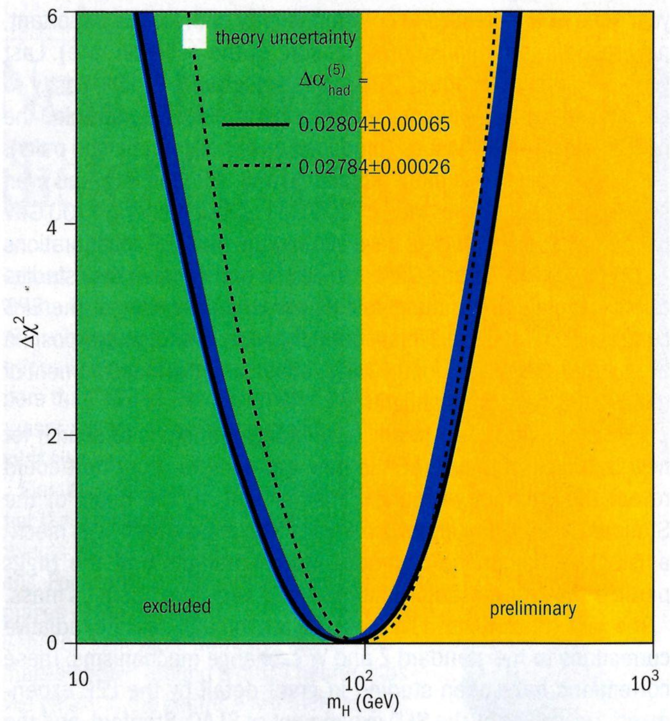
This year looks even more promising, with LEP reaching, and even slightly surpassing, the "magic" 200 GeV collision energy (100 GeV per beam). These new data have allowed the four LEP collaborations – ALEPH, DELPHI, L3 and OPAL – to extend and improve their studies at high energy. Of the many results presented recently at the EPS conference in Tampere, Finland, and the lepton–photon symposium at Stanford, the search for the Higgs boson and the measurement of the W mass were the highlights.

One of the first tasks in any new energy domain is to search for new particles. However, LEP is now exploring territory that could reveal the symmetry-breaking mechanism, at the heart of the Standard Model, that endows particles with mass (the "Higgs mechanism"). Although the Standard Model predicts that the Higgs particle should exist, unfortunately it says very little about its mass.

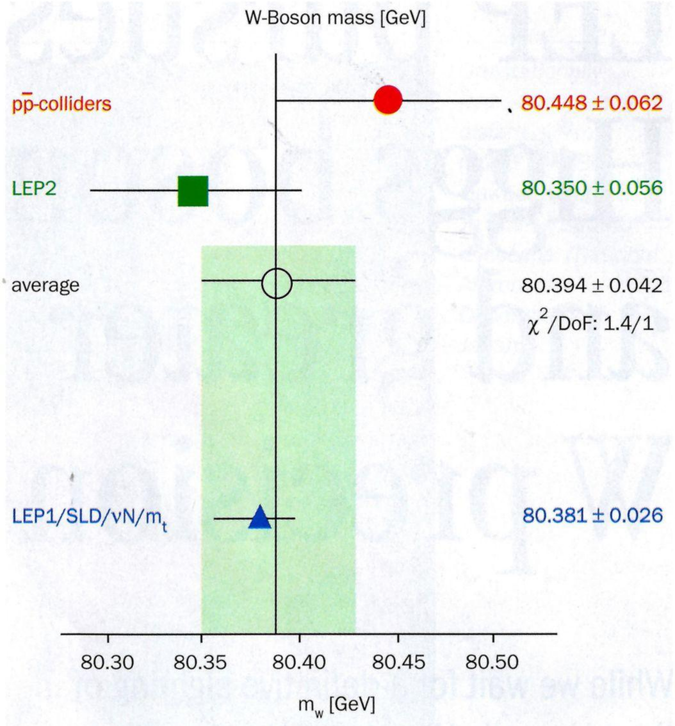
The Higgs should make its presence felt through delicate radiative corrections to the standard Z and W exchange mechanisms. These corrections have been studied in great detail by the LEP experiments, as well as by the SLD experiment at SLAC, Stanford, and the D0 and CDF experiments at Fermilab's Tevatron proton–antiproton collider. These studies indicate that the Higgs boson is relatively light. A fit to the LEP and SLC results on Z exchange, as well as the determinations of the W boson and top quark masses from LEP and the Tevatron, predict that the Higgs boson should be lighter than about 220 GeV, with a best fit at around 90 GeV. This is below the point where LEP is currently operating. A low-mass Higgs would be exciting. However, these suggestions are only indirect evidence.



Ever increasing – the integrated annual luminosity (a measure of the collision rate) delivered by CERN's LEP electron–positron collider.



Tantalizingly close – results of the Standard Model fit to the Higgs boson mass (parabolic curves) compared with the excluded region from the direct searches (yellow area).



The direct measurement of the W mass from LEP and proton–antiproton colliders compared with the indirect determination.

The LEP experiments have been diligently searching for direct evidence of the Higgs since the beginning of LEP data taking. So far nothing has turned up. With no sign of a signal yet, the experiments express the non-observation as an upper limit on the Higgs production rate. At a given collision energy this depends on the Higgs mass and the upper limit on production rate can be converted into a lower limit on the Higgs mass.

Recently, following the example of the LEP Electroweak Working Group's efforts to combine electroweak measurements, the LEP experiments have been combining their search results. The hope is that by combining the four experiments into a "meta-experiment", with four times the luminosity, a signal might be detected that would be too small for an individual experiment to discover. Failing that, at least any mass limits could be increased.

Based on last year's data, at a collision energy of 189 GeV, the combined lower limit on the Higgs mass from the four LEP experiments was 95.2 GeV. With the increased energy this year, the individual limits have also been increased to close to 100 GeV. It is too early to report on the combined limit. With the current limits so tantalizingly close to the value expected from the indirect evidence, the physicists at LEP are eagerly awaiting more data at even higher energies. The Higgs boson may be just round the corner.

W for weight

Compared with the lack of hard predictions on the Higgs boson, the Standard Model has somewhat more to say about the mass of the W boson. Via many of the same measurements that are used to constrain the Higgs boson indirectly, the experimenters (with a great deal of help from the theorists) have coaxed the Standard Model into predicting the mass of the W boson with an error of only 26 MeV (in 80 GeV). Now the challenge is to measure the W boson mass directly to the same accuracy, which will be a stringent test of the Standard Model.

This has been a major objective at LEP since 1996, when the energy was first raised above the threshold for producing pairs of W bosons. Since then the LEP experiments have been busy studying W bosons. Last year saw a fourfold increase in the LEP datasets, allowing the experiments to make dramatic improvements on the determination of the particle's mass.

By now, each experiment has collected more than 4000 W pairs. With this amount of data the LEP experiments have been able to overtake their colleagues at proton–antiproton colliders for the best direct W mass determination. The uncertainty on the LEP result is now 56 MeV, versus 62 MeV for the hadron collider result. Both measurements are in agreement with the indirect determination.

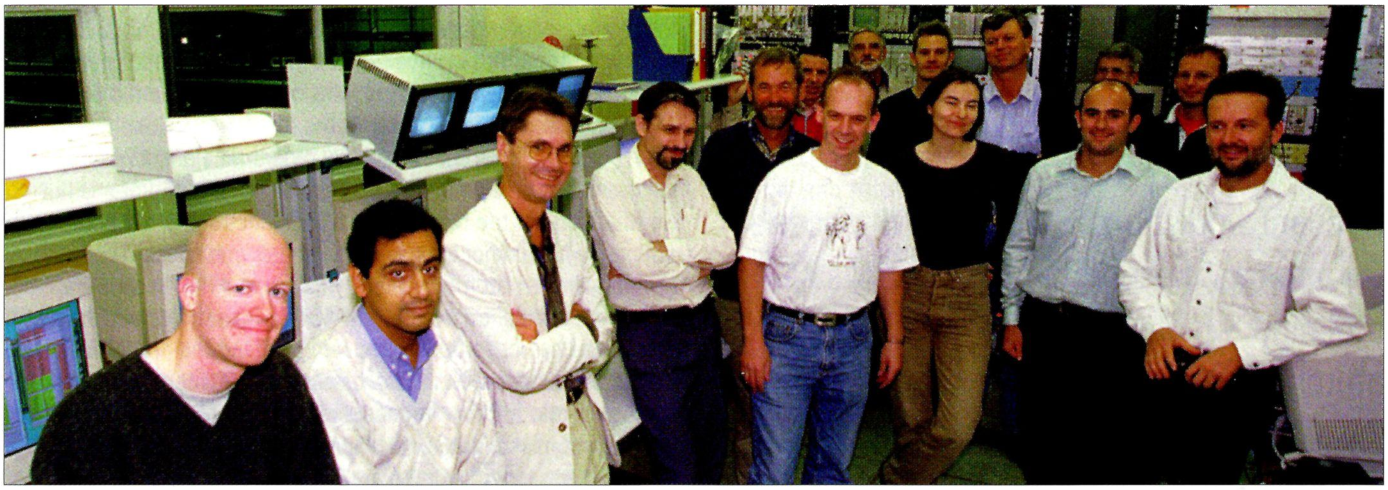
This year's data will almost double the available statistics, and there are still more data to come next year. The LEP experimenters are hopeful that the final direct LEP W mass value will have an error of around 30 MeV, which is close to the error obtained indirectly.

The very first events were recorded by the LEP experiments on 13 August 1989. At that time the LEP energy was 91 GeV, which is right on the Z peak. Now, more than 10 years later and more than 100 GeV higher in energy, both the LEP machine and the LEP experiments are still going strong and the excitement is still mounting.

Bob Clare, *MIT.*

CERN gears up for deceleration

Antiprotons have been a highlight of close-of-the-century physics. CERN's Antiproton Decelerator will continue this tradition into the 21st century.



Getting ready for low energy – CERN's Antiproton Decelerator team in its second home, the machine's control room.

CERN is best known for pushing the high-energy frontier of physics, but, with its new Antiproton Decelerator, the low-energy frontier is about to resume its place at the heart of the laboratory's experimental programme.

The Antiproton Decelerator (AD) is scheduled to switch on for physics this month, and an important milestone was reached this summer when, for the first time, the AD team decelerated a beam of protons to the AD's target momentum of just 100 MeV/c.

It might seem strange that milestones for the AD are measured in terms of achievements with protons, but, as Flemming Pedersen of the AD team explained, "We already know how to make antiprotons. The real challenge is low fields."

With an AD beam momentum of just 100 MeV/c, the magnetic bending fields, which hold the beam in orbit, are so low that even the magnetic field of the Earth must be taken into account. Protons are used instead of antiprotons in the setting-up phase because higher intensities can be achieved, which make for easier diagnostics.

Decelerating the beam

Beam particles enter the AD with a momentum of 3.5 GeV/c, which is about 35 times as high as when they leave it. The beam is rapidly decelerated to 2000 MeV/c before undergoing stochastic cooling. Reducing the energy further is a delicate task, owing to the origin of the AD's components. The AD is not a purpose-built machine – it has been assembled using components from the Antiproton Collector, the job of which was to collect antiprotons at 3.5 GeV for CERN's historic proton–antiproton collider project of the 1980s.

Bending magnets that are designed for constant 3.5 GeV operation are not ideal for the AD, where the field is constantly cycled. In particular, eddy currents, provoked by changing the magnetic field in the AD, can become large, and these can disturb the beam. To avoid this problem the momentum is reduced from 550 MeV very slowly.

When the beam reaches 300 MeV/c there is another pause. This time the technique of electron cooling, better adapted to very low-energy beams, is used. Like the magnets, the electron cooler is recycled. It came from CERN's previous low-energy antiproton facility, LEAR, which was the world's second application of the technique pioneered by Gersh Budker at Novosibirsk in the late 1960s.

For the final approach to 100 MeV/c, the beam is slowed down again. Here the Earth's magnetic field has to be considered, along with remanent fields induced in the AD's metallic components.

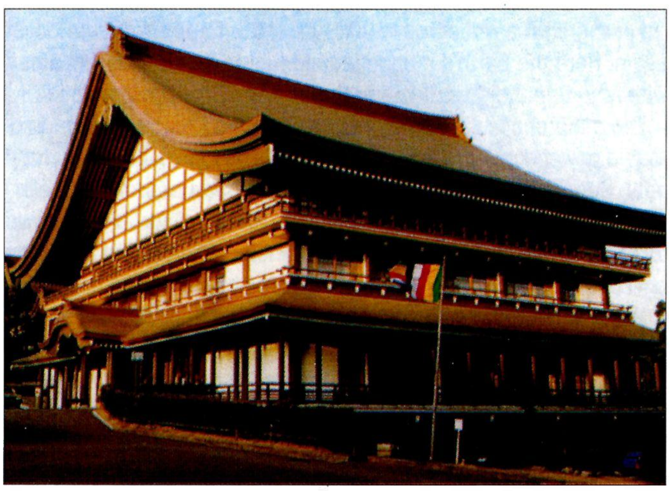
The main challenge in reaching 100 MeV/c was to produce very stable power supplies that would control eddy currents in the magnets. Soon after the 100 MeV/c challenge had been met, decelerating to 100 MeV/c had become routine and the AD was shut down to allow physicists to install the three experiments that will start taking data with the new machine.

When work resumed in September, the first task was to consolidate what had already been achieved with protons and to add a further electron-cooling stage at 100 MeV/c before the beams are extracted for delivery to experiments. Next on the agenda was reversing the polarity of the bending magnets to handle antiprotons. Some further setting up is expected because, as Pedersen pointed out, "We can't reverse the polarity of the Earth's magnetic field!" □

Zen and the art of low-energy antiproton experiments

A recent workshop in Japan set the scene for a range of experiments at CERN's AD machine, which will synthesize and explore atoms of antimatter. *John Eades* reports.

The logo of the ASACUSA experiment collaboration at CERN's Antiproton Decelerator on a Japanese 80 ¥ postage stamp, which depicts the famous Asakusa temple in Tokyo.



Physics zen – the Sojiji temple.

As CERN's Antiproton Decelerator comes into operation a new era begins for high-precision studies of antiprotonic atoms and antihydrogen, as well as for the antiproton itself and the way in which it interacts with ordinary atoms.

The imminent arrival of these high-quality antiproton beams of extremely low energy (5 MeV) was heralded at the International Workshop on Atomic Collisions and Spectroscopy with Slow Antiprotons, held in Tsurumi on 19–21 July.

The workshop included a Zen Buddhism course (Zazenkai). Perhaps for the first time in a physics workshop, jet-lagged attendees were woken up at 3.30 a.m. for meditation practice in the temple.

