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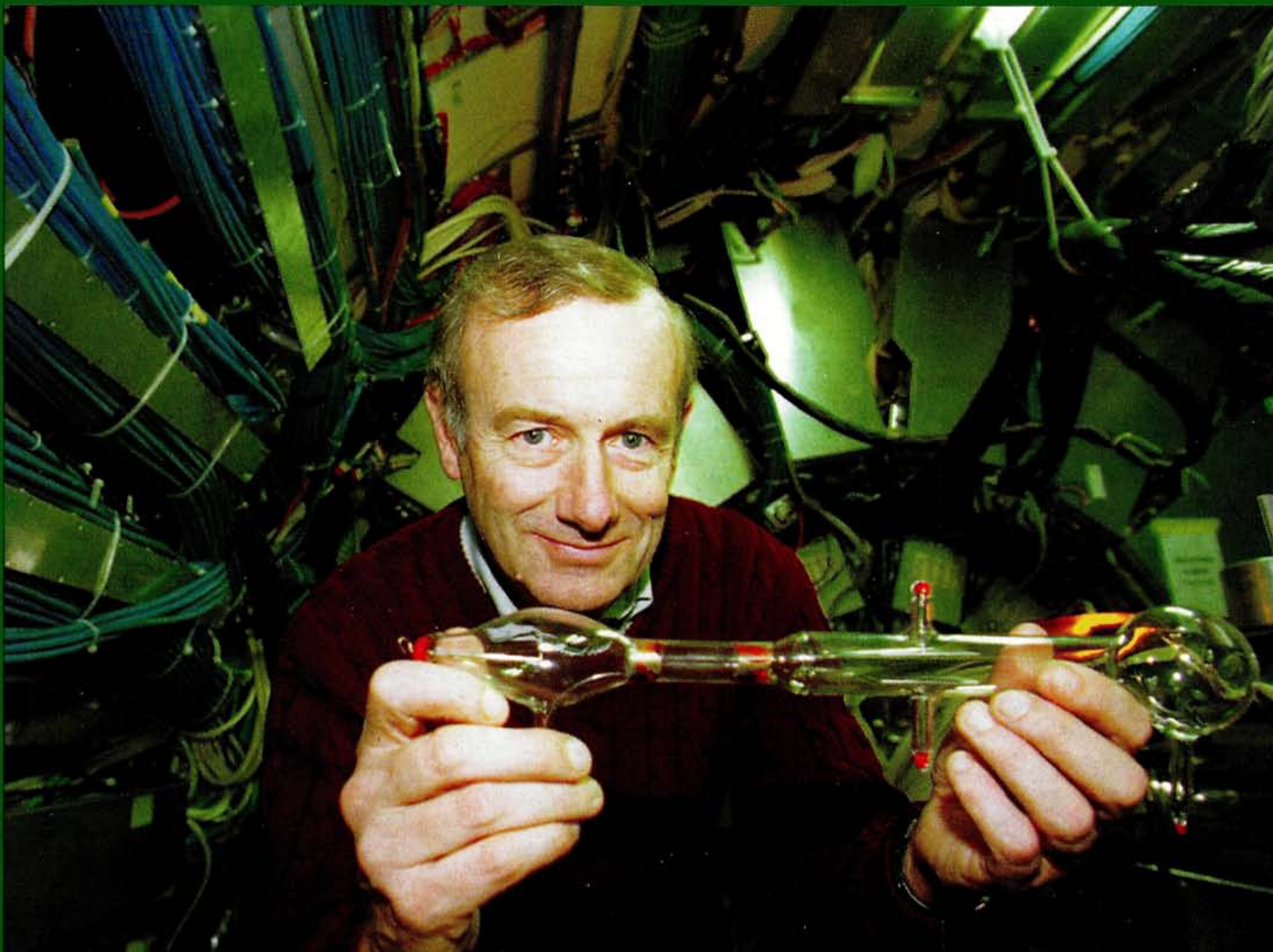

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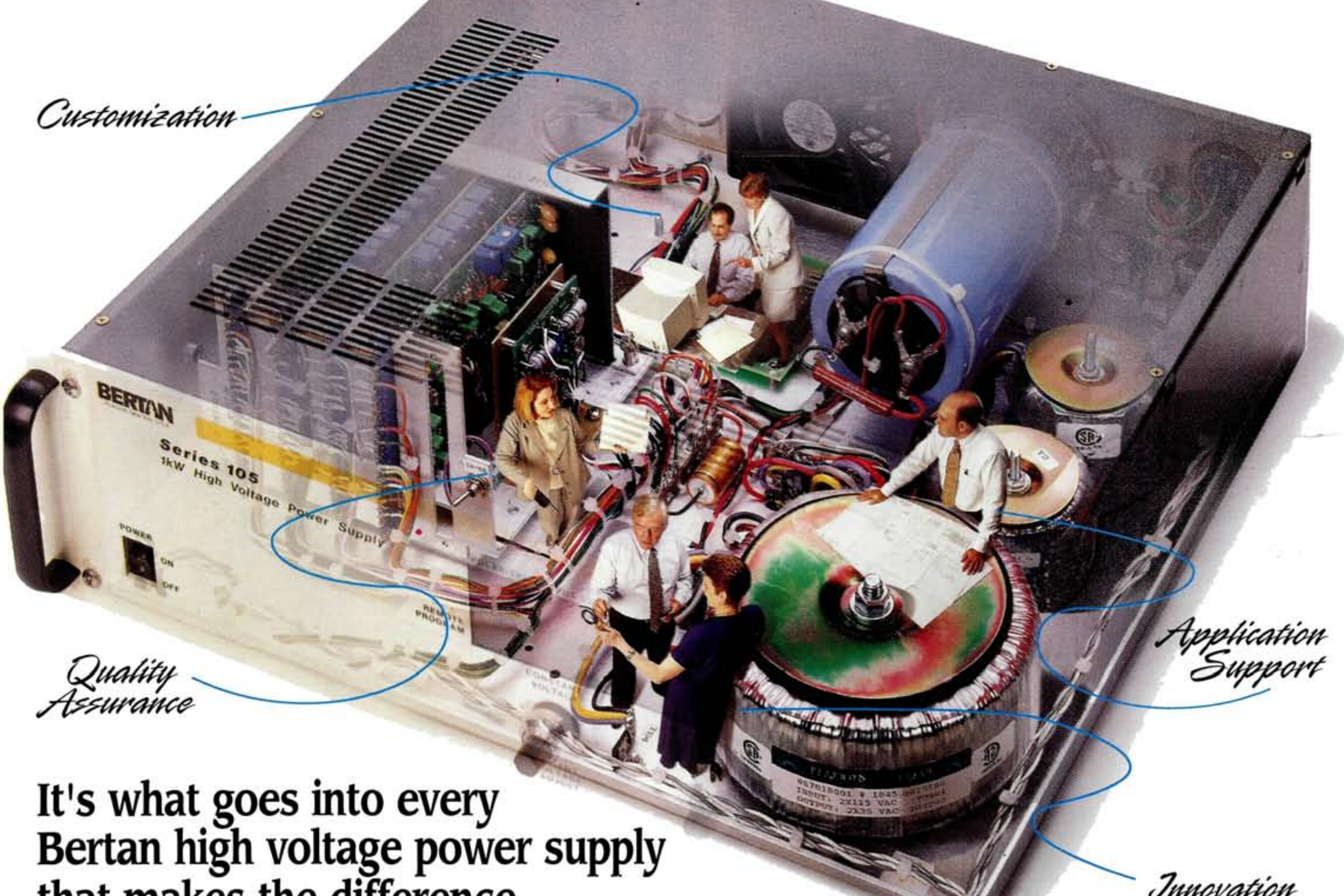

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Covering current developments in high-energy physics and related fields worldwide

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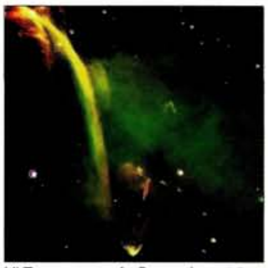
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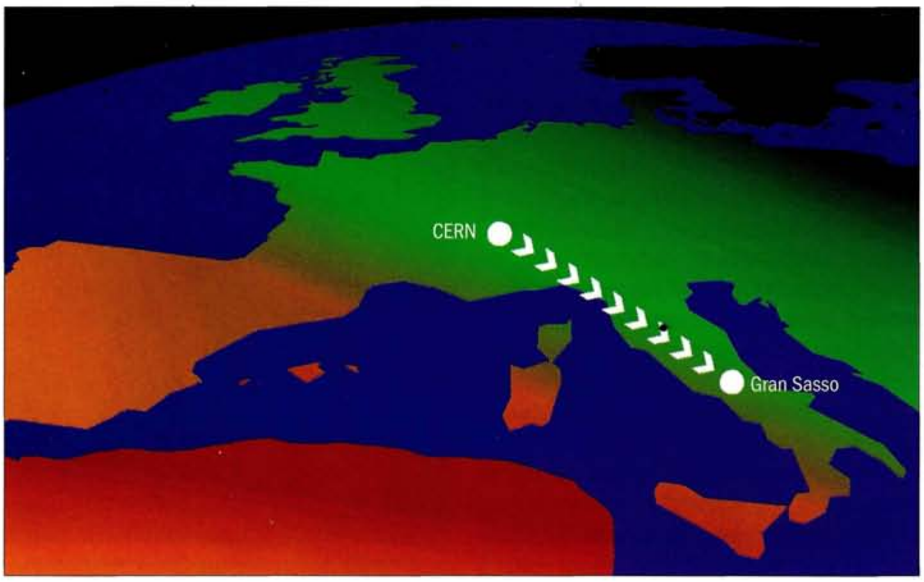
QuarkNet reaches out p18


Technology at CERN p35

Cover: A century of electrons – Frank Close with a replica of Thomson's 1897 appartus (which was used to discover the electron) against the impressive backdrop of today's electron physics, the L3 experiment at CERN's LEP electron–positron collider (p15).

Neutrinos will cross the Alps



Transalpine beams – neutrinos will be sent from CERN to the Italian Gran Sasso Laboratory, located 730 km away.

In a move that significantly extends the scope of European collaboration in particle physics, CERN is collaborating with the Italian National Institute of Nuclear Physics in a new project. A beam of high-energy neutrinos will be sent from CERN to detectors that will be built at the Italian Gran Sasso Laboratory, 730 km away from CERN, and 120 km from Rome.

The first historic Alpine crossing was General Hannibal's march on Turin, in about 200 BC. The advent of modern communications brought a need for transalpine railway links. The first tunnel to breach the Alps was the 14 km Fréjus/Mont Cenis tunnel, the construction of which began in 1851. It was soon followed by the 14 km St Gotthard tunnel in Switzerland. Now physics crosses the Alps too.

However, neutrinos need no tunnel to cross a mountain range – most of them can pass through rock. Contemptuous of matter, a neutrino beam can even pass through the 13 000 km of the Earth and emerge on the other side. There is, however, a slight neutrino casualty rate that makes experiments with neutrinos possible. If there are plenty of neutrinos, it is probable that enough of them will interact to produce a detectable signal. Of the 10^{18} neutrinos to be sent to Gran Sasso annually from CERN, about 2500 will interact, *en route*, with each 1000 tons of target material.

It took about half a century to discover that the neutrino (nature's most unpredictable particle) comes in three different kinds – electron, muon, or tau – according to the type of weakly interacting particle (lepton) they escort. Physicists are now convinced that these three varieties of neutrino are not immutable, as was first thought, but they subtly rearrange their lepton allegiance in flight. In physics language, the neutrinos oscillate from one kind to another as they travel.

Positive evidence for neutrino oscillations so far comes, overwhelmingly, from extraterrestrial neutrinos: from the Sun or from the interactions of high-energy cosmic rays in the atmosphere. To probe these oscillations under controlled conditions requires synthetic neutrinos. These neutrinos are produced via the decay of high-energy particles, which are generated by beams in an accelerator (*CERN Courier* November 1998 p13). The oscillations depend on the distance between the neutrino source and the detectors – the baseline.

For the new project, protons from CERN's SPS synchrotron, with an energy of up to 450 GeV, will be focused on a target to produce pions and kaons. These particles will then be magnetically focused to point towards the Gran Sasso Laboratory. After about 1000 m, most of these pions and kaons will have decayed, producing electron- and muon-neutrinos. The remaining strongly interacting particles will be removed by a beam stop (which the neutrinos can hardly "see"). CERN will construct the neutrino source, while Gran Sasso will host the detectors and provide the infrastructure at the far end.

After an initial round of proposals for experiments to detect the neutrinos, two – OPERA and ICANOE – are well defined. OPERA will use the emulsion target techniques developed for the CHORUS neutrino experiment at CERN, and further refined for the DONUT study at Fermilab. While CHORUS used a mere 700 kg of emulsion, OPERA will use 200 tons of emulsion, which will be interspersed with thin lead plates. Vital to this work are Japanese emulsion technology and sophisticated automated emulsion scanning techniques, developed in Japan and in Europe.

ICANOE is based on the liquid argon detector used to track and identify particles and developed for the ICARUS neutrino detector. It will be supplemented by the NOE magnetized spectrometer. ICANOE will use 9.3 kilotons of liquid argon in four modules, which will be separated by NOE spectrometers.

The main goal is to see the appearance of tau neutrinos in Gran Sasso. These particles will not be present in the beam when it leaves CERN, but may be produced *en route*.

Data taking for these new experiments is planned to begin in May 2005. In addition to existing equipment at CERN, two-thirds of the 71 million Swiss francs needed for the project is being provided by the Italian National Institute of Nuclear Physics (INFN). So far voluntary contributions from Belgium, France, Germany and Spain have been announced.

Long baseline neutrino studies are under way in Japan, where the KEK Lab sends particles to the 250 km distant Superkamiokande detector (*CERN Courier* October 1999 p5). In the US, the MINOS project is sending particles from Fermilab to detectors in the Soudan mine, 730 km away (*CERN Courier* October 1999 p6). The main thrust of these studies is to chart the disappearance of neutrinos that were initially present in the beam.

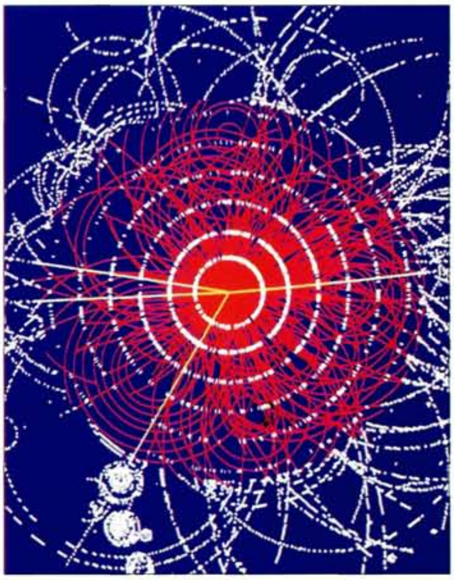
LHC workshop studies new physics

With construction work for CERN's LHC and its big detectors under way (and *en route* to the scheduled commencement of the programme in 2005) a workshop, Standard Model Physics (and more) at the LHC, was held at CERN. The first plenary meeting took place on 25–26 May 1999. The second, and final, meeting was held on 14–15 October 1999.

The goal of the workshop, not evident from its subdued title, was to promote physics studies at the LHC beyond the main focus of the LHC physics programme. The physics community is very much aware of the need to ensure that physics remains lively during the long years of LHC machine and detector construction. Exploring additional possibilities – beyond the spearhead search for the long-awaited Higgs particle and other new objects, especially supersymmetric ones – were, therefore, very much to the fore.

To attack specific physics objectives, working groups were set up on QCD, electroweak interactions, top quark physics, and beauty physics. Subgroups were formed on the production of B-particles and on the decays of B-particles. In each group, theorists, together with experimentalists from ATLAS, CMS and LHCb, acted as convenors. Heavy-ion physics held its own workshop.

The meetings attracted many participants. Included were a substantial number of theorists from outside of CERN. The organizers were happy to see distinguished visitors from the US. Some of the visitors took an active role as convenors and many presented talks. The participation of experimentalists, on the other hand, reflected that most of them were either busy making LHC detectors or were still working on current experiments. Overall, the experience was positive, and similar meetings will take place in the future. The plenary meeting in October presented the preliminary results of the workshop. A more complete and final version will soon be published.