Progress on the AD programme

In the more conventional sessions, 55 participants from 25 institutions in Europe, Japan, Russia and the US discussed theoretical, technical and experimental progress on the Antiproton Decelerator (AD) experimental programme. At the moment it follows two tracks. One is the ASACUSA collaboration's programme of antiproton–atom collisions and laser/microwave spectroscopy of antiprotonic helium (in which one of the two normal orbital electrons is replaced by an antiproton). The other track is the synthesis and spectroscopic study of antihydrogen atoms by the ATHENA and ATRAP collaborations.

One motivating force behind ASACUSA is that, in much the same way as the hydrogen atom spectrum revealed the properties of the proton and electron over the course of the 20th century, high-precision laser and microwave measurements of atomic transitions of the antiproton in antiprotonic helium can reveal, with commensurate precision, the properties of the antiproton itself. Such measurements constitute valuable tests of validity of underlying physics symmetries. Antiprotonic helium was chosen instead of the simpler two-body protonium (antiprotonic hydrogen – a proton and an antiproton in orbit round each other) atom because it is stable against annihilation for some microseconds after formation, while protonium, under normal conditions, is not.

ASACUSA experiments that are already approved include a microwave triple resonance experiment on hyperfine splitting caused by the interaction of the electron spin and antiproton orbital moments, and a search for laser-induced transitions between, so-far unobserved, atomic levels.

In addition, a new high-resolution laser system is expected to reduce the measurement precision of all transition frequencies to less than one part per million – the level at which quantum electrodynamic effects appear. This has already been achieved in experiments that were studying another transition at CERN's LEAR low-energy antiproton ring, which closed in 1996.

The status of ASACUSA on these fronts was reported by K Komaki and M Hori (Tokyo). The interpretation of spectral features of antiprotonic helium in terms of the properties of the atomic constituents requires energy-level calculations with precision similar to that of the experimental values, and this was discussed by Y Kino (Sendai), D Bakalov (Sofia), V I Korobov (Dubna) and G Korenman (Moscow).

Another goal of ASACUSA is to extend to lower energies the Aarhus and Tokyo LEAR experiments on the atomic interactions of antiprotons. This has sparked considerable theoretical interest. Contributions came from H Knudsen (Aarhus), P Krstic (Oak Ridge) and A Igarashi (Miyazaki) on ionization and energy loss for antiprotons interacting with matter. Such experiments require 10–100 keV rather than 5 MeV antiprotons. They will be produced by inserting a decelerating radiofrequency quadrupole (RFQ) in the AD beam.

This is under construction in CERN's Proton Synchrotron division and will soon be tested in Aarhus. Antiprotons from the RFQ may be used directly or, for certain ASACUSA experiments, collected and cooled in a multiring harmonic trap (T Itchioka, Tokyo), where they will be reaccelerated to electron-volt or kilo-electron-volt energies.

Traps for charged (as well as neutral) particles feature prominently in the plans of the ATHENA and ATRAP collaborations. Here the main aim is to use the laser probes to compare identical atomic transition frequencies in hydrogen and antihydrogen.

Such experiments have an important advantage over those using antiprotonic helium. They are direct comparisons, in which symmetry-conjugate systems are compared without any need for theoretical input. On the other hand, the technical problems associated with producing antihydrogen are much more complex than is the case for antiprotonic helium, which is created in abundance whenever antiprotons are slowed to electron-volt energies in helium gas. In particular, the antihydrogen must be synthesized at micro-electron-volt rather than electron-volt energies.

For this, AD antiprotons and positrons from radioactive sources must first be collected as plasmas in suitable containers and cooled to liquid helium temperatures. M Holzscheiter (Los Alamos) reported on the progress of the ATHENA experiment, which aims to synthesize antihydrogen atoms at sub-Kelvin temperatures. K Fine (CERN) and H Totsuji (Okayama) discussed the behaviour of these plasmas in Penning traps (with hyperboloidal electrodes) and in Penning-Malmberg traps (cylindrical ones), both of which are adequate as plasma bottles for these processes.

Future proposals

As befits the promise offered by the birth of a new machine, many ideas that go beyond the current AD programme were presented in Tsurumi. They include the possibility that atomic protonium, so far ignored because of its short lifetime, may live long enough under near-vacuum conditions to be the subject of ASACUSA-type experiments (R S Hayano, Tokyo). Another possibility is the existence of metastable antiprotonic lithium (K Ohtsuki, Chofu-shi) and of antiprotons in solution in liquid helium (T Azuma, Tsukuba). H Schmidt-Böcking (Frankfurt) presented a proposal for a table-sized antiproton storage ring.

The Tsurumi workshop was organized by Yasunori Yamazaki of the Tokyo University Komaba campus and RIKEN, and it was sponsored by the Antimatter Science Project of the University of Tokyo, the Danish Natural Science Research Council's Centre for CERN-related Atomic and Nuclear Physics and the Japanese RIKEN (Rikagaku Kenkyuujo) Institute.

In his concluding remarks, Mitio Inokuti (Argonne) commented on the confidence and excitement with which this worldwide physics community awaits AD beams. Tantalizing hints of this physics were revealed during the era of LEAR, of which the AD is now a worthy successor.

John Eades, *CERN.*

Big experiments involve big collaborations – a CHORUS of approval.

Taking scientific note

The problem of publishing physics papers that have long lists of authors and reconciling it with the need to give due recognition to the contributions of individuals or small groups has long been recognized. An answer has now been found.

A major physics experiment is the sum of many components, the main components being the individual physicists. The collaborations on the experiments at CERN's new LHC collider can involve thousands of people.

While these researchers draw collective pride in their accomplishments, the career of an individual scientist ultimately depends on personal contributions. When the progress of the experiment depends on the efforts of many physicists scattered all over the globe, how can the individual physicists document his or her personal achievements?

To solve this dilemma, an initiative for a totally new type of scientific publication, which complements the traditional collaboration articles, was launched in 1998 by the High-Energy and Particle Physics (HEPP) Board of the European Physical Society and was discussed with the European Committee for Future Accelerators (ECFA). The ECFA is a parliament of European particle physicists whose concerns cover all aspects of particle physics.

The result was a common ECFA/EPS committee and a working group on publications policy for future large experiments, co-chaired by the ECFA and EPS-HEPP secretaries. The committee included representatives from major experiments at CERN's LHC collider and an observer from the Division of Particle and Fields of the American Physical Society.

The working group made recommendations to the ECFA and to the EPS-HEPP board. These have been discussed and, with remarkable speed, so far accepted in principle by major European and US research journals. The full statement on these new "scientific notes" is published here for the first time.

The proponents of the new publishing format said: "A combination of scientific publications of the large collaborations with associated scientific notes provides a way of recognizing individual contributions while maintaining responsibility for published results with the collaborations. We hope this will provide new guidelines for other fields of science where large collaborations are involved." □

New class of publications that will recognize individual contributions in future experiments

The text of the official statement on the creation of the new "scientific notes" class of publications.

The career advancement of experimental high-energy physicists at universities and research institutes has become harder in the last 10 years due to the large number of authors appearing on each publication within the field. This large number of authors makes it harder to evaluate the individual contribution when comparing with other fields in science.

Collaborations associated with forthcoming LHC experiments are typically several times larger than existing experiments. Thus, if no action is taken, the problem of recognizing individual contributions to experiments will become even more acute.

It is understood that the LHC experiments presently expect that all scientific results using data from these experiments will be published in the name of the full collaboration that is running the experiment.

This new recommendation attempts to address the above issues, while providing a way for fair recognition to the individuals. It is intended to provide a concrete procedure for the period before data taking and outlines the way to be followed thereafter.

1. The editors of scientific journals have been contacted to establish a new class of publications under the name "scientific notes". These notes will contain results of analyses, detector development and improvements, detector and physics simulations, software, algorithms and data handling. The results presented in these notes will be part of the official results of the experiment and should be quoted, whenever relevant, in official communications or publications of the full collaboration. It is intended that such notes should describe a unique result or methodology as accepted by the collaboration and be of interest to a wider scientific community. It is intended that these notes should be of sufficiently high quality that they count as valid publications, credited to the named authors.

In this spirit, the following requirements are proposed:

- they will be published in the name of the direct authors of the work;
- they will need to be approved and submitted by the collaboration spokesperson;
- they will have to pass a review procedure that will not only involve members of the experiment but also external reviewers;
- they will be part of the public domain. Most preferably, they should also appear in the electronic media.

2. Publications of the full collaboration will normally include the name of the collaboration and the list of participating institutions with a secure reference to the electronic media and in print to the author list (for printed journals, a full author list should appear periodically). This will eliminate the need of printing many pages of names in each publication, while giving recognition to the institutes involved.

3. Publications of the full collaborations and conference presentations given in the name of the collaborations will refer, as far as possible, to the published scientific notes. This will make the publications easier to read and will give the proper credit to the scientific notes (which contain the names of the direct contributors).

4. Publications of the full collaboration are deemed to include:

- articles from the full collaboration in refereed journals;
- proposals and reports submitted to official bodies in the name of the collaboration;
- articles from a very large subgroup (like a subsystem) of the collaboration in official journals.

Collaborations associated with forthcoming LHC experiments are typically several times larger than existing experiments. Thus, if no action is taken, the problem of recognizing individual contributions to experiments will become even more acute

Eclipse of a visionary

Bjørn Wiik, visionary and talented director-general of the DESY Laboratory, Hamburg, died in a domestic accident in February, leaving the laboratory,and a major part of the world's high-energy physics community, temporarily leaderless. A memorial seminar at DESY reminded the community of its debt.

During the 26 years that Bjørn Wiik spent at DESY, he decisively shaped its destiny as one of the world's major physics centres. He did this in a series of roles – leading scientist, HERA project leader, and chairman of the DESY directorate, but most of all as an exceptional scientist and leader whose charm and enthusiasm captivated all who met him. Wiik's calm and soft-spoken manner concealed a penetrating vision and an iron will, which left their mark on world science.

On 7 July 1999, nearly 800 friends and colleagues gathered at DESY to pay a final tribute, both scientific and personal, at a memorial meeting. Among the guests were Wiik's wife and their three children, the Norwegian consul, DESY founding father Willibald Jentschke, and Peter Brix, Wiik's thesis supervisor from Darmstadt.

On 7 July, nearly 800 friends and colleagues gathered at DESY to pay a final tribute, both scientific and personal, to Bjørn Wiik, visionary and talented director-general of the DESY Laboratory, Hamburg, who died in a domestic accident in February. Among them were (left to right) Mrs Becker-Wiik and (second row) their three children; Hamburg City Mayor Ortwin Runde; Albrecht Wagner, who succeeds Wiik as head of the DESY Directorate; Peter Schmüser of Hamburg (second row); and DESY founding father Willibald Jentschke.

As emphasized in the opening address by his successor, former DESY research director Albrecht Wagner, Wiik was an outstanding figure in European and world particle physics. His interest and talent extended from theoretical to detector and accelerator physics, all of which benefited from his scientific excellence and uniqueness. Moreover, his impressive political talent allowed him to influence politicians and citizens alike – all the more remarkable as a Norwegian at the head of a German national research centre.

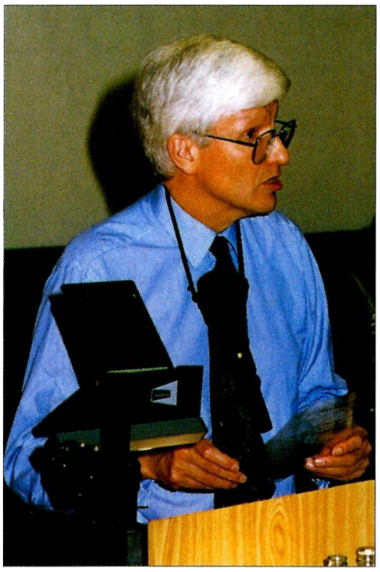
As the son of a Norwegian resistance leader during wartime German occupation, Wiik was not exactly predestined for close co-operation with Germany. However, it was his father who urged him to study in Darmstadt to get to know "the other" Germany. One of Wiik's oldest friends, Roland Engfer from Zürich, he remembered the years spent at Darmstadt Technical University – the years that allowed Wiik to get to know "the other" Germany, and that laid the foundation of his career as a world leader in particle physics.

After seven profitable years at SLAC in Stanford, Wiik returned to Germany to take up an appointment at DESY, which he felt was the ideal place for him to contribute to physics. Volker Soergel, Wiik's predecessor as head of the DESY directorate, retraced Wiik's time at the laboratory from its very beginning, when Erich Lohrmann heard of the exceptional young physicist and invited him to the Hamburg laboratory in 1972.

Wiik's physics work eventually led him to share the European Physical Society's 1995 High-Energy Physics prize for discovering the first direct evidence of the gluon using the TASSO experiment at the PETRA electron–positron collider in 1979.

From the early 1970s, Wiik nurtured the novel idea of an energy-asymmetric electron–proton collider, a vision that eventually came to fruition with the commissioning of DESY's flagship accelerator, HERA, in 1992.

A talented orchestrator, he led the work for HERA's ambitious superconducting proton ring. Despite DESY's relative inexperience in



A tribute to Bjørn Wiik. Former CERN director-general Chris Llewellyn Smith met Wiik in the early 1970s at SLAC, Stanford. Their seminal ideas for an energy-asymmetric electron–proton collider pointed the way towards DESY's flagship HERA machine. (DESY.)

both superconductivity and proton machines, HERA was completed on time and within budget. Its physics harvest is now surpassing all early promises.

In 1993, Wiik took over from Soergel as DESY's director-general. Under him, DESY's characteristic symbiosis of particle physics laboratory and multidisciplinary synchrotron radiation research centre gained even more importance, the latest achievement being a proposal to set up a structural biology group.

He also played a major role in worldwide efforts to develop the next generation of electron–positron linear colliders, pushing the idea and promoting R&D work for an international 33 km superconducting TESLA machine with integrated X-ray lasers for multidisciplinary research. As Albrecht Wagner put it, Wiik left the particle physics community with a void but also a vision, which is now up to the laboratory to realize.

Hamburg mayor Ortwin Runde valued Bjørn Wiik as a man of high moral integrity, with an exceptional capability to motivate and integrate – an outstanding example of his sense of responsibility towards both politicians and the public.

Hermann Schunck, chairman of DESY's Administrative Council, speaking for the Federal Minister for Education and Research (Mrs Bulmahn), called for an effort to make Wiik's ideas and visions become a reality.

Jürgen Lüthje, president of Hamburg University, underlined the exemplary collaboration between DESY and the university.

Detlev Ganten, chairman of the Hermann von Helmholtz Association of National Research Centres (HGF), remembered Wiik as a truly interdisciplinary thinker who promoted the collaboration between the rather disparate HGF institutes with great dedication and judgement.