Standard physics and more – a simulated preview of physics at the ATLAS detector at CERN's LHC proton collider.

In one year the LHC should produce between 10 and 100 million top quarks and antiquarks, so the top quark mass will be measured with an unmatched accuracy of 1–2 GeV. In the rare decays of this quark, stringent limits can be set on flavour-changing couplings. Single top quark production through weakly charged currents was studied in detail, along with the new possibility of measuring top to bottom quark transitions, and of studying the top quark polarization.

The electroweak working group presented some remarkable theoretical calculations. These included radiative corrections to single W or Z boson production (with effects in the same order as the experimental errors), and the QCD and electroweak corrections on the associated production of two bosons. On the experimental side, it was shown that the W mass can be measured to an accuracy of about 15 MeV, better than in any previous experiment. However, the precision on the electroweak mixing angle, ~0.00025, is not competitive with what has been achieved at electron–positron colliders. On the search for new physics, the capabilities of the LHC on contact interactions, new vector bosons, anomalous gauge couplings and strongly interacting WW scattering, etc, were reviewed.

For beauty production, benchmark calculations, b-tagging, measurement accuracies and efficiencies, quarkonia, and small-x structure (relevant for b-production predictions) were among the topics addressed. The goal of the B-decay working group was to provide a more complete picture of the B-physics performance and to search for new strategies in the quest for CP violation in B-decays. Studies of promising new channels, and/or methods, included: B-decays into charmed D-meson pairs; the J/psi plus Ks; pion and kaon pairs; and three pions. The DD channel here looks very promising.

The QCD working group presented a thorough report on quark–gluon structure, a discussion on jet definitions and algorithms, strategies for systematic computations of radiative corrections, and related results on some specific processes, for example, those that involve photons.

All the transparencies of the talks given at the workshop can be found at "http://home.cern.ch/~mlm/lhc99/lhcworkshop.html".

CERN finalizes new agreement with ISTC

A collaboration agreement between CERN and the International Science and Technology Centre, finalized in November and worth some 12 million Swiss francs, is a large step forward in CERN–ISTC co-operation. The proposed agreement covers equipment for the big ATLAS and CMS experiments. From 2005 these experiments will use CERN's new LHC proton collider. The agreement is within the framework of the ISTC Partnership Project (more next month). Contributions to all such ISTC projects had previously amounted to about $14 million and the new CERN projects add some $8 million to this sum.

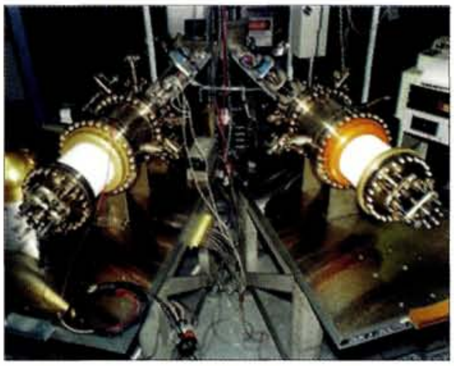
The lion's share of this new co-operative effort goes towards the lead tungsten crystals for the CMS experiment's electromagnetic calorimeter (*CERN Courier* May 1999 p6). ISTC scientists will also deliver the huge wheels (24 m in diameter) to support the muon chambers on the outside of the ATLAS experiment. This mutually profitable new avenue for research and development work should lead to fresh proposals and contracts.

Two electron guns fire at Jefferson

Spin-oriented (polarized) electron beams are high on the agenda at the Jefferson Laboratory, Newport News, Virginia (*CERN Courier* December 1999 p6). To ensure uninterrupted delivery of these beams, a second polarized electron gun has been added.

About 50% of all the Laboratory's experiments require polarized beams and an even larger fraction of the major experiments use them. With the Continuous Electron Beam Accelerator Facility (CEBAF) delivering beams to two or three halls simultaneously, in practice the polarized source has to run 100% of the time. The Laboratory has been running polarized beams since April 1998 and plans to continue into the spring of 2001.

Several other improvements were made to the polarized source. For example, in the past, temperature fluctuations near the lasers that illuminate the photocathodes affected beam stability. An air-conditioned housing has now been built around the three lasers. Improved laser controls and electronics hardware were also installed. Work is in progress to reconfigure the laser systems so that switching beam delivery between the polarized guns can be done with the push of a button.



Two polarized electron guns at the Jefferson Laboratory, Newport News, Virginia.

A key component of both electron guns is their dime-sized gallium arsenide photocathode. These photocathodes gradually lose their emitting properties over time. Although the laser can be refocused on different sections of the photocathode, eventually, the material's effectiveness decreases and the entire crystal must be replaced.

During replacement, Injector Group personnel must open the ultra-high-vacuum chamber within the injector. Although this process lasts only minutes, re-establishing the ultra-high vacuum involves bakeout and can take up to 50 hours.

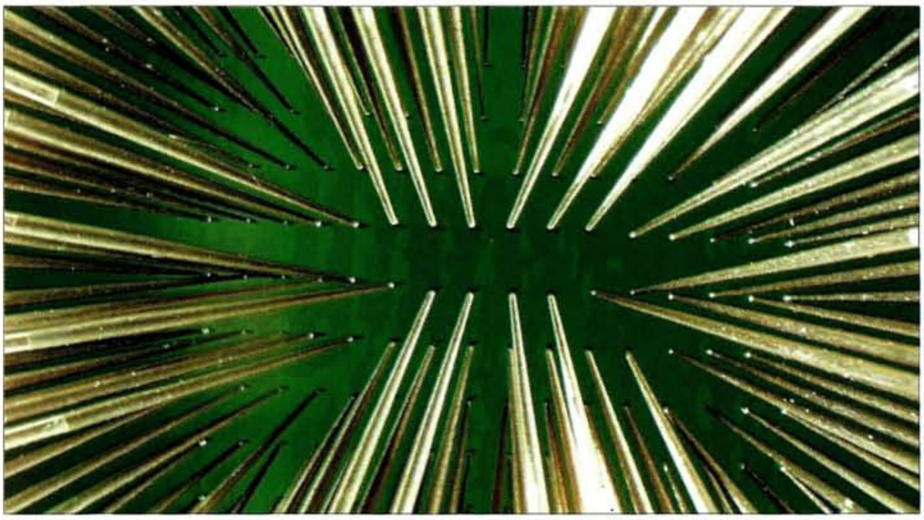
With two polarized guns, one can be taken out of operation as necessary. With planned upgrades to the laser system and continued investigations into more efficient and durable photocathode materials, researchers should be able to take full advantage of their allotted beam time in the coming months and years.

Heidelberg merger forms Kirchhoff Institute

The former Institutes for High-Energy Physics and for Applied Physics at the University of Heidelberg have recently joined forces to become the new Kirchhoff Institute for Physics. The Institute was named after Gustav Robert Kirchhoff who carried out his fundamental work on radiation laws and spectral analysis in Heidelberg more than 100 years ago.

At the formal inauguration on 2 November 1999, Kirchhoff Institute director Karlheinz Meier presented an overview of the wide spectrum of teaching and research. These activities cover pure research areas like experimental particle physics and low-temperature physics as well as applications and interdisciplinary work in biophysics, medical physics, microelectronics and computer science. The new institute is participating in a couple of particle physics experiments at DESY and CERN. It also hosts the Heidelberg ASIC integrated circuit laboratory founded and operated by three physics institutes in Heidelberg.

The merger has already initiated fruitful co-operations between applied and pure science. Particle physicists have developed microelectronic light sensor chips with fast integrated-signal processing, for applications in ophthalmology, based on experience with particle physics detectors. The low temperature group, lead by Siegfried Hunklinger, detects very low-energy photons, with unprecedented resolution, using a magnetic probe at very low temperatures.



Kirchhoff Institute developments – a probe card for the test of a microchip, developed in Heidelberg, for the preprocessor of the ATLAS experiment trigger system at the LHC.

The Kirchhoff Institute employs about 120 people in two separate buildings. The inauguration was preceded by the laying of the foundation stone for a new institute building, to be equipped with modern infrastructure: cleanroom facilities, experimental halls, workshops and lecture halls. The building should be complete in the summer of 2002.

Neural computation points the way

Neural computation – analysing data by simulating the way the brain works – is another area of application where high-energy physics is in the vanguard of development. This state-of-the-art physics was demonstrated at the recent Neural Computation in High-Energy Physics Workshop, NCHEP-99, held in Ma'ale Hachamisha (near Jerusalem), Israel. The workshop was organized by Halina Abramowicz and David Horn of Tel Aviv and gathered together 30 participants from 10 countries. The workshop showed that the brain-modelled computational techniques, with which high-energy physicists have been experimenting for 10 years now, have definitely come of age.

Highlights on the triggering front included a status report, presented by Christian Kiesling of MPI Munich, on the much-heralded neural net trigger of the H1 experiment at DESY. This trigger was essential in extending the acceptance of the photon–proton energy for elastic J/psi production over the entire kinematic range of DESY's HERA electron–proton collider (figure 1), and well beyond that obtainable using the standard techniques. Another such highlight was a talk, presented by Joao Varela of LIP Lisbon, on a modular neural electron/photon trigger for the level-1 trigger of the CMS experiment at CERN's LHC collider, which is benchmarked at 40 MHz in a test beam.

Talks, to place neural techniques within the broader spectrum of high-energy physics techniques, also included: the Silicon Vertex Tracker, now well under way at the CDF experiment at Fermilab (Franco Spinella, INFN Pisa); and overviews, presented by Grzegorz

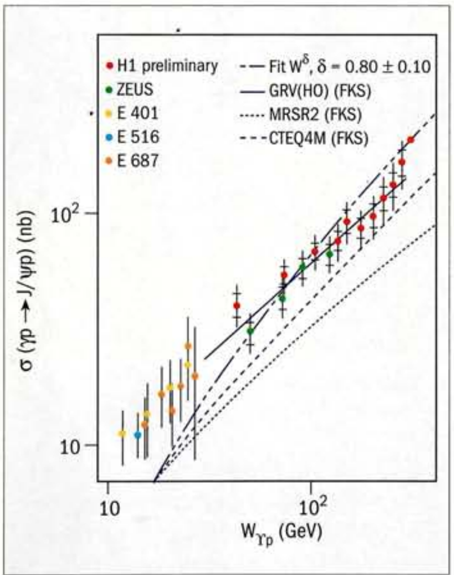


Fig. 1: The graph shows the total cross-section for exclusive J/psi photoproduction as a function of the photon–proton centre-of-mass energy. The data are from DESY's HERA electron–proton collider (H1 and ZEUS experiments) and from previous fixed target studies. Note the wide range of the H1 points, especially at the high end of the kinematic region, which are accessible via a neural network trigger.

Wrochna of Warsaw and Saul Gonzalez of CERN, respectively, of the LHC experiments' CMS and ATLAS trigger systems. Possible future applications, presented by Erez Etzion and Gideon Dror of Tel Aviv, included a muon transverse momentum trigger for ATLAS and a z-vertex postion finder for ZEUS.

Finally, Bruce Denby of Versailles and Jose Seixas of Rio de Janeiro gave overviews of neural network hardware platforms, which included Digital Signal Processors (DSPs) and Field Programmable Gate Arrays.

Neural network methods have now become accepted as part of the standard toolbox of off-line data analysis techniques. This was witnessed by two D0 (Fermilab) results, a leptoquark production limit (presented by Silvia Tentindo-Repond of Florida State), and a precision measurement of the top quark mass (presented by Harpreet Singh of UC Riverside). DELPHI and OPAL members also talked about further studies in the Higgs quest, rare B-decays, and tau-exclusive branching ratios. Anatoli Sokolov of IHEP, Moscow, gave a comprehensive overview of off-line applications, as well as some hints for the future.

At the end of the workshop, David Horn presented highlights of the Neural Computation in Science and Technology Conference, which had taken place at the same venue immediately before NCHEP-99. According to him, if high-energy physicists wish to remain up-to-date in this field, they will have to familiarize themselves with some of the more modern techniques such as Independent Component Analysis, Support Vector Machines, advanced clustering techniques, and genetic optimization.

NCHEP-99 was sponsored by the Israel Science Foundation. Further information is at "http://neuron.tau.ac.il/NCHEP-99".

Majorana mass limit reaches an all-time low

The lowest mass limit, so far, on the Majorana electron neutrino comes from the Heidelberg–Moscow search for double beta decay, after 10 years of running.

In normal beta decay, a nuclear neutron transforms into a proton by emitting a neutrino. A far more exotic possibility is two successive beta decays, in which the neutrino emitted in the first decay would be absorbed by the second decay. The resulting isotope would have two more protons, and no neutrinos would emerge. This can only happen if the neutrino and its antiparticle are indistinguishable from one another (a Majorana particle), as opposed to a conventional Dirac neutrino, whose particle and antiparticle are distinct.

Using an 11.5 kg sample of germanium-76, in the Gran Sasso Laboratory, the Heidelberg–Moscow search has now established that neutrinoless double beta decay, if it happens at all, does so with a lifetime of at least 10^{25} years: a world record. The corresponding effective Majorana neutrino mass (a superposition of the different neutrino mass eigenstates) has to be less than 0.2 eV.

This complements information obtained from solar and atmospheric neutrino oscillation experiments, which determine differences in neutrino mass eigenstates. The new mass limit has implications for the neutrino mass matrix, and for cosmology in the Majorana neutrino scenario. In addition to limits on the neutrino mass, the experiment places limits on other new physics effects.

A full report will appear in a forthcoming issue of *CERN Courier*.

Bohrium finds a place in the Table

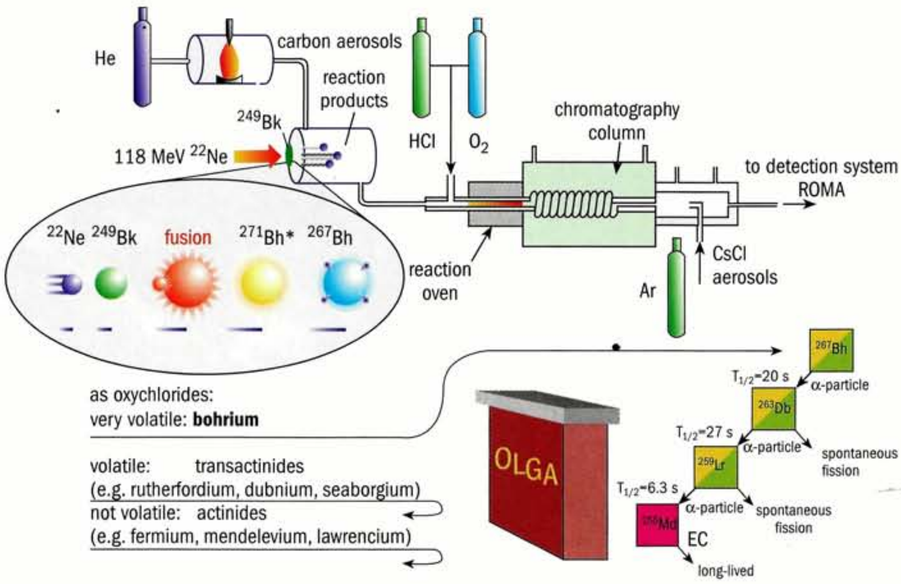
An international collaboration of radiochemists has carried out the first chemical study of the transuranic element bohrium (atomic number 107) using the Philips cyclotron at the Swiss Paul Scherrer Institute.

While the recent discovery of elements 114, 116 and 118 have grabbed the scientific headlines, these experiments do not yield any information about chemical properties. Such information is a pre-requisite for the classification of an element in the Periodic Table. From a chemist's point of view, the Periodic Table ended with seaborgium, which has an atomic number of 106.

The bohrium experiment aimed to close the information gap, and investigate whether the element belongs to Group VII (which includes the elements rhenium and technetium). However, chemistry is by no means straightforward. Relativistic effects can strongly distort the electronic structure of elements and, in turn, lead to unexpected deviations in chemical properties compared with lighter homologues in the Periodic Table.

In the first experiment, performed in spring 1999 at the 88-inch cyclotron at the Lawrence Berkeley National Laboratory (LBNL), a new, long-lived isotope of bohrium, with a mass number of 267, was produced in the reaction between neon-22 ions and a berkelium-249 target. This new isotope was found to have a half-life of about 20 s, which is long enough for chemical investigation.

Previous investigations of heavy-element compounds that gave sufficiently high reaction rates and unambiguously identified themselves as members of a given group, showed that the most promising method of confirming bohrium as a Group VII element was by studying its oxychloride. In the case of Group VII elements, these molecules become volatile at much lower temperatures than those of the actinides (Group III) and the neighbouring transactinides (Groups IV–VI).



A schematic view of the apparatus for bohrium chemistry, illustrating the various steps that are involved in producing and isolating the element's oxychloride. Because of its volatility, bohrium can be distinguished from its neighbouring elements in the on-line gas-chromatography apparatus (OLGA) and its presence can be determined from its decay chain in the rotating wheel multidetector analyser (ROMA).

During a one-month period of beam time at PSI in September 1999, a 600 g/cm^2 target of berkelium-249 was bombarded with 2×10^{12} neon-22 ions/s. The target material was provided by the US Department of Energy and prepared on thin beryllium foils by LBNL.

Using a gas transport system, the products were continuously injected into an on-line gas-chromatography apparatus (OLGA), which was capable of measuring the volatility of the pre-formed oxychlorides. Confirmation of the presence of bohrium, with single-atom sensitivity, was achieved using a rotating wheel multidetector analyser (ROMA). The analyser was equipped with solid-state detectors to register both the alpha-particle emission and spontaneous fission events, which are characteristic of the decay of such heavy nuclei.

Using a total of just six detected atoms, it was shown that bohrium indeed forms volatile oxychlorides at a temperature of 180 °C, within the expected range of 200 °C for Group VII elements. This, together with the registered alpha-decay chains, starting at bohrium-267 and passing through dubnium-263 (atomic number 105) and lawrencium-259 (103) to the long-lived mendelevium-255 (101), show that bohrium is an ordinary member of Group VII.

Heinz Gäggeler, PSI, Berne.

Alcatel merges with AHTS

Alcatel has signed the final agreement to take control of the superconductivity activities of Aventis Research & Technologies, a subsidiary of Hoechst.

Through this agreement, Alcatel acquires the know-how of Aventis High-Temperature Superconductivity (AHTS) in the design and production of superconductor materials. Thus, Alcatel adds an existing industrial and commercial entity to its significant research and development capacity.

This integration should give the Group the ability to offer the entire superconductor wire production range (from raw materials up to transformation processes), to improve synergy between the various R&D teams and, as a result, achieve production of excellent, high-performance wires and bulk parts.

The activities of Aventis take place in Hurth, near Cologne, where all the industrial equipment is installed.

Edited by Alison Wright

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

Einstein tops physicist pop chart

Albert Einstein is the greatest physicist of all time, according to a survey of 100 leading physicists conducted by *Physics World* (the journal of the British Institute of Physics). In second place is Isaac Newton, closely followed by two other founding fathers of physics, Galileo Galilei and James Clerk Maxwell. However, seven of the ten are 20th-century particle physicists. Bohr, Rutherford, Dirac, Schrödinger, Heisenberg and Einstein himself were all major players in the great quantum revolution, which took place in the early years of the 20th century. Richard Feynman, in 7th place, epitomizes the emergence of modern field theory.

The votes for most important discoveries of all time went to quantum mechanics, Newton's mechanics and gravitation, and Einstein's relativity. The respondents were also asked what were the greatest unsolved problems in physics. Quantum gravity, high-temperature superconductivity and consciousness were among the choices, although one wit replied "getting tenure". *PW*

Top 10 physicists of all time

1. Albert Einstein
2. Isaac Newton
3. James Clerk Maxwell
4. Niels Bohr
5. Werner Heisenberg
6. Galileo Galilei
7. Richard Feynman
8. Paul Dirac
8. Erwin Schroedinger
10. Ernest Rutherford

Scientists develop non-contact sonic device

US scientists have developed a new ultrasound scanning apparatus that can produce body scans without the need for contact between the device and the patient.

Ultrasound scanning, which reflects high-frequency sound waves inside the body, is a useful technique in medicine, particularly in imaging foetuses in the womb. Conventional techniques require the device to be in direct contact with the patient's skin. So for patients with severe burns doctors cannot use ultrasound. In these cases doctors rely on a visual inspection. However, severe damage below the surface of the skin may go undetected.

Because air has such a high impedance (density multiplied by the speed of sound through it) compared with the ultrasound device, an air gap between device and patient acts as a barrier to the sound waves, most of which are then reflected straight back to the device without reaching the patient at all.

With the new non-contact device, the sound waves pass through a multi-layered material. Each successive layer has a greater impedance than the last, and gets progressively closer to the value for air. This "impedance matching" improves the transmission of ultrasound through the body, and can produce clear images in around a minute with the device held 5 cm above the surface of the skin.

The researchers now hope to develop the device further in larger clinical studies, and produce real-time images. *AIP*

Vacuum tubes strike back

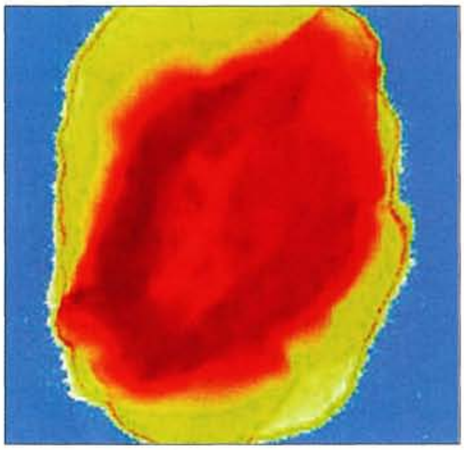
Vacuum tubes, re-invented by physicists in Cambridge, UK, could pose serious competition to current semiconductor technologies.

The anode-gate-cathode device (nanotriode) is based on a sandwich of Al, W and SiO_2 layers. In a cavity inside the sandwich are W pillars, each topped with a grain of AuPd. Electrons are emitted by the cathode pillars into the vacuum cavity and move towards the W anode layer. Because the electrons are moving in a vacuum rather than a semiconductor, the nanotriode offers faster switching times, temperature independence and radiation hardness. Research will concentrate on reducing the operating voltage and investigating the longevity of the nanotriode with a view to developing large-scale integrated devices. *AIP*

Lasers accelerate particle production

Recently, the Livermore laser generated an intense proton beam, of up to 50 MeV in energy, from a single pulse of the Petawatt laser – which is the most powerful laser in the world. Meanwhile, the VULCAN laser at the UK Rutherford Appleton Laboratory has launched a 30 MeV proton beam and lead ions with energies of up to 420 MeV.

Electrons are torn from a target of a 1.8 μm thick aluminium foil by the laser pulse. The electrons then collect behind the target. This negatively charged cloud of electrons drags positive ions from the back of the target and accelerates them at a rate that may be as great as 1 MeV/μm. Eventually this system could act as an alternative to conventional ion accelerators for producing high-energy ion beams for use in cancer therapy and electronics manufacturing. *AIP*



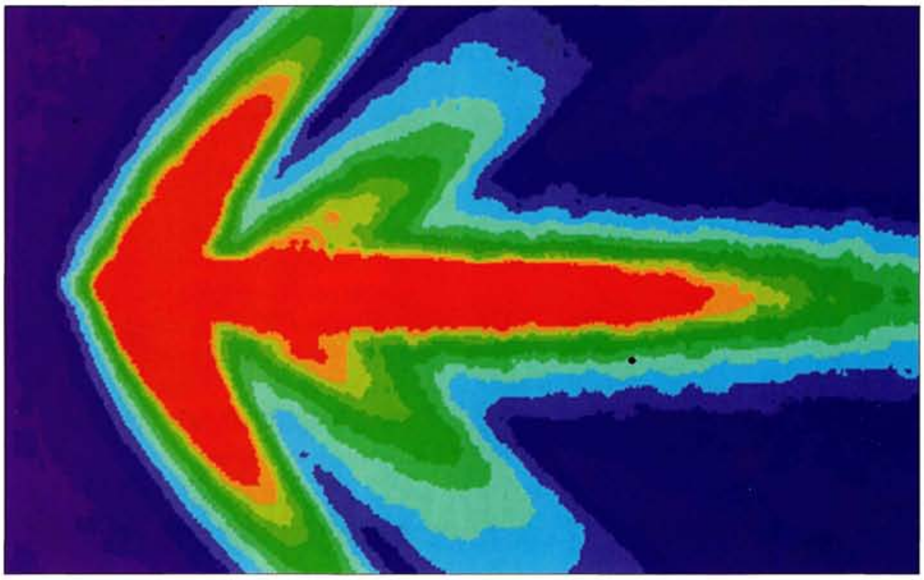
Laser acceleration – a Michigan high-intensity laser incident on a 1.8 μm thick aluminium foil can produce a proton beam up to several MeV in energy. It is seen here in cross-section from just behind the target.

Mach cones studied in plasmas

Plasmas, which are made of charged particles like ions or electrons, are useful in experiments for condensed matter physics. Plasmas are good models of gases, however, by adding dust to the system the plasma can mimic a liquid or a solid (where the particles remain almost stationary and interact only with their nearest neighbours).

Scientists in Iowa are using "dusty" plasmas – electrons loaded with micron-sized spheres – to study the structure and movements within the plasma at a microscopic level. By firing a supersonic particle into the plasma they can observe the pattern of shock waves produced. This pattern is known as a Mach cone.

The formation of Mach cones in solids has interesting applications in seismology. For example, sound waves travelling in a liquid-filled bore hole move faster than the speed of sound in the surrounding rock. This causes a Mach cone to propagate through the rock. *AIP*



A supersonic particle fired into a plasma of electrons and micron-sized spheres, creates a pattern of shock waves known as a Mach cone.

Edited by Emma Sanders

A masing new ruler

Observations of astronomical water masers have provided us with a new measure of distance in space.

Maser emission was detected by a team using the US Very Long Baseline Array (VLBA), from material rotating around a black hole in the centre of galaxy NGC 4258. With the rotation disk very nearly edge on, both the maser's angular velocity and acceleration could be measured. Then, using geometry, its distance from the galaxy could be calculated.

Uncertainties in the value of the Hubble constant, and thus the age of the universe, are mainly caused by errors in measuring large distances. "Standard candles" – Cepheid variable stars and type 1 supernova remnants – used for distance measurements, sometimes give wildly differing results. Errors occur because of "blending", where the stars appear to be brighter than they actually are because their image is mixed with that of nearby stars.

XMM is launched

On 10 December 1999, an Ariane 5 rocket launched the European Space Agency's X-ray multi-mirror satellite (XMM). XMM is Europe's largest scientific satellite. It is 10 m tall and has 120 m^2 of mirrors, which are coated in a 0.5 μm thickness of gold. The telescope will be the most sensitive in the world. It is set to revolutionize the study of X-ray sources including black holes, exploding stars and gamma-ray bursters (*CERN Courier* July 1999 p13).

XMM prepares for take-off. (ESA.)

The Hubble century

The spectacular universe is revealed by the Hubble Space Telescope: an interaction between 2 spiral galaxies NGC 2207 and IC 2163. (NASA/ESA.)

Finding one's place in the world – Edwin Hubble at the Mount Wilson telescope. (Space Telescope Science Institute.)

The name of Hubble will be eternally linked with 20th-century astronomy. At the beginning of the 20th century astronomers knew of planets and stars, and anything else was called a nebula (derived from the German word for fog). US astronomer Edwin Hubble was to change all that.

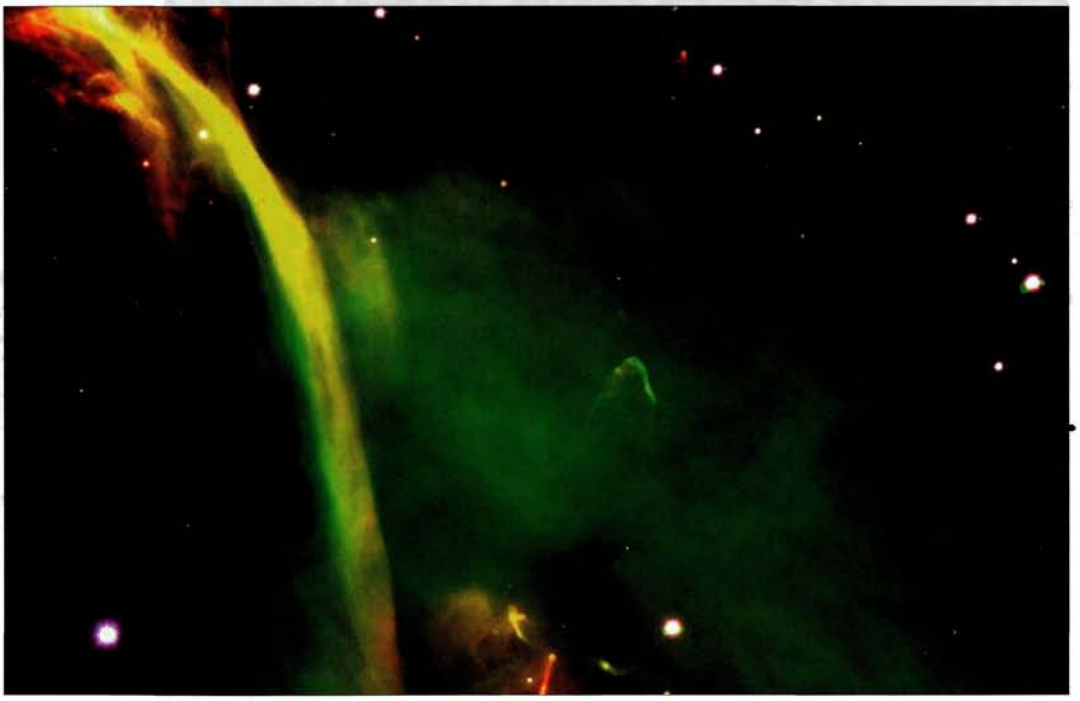
In his 1936 book *The Realm of the Nebulae*, Hubble said, "They are scattered throughout space as far as telescopes can penetrate. We see a few that are large and bright. These are the nearer nebulae. Then we find them smaller and fainter, in constantly increasing numbers, and we know we are reaching out into space... until, with the faintest nebulae that can be detected with the largest telescope, we arrive at the frontiers of the known universe. This last horizon... is a vast sphere, perhaps a thousand million light-years in diameter."

Until Hubble applied his eye to the new 100-inch telescope at Mount Wilson in 1919, we thought that the universe consisted only of the Milky Way – our galaxy. Although a few bold astronomers talked of remote "island universes", the nebulae were merely clouds on the astronomical horizon. By harnessing the power of the world's largest telescope, Hubble saw a star in the Andromeda nebula that was about a million light-years away, more than ten times the diameter of the Milky Way. A curtain had been lifted on a much larger universe. Nebulae – now known as galaxies – are clouds of distant stars beyond the Milky Way.

Having drawn back the curtain, Hubble's work went on to show that this larger universe is continually expanding. In what we now call the "Hubble flow", distant galaxies appear to be rushing away from us. Hubble's law states that the further away the galaxy, the faster it appears to recede. The constant of proportionality – the Hubble constant – fixes the age of the universe. Back in Hubble's day astronomers did not receive Nobel prizes.

The thick blanket of the Earth's atmosphere totally blocks the light from the faintest and furthest stars. In 1990, the first major astronomical satellite to be placed in orbit above this star-blocking layer was aptly named the Hubble Space Telescope. Initially hampered by faulty optics, this new eye on the universe has gone on to reveal images of unparalleled beauty and significance and it has revolutionized optical astronomy in a way that is worthy of its namesake. The Hubble Space Telescope has shown that the universe is about 12 thousand million light-years across. This is not that much bigger than Hubble had described in 1936, however, is far more spectacular than he could have imagined from the images obtained from the Mount Wilson telescope.