CERN director-general Luciano Maiani recalled Wiik's valuable collaboration with CERN, as chairman and as a member of the SPS experiments committee on which they served together, and his far-sightedness.

Ralph Eichler, chairman of DESY's Scientific Council, closed the first part of the seminar with a more personal view, recollecting many examples of Wiik's practical philosophy – like taking the cross-country skiing trail at the Nordic Winter School in the opposite direction to everyone else in order to talk to every workshop participant.

Introducing the scientific part of the seminar, Maury Tigner from Cornell described the impact of superconductivity on particle physics. As well as the HERA proton ring, Wiik also shaped the international effort towards a new generation of electron–positron colliders via the TESLA route.

Rather than dwelling on the past, SLAC director Burt Richter looked at the ongoing role of electron–positron colliders, a field bristling with activity. With science budgets under pressure all over the world, Richter insisted on the necessity to push a single project.

Former CERN director-general Chris Llewellyn Smith recalled the important roles that Wiik had played on various committees at CERN. These included the Scientific Policy Committee, and chairing the 1991 external review of the LHC Project. Further afield he was a key figure in European and world particle physics, particularly in the European Committee for Future Accelerators (ECFA), and in the International Committee for Future Accelerators (ICFA), of which he had been chairman since 1997.

Llewellyn Smith then turned to "deep inelastic scattering" – using high-energy beams to reach the deep interior of the proton – and the historic steps that ultimately led to HERA.

HERA data have now shed important light on nearly all of the open questions underlined in the milestone 1977 paper by Wiik and Llewellyn Smith, which pointed out the potential of such a collider. HERA's electrons probe protons at an unprecedented level, allowing the interactions between quarks and gluons to be studied in new depth. Photoproduction has revealed the dual behaviour – hadronic and point-like – of the photon. Neutral and charged current effects vividly demonstrate electroweak unification.

Turning away from particle physics, Jochen Schneider, head of the Hamburg Synchrotron Radiation Laboratory (HASYLAB), presented DESY's second research field, of which Wiik was extremely proud. Synchrotron radiation research has a long tradition at DESY, going back to 1964. Now, with the former electron–positron collider, DORIS, transformed into a dedicated synchrotron radiation source, HASYLAB users – including 650 biologists – outnumber the particle physicists by far. Wiik felt that DESY was a good place for such a cohabitation, because both fields had a common need in tools, which furthered a fruitful collaboration.

For the future, he envisaged bringing them even closer together within the TESLA project, which includes an X-ray free-electron laser (FEL) for multidisciplinary research. Driven by the superconducting linac, those X-ray FELs will deliver coherent X-ray pulses of between 100 and 300 fs, which far surpass the brilliance of existing synchrotron radiation sources. DESY is building a prototype FEL facility in the vacuum ultraviolet range, to go into test operation in 2002.

Wiik's calm and soft-spoken manner concealed a penetrating vision and an iron will, which left their mark on world science

Without Wiik, DESY would not be the world focus that it is. □

Subnuclear Physics 1998 at the Ettore Majorana Centre for Scientific Culture, Erice, Sicily. Left to right: Ludwig Fade'ev, Jacov Azimov, Masatoshi Koshiba, centre director Antonino Zichichi, Ed Witten, Bjørn Wiik, Sheldon Glashow and Gerard 't Hooft. The 1999 meeting included a tribute to Bjørn Wiik.

A tribute to Bjørn Wiik

Bjørn Wiik's important role in furthering international collaboration was also highlighted at a special gathering at the Ettore Majorana Centre for Scientific Culture, Erice, Sicily.

The International School of Subnuclear Physics at Erice, Sicily, which took place from 29 August to 7 September, included a special ceremony: "A tribute to Bjørn Wiik: the man, the physics, his projects".

In the presence of Mrs Margret Becher-Wiik and members of the Wiik family, the director of Erice's Ettore Majorana Centre for Scientific Culture, Antonino Zichichi, began by emphasizing Wiik's important role in establishing a successful collaboration between DESY and Italian industry, for superconducting magnet technology and fabrication of the proton ring of the HERA project.

A message from the Italian Minister for University and Scientific and Technological Research, Ortensio Zecchino, stressed his deep appreciation for Wiik's contribution to a vigorous and fruitful collaboration between the two countries. The minister expressed his strong support for the INFN strategic scientific programme and its concrete accomplishments – the Gran Sasso Laboratory, the strong Italian involvement in LEP at CERN and in HERA at DESY, and the successful detector R&D work in the framework of the LAA Project, itself an important contribution for reseach at future proton machines.

Kjell Johnsen of CERN reviewed Wiik's life, his childhood in Norway, his time as a student in Darmstadt, and his research at SLAC and at DESY. As chairman of the HERA machine committee, Kjell Johnsen was well placed to highlight Wiik's achievements as an accelerator physicist, who was responsible for the construction of the HERA proton ring.

Günter Wolf of DESY reviewed Wiik's scientific work from his first photon physics experiment at Darmstadt to HERA physics, which included the 1979 discovery of gluon jets, for which he and his TASSO colleagues were awarded the 1995 European Physical Society High-Energy and Particle Physics prize.

Horst Wenninger of CERN described Wiik's ultimate superconducting vision – the TESLA International Research Project at DESY, which is an electron-positron linear collider with an integrated X-ray laser. He showed Wiik's original 1992 proposal to construct and test prototype superconducting radiofrequency structures for linear colliders and then reported on the excellent progress of the TESLA collaboration in achieving accelerating fields of up to 35 MV/m. The TESLA Test Facility at DESY begins operation this year in its first step towards self-amplified spontaneous emission (SASE) X-ray free-electron lasers. This is preparing the ground for the construction of a 500 GeV superconducting linear collider. □

The Sun: a brilliant past a

The Sun may be the centre of our world, but it is not a typical star. At a special meeting, arranged by l'Observatoire de Paris at the Moët et Chandon manor at Epernay for the total solar eclipse of 11 August 1999, CERN physicist *Douglas R O Morrison* shed light on the Sun's past, present and future.

Stars are formed from huge masses of gas and dust. From fluctuations, a centre forms and then, under gravity, more and more matter gradually accumulates until a core is formed, which attracts more gas and dust. This core – a protostar – will get hotter. Under the effect of gravity, the protostar will contract and, if the core is big enough, nuclear reactions (fusion) will cause it to ignite. Thus a star is born.

Multiple star systems

This is how I used to imagine that stars were formed. When I looked up at the sky, I saw our Sun as a solitary star and the sky full of single stars. The idea of binary star systems with two stars rotating round one another seemed quite unnecessary. It therefore came as a shock when I learned that only 15% of stars are single, while 65% are in binaries and the remaining 20% are in clusters of three or more. This seemed contrary to the concept of a big cloud of gas and dust condensing.

For me, the explanation came in an early photograph from the Hubble Space Telescope (figure 1). It showed a star-forming region of Freudian complexity that explains the birth of multiple star systems. We are fortunate that our star is a solitary one.

When the Sun was born, some 4600 million years ago, its gas was composed of 72% hydrogen, 24% helium and the remainder was a variety of elements, which had been formed almost entirely in supernova explosions and then blown out into space. The mass of the Sun is 2×10^{27} tons, or 2000 million million million million tons.

When a star is formed, its contraction makes it spin faster (like an ice skater pulling in his or her arms). Such a T Tauri star is distinctively bright for its mass. However, as it spins, it throws off mass, losing some 2000 million million million tons every year. It soon slows down, and today our Sun is losing some 20 million million tons per year (or 700 000 tons per second) as solar wind.

Solar flares

This stellar erosion can be seen during a total solar eclipse. The radius of the Sun is about 700 000 km, so the easily visible part of the solar wind, seen during an eclipse, extends out from the surface by more than a million kilometres. Occasionally a large flare will occur. An example of this is shown in figure 2.

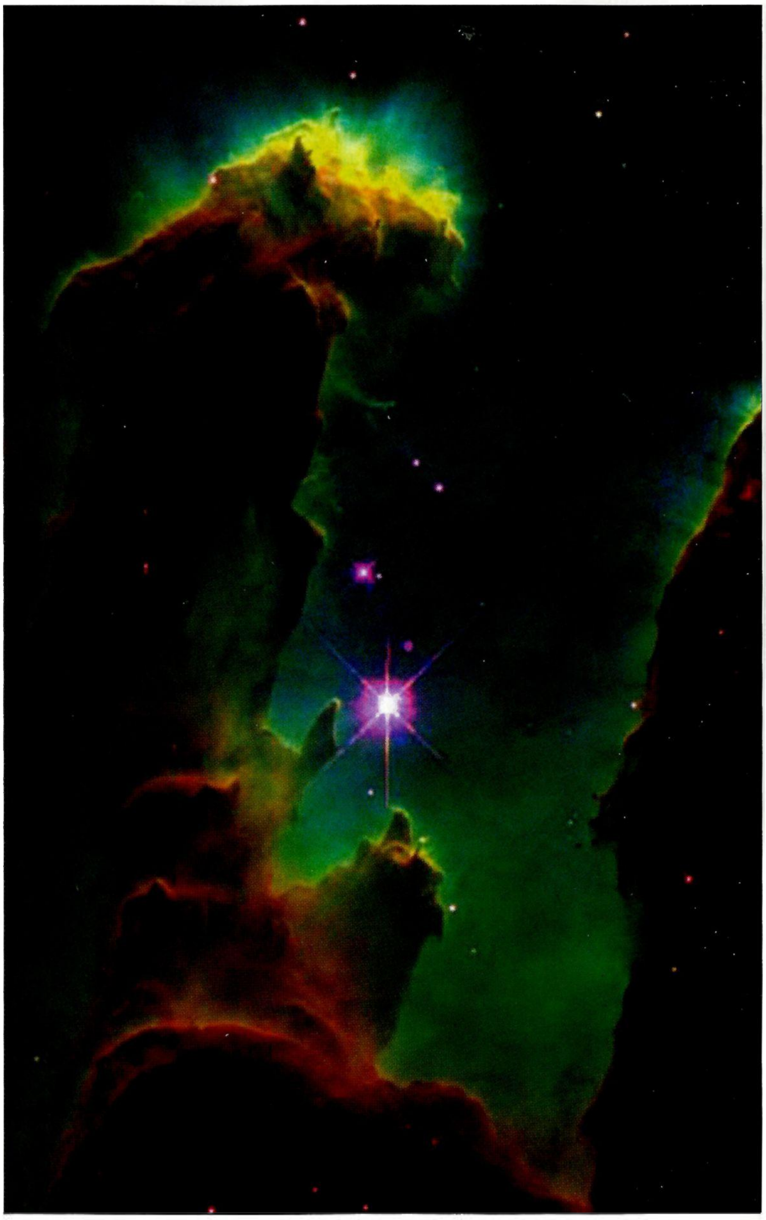


Fig. 1: A Hubble Space Telescope image of a star-forming region.

The fate of a protostar core depends on its mass. If the protostar weighs less than 0.08 solar masses, the temperature of the core is not high enough to initiate nuclear fusion reactions and the protostar remains as an inert Brown Dwarf.

If the protostar weighs more than 8 solar masses, something new happens: the density of the core becomes so great that the inner 100 km or so of the star collapses within a few milliseconds, and the resulting ionized plasma is compressed into neutrons. Such a neu-

nd an even brighter future

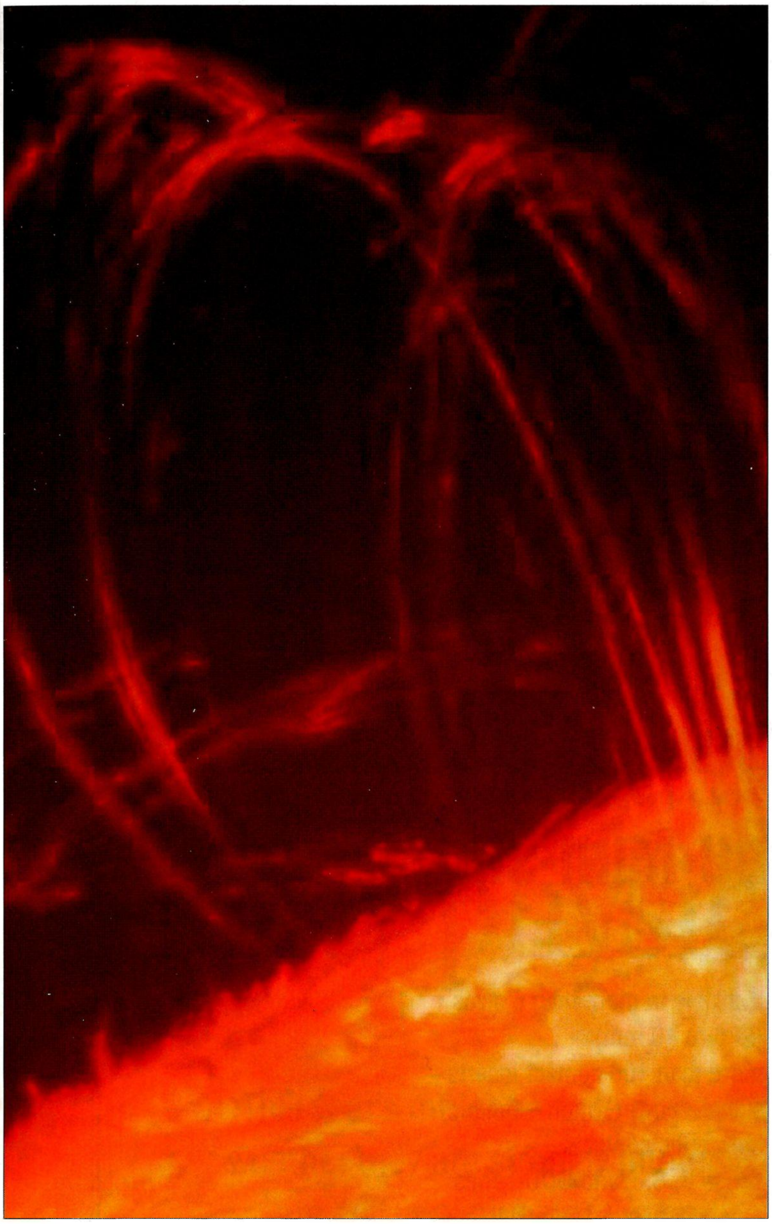


Fig. 2: The hours following a solar flare reveal a series of loops above the surface of the Sun – best seen when viewed in the light emitted by hydrogen in the red region of the solar spectrum (H-alpha emission). These loops formed after an active region flared on 26 June 1992. This image was obtained by the Swedish Solar Telescope on La Palma in the Canary Islands.