Picture of the month

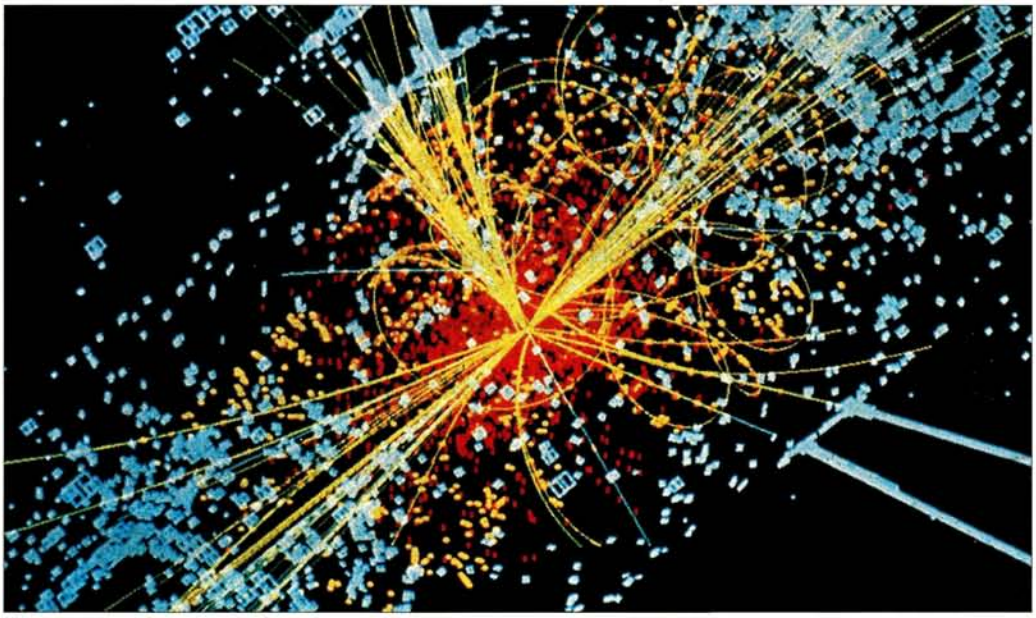


This impressive millennium fireworks display was captured by the Very Large Telescope in November 1999. It is a Herbig–Haro object: a protostar with two jets shooting out gas into the surrounding interstellar medium at velocities of up to 250 km/s. The irregular appearance of the jets suggests that there are periodic outbursts where large chunks of material fall onto the protostar from a surrounding disk.

The Very Large Telescopes are run by the European Southern Observatories at the Paranal Observatory, based in Chile.

The electron century

In 1900 nobody could have even dreamed of the way in which science would evolve over the 100 years that followed. Theorist and science writer *Frank Close* reviews the past century and looks forward to the next.



Going back to the beginning of time – a simulation of physics at CERN's LHC collider.

If the structure of DNA and the nature of life qualify as the most profound discoveries of the 20th century, what will be those of the next? Such are the questions beloved by pundits as the calendar turns in this special year. We know that these questions are unanswerable. However, to appreciate quite how unpredictable the future is, it may be worth imagining that we were being asked such a question 100 years ago.

In the late 19th century some scientists believed that the basic principles of physics had been discovered and only the details remained to be worked through. An outstanding problem – the apparently perverse behaviour of the spectrum of radiation emitted by hot bodies – was solved 100 years ago with the invention of quantum theory. Our view of the world was utterly changed. Can we draw any parallels with the present? Perhaps the writer of a similar article 100 years from now will give the answer.

As the 19th century drew to its end, three great discoveries defined the 20th century and illuminated the nascent science that we now call particle physics. In less than three years, between late 1895 and 1897, Röntgen discovered X-rays, Becquerel found radioactivity and Thomson isolated the electron. For me, the discovery of X-rays and the electron typify the one hundred year leap from then to where we are today.

Ask a member of the general public about X-rays and they will think of shadows of broken bones: ask a scientist, and they will point to X-ray crystallography. As Röntgen prepared to receive the first Nobel prize in physics in 1901, no-one foresaw Bragg's work in X-ray crystallography, let alone that, half a century later, Crick and Watson would use this tool to resolve the structure of DNA. What many would regard as the most profound discovery in biology is, by many readers of *CERN Courier*, recognized as applied physics.

Genetics in the 21st century is likely to be as revolutionary as electronics has been in the 20th century. It is electronics, and all else that has flowed from the discovery of the electron, that touches most people in our field today.

Nature's fundamental pieces

J J Thomson marched into the Royal Institution on the 30 April 1897 and announced his discovery of the electron, a fundamental constituent of all atomic elements. After Thomson duly won a Nobel prize (1906), for showing that the electron is a particle, his son, G P Thomson subsequently won the prize in 1937, for showing that the electron is a wave. That, however, is another story.

Jump forward in time to the late 1960s, and beams of electrons, accelerated over a distance of 3 km, were fired into targets of protons and neutrons at SLAC. These experiments showed that the cosmic onion does not end with the atomic nucleus. The ultimate nuclear constituents (for the 20th century at least) are the quarks.

The century had begun with the belief that atomic elements were nature's fundamental pieces. It ended with the discovery of electrons and quarks. The electron is but one member of a family of six, known as leptons; there are six varieties of quark as well. No-one at the end of the 20th century knows for certain why six of one and half a dozen of the other is nature's scheme, but the answer will probably be known by the end of the 21st century.

A century of electrons: Frank Close with a replica of Thomson's 1897 apparatus, used in the discovery of the electron. He stands against the impressive backdrop of today's electron physics: the L3 experiment at CERN's LEP electron–positron collider.

In 1897 J J Thomson, alone in his Cambridge laboratory, discovered the electron by means of a small glass tube, which was less than 27 cm long. By 1997 electrons were speeding around CERN's LEP ring (a journey of 27 km) to meet their nemesis, positrons, which were unknown to Thomson but, mysteriously, known to mathematics before their discovery by humans.

Antimatter

It was with the discovery of the positron, and the anti-world, that the electron revealed the deep power of mathematics. In 1928, Paul Dirac took the two great theories of the 20th century – relativity and quantum mechanics – and applied them to the electron. The mathematics simply would not balance.

The greatest implication of Dirac's equation (as it will be known for all time) was that it opened a window to an entirely new world. His equation had two solutions, one being the familiar negatively charged electron, while the other implied the existence of a bizarre mirror-image version, identical in all respects except that the sign of its electrical charge is positive rather than negative. This anti-electron, more succinctly known as the positron (positive electron), is an example of antimatter.

Dirac's prediction of the positron seemed to many at the time to be science fiction. Up to that point the only particles known or predicted, existed as constituents of the matter around us, namely electrons in the periphery of atoms and protons and neutrons, which comprise the atomic nucleus. The positron, which had emerged from his equations like a rabbit from a magician's cloak, had no place at all. However, the questions ended in 1932 when the positron was found in cosmic radiation, with a positive charge and an identical mass to its electron sibling.

Dirac's theory, that for every particle there exists an antiparticle counterpart, is now recognized to be an essential truth: a glimpse of a profound symmetry in the fundamental tapestry of the universe. And here we have another of the great puzzles that are with us at the turn of the century. If, as experiment suggests, the Big Bang created particles of matter and antimatter in equal amounts, and they annihilate upon meeting, how is it that there is any material universe remaining? Where has all the antimatter gone? Crick and Watson revealed the nature of life as we now know it, but how did the universe manage to survive long enough, made of matter, to have provided the necessary circumstances for life to emerge?

While the annihilation of matter and antimatter is a puzzle for understanding our existence, it is, nonetheless, the annihilation of the simplest pieces, electrons and positrons, that has been the key to LEP. Accelerated around the 27 km ring, the collisions of positrons electrons and their mutual annihilations produce, in a small volume, for a brief moment, energies that are far greater than are found in any star and akin to those prevalent in the universe when it was less than a billionth of a second old. Particles of matter and antimatter pour out from these "mini-bangs", replaying the basic processes that occurred at the Big Bang. To capture the fleeing particles, which are travelling close to the speed of light, huge detectors are required.

Recreating the Big Bang

It is when you stand alongside one of these behemoths and compare it with the little tube that Thomson used, that you see 100 years of science and technology in metaphor. It was relatively easy for Thomson to isolate the electron because the universe had already done much of the preparatory work. Over the previous 10 billion years, electrons had been created, trapped in atomic elements and stored there in the solid matter of the new-born Earth until we arrived. They were ubiquitous in 1897 Cambridge. A small tube and genius, then asset-stripped the atoms aided by relatively primitive tools (which used electric and magnetic forces to move the electrons around) to reveal their existence and their properties.

Today, by contrast, we are looking at exotic forms of matter: heavy quarks, supersymmetric particles and the Higgs boson, all of which, theorists believe, existed briefly in the afterglow of Creation but now are no longer here. To find them, we have to restore the conditions of the new-born universe.

There are no mass produced test tubes that can make an experiment of such magnitude. There is no customized "Big Bang apparatus" for sale in the scientific catalogues so that we can experience the first moments of the universe in our living rooms. This is not mere hype. To journey to the start of time you have to build all the pieces for yourself, by transforming the earth, rocks and gases of our planet into tools that extend our senses. That is how it has been at LEP, and how it will be for CERN's LHC.

Sand provides the raw material for the nervous system of computer chips, which will orchestrate the enterprise. Hydrogen gas, from which protons can be stripped, will supply the beams for the LHC. Ores dug from the ground, melted, transformed and turned into magnets will be capable of guiding beams of protons at 99.9999% of the speed of light. A myriad of other tools, which are the result of centuries of invention, are being assembled. When all is done, these tools of the millennium will reveal the universe, not as it is now, but as it was at Creation. This is a far cry from Thomson's day.

No-one at the end of the 20th century knows for certain why six of one and half a dozen of the other is nature's scheme, but the answer will probably be known by the end of the 21st century

The results will be gathered, not by a single person as in Thomson's case, but by a team of thousands, working on several continents, communicating via the internet, which is powered by electrons. Not only science and technology, but

Paul Dirac – his prediction of antimatter from basic symmetry principles revolutionized our view of the universe.

even the sociology of research has evolved over these past one hundred years.

Our story began with the first Nobel prizes. Becquerel's discovery of radioactivity (1903) is where I shall complete the tale. The agents of the weak force, the cookers of the elements, were discovered at CERN in the 1980s. At LEP in the 1990s, millions of examples of these Z and W particles have been made and measured to astonishing precision. As the mathematics of Dirac revealed the existence of the positron, so has 't Hooft and Veltman's theory of the weak force enabled quantitative descriptions of the measurements at LEP. LEP had insufficient energy to materialize a top quark. Nonetheless, courtesy of 't Hooft-Veltman mathematics, its properties can be deduced in advance of its triumphant discovery at Fermilab. Now, on the threshold of the 21st century, we are in an analogous situation with the Higgs boson. The precision of LEP and the mathematics give us foresight of another research prize.

So the theory of 't Hooft and Veltman, earning the final physics Nobel prize of the 20th century, may be giving us a glimpse of one of the first great breakthroughs of the 21st century. Will the discovery of the Higgs boson, and its associated phenomena, turn out precisely as the theorists expect? Or will there be some unexpected twists: the first hints of profound truths that are at present beyond our ken? Theorists throughout history have created beautiful descriptions of the universe, often with astonishing implications. Ultimately it is experiment that decides by distinguishing fact from fancy.

What will *CERN Courier* be celebrating in its issue 100 years hence? Röntgen, Becquerel and Thomson could not have imagined DNA, Zs and Ws, electroweak theory, the World Wide Web, nor LEP and LHC (machines that take us to the start of time). If there is any message from this that we can be sure is a guide for the coming century, it is this: prepare for surprises.

Frank Close, *Rutherford Appleton Laboratory. Distinguished theorist and science writer Frank Close recently spent some time at CERN promoting particle physics "outreach". His latest popular book –* Lucifer's Legacy: The Meaning of Asymmetry *– is published in March by Oxford University Press. Frank Close received the OBE in the UK News Year's Honours List, for services to research and the public understanding of science.*

Caught in the QuarkNet

The QuarkNet teachers standing on the steps of Wilson Hall at Fermilab. The teachers travelled to the laboratory for a one-week institute.

Large international collaborations formed around experiments at CERN's future LHC collider include outreach and education as part of their mission. Among the recipients of LHC data will be eager high school students.

The year is 2005, CERN's LHC collider is running, and discoveries are on the horizon. Pete Bruecken and Jeff Dilks, high school teachers from Iowa, are telling students about their experiences of building detectors and carrying out beam tests at CERN. The students are even more interested when they learn that they will be analysing some new data from the LHC experiments that their teachers had a part in building.

As part of the QuarkNet programme, hundreds of teachers with similar experiences will have their students doing the first analyses of LHC datasets. These will be small datasets, filtered to be useful to students. This is an exciting opportunity because no-one else has analysed these data yet. There is always the possibility that the students will be part of an important discovery; the odds may be small but the potential is enormous. Furthermore, they will be communicating with students in other classrooms around the world, comparing notes about their findings and viewing the action at CERN, live via the Web. They will also be learning basic physics. Ultimately QuarkNet will reach 720 teachers and over 100 000 students.

Teachers Bruecken and Dilks were among 24 teachers who joined QuarkNet in 1999. After a week at Fermilab in June, learning about particle physics, they participated in seven weeks of research, which was funded by QuarkNet. Together with Prof. John Hauptman at Iowa State University, Bruecken and Dilts constructed an incredibly fast detector, which, essentially, could collect energy and spatial information at the speed of light and then empty the calorimeter of signal in a nanosecond. Hauptman said, "The amazing thing about this module is that it was largely built on zero funds...and QuarkNet was essential for its success."

The local newspaper reported, "Just imagine it: high school students watching cutting-edge particle physics experiments, analysing data and collaborating with scientists. How's that for science homework?" QuarkNet plans to fly a number of students to CERN for the first physics runs so that they can report back on the events.

Introductory physics is present in much of high-energy physics. For students, concepts such as conservation of momentum and energy are ubiquitous. Particle physicists use these concepts as they study the fundamentals of nature. Why not let students explore classical physics through the lens of particle physics? Wouldn't this bring much more interest to their studies?

QuarkNet seeks to create such a lens. The project's main goal is to involve high school students and teachers in the ATLAS and CMS experiments as well as in Run 2 of the CDF and DØ experiments at Fermilab. A year ago, Keith Baker (Hampton University), Marge Bardeen (Fermilab), Michael Barnett (Lawrence Berkeley National Laboratory) and Randy Ruchti (University of Notre Dame) organized the project. To carry out the programme, QuarkNet has hired four teachers/educators to run the summer activities, assist the centres in the development of their programmes and help monitor the success of the project. QuarkNet is supported by the US National Science Foundation, the US Department of Energy and the participating universities and laboratories. While QuarkNet began in the US, there have been expressions of strong interest from CERN and from other European countries.

Teachers aboard experiments

QuarkNet invites teachers to join groups of particle physics experimenters (their mentors) for an eight-week summer research assignment. This immersion in research gives the teachers time to become familiar with the experiments and provides them with an overview of particle physics. Physicists, from a university or laboratory, recruit the teachers from nearby schools. The institution's needs and the

Kelly Clark of California (left) and Matthew Hitchings of Indiana work to calculate the top quark mass from data collected at the Fermilab DØ experiment.

teacher's personal skills determine the research assignment. QuarkNet provides a stipend (a salary) for these teachers and, for those who leave home for extended periods of time, living expenses.

During the academic year, teachers invite their students into the project by integrating some aspect of their summer work into their physics curriculum. This does not mean that students must study the Standard Model. Students could study the conservation of momentum via analysis of data from a collider event. They could also discover the vital role of computers in modern science by examining thousands of events: a task that is impossible to do by hand. They may consider protons moving through the LHC as they investigate the force that magnetic fields exert upon moving, charged particles. Each of these, and other curriculum ideas, will be developed by the teachers and QuarkNet staff as the programme matures.

During the school year, after their summer research assignment, QuarkNet teachers invite 10 other teachers from their area into the project. These associate teachers participate in a three-week institute, which is planned and hosted by the QuarkNet teachers and their local physicist mentors. Here they explore particle physics research and the classroom application of classical physics topics to the world of particle physics.

QuarkNet centres

This group of 12 teachers and at least two physicist mentors comprise a QuarkNet centre. During the summer of 1999, QuarkNet established 12 centres at universities and laboratories from California to Massachusetts, and in many places in between.

Teachers participated in a one-week orientation workshop at Fermilab in preparation for the summer research assignments. During the week, the teachers attended talks on everything from accelerators to cosmology, and enjoyed tours of CDF and DØ along with explanations of upgrades for Tevatron Run II. They worked with hand-held cosmic-ray detectors brought from Notre Dame, and engaged in computer activities using Fermilab Run I data, computer simulations and material from the Web. The workshop featured time for teachers to pose questions to principal investigators Randy Ruchti and Michael Barnett and to synthesize a deeper understanding of physical phenomena. In addition, teachers discussed the classroom implementation of their research work on one of the four major collider experiments.

During their summer research the teachers took on varied and challenging projects. Larry Wray and Rosemary Bradley of Langston University in Oklahoma, under mentor Tim McMahon, worked on a project related to the "powers of 10". Ulrich Heintz at Boston University involved Rick Dower in using LabView to write interface and data-collection software for measuring the characteristics of a silicon tracker wafer to be used in DØ. He did this and then repeated his measurements in a neutron beam, generated by the low-energy (approximately 4 MeV) proton accelerator at the University of Massachusetts in Lowell, to test the effect of radiation on the wafer.

The CMS project

Much of the work for QuarkNet 1999 involved the CMS project at CERN. Kevin McFarland, of the University of Rochester, had Susen Clark and Paul Pavone test the long-term stability of scintillating crystals (to be used as reference standards for CMS). These two teachers also built a "muon telescope" cosmic-ray detector for classroom demonstrations. The work of the Iowa centre in CMS was explained well by John Hauptman of Iowa State University: "Nural Akchurin in Iowa City and I, in Ames, have a lot of good work to do, and Jeff [Dilks] and Peter [Bruecken] were right in the middle of it. Peter analysed radiation damage data, designed and built mechanical mounts for a new calorimeter, and next week he will start taking data in the LEP injector beam at CERN. Jeff was responsible for designing and building a new calorimeter in Ames, testing it at CERN this summer, and analysing data from it."

At Notre Dame, LeRoy Castle and Dale Wiand worked with Randy Ruchti to design Optical Decoder Units (ODUs) for CMS. Both teachers became involved in negotiation with other CMS production sites to find satisfactory solutions to questions on how to best place the ODUs in the detector structure.

How does this experience influence teaching and learning? Students in Ames, Iowa were performing an experiment in their physics class. They had divided up the parameter space of a dataset so that they could save class time, but still cover the necessary measurement parameters. Jeff Dilks had his students share their measurements by writing their data on the white board. A plot of the measurements showed absolutely nothing. Over the weekend Dilks considered his options. He resolved to use this opportunity to show his students that science does not always yield what is expected.

On the Monday he started class by informing the students that their work truly models what goes on in the "real world" of science. The results that they had shared on Friday were nonsense and indicated that new and more precise measurements were required. The class discussed what changes could be made, assigned parameters and performed their measurements once again. This time a quick plot of those measurements showed some interesting results. The lesson was learned; science is an involved process that has starts and stops, and it often yields results that beg more questions.

Marjorie G Bardeen, *Fermilab*, **R Michael Barnett**, *Lawrence Berkeley National Laboratory*, **Kenneth W Cecire**, *Hampton University*, **Thomas A Jordan**, *Fermilab*.

Lessons learnt from the heavy tau lepton

A quarter of a century ago, Martin Perl discovered a new particle: the tau lepton. This weakly interacting particle is so heavy that it can decay into strongly interacting particles and provide very special physics conditions. It is described here by long-time tau specialist *Antonio Pich*.

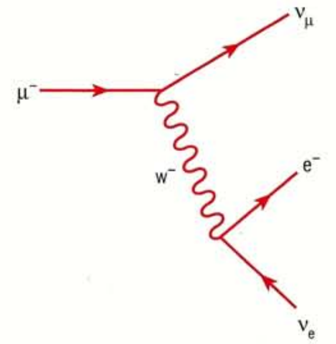


Fig. 1: The decay of the muon.

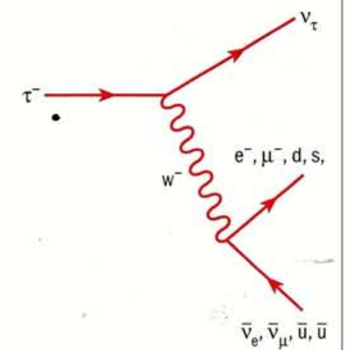


Fig. 2: The decay of the tau.

In 1975 Martin Perl found a new exotic lepton in electron–positron collisions at the SPEAR ring at SLAC, Stanford. The electrically charged tau turned out to be a heavy brother of the muon and the electron. The tau is 170 times as heavy as the muon and 3500 times as heavy as the electron, and has roughly the properties to be expected for such a particle. Owing to its very short lifetime (2.9×10^{-12} s) and the presence of unseen particles (neutrinos) in its decays, the detailed investigation of the tau has been an experimental challenge ever since its discovery.

In the past few years, the four experiments at CERN's LEP electron–positron collider have each produced a very clean sample of tau pairs (some 0.2 million) with low backgrounds. The very good particle identification of the LEP detectors and the use of modern silicon microvertex technologies have created a wonderful environment in which to investigate the tau.

At the same time, the CLEO II detector at Cornell's CESR electron–positron ring has collected more than 10 million tau pairs, making it possible to study the rare tau decays. As a result, tau physics has reached a level where precise tests can be performed.

Lepton universality

The existence of different families is one of the most important open questions in particle physics. The basic matter structure of the Standard Electroweak Theory with the up and down quarks (the electron and the electron neutrino) appears to have two heavier replicas with identical interactions: the charm and strange quarks with the muon and the muon neutrino; and the top and bottom quarks with the tau lepton and its neutrino.

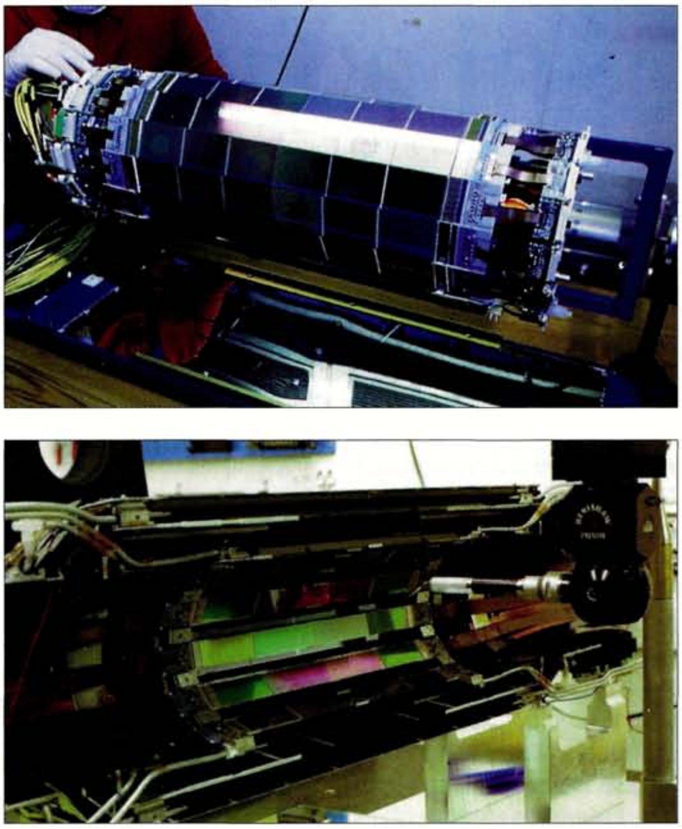
We do not understand what causes this triplicity, nor do we know what generates the different masses. However, we expect the heavier family to be more sensitive to whatever dynamics are related to the generation of mass. This makes the tau an ideal particle to use to investigate these gaps in our understanding. Is the tau really identical to the electron and the muon?

In the Standard Model, the tau decays in the same way as the muon: through emission of a W boson (shown in figures 1 and 2). However, the tau's heaviness makes several extra decay modes kinematically accessible. The tau can either decay leptonically into its lighter electron and muon brothers, accompanied by appropriate neutrinos, or it can decay into quarks. Because quarks can appear in three different "colours", the probability of a hadronic decay is three times greater than leptonic decay. The detailed analysis of the tau decays shows an excellent agreement between the measured branching fractions and the Standard Model predictions.

Comparing the different tau decays with the weak decays of the muon and the charged pion, we can test whether the different leptons couple to the W with the same strength. Within the present (and impressive) experimental accuracy of 0.2%, the electron, the muon and the tau appear to have exactly the same W interactions. The same observation can be made directly from the analysis of W decays at LEP II and the proton–antiproton colliders, although, the present experimental sensitivity is not as good in this case.

The leptonic couplings to the neutral Z particle have been accurately measured at LEP and SLC (SLAC, Stanford), through the study of lepton–antilepton production in electron–positron collisions. Again, the experimental data show that the three known leptons have identical interactions with the Z boson, at the present level of experimental sensitivity.

Because the tau decays within the detector – a tau produced at



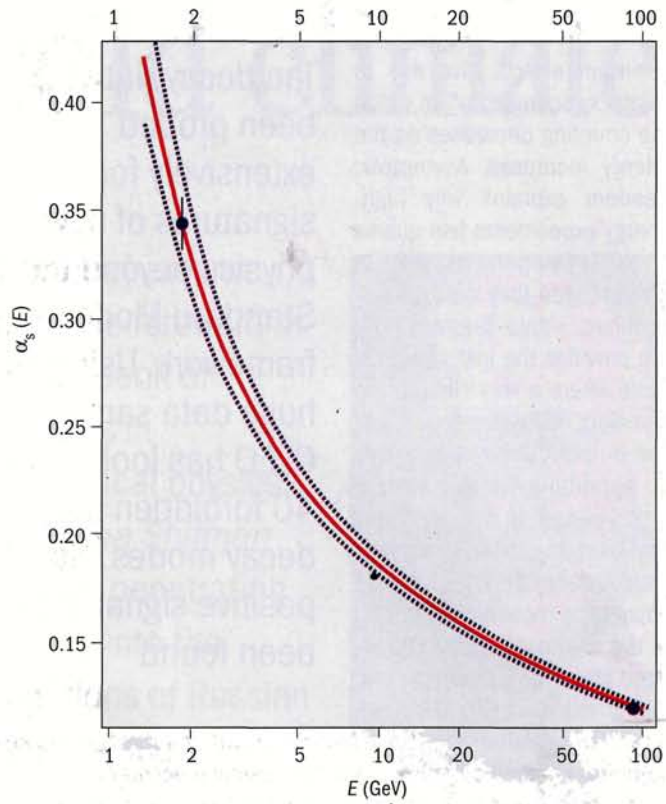
In the experiments at CERN's LEP electron–positron collider, modern silicon microvertex detectors, such as those used at ALEPH (top) and DELPHI (bottom), monitor the production of short-lived particles close to the beam pipe. Such detectors have made a major contribution to the physics of the tau lepton.

LEP travels 2.2 mm before decaying (a tau produced at CLEO travels 0.24 mm) – one can measure its spin orientation (polarization) from the distribution of the final decay products. The present data show that only left-handed taus decay. This is in good agreement with the Standard Model. An upper limit of 3% has been set on the probability of a (disallowed) decay from a right-handed tau.

A lepton with strong interactions

Leptons do not couple to the gluonic carriers of the strong interaction. However, an electroweak boson emitted by a lepton can produce quarks, which are strong interacting particles. Electrons and muons only feel this effect indirectly, through tiny quantum corrections. The heavier tau can decay hadronically, which makes the tau a unique tool for studying strong interaction dynamics in a clean way.

Between 1988 and 1992, a series of papers by Eric Braaten, Stephan Narison and the author showed that the hadronic decay of the tau can be theoretically predicted from first principles, as a function of the quantum chromodynamics (QCD) coupling α_s. Summing over all possible hadrons produced in the decay, avoids the problems related to the messy rearrangement of quarks into hadrons. The decay probability can then be computed at a more fundamental level in terms of quarks and gluons. The result is known up to the third order in a perturbative expansion in powers of α_s. Comparison of the theoretical predictions with the experimental measurements gives a precise determination of α_s at the tau mass region.



The strong coupling α_s, measured in tau decays at the energy corresponding to the tau mass (1.777 GeV), is nearly three times as great as that extracted from Z decays (91.187 GeV). The curves show the theoretically predicted energy dependence, using the value measured at the tau mass as input. The marked decrease of the coupling strength with increasing energy is a dramatic illustration of the "asymptotic freedom" of quarks – the higher the energy, the less force the quarks feel.

An extensive experimental effort was initiated in 1992 by an ALEPH group at LEP, which was led by Michel Davier at Orsay. This was soon followed by similar work from other experiments. The four LEP collaborations and CLEO have all performed their own measurements of α_s. Moreover, ALEPH and OPAL, through a careful analysis of the distribution of the final decay hadrons, have been able to measure, separately, the tiny non-perturbative corrections and obtain values in good agreement with theoretical expectations.

The resulting determination, $\alpha_s(m_\tau) = 0.345 \pm 0.020$, shows that the coupling, measured at the tau mass scale, is very different from the values obtained at higher energies. The value extracted from the hadronic decays of the Z boson, 0.119 ± 0.003, differs from the tau decay measurement by eleven standard deviations.

The comparison of these two measurements is of fundamental importance within our present understanding of quantum field theory. Quantum corrections, mainly generated through the virtual production of particle–antiparticle pairs, modify the values of the bare couplings in a way that depends on the energy scale. This is a very important effect, which, in the context of non-abelian gauge field theories (like the electroweak theory or QCD), is deeply related to the 1999 Nobel prizewinning work by 't Hooft and Veltman.

Gross, Politzer and Wilczek showed that in non-abelian theories quantum effects give rise to "asymptotic freedom", in which the coupling decreases as the energy increases. Asymptotic freedom explains why high-energy experiments feel quarks as nearly free particles, while at low energies they are strongly confined within hadrons. The tau provides the lowest-energy scale where a very clean measurement of the strong coupling can be performed, which gives an opportunity to test asymptotic freedom in a quantitative way. Using the theoretically predicted dependence of α_s on energy, the measurement of α_s at the tau mass can be translated into a prediction of α_s at the Z mass scale: 0.1208 ± 0.0025. This value is in close agreement with the direct measurement from hadronic Z decays, and has a similar accuracy.

Tau decay data has been probed extensively for signatures of new physics beyond the Standard Model framework. Using its huge data sample, CLEO has looked for 40 forbidden tau decay modes. No positive signal has been found

Tau decays, which result in an even number of pions, have also been used to measure the hadronic vacuum polarization effects that are associated with the photon. It is possible, therefore, to estimate how the electromagnetic fine structure constant is modified at LEP energies. The uncertainty of this parameter is one of the main limitations on the extraction of the Higgs mass from LEP/SLD data. From the ALEPH data, the Orsay group is able to reduce the error of the fitted log(M_H) value by 30%.

The same tau data can pin down the hadronic contribution to the anomalous magnetic moment of the muon. Recent ALEPH and CLEO analyses have improved the theoretical prediction by setting a reference value to be compared with the forthcoming measurement of the E821 experiment, which is running at Brookhaven.

Weighing the strange quark

About 3% of tau decays produce a strange quark. The four LEP experiments have investigated these decays. In particular, ALEPH has analysed kaon production in tau decay and the associated distribution of the final hadrons. The difference between the dominant decay producing a down quark, and that producing a strange quark is sensitive to the mass difference between the down and strange quarks. Because the former is much lighter, the ALEPH measurement can be translated into a good determination of the strange quark mass at the tau mass scale: 119 ± 24 MeV.

Quark masses are also dependent on energy; quarks weigh less at higher energies (and weigh more at lower energies). At 1 GeV, for instance, the strange quark mass becomes 164 ± 33 MeV. These measurements have important implications for the theoretical prediction of CP violation in kaon physics. Future tau analyses at the BaBar and BELLE detectors should provide a more accurate determination of the strange quark mass.