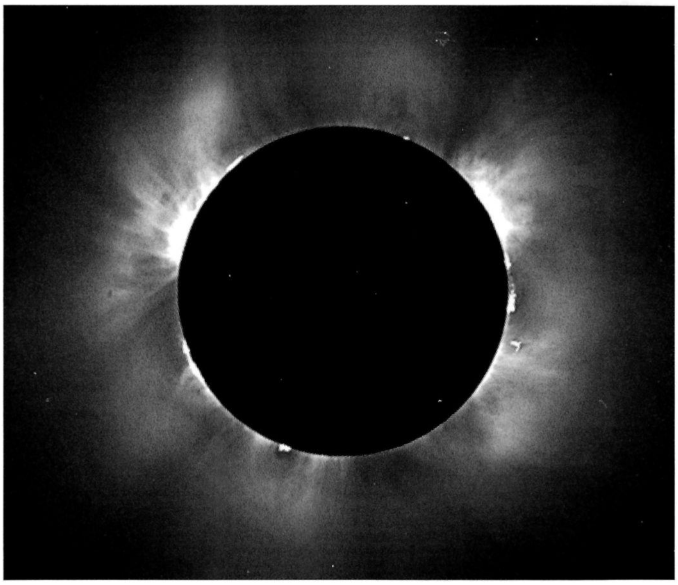


Fig. 3: C Cavadore from ESO, and L Bernasconi and B Gaillard from l'Observatoire de la Cote d'Azur, took this photograph of the eclipse (11 August 1999) at Vouzier, which is between Reims and Nancy (France, Champagne-Ardennes).

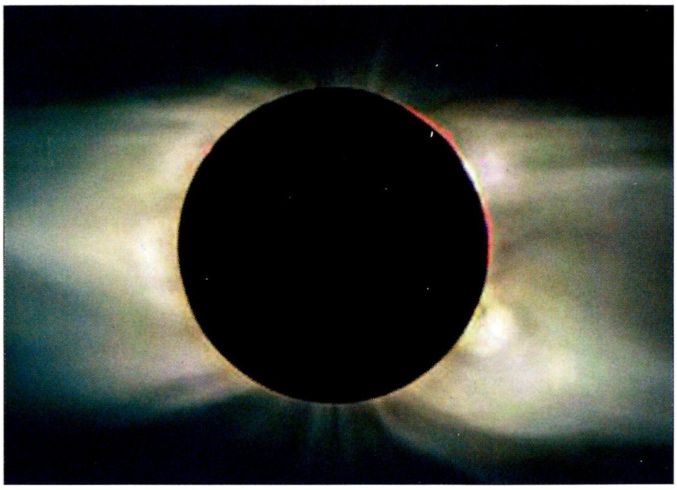


Fig. 4: The total solar eclipse of 26 February 1998. This picture comprises three radial gradient images taken by Jonathan Kern from the Willams College site (Aruba), and later processed and composited by Wendy Carlos. (Copyright 1998 Wendy Carlos and Jonathan Kern.)

tron star has an enormous density – about 100 million tons/cm^3.

The sudden collapse of the core generates a shock wave that compresses the neutron star even further. This rebounds, and the outward-moving shock wave then hits the remainder of the star, which, meanwhile, has hardly moved. The blast blows the shell apart and ignites it to produce the visible supernova.

If the star so formed is still massive – about 20–30 solar masses – then the neutron star can collapse further to give a black hole.

The basic reaction that initiates star formation is the fusion of two hydrogen nuclei (protons) to form deuterium, followed by the deuterium rapidly combining with another hydrogen nucleus to give helium-3. This happens very quickly – the deuterium only exists for a second before fusing with a proton. One could say that the deuterium acts as a catalyst, which converts three nuclei of hydrogen into helium-3. The helium-3 is then converted into a stable helium-4 nucleus via several routes.

Helium-4 is very stable and is generally the end of the chain. To go further, an unusual fusion reaction needs to take place between three helium-4 nuclei to give carbon-12. This can further react to give nitrogen and oxygen. This is called the CNO cycle. The next element, fluorine, can then be formed in the NOF cycle.

The Sun, which is essentially a plasma with no rigid structure, is fuelled mainly by hydrogen in its core, which is at a temperature of 15 million degrees centigrade. Its density decreases rapidly with distance from the core, where it is about 150 g/cm^3. At the surface, the density is only a millionth of a gram per cubic centimetre and the temperature is about 5500 °C.

Bright future

As the Sun continues to burn, the temperature will rise and the core will contract, which raises the temperature even higher and makes the envelope expand. Eventually the Sun will become a Red Giant, at which point most of the hydrogen in the core is burned.

Then the core will contract further and become steadily hotter and hotter until it reaches a hundred million degrees centigrade. At this point the helium-4 will ignite and carbon-12 will be formed in a thermonuclear explosion. For the following 100 million years, the star will continue to be very bright.

The carbon can provide extra nuclei of helium-4 to generate oxygen-16 and neon-20, etc (the CNO and NOF cycles will not occur because the necessary hydrogen has already been consumed). Next, the carbon and oxygen will burn, but the thermonuclear furnace will eventually cut out and the core will become inert.

However, outside the core, the remaining hydrogen and helium gas will continue to burn for some time. This will drive off much of the gas and eventually the star will become a White Dwarf with a remnant mass of about half that of the Sun. This hot star will be visible for billions of years, but will eventually cool and become an invisible Black Dwarf.

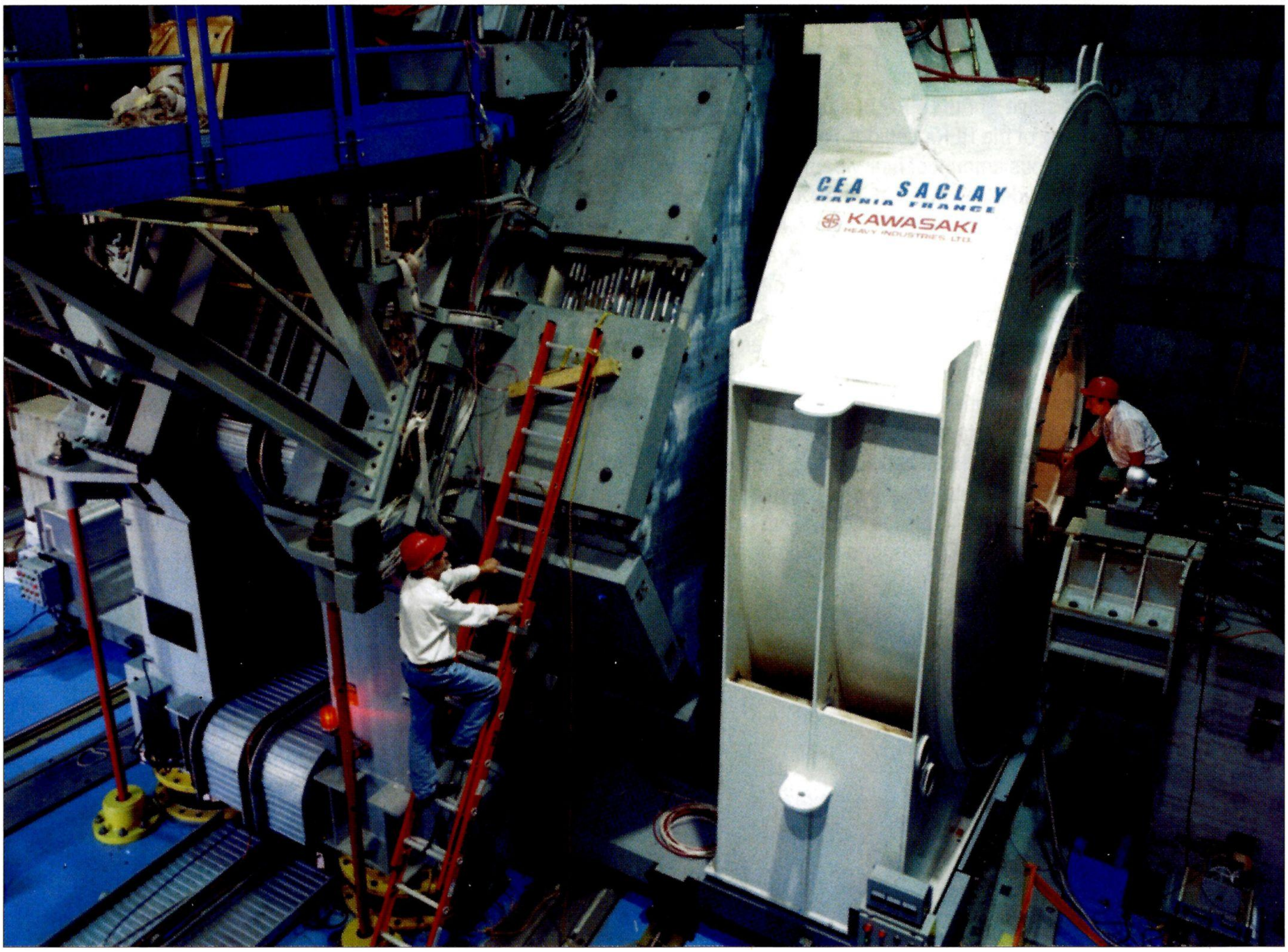
When our Sun becomes a Red Giant, its expansion will first swallow Mercury (58 million kilometres away), absorb Venus (108 million kilometres away), engulf the Earth (150 million kilometres away) and finally approach Mars (228 million kilometres away).

Fortunately for us this fate is about 5000 million years away. The Sun is a vigorous adult star that still has a brilliant future.

Further reading

J Audouze and G Israel (eds) 1988 *Cambridge Atlas of Astronomy* (Cambridge University Press).

Douglas R O Morrison, *CERN*.



Construction of the BaBar detector at the PEP-II B factory, SLAC, Stanford.

Heavy physics implications

This year's major particle physics meeting showed that heavy "flavours", whether they are strongly interacting quarks or weakly interacting leptons, are still very much at the cutting edge of today's laboratory studies.

Heavy particles are hard to come by. As a result, precision measurements in this sector are widely admired and highly prized. This physics was a main focus at the International Lepton-Photon Symposium in Stanford (*CERN Courier* October p2). Existing experiments are homing in on the production of particles containing heavy quarks, and a series of major new experiments is being developed.

Spearheading this new generation of experiments are the B factories at SLAC, Stanford and the Japanese KEK Laboratory. The electron-positron annihilations in these colliders – PEP-II and KEKB respectively – are a rich source of B particles that contain the fifth ("beauty", "bottom" or simply "b") quark. The decays of these B particles should reveal new insights into CP violation – the subtle symmetry breaking assumed to be responsible for a matter-antimatter symmetric Big Bang, which eventually produces a visible universe composed entirely of matter.

The other B physics players in the race include, notably, Cornell's CESR electron-positron collider, which is equipped with the CLEO detector. CESR and CLEO have been working in tandem for some 20 years and have made a series of landmark contributions to B physics. Experiments at CERN's LEP electron-positron collider have also made many valuable contributions to this work.

In the wings of the B stage is the HERA-B experiment at DESY, which uses the proton ring of the HERA collider. Fermilab's Tevatron remains a source of a copious amount of heavy particles. Significant B physics potential is provided by the CDF and D0 detectors at Fermilab's Tevatron proton–antiproton collider, which is now fed by the new Main Injector. Detector upgrades and collision rate improvements will ensure that the Tevatron remains a focus of B physics.

For the future, the LHCb experiment at CERN's LHC collider and the BTeV project at Fermilab are getting their acts together.

After a "Brief report from the B factories", an introduction to the lepton–photon symposium, attention was focused on heavy-quark physics. Ronald Poling of Minnesota showed how the experiments at CERN's LEP electron–positron collider have charted semileptonic decays. The B physics scenarios, which have been explored at LEP at high energy and by CLEO at CESR via upsilon decays, are becoming increasingly reconciled with the LEP scenario, which is closer to theoretical predictions.

In measuring the parameters that describe the various interquark decays, CLEO has made charmless B decay (b quarks that decay directly into light quarks) its special hunting ground. In the more usual b decays (into charmed quarks) measurements from different experiments are converging.

While describing heavy-quark lifetimes and mixing, Guy Blaylock of Massachusetts highlighted valiant efforts to measure and understand why different charged states of heavy quarks have different lifetimes. In the present parametrization of quark decays, the mixing of B quarks is expected to be large, while that of D (charm) quarks is expected to be small. The former, says Blaylock, will lead to better measurements of the existing scheme, while the latter will provide a window for new physics effects.

Heavy particles are hard to come by. As a result, precision measurements in this sector are widely admired and highly prized

And so to CP violation – the subtle violation of a symmetry that, ideally, should reflect a particle into a mirror image of its antiparticle and vice versa. Two major experiments have recently announced new measurements of "direct" CP violation (*CERN Courier* September p6) brought about by quark transitions. Edward Blucher of Chicago spoke for the KTeV study at Fermilab and Giles Barr of CERN for the NA48 experiment. CERN experiments have had quantitative evidence of this effect since 1993, while a contemporary Fermilab experiment had published a result compatible with zero direct CP violation. After many years of anguished doubt, direct CP violation now looks here to stay. However, the years of dilemma underline the difficulty in making these measurements. With the objective of measuring direct CP violation to within 5%, both experiments have a lot more data to analyse. The CERN study continues.

Sergo Bertolucci described how the KLOE detector, at the new DAFNE phi factory at the Italian Frascati Laboratory, will explore additional aspects of neutral kaon physics via phi decays and could round off the kaon picture. Hopefully, B physics will soon open a new, and wider, window on CP violation, which has so far been confined to the strange world of the neutral kaon.

Complementary to the heavy quark is the heavy tau lepton, which is the only weakly interacting particle heavy enough to decay into strongly interacting particles. Tau specialist Antonio Pich of Valencia surveyed the tau scene at Stanford. Tau physics at electron–positron colliders, including spin effects, provides a valuable laboratory in which to explore the physics of weak interactions and the behaviour of heavy quarks.

"B decays, the unitarity triangle and the universe" was the challenging title assigned to Adam Falk of Johns Hopkins for his review of heavy-quark physics. The interrelation of the various possible quark decays has a self-consistent parametrization (the Cabibbo–Kobayashi–Maskawa matrix), which gives some degree of predictive power but cannot be derived from first principles. What makes it work?

The imaginative title was a reference to the current dogma that CP violation, a mechanism that is much studied and well documented but still not entirely understood, is ultimately responsible for the disappearance of the antimatter half of the Big Bang.

The new B sector will subject this physics to much wider scrutiny and could reveal as yet unseen effects. Falk asked if the necessary formalism was ready to enable all of these processes to be analysed consistently.