Tau decay data has been probed extensively for signatures of new physics beyond the Standard Model framework. Using its huge data sample, CLEO has looked for 40 forbidden tau decay modes. No positive signal has been found, which puts stringent upper limits (of a few parts per million) on the probability of many decays into final states without neutrinos. Anomalous electric and magnetic electroweak dipole couplings of the tau and possible CP-violating decay amplitudes have also been searched for, with negative results. Within the present experimental accuracy, the tau appears to be a standard lepton.

Tau decays are accompanied by neutrinos, so kinematical analysis of hadronic tau decays gives an upper limit on the tau neutrino mass: 18.2 MeV. However, nobody has been able to detect a tau neutrino so far. The DONUT experiment at Fermilab is expected soon to provide the first experimental evidence of the tau neutrino through the detection of its interaction with a nucleon via the produced tau.

This is an important goal in view of the recent neutrino results, which suggest tau-muon neutrino oscillations, and neutrino mass squared differences of around 0.003 eV^2. These results could be checked by the new-generation long baseline neutrino experiments.

In 25 years we have seen remarkable progress in our knowledge of the tau and its neutrino. However, there is still much room for improvement, and, no doubt, the tau will continue to play an important role in the continuing search for new physics.

Antonio Pich, *IFIC, Valencia.*

Physics in a cold climate

This brief excerpt from the foreword of a new book of lectures in theoretical physics by *Misha Shifman* gives a penetrating insight into the traditions of Russian physics and the life of a theoretical physicist under the Soviet regime.

Misha Shifman – physics with meaning.

For about twenty years, I was a member of the theory group at the Institute of Theoretical and Experimental Physics, Moscow (ITEP). The ITEP was more than an institute, it was our refuge where the insanity of the surrounding reality was, if not eliminated, reduced to a bearable level.

Doing physics there was something which gave a meaning to our lives, making it interesting and even happy. Our theory group was like a large family. As in any big family, of course, this did not mean that everybody loved everybody else, but we knew that we had to stay together and rely on each other, no matter what, in order to survive and to be able to continue doing physics. This was considered by our teachers to be the most important thing, and this message was always being conveyed to young people joining the group. We had a wonderful feeling of stability.

Rules of survival

The rules of survival were quite strict. First, seminars – the famous Russian-style seminars. The primary goal of the speaker was to explain the results, not merely to advertise them. And if the results were nontrivial, or questionable, or just unclear, this would surface in the course of the seminar, and the standard two hours were not enough. Then the seminar could last for three or even four hours, until either everything was clear or complete exhaustion, whichever came first. I remember one seminar in Leningrad in 1979, when Gribov was still there, which started at eleven in the morning. A lunch break was announced from two to three, and the seminar continued until seven in the evening.

In ITEP we had three, sometimes more, theoretical seminars a week. The leaders and the secretaries of the seminars were supposed to find exciting topics, either by recruiting ITEP or other "domestic" authors, or, often, by picking up a paper or a preprint from elsewhere and asking somebody to report the work to the general audience. This was considered a moral obligation.

The tradition dated back to when Pomeranchuk was the head of the group, and its isolation had been even more severe. In those days there were no preprints, and getting fresh issues of *Physical Review* or *Nuclear Physics* was not taken for granted. When I, as a student, joined the group a few years after Pomeranchuk died, I was taken to the Pomeranchuk memorial library, his former office, where a collection of his books and journals was kept.

The few months following the discovery of J/psi were the star days of quantum chromodynamics, and probably the highest emotional peak of the ITEP theory group. Never were the mysteries of physics taken so close to our hearts

Every paper in every issue was marked with a minus or a plus sign, by "Chuk's" hand. If there was a plus, there would also be the name of a student who had been asked to give a talk for everyone's benefit. Before the scheduled day of the seminar, Pomeranchuk would summon the speaker to his office to assess whether the subject had been worked out sufficiently and the speaker was "ripe enough" to face the audience and their bloodthirsty questions.

Scientific reports of the few chosen to travel abroad were an unquestionable element of the seminar routine. Attendance at an international conference by no means was considered as a personal matter. Rather, these lucky guys were believed to be our ambassadors, and were supposed to represent the whole group. This meant that at a conference, you could be asked to present important results of other members of the group. Moreover, you were supposed to attend as many talks as possible, including those which did not belong to your field, make extensive notes, and, on your return, deliver an exhaustive report of all new developments, interesting questions raised, rumours, etc.

The rumours, as well as nonscientific impressions, were like an exotic dessert. I remember that after a visit to the Netherlands, one colleague mentioned that he was very surprised to see people on the streets smiling. He could not understand why. Then he finally figured it out: "because they were not concerned with building communism." This remark almost immediately became known, and cost a few years of "inexplicable allergy" to any western exposure.

Moscow – the old and the new. (G Fraser.)

Arts rather than science – Moscow's Arbat district.

"Coffee seminars" typically lasted until nine, sometimes much later, for instance, in the stormy days of the 1974 "November revolution". The few months following the discovery of J/psi were the star days of quantum chromodynamics, and probably the highest emotional peak of the ITEP theory group. Never were the mysteries of physics taken so close to our hearts as then. A spontaneously arranged team of enthusiasts worked practically nonstop. A limit to our discussions was set only by the Moscow metro – those who needed to catch the last train had to leave before 1 a.m. Living in the capital of that empire had its advantages. All intellectual forces tended to cluster in the capital. So, we had a very dynamic group where virtually every direction was represented by several theorists, experts in the given field. If you needed to learn something new, there was an easy way to do it. It was much faster and more efficient than reading through journals or textbooks. You just needed to talk to the right person.

Educating others, sharing your knowledge and expertise with everybody who might be interested, was another rule of survival. Different discussion groups and large collaborations were emerging all the time, creating a strong and positive coherent effect. The brain-storming sessions used to produce, among other results, a lot of noise. So, once you were inside the old mansion occupied by the theorists, it was very easy to figure out which task force was where – you just had to step out into the corridor and listen.

Fashionable physics

There is strong pressure in the world community to stay in the mainstream: to work only on fashionable directions and problems under investigation in dozens of other laboratories. This pressure is especially damaging for young people who have little alternative. Of course, a certain amount of cohesion is needed, but the scale of the phenomenon we are witnessing is unhealthy.

The isolation of the ITEP theory group had a positive side effect. Everybody, including the youngest members, could afford to work on unfashionable problems without publishing a single line for a year or two. On the other hand, it was considered indecent to publish results of dubious novelty, incomplete results, or just papers with too many words per given number of formulae.

Dense papers were the norm. This style, probably perceived by readers as a chain of riddles, is partly explained by tradition, presumably dating back to the Landau times. It was also due to Soviet conditions, where everything was regulated, including the maximal number of pages any given paper could have.

M A Shifman, *Theoretical Physics Institute, University of Minnesota, USA.*

ITEP Lectures in Particle Physics and Field Theory

(2 volumes) by M A Shifman, World Scientific, ISBN 981022 639 X, (hbk £77, 875 pages).

Topics include: heavy quarks in quantum chromodynamics; snapshots of hadrons, or, the story of how the vacuum medium determines the properties of the classical mesons which are produced, live and die in the QCD vacuum; ABC of instantons; beginning supersymmetry; nonperturbative dynamics in supersymmetric gauge theories; instantons versus supersymmetry; two-dimensional conformal field theory; and new findings in quantum mechanics. The book is aimed at beginners.

Participants at the International Conference on Elastic and Diffractive Scattering (EDS 99) held at Protvino near Moscow.

Deciphering the enigma of elastic scattering

Understanding most of what happens in high-energy particle scattering should be easy, but it isn't. A recent international conference underlined a traditional dilemma.

While we claim to understand more and more about how elementary particles interact, modern particle physics is increasingly being characterized by bigger and bigger experiments, which are searching for smaller and smaller effects. Most of what happens in high-energy scattering processes is put to one side and is deemed unfashionable. However, what is thought to be unfashionable by some is not necessarily uninteresting to everyone.

The largest single such process is elastic scattering – where the incoming particles bounce off one another. However, even this straightforward process is difficult to understand quantitatively. Central to this physics is the concept of the pomeron mechanism. What exactly is the pomeron? Our current understanding of these processes was summarized in an article by Sandy Donnachie in the April 1999 issue of *CERN Courier* (p29).

Every two years, dedicated enthusiasts of this physics meet for the International Conference on Elastic and Diffractive Scattering. Initiated in 1985 by B Nicolescu and J Tran Thanh Van, the first meeting was held in the Chateau de Blois, France – hence the series has earned the name Blois Workshops. The latest Blois meeting was held at Protvino, near Moscow, this summer.

Fundamental dilemma

There appears to be a dilemma that involves our understanding of fundamental processes. The general features of the bulk of high-energy scattering processes are difficult to reconcile with quantum chromodynamics (QCD) – the field theory of quarks and gluons.

Reports at major physics conferences around the world say that quantum chromodynamics "works perfectly well at high energies". This is true. However, it has to be qualified by insisting on high-momentum transfers.

On the other hand, diffractive and elastic scattering are characterized by small momentum transfers where traditional QCD approaches are difficult. Nevertheless, theoreticians have tried bravely to understand the pomeron through QCD. After lengthy and cumbersome calculations, Russian theorist L Lipatov and his collaborators managed to obtain some insight into the "hard" pomeron.

Elastic and diffractive discussions – left, V Petrov (Protvino) with E Predazzi (Torino).

Fortunately this arrived in time for the first results from the HERA electron–proton collider at DESY. The results indicated that, reaction rates for processes that involved the absorption of a virtual photon by a proton, grow in energy much faster than, say, proton–proton reaction rates.

Many physicists believe that the hard pomeron is responsible for this rapid growth. With the situation becoming more complicated with more detailed QCD analysis, the elastic-diffractive community came to the Blois workshop in Protvino.

Results from H1 and ZEUS

Centre stage at the workshop were recent results obtained from the two major collaborations at HERA: H1 and ZEUS. Complemented by hard-diffraction studies at Tevatron, these results confirmed general trends that had been observed previously and had posed a number of problems.

- Why do reaction rates grow faster with energy when the virtual photon becomes even more virtual?
- Is there a new, hard pomeron that is dependent on the particular scattering process?
- Are there distinct pomerons (hard and soft) or is there one single pomeron that manifests itself in different ways depending on the kinematics?

Theoreticians presented a range of possible answers. N Tyurin (IHEP, Protvino), in the framework of a specific approach (U-matrix), argued that unitarity allows new possibilities (antishadowing) and that preasymptotic behaviour may mimic fast energy growth. A Kaidalov (ITEP), using the ITEP-Orsay quasi-eikonal approach, developed an interesting scenario of "undressing" the pomeron with a highly virtual photon. E Predazzi (INFN, Torino) gave an original view on ways in which one can detect unitarity effects in elastic and diffractive scattering. A young theoretician from IHEP, A Prokudin, insisted that all of the data from HERA do not rule out the "good old soft pomeron" and that there is no need for anything else.

This also found support in the excellent talk by M Kienzle (CERN), which was devoted to photon-photon interactions at LEP. The first experimental results on the total cross-sections were summarized.

However, the hard pomeron was not discredited at the conference. The discrepancies that were uncovered initiated a useful impromptu discussion session. One of the subjects that was covered was "What is the pomeron?" In the course of the discussion session it was realized that, very often, the same term is used to designate different contents.

Pomeron and odderon conclusions

The status of the perturbative pomeron was summarized in the mini-review on BFKL by one of the authors of this mechanism, E Kuraev from JINR (Dubna). In many cases the results are too preliminary for immediate use (or misuse) in phenomenological models. The work on this subject is, without doubt, extremely important.

Another feature of this physics is the odderon, which supplements the main pomeron mechanism and accounts for differences between, for example, proton-proton and proton-antiproton scattering. A special session devoted to the still elusive odderon was led by one of its most enthusiastic advocates, B Nicolescu.

The theoretical legitimacy of the odderon comes from recent QCD calculations. There are good prospects for its detection in exclusive processes at HERA. Drawing odderon conclusions from the latest CERN proton-antiproton diffractive scattering experiments seems very difficult and model dependent.

Further studies

High-energy elastic and diffractive studies are needed to resolve the picture. Included in these studies are the TOTEM project for CERN's LHC collider, presented by S Weisz (CERN), and Brookhaven's RHIC heavy-ion collider, presented by S Nurushev (IHEP, Protvino). Some specialized projects related to polarization phenomena were reviewed by A Krisch (Michigan).

The need for further experimentation at the LHC was also advocated by A Martin (CERN), to test the saturation of the fundamental Froissart bound on high-energy scattering behaviour and to see if dispersion relations continue to hold true or a breakdown of locality occurs.

Reports at major physics conferences say that quantum chromodynamics "works perfectly well at high energies". This is true. However, it has to be qualified by insisting on high-momentum transfers

The overall impression gained from the Protvino workshop is that elastic and diffractive scattering, despite being unfashionable, is very interesting and has a direct bearing on the most fundamental problems of this physics. A great variety of differing opinions were expressed (often mutually contradictory) and even disputes took place. This suggests a healthy future for research into elastic and diffractive scattering. □

RECRUITMENT

Postdoctoral Research Position

The Relativistic Nuclear Collisions Program (RNC) of the Nuclear Science Division at **Lawrence Berkeley National Laboratory** is seeking outstanding candidates to fill a postdoctoral position for the spring of 2000. The RNC Program plays a lead role in the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. Candidates having interest in all aspects of heavy ion physics at RHIC are invited to apply. We are especially seeking to expand our efforts in the areas of high pT physics and heavy flavor production. In STAR, RNC has major responsibilities for the central TPC detector, TPC electronics, and related software. We also have strong detector R&D programs and we are beginning to exploit the National Energy Research Supercomputing Center at LBNL, which provides a valuable computing resource to the Nuclear and High Energy Physics communities.

This is a two-year term appointment with the possibility of renewal. Interested candidates should have obtained a Ph.D. in nuclear or high energy physics within the last three years.

Applicants are requested to submit a CV, a list of publications and arrange to have three letters of reference sent to: **Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 937-0600, Berkeley, CA 94720** or fax: **(510) 486-5870**. Our preferred method is **email, employment@lbl.gov (ASCII text only, no attachments, please)**. Please reference **job number NS011357/JCERN**. Visit our website at **www.lbl.gov**. Berkeley Lab is an AA/EEO employer.

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DESY

DESY announces several

"DESY-Fellowships"

for young scientists in experimental particle physics to participate in the research mainly with the HERA collider experiments H1 and ZEUS, with the fixed target experiments HERA-B and HERMES and in R & D work for TESLA.

New fellows are selected twice a year in April and October.

DESY-Fellowships in experimental particle physics are awarded for a duration of two years with the possibility for prolongation by one additional year.

The salary for the fellowship is determined according to tariffs applicable for public service work (II a MTV Ang.).

Interested persons, who have recently completed their Ph.D. and are under 32 years of age, should submit an application consisting of a curriculum vitae, copies of university degrees and a publication list, and should arrange to have three letters of recommendation sent directly to:

DESY, Personalabteilung, Notkestr. 85, D-22607 Hamburg
by 31 March, 2000 **Code-Number 119/99**

Applications are particularly welcomed from qualified women and people with disabilities as they are currently under represented within the workforce. Women are especially encouraged to apply.

As DESY has laboratories at two sites, in Hamburg and Zeuthen near Berlin, applicants may indicate at which location they would prefer to work. The salary in Zeuthen is determined according to II a, BAT-O.

Brookhaven National Laboratory

PHYSICIST

The STAR Experiment in the Physics Department of Brookhaven National Laboratory currently has an opening for a physicist. The STAR Group is seeking an experienced candidate for the position of Computing and Software Leader. You will be responsible for the ongoing development, implementation and operation of the offline and online computing systems and for leading a large collaborative software effort which will be closely coordinated with other STAR detector efforts.

A Ph.D. is required and several years' experience in the field of high energy or relativistic heavy ion physics, along with a thorough knowledge of both offline and online software at the infrastructure and application software level for modern physics detectors. Excellent communication skills and the ability to lead a large collaborative software effort focused on offline and online software for the STAR Project is also essential.

Interested candidates should submit their CV indicating position #MK8795 to **M. Kipperman, Brookhaven National Laboratory, Bldg. 185, PO Box 5000, Upton, NY 11973-5000.**

BNL is an equal opportunity employer committed to workforce diversity.