At the turn of the millennium, heavy-quark physics is also poised to enter a new era. □

Deep import of deep inelastic scattering

The quest goes on to try to pin down the detailed inner structure of the proton. The problem is that, the harder physicists look, the more structure they find.

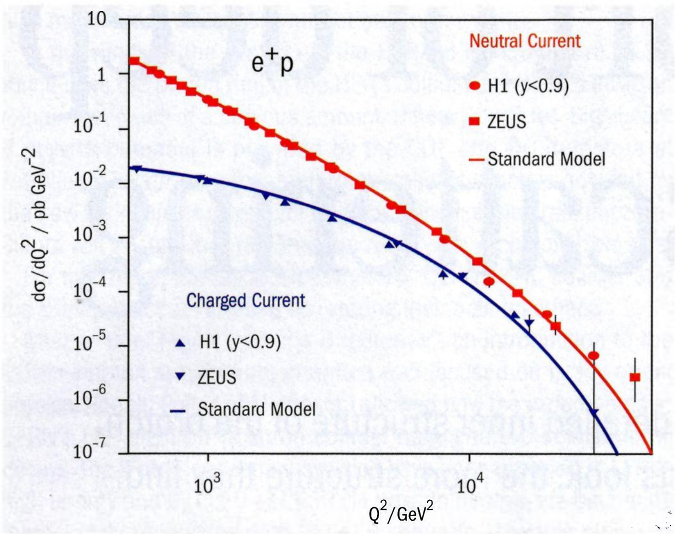
Deep implications of deep inelastic scattering. Left to right: Ulrich Gensch, head of DESY Zeuthen; Brandenburg Minister of Culture and Research, Steffen Reiche; DESY research director and chairman of the directorate, Albrecht Wagner; local organizing committee chairman, Max Klein; and former head of DESY Zeuthen, Paul Söding.

In the late 1960s, when experimentalists using electron beams at SLAC, Stanford, discovered that the proton contained tiny scattering centres, a new type of physics opened up: deep inelastic scattering (DIS). Ever since, physicists have tried to peer deeper and deeper into the depths of the proton. The work of the HERA electron–proton collider at DESY, Hamburg, was to probe this inner proton structure in more detail than had ever been done before.

This is one of the great success stories of HERA. However, to capitalize on this new window on the proton also calls for intense study and coordinated effort. After the advent of HERA, about seven years ago, a series of specialized workshops began.

Scattering involving the constituent "partons" hidden inside the proton is the natural scenario for quantum chromodynamics (QCD), which is the field theory of the constituent quarks and gluons. DIS99 (the seventh DIS conference) was hosted by DESY Zeuthen, south of Berlin, earlier this year.

New results from the HERA collider experiments were summarized by Bernd Löhr (DESY) for ZEUS and by Tancredi Carli (Munich) for H1. Cecilia Gerber (Fermilab) reported on the Tevatron experiments and Roland Windmolders (Mons) reviewed spin physics results.



Positron–proton scattering mediated by neutral (top curve: photon, Z boson) and charged (bottom curve: W boson) carriers as measured by the H1 and the ZEUS collaborations at the HERA electron–proton collider at DESY, Hamburg. The neutral current measurement extends over many orders of magnitude. For squared momentum transfers (Q^2) of the order of the mass of the weak interaction particles squared, the strength of the neutral and charged current interactions becomes comparable – a long-predicted feature of the standard electroweak theory. Meanwhile, data have been taken and analysed with electrons scattered off protons where the charged current interaction even exceeds the neutral current interaction because the exchanged W boson couples dominantly to the more abundant u quarks instead of d quarks). The very high Q^2 region will be explored in detail in the HERA high-luminosity running, which is scheduled to start in early 2001.

Recent developments in QCD were summarized by Willy van Neerven (Leiden). Two days of parallel sessions focused on structure functions, diffraction, final states and spin physics.

The working group on structure functions was conducted by Ursula Bassler (Paris), Eric Laenen (NIKHEF), Arnulf Quadt (CERN) and Heidi Schellman (Northwestern).

Structure functions

HERA probes low x, which is the momentum fraction carried by the struck quark, down to about 10^{-6}. New precision is accompanied by impressive theoretical work on the gluon dynamics in this domain and on the transition between the deep inelastic and the photoproduction regimes.

Standard perturbative QCD field theory has no apparent difficulties in accounting for the behaviour of the proton structure down to surprisingly low values of x and of momentum transfers (Q^2). Efforts are under way to extend QCD calculations, covering the "next to next to leading order". This is a challenging task, which will substantially reduce the theoretical uncertainties.

The emerging role of HERA as a machine for precision tests of QCD is comparable to that of CERN's LEP electron–positron collider for testing the electroweak theory. With increasing HERA collision rates, the data at large Q^2 approach the region where proton structure is probed by the W and Z weak bosons and the gluon and quark distributions become measurable even at large x, where uncertainties are currently still sizable.

The puzzling excess of high Q^2 events at large x, which were first observed by H1 and ZEUS in 1997, was reported to be reduced after more data had been accumulated. The many new results from various sectors led Heidi Schellman to conclude that the "rest of the world keeps up with DESY".

Diffractive interactions

The working group on diffractive interactions was organized by Mike Albrow (Fermilab), Riccardo Brugnera (Padova), Markus Diehl (DESY) and Douglas Jansen (Heidelberg). One early observation at HERA was that about 10% of electron–proton events have little to show in the forward, proton direction. The electron interacts with something accompanying the proton rather than the proton itself. This stimulated the revival of interest in "diffractive" scattering.

Impressive new data should lead to a better understanding of this diffractive deep inelastic and photoproduction scattering. Theoretical work showed that the diffractive electron–proton interaction, as for other hard-scattering processes, factorizes into a convolution of a parton distribution with an elementary scattering process. In hard hadron–hadron processes, however, additional soft interactions between the two initial hadrons can occur. Such interactions are expected to suppress the diffractive effects. This may explain the apparent differences between the HERA and Tevatron (proton–antiproton) measurements. Successful attempts were reported to implement diffractively produced string topologies into the simulation of the electron–proton interaction final state.

The session on hadronic final states was another example of the fruitful collaboration between the HERA, LEP and Tevatron experiments. The session was coordinated by Marcello Cacciari (CERN), Frank Chlebana (Fermilab), Laurel Sinclair (Glasgow) and Mark Weber (Heidelberg). Deep inelastic processes producing two narrowly confined sprays of particles ("dijets") were used to determine the gluon distribution at large x by the H1 experiment and the quark–gluon interaction coupling constant by the ZEUS experiment. Inclusive jet production at the Tevatron provided a new determination of this quantity, comparable to previous fits of deep inelastic scattering structure.

Dijet production also reflects the quark–gluon structure of the photon, and LEP and HERA data were presented on the gluon content of the photon. Some photon distribution parametrizations require revision owing to new measurements of the virtual photon structure. Isolated leptons with high transverse energy, observed by H1, so far have no conclusive interpretation. Theoretical and simulation work focused on the low x region and the description of gluon emission.

Spin physics

The parallel session on spin physics was organized by Michael Düren (Erlangen) and Werner Vogelsang (Stony Brook). Among new experimental results was the first indication of a positive gluon polarization, obtained from unlike charged pairs of hadrons produced at large momentum transfer, and the unexpected observation of a spin asymmetry in rho-meson production by the new HERMES experiment at HERA.

Data from SLAC (Stanford), CERN and DESY experiments determined the spin structure function. Its behaviour is in agreement with QCD. These measurements, as well as results from SMC and HERMES, allow the polarized up and down quark distributions to be determined accurately at larger x. However, the polarized gluon distribution is not yet known and the unaccountability of the proton spin in terms of its constituents – the "spin crisis" – remains. Its resolution will require data from the upgraded HERMES experiment and from the next generation of polarization experiments – COMPASS at CERN and STAR/PHENIX at the polarized RHIC collider – in order to disentangle the quark and the gluon contributions to the proton spin.

The future of DIS

A special session looked at the future of deep inelastic scattering. The first presentation, by Jorge Morfin (Fermilab), reported Fermilab's plans for future neutrino experiments using the NuMI beam, and studies of neutrino beams from a muon collider. Dietrich von Harrach (Mainz) explained how spin physics could be extended to low x and high Q^2 as well as to the polarized photon structure by accelerating polarized protons in HERA. Another future HERA option, as emphasized by Mark Strikman (DESY/Pennsylvania state), is the acceleration of nuclei in order to study electron–neutron scattering in the HERA kinematic range, as well as other nuclear phenomena using heavy nuclei, which cannot be accessed with the currently attainable beam energies in electron–proton collisions.

To mark DIS99, HERA ran at the record luminosity of two inverse picobarns per week. Albrecht Wagner (DESY) reported on the preparations to quadruple HERA's luminosity during next year's shutdown and presented DESY's showcase TESLA, a superconducting linear electron–positron accelerator in the 500 GeV to 1 TeV range, which could be combined with an X-ray free-electron laser. Wagner and Yves Sirois (Paris) pointed out that TESLA could also be used to collide electrons of up to 500 GeV with protons in HERA of nearly 1 TeV, which would allow the inner structure to be explored down to 2×10^{-19} m. DESY has initiated a study of this option in the TESLA technical design report.

Erwin Gabathuler (Liverpool) summarized the workshop. The low x behaviour, which is measured with increasing precision by the HERA experiments, is essential in understanding what happens at high gluon densities, and also to predict reliably what will happen to CERN's LHC interaction rates. Increasing precision leads to crucial tests of QCD, including unexplained events at extremely high Q^2 and transverse energy. Machine and detector upgrades lead HERA into the next millennium with a challenging mid-term programme to use electroweak interactions for probing the nucleon structure. The next DIS conference will take place in Liverpool next April.

The proceedings of DIS99 are dedicated to the memory of DESY director Bjoern Wiik, who died in February. His outstanding personality and scientific achievements were recalled by Aharon Levy (Tel Aviv), chairman of the workshop's international advisory committee, and Brandenburg minister of culture and research Steffen Reiche, who underlined the importance of realizing Bjoern Wiik's vision, which led to the creation of HERA and has shaped, so decisively, the plans for TESLA.

At the recent DIS99 workshop Erwin Gabathuler of Liverpool emphasized the need for "precision and more precision".

Max Klein, *DESY Zeuthen.*

Summers in St Croix revisited

An unlikely blend of geography, sponsorship and physics focus seems to work. Founding director *Tom Ferbel* describes a 20-year tradition of NATO-sponsored physics study institutes in the West Indies.

St Croix Physics Institute director Tom Ferbel at work.

My wife Barbara and I picked Bermuda for our first family vacation. However, a delay in our bubble chamber run at SLAC forced us to change plans and we wound up instead in the less popular, sleepy island of St Croix in the US Virgin Islands (part of the Leeward Island archipelago). It was hot, beautiful and relaxing.

Some 10 years later, I heard that the West Indies Lab at St Croix was opening a conference centre and I thought it would be wonderful to offer our hard-working graduate students and postdocs at Fermilab an opportunity to have a bit of fun in the sun and, simultaneously, learn some particle physics. There were already several schools for theorists at that time, so I decided to propose a summer institute for experimenters.

It turned out to be far easier to make the proposal than it was to find support for it. After I failed with our standard funding agencies, Maurice Jacob suggested that I turn to NATO. Being a confirmed pacifist, I felt awkward dealing with NATO. However, their totally defence-oriented posture (at that time) persuaded me to try Jacob's idea. It worked. For the past 20 years, NATO's Division of Scientific Affairs has been generous and flexible in its support of the biennial Advanced Study Institute (ASI). In addition to NATO, the ASI at St Croix has been supported throughout by the US Department of Energy, the US National Science Foundation, Fermilab and the University of Rochester.

Only once did NATO balk at the school being held in the Virgin Islands, so that year it was transferred to Lake George in New York State. However, NATO agreed that St Croix was probably no more exotic to Americans than Corsica is to Europeans, and we were allowed to return to the Caribbean.

St Croix is, of course, quite exotic, but we managed to survive the monstrous cockroaches, poisonous trees and fruit, the unbelievably strong sun and even the hurricanes. It has been a great adventure, from both a scientific and a social perspective. Many of the students have become respected leaders in the field and, as far as I can recall, only two eventually switched to theory. Former lecturers have continued to make important contributions to particle physics and an unusually large number have become directors of laboratories such as CERN, DESY, Fermilab, ITEP, ITP and SLAC.

The scientific programme

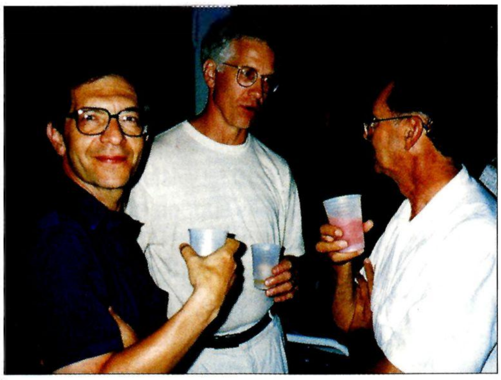
The speakers were almost always superb and the students fully engaged. Although the lectures were intense, everyone had fun. The informal interactions and relaxed atmosphere often rekindled enthusiasm for physics in students whose morale was ebbing at the end of their PhD studies, and the cameraderie led to the forging of lasting professional ties and friendships among the participants.

The scientific programme was always the main focus at the ASI, with lectures that consisted of a mixture of the most exciting topics in the field – developments in accelerators, particle detectors, aspects of data acquisition and reconstruction, statistics and, of course, the latest results from the forefronts of experimental particle physics and particle theory. Occasional diversions into astrophysics and cosmology were always welcome and enjoyable.

I can recall many unforgettable images. Our trips into the rain forest and to the reefs of the Buck Island Underwater National Park were great. Konrad Kleinknecht is still proud of having rescued an overenthusiastic Yau Wai Wah from drowning, after Wah jumped into the water to get a closer look at the sea menagerie, without the benefit of a life-jacket or any previous swimming experience.

It was fascinating to hear Bob Wilson lecture on his schemes for building a charm/tau factory to fit in the parking lot of Columbia's Nevis Labs. At that same session, I persuaded the youthful Chris Quigg to offer a series of six lectures (to save money on speakers), and the poor fellow spent most of his time at St Croix writing transparencies. He also discovered that the 150 proof Cruzian rum served as an excellent eraser of permanent markers, so he could not have been working all of the time.

Students and lecturers rarely missed any of the sessions.



St Croix Physics Study Institute director Tom Ferbel (left) with Mark Strovink and Bob Palmer (right).

Consequently, when most of our Mediterranean participants did not show up for an evening discussion, we realized that something was awry. It turned out that Capt. Guido Martinelli had rented a large sailboat and, far out of Christiansted harbour, its rudder had broken. It kept going round in circles until Rosy Mondardini saved the day by reaching the Coast Guard on the short-wave radio.