UCSB High Energy Physics Group

Postdoctoral Research Physicist

University of California, Santa Barbara

The experimental high energy physics group at the University of California, Santa Barbara has an opening for a physicist starting in early 2000. We are looking for someone to join the group led by faculty members David Caldwell and Harry Nelson; the group is searching for Dark Matter with the ongoing CDMS-I and recently funded CDMS-II experiments, and analyzing 14 1/fb of data from the CLEAR II and II.V experiments.

The successful candidate will work primarily on the data acquisition systems of the CDMS experiments, and on the analysis of physics data from either CDMS or CLEO. Appointment is expected to be at the postdoctoral research physicist level, although it could be at the assistants research physicist level if qualifications warrant.

Interested candidates should submit a letter of application and curriculum vitae to:

Professor Harry Nelson, Department of Physics, University of California, Santa Barbara, CA 93106-9530. Email: postdoc@hep.ucsb.edu

Candidates should also arrange to have three letter of recommendation sent to the same address. For primary consideration, applications should be received by Feb 1, 2000; the position will remain open until filled.

We encourage applications from minority and women candidates

UWE BRISTOL

Research Fellowships - Distributed Object Management, Geneva

www.uwe.ac.uk/jobs

The Centre for Complex Co-operative Systems (CCCS) has been active in distributed data and process management projects for a number of years. These projects have applied distributed systems, database and object-oriented design and programming technologies to address problems in complex domains. CCCS now has up to two fixed term opportunities for Research Fellowships currently working with the CMS experiment at CERN, Geneva. All positions will only be filled by candidates displaying significant technological potential and/or academic standing.

Research topics under investigation include: workflow and product integration, engineering data management and distributed object communication. Applicants should have a doctorate or many years of research experience and should have already produced quality journal or conference papers. All applicants should be well motivated, have a strong interest in research and have some or all of the following skills: fluency in C and C++/Java; experience with Object Oriented Design techniques (eg UML); originality of thought, creativity and innovation; knowledge of distributed systems and/or database systems; experience with applied computing in a project environment.

For an informal discussion of CCCS activities please ring Richard McClatchey on 0044 498 742856. The positions are available from 1 April 2000 to 31 March 2002. Salary will be in the range £19,800 to £24,800.

For further information and to apply either visit our Website page or telephone our 24 hour answerphone service on 0117 976 3813 for an application form to be returned by 25 February 2000.

Please quote reference number R/402/CR

University of the West of England, Bristol

The Max Planck Institute for Physics, Munich
Invites applications for a

STAFF POSITION IN THEORETICAL PHYSICS

with major orientation towards particle physics phenomenology. The appointment may be five year or permanent, depending on qualifications. Salary and benefits will be determined according to BAT scale (german civil service).

The Max Planck Society would like to increase the participation of women in its research activities and encourages women to apply. In cases of equal qualification, preference will be given to the handicapped.

Applications, including Curriculum Vitae, list of publications and names of three referees, should be sent before 1 March 2000 to: **Leo Stodolsky, Max-Planck-Institut fuer Physik, Foehringer Ring 6, 80805 Munich, Germany. Information concerning the Institute is available at http://www.mppmu.mpg.de**

Radiofrequency Physicist

The Lawrence Berkeley National Laboratory is seeking a radiofrequency physicist or engineer to join the Beam Electrodynamics Group of the Center for Beam Physics, Accelerator and Fusion Research Division. The group is involved in the design, testing, and commissioning of RF and microwave devices and systems for control and diagnostics of charged particle beams.

The successful applicant will work primarily on R&D projects for the Next Linear Collider (NLC), and the muon collider and neutrino factory R&D programs. In addition, the Group also has research interests in accelerator systems and components covering a broad range of frequencies up to mm-wave, and including high power RF systems, broadband feedback systems, and novel accelerating structures. Will have responsibility for the conceptualization, design, and laboratory measurements of a variety of RF and microwave systems and components for different applications in particle accelerators, using the facilities available in the Lambertson Beam Electrodynamics Laboratory at LBNL. Will also participate in measurements of the devices and systems in operating accelerators at various locations.

Qualifications include sound working knowledge of electromagnetism in application to the design, fabrication, and measurement of RF structures, at the level of Ph.D. or equivalent experience in physics or engineering. Experience preferred in the following: RF and microwave measurements using standard laboratory equipment, including vector network analyzers, time domain reflectometers, and spectrum analyzers; computer-aided design programs for 2-D and 3-D high-frequency electromagnetics; basic knowledge of accelerator physics.

This is a two-year term appointment, with the possibility of renewal. Please submit one copy of your resume via email (our preferred method) to: **employment@lbl.gov (no attachments, please). Reference job number AFR10129/JCERN in your cover letter. Or mail to: Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 937-0600, Berkeley, CA 94720. Or fax: (510) 486-5870. Visit our website at www.lbl.gov**. Berkeley Lab is an AA/EEO employer.

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CERN COURIER RECRUITMENT BOOKING DEADLINE

March: 11 February **April:** 10 March **May:** 7 April

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E-mail chris.thomas@ioppublishing.co.uk
cerncourier.com

RESEARCH ASSOCIATE POSITION

Experimental High Energy Physics

Carnegie Mellon University

The Department of Physics at Carnegie Mellon University invites applications for one postdoctoral Research Associate position in experimental high energy physics. The individual who fills this position will work on detector development for the future CMS experiment at the LHC, in particular, the front-end anode electronics for the CMS endcap muon system. Participation in data analysis for the on-going L3 experiment at LEP will also be encouraged. The successful candidate will work both at Fermilab and at CERN. Applicants should submit a curriculum vitae, and arrange to have three letters of recommendation sent directly and as soon as possible to:

Professor Thomas Ferguson
Department of Physics
Carnegie Mellon University
Pittsburgh, PA 15213, USA
(e-mail: ferguson@cmphys.phys.cmu.edu)

The vitae and recommendations can be sent either by normal or electronic mail. We will begin to consider applications on Feb. 15, 2000.

Carnegie Mellon is an equal opportunity/affirmative action employer

SNS Accelerator Systems Associate Division Director

The Spallation Neutron Source (SNS) Project at the Oak Ridge National Laboratory (ORNL) invites applications for the Associate Division Director, Accelerator Systems Division. The Spallation Neutron Source (SNS) is a next-generation 2-MW neutron source dedicated to materials science, and is a joint-venture project involving five Department of Energy laboratories (Argonne, Brookhaven, Los Alamos, Lawrence Berkeley and Oak Ridge). When completed in 2005, the SNS will produce the most powerful pulsed neutron beams in the world for neutron scattering R&D.

Successful candidate will advise the SNS Accelerator Systems Division Director on the physics basis for formulating the design of the SNS accelerator systems. Provide intellectual leadership in identifying, analyzing and helping to mitigate trouble spots in the physics design of the accelerators. Coordinate, lead and integrate accelerator physics activities, application software development and diagnostics and commissioning plans involving several division organizations. Establish, with the Accelerator Physics Group Leader, physics-related R&D requirements, develop related funding plans and work schedules, and represent the division director in his/her absence.

Successful candidate will have a PhD in physics and at least 10 years' experience in successful development of the physics design of linacs, synchrotrons and/or storage rings, or an equivalent combination of education and experience. At least 5 years' experience managing accelerator physics teams or accelerator design and construction teams required. Excellent written and oral communications skills are necessary. Must also have demonstrated experience in preparing and making presentations to review/advisory committees and at conferences and workshops.

Qualified candidates should submit a curriculum vitae with a list of three or more references to: Selection Committee, ATTN: P.H. Miller, SNS Project, 104 Union Valley Road, Dept. CC-9181, Oak Ridge, TN 37831; e-mail: tho@ornl.gov. Please reference job title when applying. Applications will be accepted until the position is filled.

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Post Doctoral Positions in Experimental Particle Physics

The **Fermi National Accelerator Laboratory (Fermilab)** has openings for post doctoral research associates in experimental particle physics. The Fermilab research program includes experiments with the 2 TeV proton – antiproton collider, neutrino oscillation experiments, and fixed target experiments. There are several positions for recent Ph.Ds to join the CDF and DZero collider efforts which have major detector upgrades in progress and are scheduled to begin data taking in early 2001. There are also opportunities to join the upcoming neutrino oscillation experiments MiniBooNE or MINOS, the Cryogenic Dark Matter Search, fixed target experiments for data analysis, as well as detector R&D efforts. Positions associated with these experimental efforts are also available in the Computing Division for candidates interested in modern computing techniques applicable to HEP data acquisition and analysis.

Successful candidates are offered their choice among interested Fermilab experiments. Appointments are normally for three years with one year renewals possible thereafter. Every effort will be made to keep a Fermilab RA until he or she has the opportunity to reach physics results from his or her experiment.

Applications should include a curriculum vita, publication list and the names of three references. Applications and requests for information should be directed to: **Dr. Michael Albrow, Head – Experimental Physics Projects, [Albrow@fnal.gov], Fermi National Accelerator Laboratory, M.S. 122, P.O. Box 500, Batavia, IL 60510-0500**. EOE M/F/D/V

Fermilab

ASSOCIATE SCIENTIST POSITION – D-ZERO PROJECT

The **Fermi National Accelerator Laboratory** is searching for an outstanding candidate to fill an Associate Scientist appointment within the D0 experiment at the Tevatron Collider. This is a tenure-track position. The D0 detector is presently being upgraded for operation in the higher luminosity environment of Run II, starting in spring 2001. Run II offers unequaled physics opportunities at the world's highest energy accelerator, including B-physics, QCD, precision measurements of W and Z bosons and the top quark, and the search for physics beyond the standard model.

The successful candidate will participate fully in the preparation and operation of the D0 experiment and in the subsequent analysis of the data; develop an expert level understanding of aspects of the major detector hardware and software systems; and take responsibility for the successful implementation and operation of some substantial subproject. Additional responsibilities will include developing methods to ensure proper operation of aspects of the experiment and its software, as well as carrying out independent physics analyses. Excellent verbal and written communications skills, and the ability to work independently as well as a leader of a team, are essential.

A Ph.D in high energy physics or its equivalent is required. A general understanding of current detector technology used in high energy physics, and familiarity with standard experimental methodology, test equipment and modern computing and analysis methods are also essential. Candidates should have demonstrated their ability to work independently and to take responsibility for medium scale projects. Applicants for **position #000009** should submit a curriculum vitae and 3 letters of reference to: **John Womersley, Co-spokesman, D0 Experiment, MS357, P.O. Box 500, Batavia, IL 60510 or by e-mail to womersley@fnal.gov**

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

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GSI Darmstadt

the National Laboratory for Heavy-Ion Research, a member institute of the Helmholtz-Society of German Research Centers, invites

Accelerator Physicists
Ref. 3320-98.48

to apply for two postdoctoral positions in the ion source development group.

Successful candidates are expected to contribute theoretical and experimental work to the development of pulsed high-current ion beams from electron cyclotron resonance ion sources (ECRIS). The work - supported by the RTD program of the European Community - is part of a research project shared between CEA and ISN-Grenoble/France, INFN-LNS-Catania/Italy, CERN-Geneva/Switzerland, and GSI-Darmstadt/Germany. Major GSI contributions to the project are theoretical (numerical) and experimental investigations on the problem of beam formation and extraction and the development of special operational modes of the ECRIS aiming at highest beam pulse currents. GSI offers excellent conditions for the experimental investigations. An ECRIS test bench including a beam spectrometer has been completed recently. Software tools required for the theoretical work are available for the most part.

Applicants will have a relevant PhD in physics or engineering physics. Education and/or practical experience with ion sources, particle accelerators and particle beam transport systems, beam physics or plasma physics would be preferred. Applications should include a curriculum vitae, documents on diploma and PhD examination scores, discussion of research interests with list of publications and letters of reference sent directly to the address given below.

Women are especially encouraged to apply for the position.
The appointment will be limited to 3 years.
Applicants should not be older than 32 years.

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

Further information about GSI are available via http://www.gsi.de.
For more information about applications, please, e-mail to b.franzke@gsi.de.

Applications should be submitted not later than February 29, 2000, to

GESELLSCHAFT FÜR SCHWERIONENFORSCHUNG MBH
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Accelerator Physics Postdoctoral Positions

The Deep Ultra-Violet Free Electron Laser (DUVFEL) facility of the National Synchrotron Light Source Department at Brookhaven National Laboratory presently has two accelerator physics positions available.

Experimental Physicist/Engineer

In this role, you will assist in developing new instrumentation used in the generation, diagnosis and control of high-brightness electron beams. A Ph.D in Physics or Engineering and hands on experience in one or more of the following fields are desired: accelerator instrumentation; measurement and control of S-band RF generation equipment; integration of laser transport and diagnostics in an accelerator facility; or ultrashort pulse-length measurement methods. Position #MK8443.

Physicist

You will perform simulation and analysis of high-brightness electron beams. A Ph.D. in Physics and experience with beam simulation methods and accelerator controls development are required. A record of publication in one or more of the following areas is desired: electron beam dynamics in photocathode sources; magnetic pulse compression and coherent synchroton radiation generation; transport of space-charge dominated beams; or high-gain FEL dynamics. Position #MK8444.

Interested candidates should submit their CV, indicating position #, to: M. Kipperman, Brookhaven National Laboratory, Bldg. 185, P.O. Box 5000, Upton, NY 11973-5000. Visit our website at: www.bnl.gov. BNL is an equal opportunity employer committed to workforce diversity.

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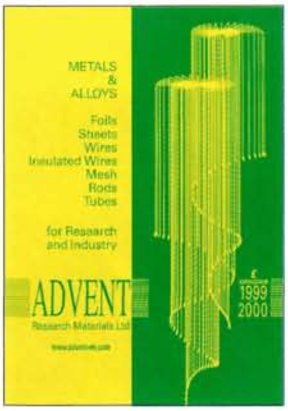

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Temperature Measurement and Control catalogue

A new Temperature Measurement and Control catalogue is available from Lake Shore Cryotronics Inc. Comprehensive details are provided for cryogenic temperature sensors, current sources, temperature transmitters, accessories controllers and monitors. The catalogue contains a comprehensive product section and a useful and detailed reference guide. Several temperature sensors are new to this year's catalogue, as are a temperature controller and a temperature monitor.

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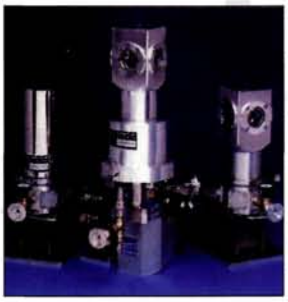

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Janis Research is proud to announce the availability of its new Crycooler Cryostats catalogue. These systems provide sample cooling temperatures from less than 8 K up to 600 K and only require electrical power for operation. Cooling capacities of up to 3 W at 20 K are standard, and both optical and non-optical, as well as "sample in vacuum" or "sample in exchange gas" configurations are shown.

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APS announces awards for 2000

The American Physical Society's awards and prizes for 2000 have been announced. The Tom W Bonner prize goes to Raymond G Arnold of The American University, for his leadership in pioneering measurements of the electromagnetic properties of nuclei and nucleons at short distance scales that addressed the fundamental connection of nuclear physics to quantum chromodynamics and motivated new experimental programmes.

The Dannie Heineman prize goes to Sidney Coleman of Harvard, for his incisive contributions to the development and understanding of modern theories of elementary particles. His contributions to symmetry breaking and the roles played by internal and space-time symmetries as well as the structure of solutions in an important model in quantum field theory have been of particular note.

The W K H Panofsky prize is awarded to Martin Breidenbach of SLAC, Stanford, for his numerous contributions to electron-positron physics, especially with the SLD detector at the Stanford Linear Collider. His deep involvement in all aspects of the project led to a number of important advances both in the measurement of electroweak parameters and in accelerator technology.

The Aneesur Rahman prize goes to Michael J Creutz of Brookhaven, for first demonstrating that the properties of quantum chromodynamics can be computed numerically on the lattice through Monte Carlo methods, and for numerous contributions to the field thereafter.

The J J Sakurai prize goes to Curtis G Callan Jr of Princeton, for his classic formulation of the renormalization group and his contributions to instanton physics and the theory of monopoles and strings.