An impressive sight was John Iliopoulos emerging from the sea with an enormous parrot fish that he had harpooned. We later ate it for dinner. Then there is the image of Nicola Cabibbo enjoying the cuddly teddy bear he was given by the students.

Most of the institutes were held at the Hotel on the Cay, on a tiny speck of sand located in the scenic harbour of Christiansted. The Cay could only be reached by motor boat from the dock at Christiansted, and it was tough luck if you got stuck after hours unless you happened to be a very strong swimmer, as Aurore Savoy and her bevy of admirers proved on several occasions.

We were close to panic at least twice, and both times it involved food. One evening at dinner, someone made some playful, but chauvinistic, remarks and a piece of food was thrown back in response. This confrontation developed as close to a Mack Sennett food fight as I have ever witnessed. My pleas for calm prevailed and they all made up and parted friends. The other near-panic situation occurred when the entire kitchen staff quit on the first day of one of our meetings. Barbara and I had to cook and serve breakfast, but fortunately by lunchtime we were rescued by the beach restaurant.

It has been a wonderful and educational experience to interact with all of the brilliant students, lecturers and advisers I have met as a result of organizing the ASI at St Croix. Next year, Misha Danilov and Harrison Prosper will be taking it over and I wish them as much satisfaction and enjoyment as I have had running it in the past.

Tom Ferbel, *Rochester. An unusually articulate and eloquent scientist, Tom Ferbel has been scientific spokesman for a series of experiments. In addition he has served on numerous committees for the American Physical Society and for major US labs, and on the editorial boards of several prominent journals. He has written and edited several notable texts.*

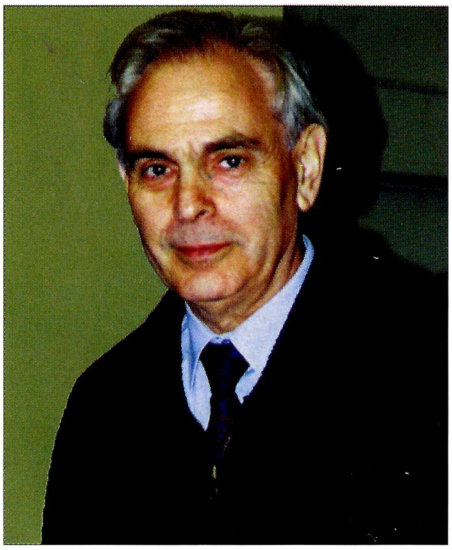
CERN honours Okun

As mentioned in the September issue (p39), Lev Okun, head of the Theoretical Physics Laboratory of Moscow's Institute for Theoretical and Experimental Physics, recently celebrated his 70th birthday.

Okun is one of the world's eminent elementary particle physicists and is a leading figure in the field of phenomenology. He was a student of I Ya Pomeranchuk (who was a student of Landau), and Landau once said about him: "He is my grandson." His early work included a perceptive paper (with Ioffe and Rudik) on C violation, which showed that the existence of a long-lived kaon does not prove C conservation. He invented a composite model of hadrons (a term he coined), long known as the Sakata–Okun model, and made many predictions using it. In advance of Cabibbo's justly famous paper, he made pioneering SU(3) predictions about the equality of the V/A ratios in pion and kaon amplitudes. Particularly noteworthy are his groundbreaking papers (with Kobzarev, Voloshin and Zeldovitch) on vacuum domain walls and vacuum bubbles. From 1991 onwards, he worked, mostly with Novikov and Vyosotsky, on the analysis of electroweak corrections in Z physics producing, among other things, a convenient "LEPtop" method.

In addition to his scientific inventiveness, Okun is blessed with extraordinary pedagogical talent and an almost unique gift for synthesis. Among his books, *Weak Interactions of Elementary Particles* and *Leptons and Quarks* are classics from which generations of experimental physicists have acquired greater understanding. He has been in continual demand as a keynote speaker at major international meetings.

Okun has been a member of the Soviet Academy since 1966 and has also received the Matteucci, Lee Page, Pontecorvo and Open Society prizes as well as a Humboldt research award. From 1980 to 1985 he served as a member of CERN's Scientific Policy Committee.



Lev Okun – widely admired.

Introducing a special birthday tribute at CERN on 21 September, director-general Luciano Maiani paid tribute to Okun as a "long-time friend of CERN" and to his key role in shaping one of the world's great schools of particle physics in Moscow, despite enormous political and economic difficulties.

Chief scientific adviser to the UK Government, **Sir Robert May** (second from right), inspects contruction work for CERN's LHC project with (left to right) UK CERN delegate **Ian Halliday**, CERN engineer **Tim Watson**, LHC project director **Lyn Evans** and CERN Scientific Policy Committee chairman **George Kalmus**.

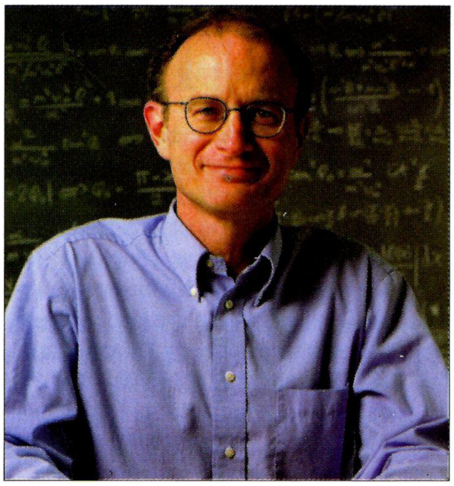
New at Brookhaven

At Brookhaven, two new organizations have been formed from the RHIC project and the Alternating Gradient Synchrotron Department.

The new Collider Accelerator Department will operate and manage the RHIC–AGS accelerator complex and experiments, manage the design and construction of the Oak Ridge National Laboratory Spallation Neutron Source accumulator ring, and design and construct a new heavy-ion facility from the Brookhaven Booster for radiobiology research. D Lowenstein is the department chairman, W T Weng is his deputy, T Roser is head of the Accelerator Division and P Pile is head of the Experimental Support and Facilities Division.

The new Superconducting Magnet Division, headed by M Harrison, is responsible for Brookhaven's role in magnet design and construction for CERN's LHC collider, as well as RHIC superconducting magnets. T Kirk continues as associate laboratory director for high-energy and nuclear physics. Former RHIC project head, S Ozaki, has been designated associate laboratory director for RHIC during the operations period.

Witherell picks his team at Fermilab



Michael Witherell – new team.

Michael Witherell, Fermilab's fourth director, slid into the driving seat this summer. He succeeds John Peoples, who recently stepped down after a decade that spanned the construction of the Main Injector, the new hub of the laboratory's particle beams, and the discovery of the top quark. Ironically, the latter came first.

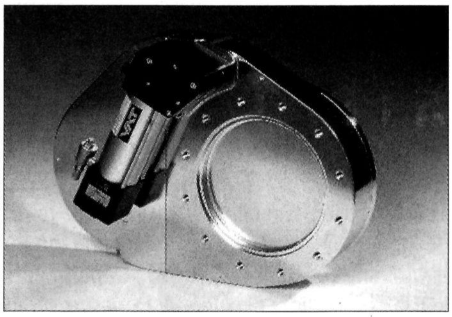
In Witherell's new management line-up, former Beams Division head, Stephen Holmes, becomes associate director for accelerators. Michael Shaevitz, formerly director of Columbia's Nevis Laboratory, becomes associate director for research.

Deputy director Kenneth Stanfield continues in his current position, as do Bruce Chrisman and George Robertson as associate directors for administration and operations support respectively.

John Marriner becomes head of the Beams Division and Tom Nash is special adviser to the director on computing and government policy. Particle Physics Division head John Cooper, Technical Division head Peter Limon and Computing Division head Matthias Kasemann continue in their positions.

NEW PRODUCTS

High-vacuum isolation valves



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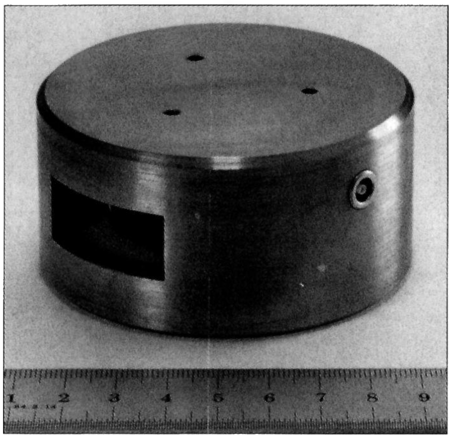
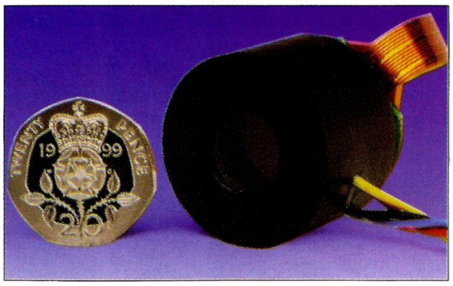
A new range of high-field homogeneity compact magnets from Metrolab has large apertures. They are available for field strengths 0.01 to 1 T. For more information e-mail "contact@metrolab.ch" or see "http://www.metrolab.com".



The new high-field homogeneity compact magnet from Metrolab.

MICRO-ICCD camera



Photonic Science's MICRO-ICCD camera.

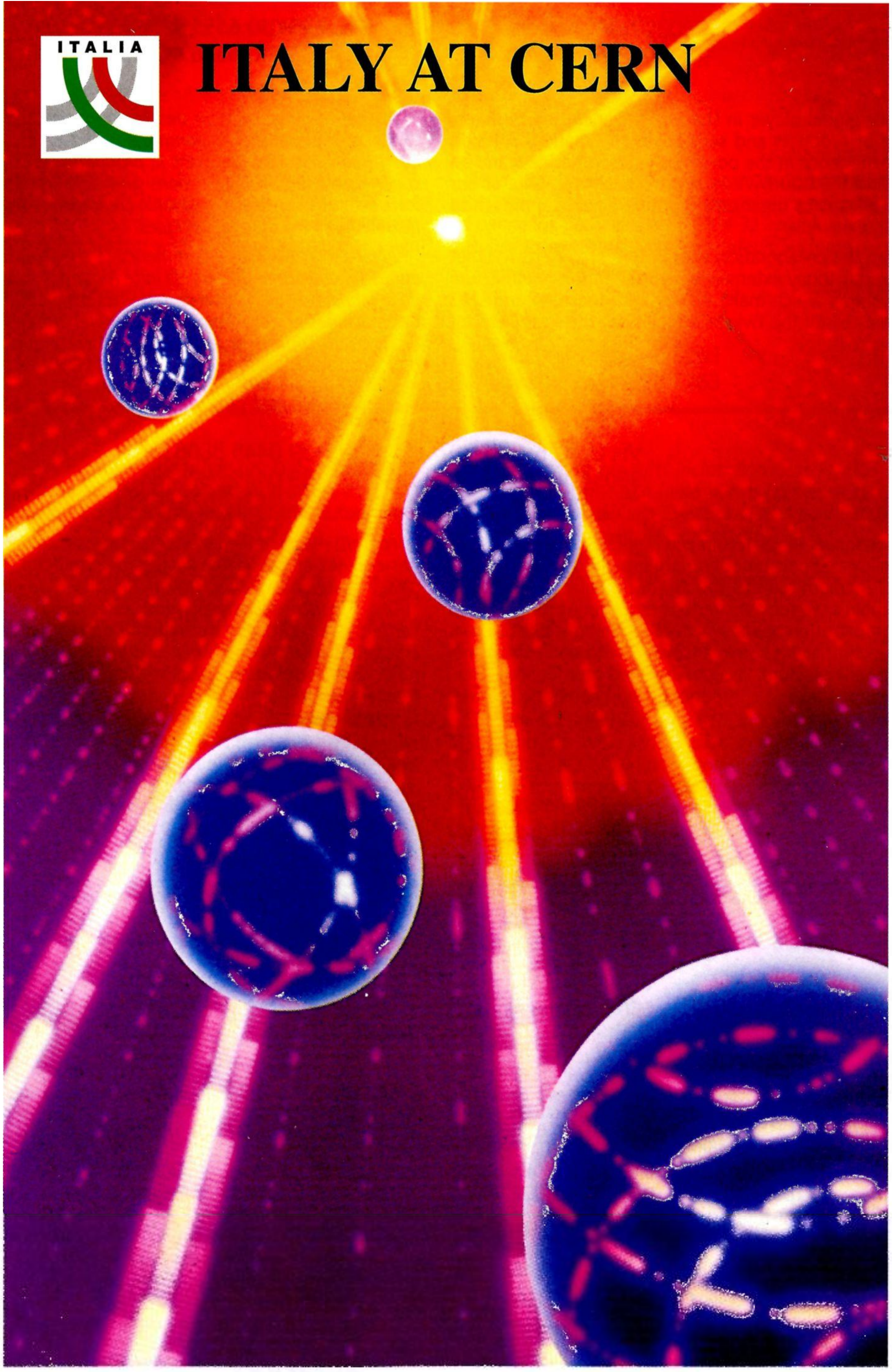
Photonic Science's MICRO-ICCD is a rugged, self-contained, intensified CCD camera in a sub-miniature housing. Designed with helmet mounted and remote pilotless vehicle operation in mind, the MICRO-ICCD has an extremely small volume and a very low mass, making it the ideal choice for all size/weight-critical low-light and night vision imaging applications.

PSL have recently taken part in trials of their new miniature ICCD camera in zero-G conditions aboard an ESA Airbus. Thirty zero-G sessions were accomplished during the flight, each session lasting approximately 30 s.

Each experiment aboard the flight is packaged as it would be on a satellite launch and runs automatically. The PSL experiment, designed with the collaboration of the University of Delft, studies the behaviour of osteoblasts in zero-G conditions.

For more information contact Diane Brau, tel. 00 33 4 76 93 57 20.

ITALY AT CERN



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ANSALDO ENERGIA began the collaboration with CERN through its Magnet Unit, in the early seventies and is today extensively involved in the manufacture of many of the magnetic systems which make up the LHC machine and LHC detectors, including the collared coilsfor the Twin SC Dipoles and the Atlas Detector barrel toroid superconducting coils.

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ANSALDO ENERGIA a commencé la collaboration avec le CERN au début des annés soixante-dix à travers "l'Unité Aimants" Ansaldo qui s'occupe actuellement de la fabrication de nombreux systèmes magnétiques rentrant dans la composition des machines et détecteurs LHC, comprenant également les "collared coils" pour les Twin SC Dipoles et les bobines supraconductrices pour le récipient toroïdal du Détecteur ATLAS.

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The New World of Mr Tompkins by George Gamow and Russell Stannard, Cambridge, ISBN 0 521 63009 6 (hbk £14.95).

George Gamow was a sort of prototype Richard Feynman – gifted, incisive, exuberant, unpredictable and occasionally eccentric. Feynman played bongo drums and opened safes, while Gamow preferred conjuring. Born in Russia in 1904, Gamow gradually emigrated westwards via Göttingen, Copenhagen, Cambridge, Paris and London. He eventually moved to the US in 1934. Gamow left a substantial scientific and literary legacy.

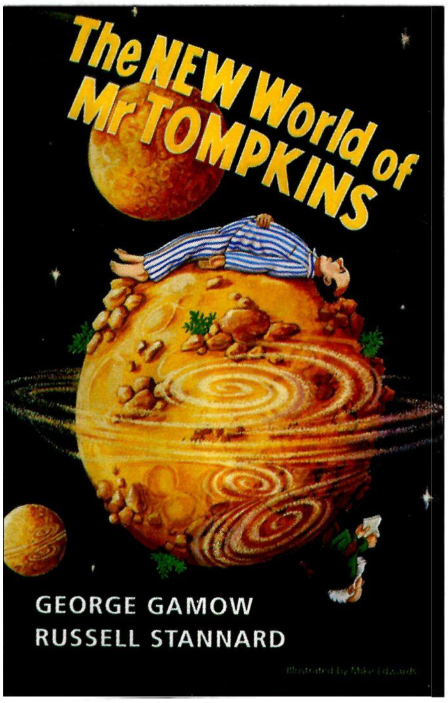
After milestone contributions to nuclear physics (which included the Gamow–Teller coupling), at Göttingen he explained the mystery of alpha radioactivity, showing how quantum tunnelling allowed low-energy particles to escape the pull of the nucleus. When Gamow brought these insights to Cambridge, Rutherford and Cockcroft realized that what goes out can also come in. In a kind of reverse radioactivity, relatively low-energy bombarding particles should be able to enter the nucleus and induce nuclear transformations. From the late 1920s, this motivated the push for particle accelerators.

Working with his student, Ralph Alpher, in Washington in the 1940s, Gamow learned that the young Hans Bethe was visiting the US and invited him to add his name to the famous "Alpher, Bethe, Gamow" papers on the origin of the chemical elements. In the late 1940s, Gamow also helped to develop the ideas that are now known as the Big Bang.

In 1938 he wrote a short science fantasy (being careful not to call it science fiction), in which he tried to explain the ideas of the relativistic curvature of space and the expanding universe. The hero of his story was a modest bank clerk called C G H Tompkins. His initials were borrowed from the standard physics notation for the speed of light, the gravitational constant and Planck's constant.

After sending the piece to several large circulation magazines and receiving impersonal rejection slips, Gamow put it to one side until his physicist friend, Sir Charles Darwin (the grandson of the author of *The Origin of Species*), suggested sending it to C P Snow, then the editor of *Discovery* magazine, published by Cambridge University Press. The text was immediately accepted and the discerning Snow demanded more.

Mr Tompkins tries valiantly to follow dry science lectures, but easily falls asleep.



However, all becomes clear in his vivid dreams. Soon the articles were collected into *Mr Tompkins in Wonderland*, published in 1940, followed by *Mr Tompkins Explores the Atom* in 1944. Each was a major success and the two volumes were reissued with additional material as a single volume in 1965. This reissue alone was reprinted some 20 times.

Thirty years after this revision, the book was still selling* but was seriously out of date. With Gamow no longer available (he died in 1968), UK physicist Russell Stannard, author of the well-known "Uncle Albert" trilogy (*The Time and Space of Uncle Albert*, *Black Holes and Uncle Albert* and *Uncle Albert and the Quantum Quest*), was invited to give Mr Tompkins a facelift. As well as updating the science to include quarks, the Standard Model and supersymmetry, Stannard has also tried to modernize the text. For example, the title of Gamow's chapter 10 – "The gay tribe of electrons" – had acquired another connotation over the years and has become "The merry tribe of electrons". An additional chapter – "Visiting the atom smasher" – provides an opportunity to introduce a politically correct female spokesperson (however, she is depicted as unfeminine and wearing a white coat).

Although concepts are gently introduced, ultimately there is little attempt to paraphrase. A 120-entry glossary, extending over 10 pages, has been thoughtfully provided.

Tompkins is a moot figure. Although he no longer exclaims "By jove!", he seems to have got stuck in a time warp. The original illustrations, revised by Gamow for the 1965 reissue, did have a certain charm. Although the pictures have been redrawn for 1999, the original style remains. Mild-mannered Tompkins is still supposed to be in his 30s but looks like a refugee from a Tintin episode. Already a dweeb in the original version, now he is an anachronism. Perhaps it is time for "The World of the New Mr Tompkins" in "now-speak", where the Internet exists and where dog-eared flip charts have been discarded in favour of Powerpoint displays.

However, the Tompkins character evokes sympathy, and the impressive literary track record of George Gamow and of Russell Stannard shows that packaging basic physics with a veneer of personification and anecdote via dreams and thought bubbles does work.

Gordon Fraser, CERN.

*The 1965 reissue is available as *Mr Tompkins in paperback* by George Gamow, Cambridge, ISBN 0 521 44771 2 (£7.95).

Neutrino Physics and Astrophysics – Proceedings of the 18th International Conference on Neutrino Physics and Astrophysics, Takayama, Japan, June 1998 edited by Y Suzuki and Y Totsuka, North Holland, ISBN 0 444 50289 0, (560 pages, $111.50/NLG 220).

These are the proceedings of the historic neutrino conference that heard the first convincing evidence from the Superkamiokande detector for effects that suggest that different kinds of neutrinos "oscillate" among themselves and therefore have mass.

CPT and Lorentz Symmetry edited by V Alan Kostelecky, World Scientific, ISBN 981 02 3926 2 (£36).

These are the proceedings of a meeting held at Bloomington, Indiana, November 1998, which look at the underlying space–time symmetries of particle physics.

Spectral Asymptotics in the Semi-Classical Limit by M Dimnassi and J Sjöstrand ISBN 0 521 66544 2 (pbk £24.92/$39.95)

This volume is part of the London Mathematical Society Lecture Note series.

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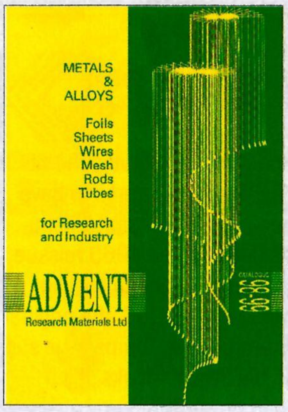

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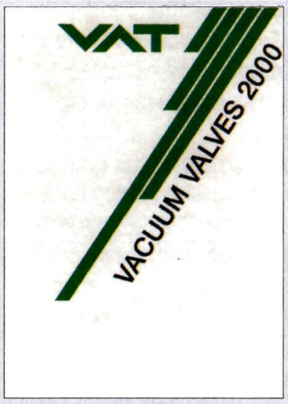

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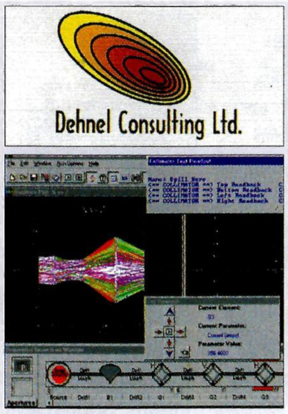

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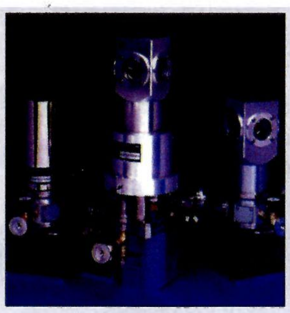

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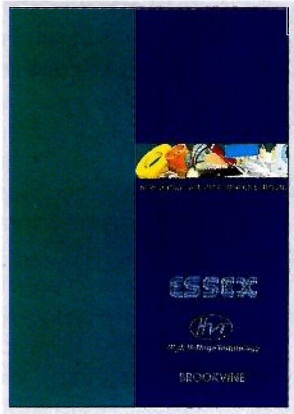

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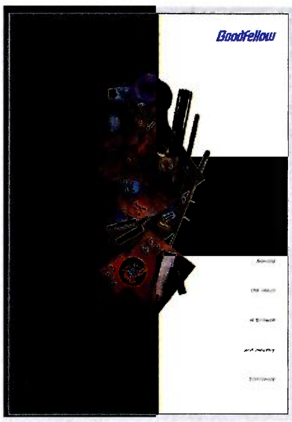

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Duke University

Tenure-Track Faculty Position

Experimental High Energy Physics.

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The position is available starting September 2000. Applications received by 15 January 2000 will be guaranteed full consideration. Please send a resume, research statement and list of publications and three letters of reference to :

High Energy Physics Search Committee, c/o Ms. Pat Hoyt, (hoyt@hep.phy.duke.edu), Physics Department, Box 90305, Duke University, Durham, NC, 27708-0305, USA.

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DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg, by December 31th, 1999 Code-No. 100/99

Handicapped applicants will be given preference to other applicants with the same qualifications. Women are especially encouraged to apply for this position.

Texas A&M University Cycolotron Institute

Postdoctoral Positions

Applications are invited for postdoctoral positions in experimental nuclear physics at the Texas A&M University Cyclotron Institute. Initial appointments would be for one year with normal renewal for one or two additional years. The scientific program at the Institute is built around a K500 superconducting cyclotron. Ancillary equipment includes a high-resolution spectrometer, a recoil ion spectrometer and high efficiency arrays for detecting neutrons, gamma rays and charged particles. Positions are available in the areas of giant resonance studies, weak interactions and intermediate energy heavy ion reactions. Applicants should send a curriculum vitae and arrange to have three letters of reference sent to **Prof. J. B. Natowitz, Director, Cyclotron Institute, Texas A&M University, College Station, TX 77843-3366.**

Texas A&M University is an equal opportunity employer and encourages applications from women and minorities.

Humboldt University Berlin

PhD Positions

at the Institute for Physics of the Humboldt University Berlin in experimental and theoretical particle physics are available within the "Graduiertenkolleg". 'The Standard Model of Particle Physics - analyses of its structure, precision tests and extensions'.

The experimental physics programme includes the projects HERA-B, L3, LHC-B, CMS and studies of neutrino oscillations. The theoretical groups work on Superstrings, SUSY, nonperturbative QCD, lattice gauge theories and phenomenological applications of the Standard Model.

Requirements: Diploma or Master degree in physics with excellent grades, good knowledge of English.

For more information see http://qft3.physik.hu-berlin.de/luest.gkteilchen.html

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Brookhaven National Laboratory's National Synchrotron Light Source Department has an opening for a Scientist/Engineer to serve as a member of the NSLS management team and provide guidance and technical support to a group of 50 people. This group provides electrical and computer support in the operating maintenance and upgrading of the NSLS machines. A PhD in Physics, MS or PhD in Engineering, or an equivalent combination of education and experience is necessary.

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FACULTY POSITION IN EXPERIMENTAL HIGH ENERGY PHYSICS

Department of Physics
Université Catholique de Louvain

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The appointed person is expected to teach physics courses in the university and play a leading role in both shaping and implementing the research program in experimental high energy physics. This program presently includes the study of neutrino-induced reactions and neutrino oscillations. The high-energy group is also actively engaged in preparing the CMS experiment at the future LHC accelerator at CERN. All these activities are pursued within national and international collaborations.

Only a good knowledge of English is required initially but, since the appointed candidate is to teach in French, she/he should acquire a reasonable command of the language within two years. Rank and salary will depend upon qualification and experience.

The successful candidate should sustain a strong program of research with significant undergraduate and graduate involvement. Although she/he will be primarily based in Louvain-la-Neuve, her/his research within the high-energy group will imply stays abroad to take an active part in the various collaborations.

Candidates should submit a letter of application, a curriculum vitae, a list of publications, three letters of recommendation and a copy of their five most representative publications to be sent to:
Professor M. Crochet, Rector, The Catholic University of Louvain, Halles Universitaires, place de l'Universite 1, B-1348-Louvain-la-Neuve, Belgium.

The closing date for applications is December 15, 1999.

For further information, please consult:
http://www.phys.ucl.ac.be/Offresphys.html
You can also write or call Prof. J.M. Gerard, Chairman of the Department of Physics, chemin du Cyclotron 2, B-1348-Louvain-la-Neuve, Belgium.
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University of California, Riverside
Open Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of California, Riverside invites highly qualified applicants to apply for a new faculty position in *experimental high energy physics.* This is an "open level" position and may be filled at any academic level including the senior level. The appointment will be effective July 1, 2000. The Department is seeking outstanding candidates with exceptional research records and demonstrated excellence in teaching. The successful candidate is expected to establish a leading edge research program involving graduate students and contribute to department teaching at all levels. In high energy physics the current research programs include OPAL at LEP, D-Zero at the Tevatron and CMS at the LHC. In neutrino physics, faculty are working on the LSND experiment at Los Alamos and BooNE at Fermilab. Candidates for this position are required to have a Ph.D. or equivalent degree in physics. Salary will be competitive and commensurate with qualifications and level of appointment. Candidates should submit a letter of application, a curriculum vitae, evidence of teachng skills and evidence of an outstanding research program. They should also arrange to have three letters of reference sent to the Department and be willing to submit additional references on request. Letters should be sent to:

Chair, Search Committee
Experimental High Energy Physics
Department of Physics
University of California
Riverside, CA 92521

Full review of applications will begin January 17, 2000. Applications received after this date will be considered on a case-by case basis until the position is filled.

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For further information, please also consult the following websites: http://www.epfl.ch, http://dewww.epfl.ch/, http://admwww.epfl.ch/pres/profs.html or http://research.epfl.ch/

The Nuclear Physics Laboratory at the University of Illinois at Urbana-Champaign

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For full consideration, applications should be received by **Dec. 1, 1999.** Please send applications by regular mail to : **Prof. D. H. Beck, Search Committee Chair, Department of Physics, University of Illinois at Urbana-Champaign, 1110 West Green Street, Urbana, IL 61801-3080.**

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Scientist Position in CMS
-(Project Manager for Software and Computing)-
Fermi National Accelerator Laboratory

The Fermi National Accelerator Laboratory is filling a Scientist position. The search is for a Project Manager for the Software and Computing project in the United States for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider at CERN. Fermilab will host the main computer resources and the data repository for US scientists participating in CMS. Duties include overall executive responsibility for the successful planning, implementation, and commissioning of computing resources and of the participation of US scientists in the CMS wide development of the software.

The successful candidate will lead a project with an organization of scientists and technical professionals; coordinate the preparation of schedules, cost estimates and technical specifications and the presentation of reports; and make presentations to management regarding project progress and status against established milestones.

A Ph.D. in Physics or its equivalent is required. Management and organizational skills in a highly technical environment are essential, as is exposure to science based on large facilities and dispersed collaborations of scientists. Candidates should have demonstrated experience in scientific leadership and project management skills necessary to lead and direct the project, meeting agreed upon requirements and schedule and exercising budget authority. A strong interest in experimental high-energy physics and a proven reputation in the field are also necessary. Candidates should possess a broad and deep understanding of the present state of computing technologies and the trends that project these technologies into the future. Applicants for Fermilab position #990152 should submit curriculum vitae, a list of publications, a letter expressing interest and describing related experience and a list of at least three references to:

Dr. Matthias Kasemann • MS 370
Fermi National Accelerator Laboratory • P.O. Box 500
Batavia, IL 60510 • USA

Applications should be submitted as soon as possible. A Search Committee will review submissions and invite selected applicants for interviews at Fermilab.

The U.S. Department of Energy funds the experimental program at Fermilab through a contract with Universities Research Association, Inc., which manages and operates the Laboratory. Fermilab is an Equal opportunity Employer. The Laboratory has a competitive program of benefits.

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LIGO

Research Positions LIGO Laboratory

The Laser Interferometer Gravitational-Wave Observatory (LIGO) project is an effort led by Caltech and MIT scientists to establish a gravitational-wave observatory, consisting of two facilities with laser interferometric detectors located at Hanford, Washington and Livingston, Louisiana.

Scientists will be involved in the commissioning and operation of LIGO itself, analysis of data, both for diagnostic purpose and astrophysics searches, as well as a vigorous R&D program for future detector improvements. Appointments will be at the post-doctoral level with one year initial appointments and the possibility of two subsequent one year appointments at the same rank. In some cases, appointments with an initial term of three years or of an indefinite term, may be considered. Appointment is contingent upon completion of all requirements for Ph.D.

Applications for positions at any LIGO Laboratory site (MIT, Caltech, Hanford, or Livingston) should be sent either to:

Professor Barry C. Barish, California Institute of Technology, LIGO 18-34, Pasadena, CA 91125, or to
Professor Rainer Weiss, MIT, LIGO Project, NW17-161, 175 Albany Street, Cambridge MA 02139-4307.

Applicants should request that three or more letters of recommendation be sent directly to the attention of Professor Barish or Professor Weiss. Consideration or applications will begin on December 1, 1999 and will continue until all positions have been filled.

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STELLENAUSSCHREIBUNG

Im Fachbereich 07 (Mathematik, Physik, Geographie) ist ab sofort eine Stelle mit einer/einem

Wissenschaftlichen Mitarbeiterin/Mitarbeiter BAT IIa
am II. Physikalischen Institut
(Prof. Dr. Metag)

als Zeitangestellte/Zeitangestellter gemäß §§ 57a ff. HRG und § 82 HHG mit Gelegenheit zu eigener wissenschaftlicher Weiterbildung befristet (zunächst für 3 Jahre mit Verlängerungsmöglichkeit um höchstens 2 Jahre) zu besetzen. Vollzeitstellen sind nach dem Hessischen Gleichberechtigungsgesetz grundsätzlich teilbar.

Aufgaben: Eigene wissenschaftliche Weiterbildung; hochschuldidaktische Qualifizierung; wissenschaftliche Dienstleistungen zur Organisation, zur Vorbereitung und zur Durchführung von Forschung und Lehre gemäß § 82 Abs. 1 HHG vor allem Mitarbeit bei Experimenten der Mittelenergiephysik mit dem Dileptonenspektrometer HADES am Schwerionenbeschleuniger SIS der GSI (Darmstadt) und mit dem Photonenspektrometer TAPS an den Elektronenbeschleunigern MAMI in Mainz und ELSA in Bonn. Zu den Aufgaben gehört außerdem die Mitarbeit bei der Durchführung der physikalischen Praktika, bei der Betreuung von Diplom- und Doktorarbeiten sowie die Mitwirkung bei Seminaren.

Voraussetzungen: Abgeschlossenes Hochschulstudium im Fach Physik und Promotion in Experimentalphysik. Erwünscht sind fundierte Kenntnisse in der Vorbereitung, Durchführung und Analyse komplexer Multiparameterexperimente der Mittelenergiephysik.

Die Justus-Liebig-Universität Gießen strebt einen höheren Anteil von Frauen im Wissenschaftsbereich an; deshalb bitten wir qualifizierte Wissenschaftlerinnen nachdrücklich, sich zu bewerben. Aufgrund des Frauenförderplans besteht eine Verpflichtung zur Erhöhung des Frauenanteils. - In Ihrer Bewerbung geben Sie bitte an, ob Sie eine Teilzeitbeschäftigung wünschen oder gegebenenfalls akzeptieren würden. Ihre Bewerbung richten Sie bitte unter Angabe des Aktenzeichens **Y 440/99** mit den üblichen Unterlagen bis zum 17.12.1999 an den **Präsidenten der Justus-Liebig-Universität Gießen, Ludwigstr. 23, D-35390 Gießen.** Bewerbungen Schwerbehinderter werden - bei gleicher Eignung - bevorzugt.

UNIVERSITY OF REGINA
THEORETICAL SUBATOMIC ASTROPHYSICS

The Department of Physics invites applications for a tenure-track position at the Assistant Professor level, starting July 1, 2000.

At present, our department's research activity is centered upon experimental and theoretical subatomic physics, and our preference is for the successful applicant to have expertise in theoretical particle or nuclear astrophysics, although exceptional candidates in theoretical particle physics or cosmology will also be considered. We anticipate that the next opening in the department will be in this area as well. **More information on our department can be found at: http://www.phys.uregina.ca.** At least two years of postdoctoral research experience is a requirement for this position. The successful applicant is expected to conduct a vigorous and significant research program securing external funding, and to teach effectively at both the undergraduate and graduate levels.

Applicants should submit their curriculum vitae, a discussion of research interests, and have three letters of reference sent directly to: Chair of the Search Committee, Department of Physics, University of Regina, Regina, SK S4S 0A2, Canada.

In accordance with Canadian Immigration requirements, priority will be given to citizens and permanent residents of Canada, however, citizens of all countries are invited to apply. The closing date for receipt of applications is January 15, 2000.

The University of Regina is committed to employment equity.

COMPUTER ANALYST

Brookhaven National Laboratory's U.S. ATLAS Project seeks a computer analyst with an advanced degree in Physics, or related field. Substantial experience in developing software algorithms using object-oriented programming languages for high energy or nuclear physics is required. Experience with UNIX systems, modern programming techniques, tools and languages, large scale data processing, and use or relational and object-oriented databases is highly desirable. Responsibilities include contributing to the design, development and implementation of the software infrastructure, and to assist Physicists in the software development effort.

Brookhaven offers a stimulating work environment and an excellent benefits package. For consideration, please forward your resume, indicating position #NS8734, to:

Nancy L. Sobrito, Brookhaven National Laboratory, Bidg, 185-HR, P.O. Box 5000, Upton, NY 11973-5000; email:Sobrito@bnl.gov; fax 516-344-7170.

BNL is an equal opportunity employer committed to workforce diversity.

BROOKHAVEN NATIONAL LABORATORY

PHYSICIST

The Omega Group of the Physics Department at Brookhaven National Laboratory presently has a staff, position available to work on the D0 experiment at the Fermilab Tevatron. The collaboration is currently in the process of upgrading the detector in preparation for Run II with the Main Injector, which is scheduled to begin in the spring of 2000. The Laboratory is playing a leading role in both the software and hardware efforts associated with this upgrade including offline software (tracking, vertexing, calorimeter and preshowers), online software and controls, and fabrication and commissioning of the Forward Preshower Detector. In addition to being expected to contribute to one or more of these technical projects, the successful candidate will be encouraged to actively pursue a physics topic with other BNL scientists or others in the collaboration requires a Ph.D. or equivalent in Experimental Particle Physics, Under the direction of H Gordon.

CV's list of publications, and three letters of reference, indicating position #MK8735, should be forwarded to:

M. Kipperman, Brookhaven National Laboratory, Bidg. 185, PO Box 5000, Upton, NY11973-5000.

BNL is an equal opportunity employer committed to workforce diversity. We strongly encourage applications from women and minorities in physics.

BROOKHAVEN NATIONAL LABORATORY

UNIVERSITY OF VICTORIA

POSTDOCTORAL RESEARCH POSITION
EXPERIMENTAL HIGH ENERGY PHYSICS

The High Energy Physics Group at the University of Victoria has an opening for a Research Associate to work on the BaBar experiment at the SLAC B Factory. Our group is part of the team which has ongoing responsibilities for the BaBar Drift Chamber. The successful applicant will write BaBar reconstruction software in C++, participate in data taking and play a leading role in physics analysis. A recent Ph.D. in experimental particle physics is required with demonstrated software and data analysis experience. This position is a two-year appointment, with the possibility of renewal. Candidates should supply a CV, with list of publications, description of research interests and three letters of reference to:

Professor J. M. Roney
Department of Physics and Astronomy
University of Victoria
Box 3055 Stn CSC
Victoria, B.C.
CANADA
V8W 3P6

This position will be filled as soon as a suitable candidate is identified.

Enquiries may be sent by e-mail to: mroney@uvic.ca

The University of Victoria strongly encourages applications from women, persons with disabilities, visible minorities, and aboriginal persons. In accordance with Canadian immigration requirements, this advertisement in the first instance is directed to Canadian citizens or permanent residents. However, all suitably qualified physicists are encouraged to apply.

DIVISIONAL FELLOW PHYSICIST IN NUCLEAR THEORY

The Nuclear Science Division of the **Lawrence Berkeley National Laboratory** invites applications for a position in the Nuclear Theory Group. The appointment will be at the level of a Divisional Fellow for a term of five years with the expectation of promotion to Senior Scientist upon successful review. Candidates should have a Ph.D. or equivalent experience in theoretical, nuclear, particle physics, or astrophysics, and should have a demonstrated record of outstanding and creative research ability with great promise and potential for leadership.

The current research program by active members in the Nuclear Theory Group at LBNL is primarily focussed on theoretical studies of high-energy nuclear collisions. This new position is intended for diversification into other areas such as astrophysics, nuclear structure, strong interaction, and weak interaction, which will complement the existing theoretical program and help to enhance the Nuclear Science Division's broad experimental programs.

Applicants are requested to submit their curriculum vitae, list of publications, statement of research interests and accomplishments, and the names of at least four references before the closing date of December 31, 1999 via e-mail (our preferred method) to: **employment@lbl.gov (no attachments please). Reference NS011239/JCERN. Or mail to: Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 937-0600, Berkeley, CA 94720. Or FAX: (510) 486-5870.** Berkeley Lab is an AA/EEO Employer.

BERKELEY LAB

UNIVERSITY OF CALIFORNIA, SANTA BARBARA DEPARTMENT OF PHYSICS

Faculty Position in
Experimental High Energy Physics

The Department of Physics at the University of California, Santa Barbara invites applications for a faculty position in experimental high-energy physics. The appointment can be made at any academic level from assistant to full professor, and outstanding candidates for any of these levels are encouraged to apply. The UCSB HEP program currently consists of groups working on heavy-quark physics (BaBar and CLEO) and dark-matter searches (CDMS II). We seek candidates with outstanding ability in both instrumentation and data analysis, and new experimental initiatives are welcome. The UCSB HEP group has excellent technical resources and staff, as well as a long history of major detector construction projects and analysis results. Information about our program is available at http://hep.ucsb.edu.

Candidates for the position should have a Ph.D. or equivalent degree in physics, an outstanding record of scholarship and should be committed to excellence in teaching. Candidates should submit a statement of current research interests and pursuits, a curriculum vitae, and a list of publications and should arrange for at least three letters of recommendation to be sent to:

High Energy Search Committee
Attn: Prof. Jeffrey Richman, Department of Physics,
University of California, Santa Barbara, CA, 93106
(E-mail: richman@charm.physics.ucsb.edu)

Applications will be considered starting January 1, 2000 and will be accepted until the position is filled.

The University of California is an Equal Opportunity/Affirmative Action Employer committed to excellence through diversity.

UNIVERSITY OF MINNESOTA

Research Associate in Theoretical Nuclear Physics

The nuclear theory group at the University of Minnesota expects to have a postdoctoral research associateship available beginning in the fall of 2000. A Ph.D. in physics, or the equivalent, is required by the date of appointment. The permanent group members are Paul Ellis, Joseph Kapusta and Yong Qian and their current interests include QCD, RHIC and nuclear astrophysics. Appointments are made for one year and normally are renewable for a second, subject to funding and performance. A vita and three letters of recommendation should be sent by postal mail to **Professor Joseph Kapusta, School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455.** Further details may be obtained by e-mail **Kapusta@physics.spa.umn.edu**. The application deadline is February 1, 2000.

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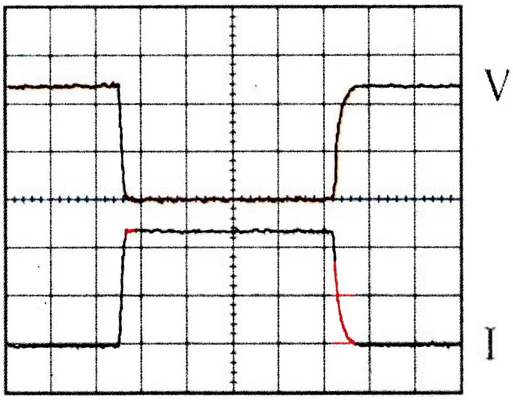

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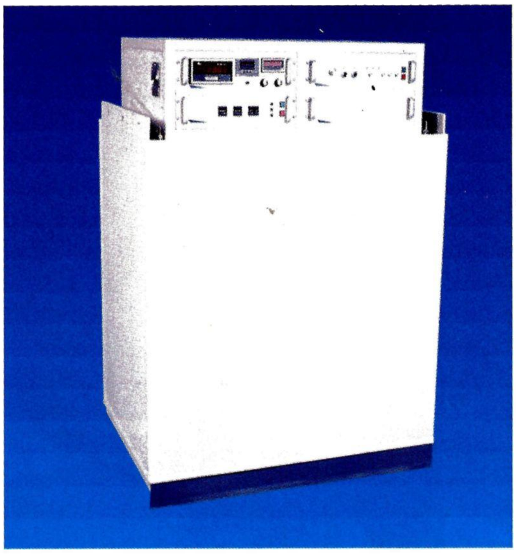

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