The Robert R Wilson prize goes to Maury Tigner of Cornell, for his notable contributions to the accelerator field as an inventor, designer, builder, and leader, and also for early pioneering developments in superconducting radio-frequency systems, his inspiration and intellectual leadership for the construction of CESR, and leadership of the SSC Central Design Group."

Former CERN director-general and 1984 Nobel laureate for Physics Carlo Rubbia is pictured here with the winner of the XXX International Physics Olympiad, Konstantin Kravtsov (Russian Federation). The event took place recently at Padua University and attracted 292 high school students from the following countires: Albania; Argentina; Australia; Austria; Azerbaijan; Belarus; Belgium; Bosnia–Herzegovina; Bulgaria; Canada; Chinese Taipei; Colombia; Croatia; Cuba; Cyprus; the Czech Republic; Denmark; Estonia; Finland; Georgia; Germany; Great Britain; Greece; Hungary; Iceland; India; Indonesia; Ireland; I R of Iran; Israel; Italy; Kazakhstan; Kuwait; Latvia; Liechtenstein; Lithuania; Macedonia; Mexico; Moldova; Mongolia; New Zealand; Norway; the Philippines; Poland; P R of China; Portugal; R of Korea; Romania; the Russian Federation; Singapore; Slovakia; Slovenia; Spain; Suriname; Sweden; Switzerland; Thailand; the Netherlands; Turkey; Turkmenistan; Ukraine; USA; Vietnam; Yugoslavia. The XXXI International Physics Olympiad will be held in Leicester, UK, in July 2000.

CERN director-general Luciano Maiani holds the Prix de la Fondation de Genève, which is awarded annually (since 1997) by the city and canton of Geneva to "people or institutions who have contributed to the radiating influence of Geneva around the world". Looking on are Françoise Demole of the Foundation, and Foundation president Ivan Pictet.

At a memorial symposium at MIT for Henry Kendall (1926–99) are (left) longtime Kendall collaborator and co-Nobel prizewinner Jerome Friedman, with session chairman Francis Low of MIT. (Maurice Jacob.)

CERN Theory Division

Guido Altarelli will become head of CERN's Theory Division from July 2000. He will succeed Alvaro de Rujula.

Some 22 companies presented their latest technology at the Italy at CERN trade fair in November 1999. Opening the exhibition, Italian Minister of Research Ortensio Zecchino said, "The co-operation of science and industry increases the returns to CERN Member States and stimulates technological transfer. The exhibition is particularly well timed, now that LHC construction is in full course, because it symbolizes the reinforcement of ties between CERN and one of its major sponsors."

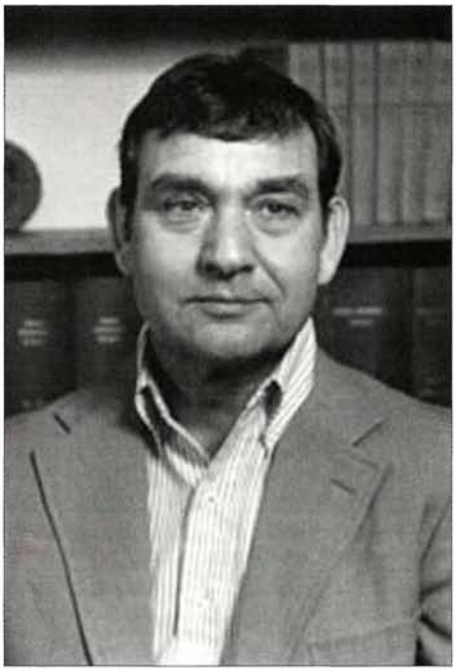
The special technology on show included: cryogenics and vacuum technologies; electric power and power electronics; special and industrial gases; and small and precision machined mechanical components. Italy contributes 13.6% of CERN's 939 million Swiss franc budget. With a total of 1033 visiting scientists and 339 staff members at CERN, of its Member States Italy is the major scientific user of CERN.

Seen here admiring a cross-section of the LHC superconducting collider are (left to right) CERN director-general **Luciano Maiani**, Italian Minister of Research **Ortensio Zecchino**, CERN Technical Support Division leader **Alberto Scaramelli**, CERN Supplies, Procurement and Logistics Division leader **Romeo Perin**, CERN–Italy industrial liaison officer **Lucio Rossi** and high-precision press tool manufacturer Malvestiti SPA director **G Malvestiti**.

The Theory Division at LAPP, Annecy, recently celebrated its 20th anniversary. Present at the celebrations were current division head **Paul Sorba** (right) with former division head **Raymond Stora**.

1999 Physics co-Nobel prizewinner **Martin Veltman** (right) in conversation with supersymmetry pioneer **Julius Wess** during a meeting in Hamburg in November 1999. The meeting was in memory of distinguished theorist Harry Lehmann, who died in November 1998. (André Martin.)

An international workshop – A Synchrotron Radiation Source at JINR: Prospects of Research – was held recently at the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow. Under discussion was the construction of a third-generation synchrotron radiation source – based on the MEA–AmPS facility presented to the institute by NIKHEF (Amsterdam – *CERN Courier* February 1999 p18).



Sam Treiman 1925–99.

Sam Treiman 1925–99

Sam Treiman, widely known for his many contributions to elementary particle physics, died on 30 November 1999 after a prolonged battle with leukemia.

His scientific work was wide ranging. However, he had the greatest love for, and the deepest impact on, weak interactions. In 1959, Treiman and Princeton colleague Marvin Goldberger derived what became known as the Goldberger–Treiman relation, which connected two seemingly disparate areas of physics: the strong- and weak-interaction properties of the proton and neutron. This discovery catalysed a series of developments that eventually led to today's Standard Model of elementary particle physics.

Treiman was a revered teacher and mentor. His first graduate student was Steven Weinberg. Treiman's exceptional teaching achievements were honoured in 1985 when he was awarded the Oersted Medal of the American Association of Physics Teachers.

He entered Northwestern University in 1942, initially intending to study chemical engineering, but his studies were interrupted by the war where he served in the US Navy as a radar technician. Treiman joined the Princeton faculty in 1952, eventually becoming the Eugene V Higgins Professor in 1977. He served as chairman of the department from 1981–7 and retired in 1998.

As a member of the High-Energy Physics Advisory Panel of the Department of Energy and a member of the Board of Governors of the Superconducting Supercollider, his advice was widely sought. Treiman was elected to the National Academy of Sciences in 1972. He was also a member of the American Academy of Arts and Sciences and the American Philosophical Society.

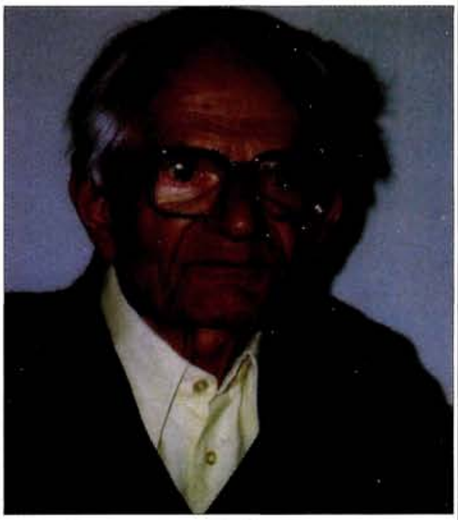
Rudolf Steinmaurer 1903–99

In August 1999 Rudolf Steinmaurer, former head of the Institute of Experimental Physics at Innsbruck, died in his 97th year. He studied physics, mathematics, meteorology and astronomy in Vienna and Graz, where Viktor F Hess entrusted him with experiments in cosmic-ray research. Cosmic-rays became the subject of his thesis. In 1931 he followed Hess to Innsbruck. In 1937, when Hess moved back to Graz, Steinmaurer stayed on and later became head of the Institute at Innsbruck.

After the war he followed with great interest the development of particle physics in Europe – which led to the establishment of CERN. When, in 1959, Austria joined CERN, Steinmaurer founded a group for high-energy physics at Innsbruck and supported the creation of a chair for Theoretical Particle Physics, now headed by Professor Rothleitner. Among Steinmaurer's students were Walter Ambach (Medical Physics, Innsbruck) and Gerd Otter (Aachen).

Having assisted Viktor F Hess in his epic pioneer work on cosmic rays, Steinmaurer may have been the last witness of those heroic times. He will be remembered as a kind and helpful man who placed a great deal of importance on the conscientious and correct execution of any duty.

Ivo Steinacker.



Rudolf Steinmaurer 1903–99.

MEETINGS

CERN and The European Space Agency are jointly organizing a workshop, called **Fundamental Physics in Space**, to be held at CERN on 5–7 April 2000. More information is available on the CERN Web site at "http://www.cern.ch/Physics/Events/Conferences/2000/0405CERNESA/". Those interested in participating in the workshop, should contact one of the meeting co-chairmen on "maurice.jacob@cern.ch" or "mhuber@estec.esa.nl".

The Crimea summer school seminar, **New Trends in High-Energy Physics** (formerly "Hadrons"), will be held between 27 May and 4 June 2000 on the southern coast of the Crimea, Ukraine. The programme will cover the theory and experiments of elastic and diffractive scattering of hadrons and nuclei; deep inelastic scattering and multiparticle dynamics; collective properties of strongly interacting matter; heavy flavours and hadron spectroscopy; duality, strings and confinement; the Standard Model and beyond; advances in quantum field theory; new physics at future colliders, and more. The preliminary list of lecturers includes: L D Faddeev, V S Fadin, S B Gerasimov, M Gorenstein, W Greiner, R Jackiw, L L Jenkovszky, A B Kaidalov, E A Kuraev, L N Lipatov, N N Nikolaev, D V Shirkov, Yu Shtanov, Yu Sitenko, A A Slavnov and H Stoecker. Please make applications to: Crimea summer school, Bogolyubov Institute for Theoretical Physics, Kiev-143, Ukraine, or e-mail "crimea2000@gluk.org"; fax (00380 44) 2665998. Further information is available at "http://www.gluk.org/hadrons/crimea2000/".

BOOKSHELF

Weaving the Web – The Original Design and Ultimate Destiny of the World Wide Web by its Inventor by Tim Berners-Lee and Mark Fischetti, Harper, San Francisco, 1999, ISBN 0 060 251586 1 ($26).

If you've ever wondered what goes on in the mind of an inventor you could do a lot worse than delve into Tim Berners-Lee's *Weaving the Web*. In it he and co-author Mark Fischetti explain the origins of the ideas that are now revolutionizing the communications landscape, and the vision that lies behind them.

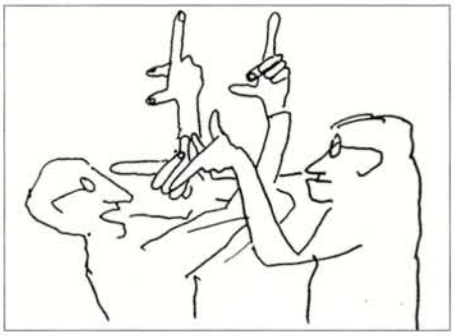
From a childhood spent discussing maths at the breakfast table and building mock-up replicas of the Ferranti computers his parents worked on, Berners-Lee moved on to building his own computer out of salvaged pieces of electronics and an early microprocessor chip.

In 1980, he went to CERN on a six-month contract. There he wrote a hypertext program called Enquire to help him keep track of the complex web of who did what on the accelerator controls project he worked on. Back at CERN at the end of the decade, Berners-Lee transported the idea behind Enquire to the Internet, with the now well known results.

Berners-Lee's book is a very personal account, and it's all the more readable for that. Like most of us, Tim Berners-Lee has a mind that's better at storing random associations than hierarchical structures. And, like most of us, his mind is prone to mislaying some of those associations. Enquire began as an effort to overcome that shortcoming and evolved into something much bigger.

Berners-Lee is an idealist, driven by the desire to make the world a better place and the profound belief that the Web can do that. Now far from the rarefied air of a pure research laboratory, Berners-Lee gives credit to the atmosphere in which his ideas were allowed to mature. "I was very lucky, in working at CERN, to be in an environment... of mutual respect and of building something very great through a collective effort that was well beyond the means of any one person," he explained. "The environment was complex and rich; any two people could get together and exchange views, and even end up working together. This system produced a weird and wonderful machine, which needed care to maintain, but could take advantage of the ingenuity, inspiration, and intuition of individuals in a special way. That, from the start, has been my goal for the World Wide Web."

James Gillies, CERN.



Magnetic discussion – a sketch by Bruno Touschek.

The Standard Model in the Making – Precision Study of the Electroweak Interactions by Dima Bardin and Giampiero Passarino, Oxford, International Series of Monographs on Physics, August 1999, ISBN 0 19 850280 X (hbk £80, 680 pages).

The past decade of particle physics experiments has been devoted to the testing of the standard electroweak theory, mainly at LEP, SLC and the Tevatron. The goal has been to probe the theory at the quantum-loop level by comparing the quantitative predictions on radiative corrections to experimental data, for as many measurable quantities as possible.

From the theoretical side, the preparation of these precision tests has been a tremendous task that has involved hundreds of theorists for over 20 years. This book offers a complete compendium of the techniques and results in the calculation of radiative corrections.

No other book offers a complete, exhaustive and authoritative description of the electroweak theory predictions for precision tests. All calculations are described in detail and the results are reported explicitly. Different techniques and approaches are introduced and compared. Most of the results are explicitly derived and discussed. The tree level results and the quantum corrections for all relevant physical processes and quantities are studied in detail.

The exposition is clear and only a basic knowledge of quantum field theory is assumed. Thus, the book qualifies as a complete reference handbook for this domain of contemporary physics. Those interested in the overall physical picture and the main implications of precision tests can find more-readable reviews elsewhere. However, this work will be invaluable for professional theorists looking for state-of-the-art reviews.

Guido Altarelli, CERN and Rome III.

Bruno Touschek and the Birth of e^+e^- Physics edited by G Isidori, INFN, Frascati, ISBN 88 86409 17 6.

Volume XIII in the Frascati Physics Series contains the proceedings of the memorial meeting held in Frascati in November 1998. The meeting marked the 20th anniversary of the death of electron-positron collider pioneer Bruno Touschek. The meeting was reported in *CERN Courier* (February 1999 p17).

Touschek made physics and physicists realize the importance of particle-antiparticle colliders, and opened the door to one of the most fruitful periods of particle physics research. Touschek himself was also an interesting and flamboyant figure. The presentations at the meeting underlined the importance of his contributions and his special character.

Chapters include: The Frascati decision and the AdA proposal, by Giorgio Salvini; Remembering Bruno Touschek, his work his personality, by Carlo Bernardini; From AdA to ACO – reminiscences of Bruno Touschek, by Jacques Haïssinski; The ADONE results and the development of the quark-parton model, by Massimo Testa; Electron-positron storage rings from ADA to LEP, by Emilio Picasso; Physics at present electron-positron colliders, by Guido Altarelli; Physics at DAFNE, by Paolo Franzini; Status of DAFNE, by Miro Andrea Preger; The physics at an e^+e^- linear collider, by Marcello Piccolo. The book also has a list of Touschek's scientific papers, some photographs and a few of Touschek's sketches.

For more infromation on Touschek see *The Bruno Touschek legacy*, by Edoardo Amaldi.

Beyond Conventional Quantization by John R Klauder, Cambridge, ISBN 0 521 25884 7 (hbk £55/$85, 300 pages).

Extensions of conventional quantum pictures can sidestep some quantum embarrassments. This book is useful to someone with a deep feel for quantum field theory.

CP Violation by I I Bigi and A I Sanda, Cambridge Monographs of Particle Physics, Nuclear Physics and Cosmology, ISBN 0 521 44349 0 (hbk £60/$95, 380 pages).

With new results from the classic kaon sector and with new B factories now coming on line, CP violation is a major boom area in particle physics. This carefully written book would make a useful introduction and guide to the difficult theory of this phenomenon.

LETTERS/NEW PRODUCTS

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please e-mail "cern.courier@cern.ch".

Millennium

"The last Nobel Prize for Physics this century goes to Gerardus 't Hooft of Utrecht and Martinus Veltman of Bilthoven in the Netherlands," claimed the November 1999 issue of *CERN Courier*. However, it seems to me a little premature to assume that the Nobel Committee will find no worthy candidates in 2000.

The temptation to go along with the ever impatient mass media may have seemed irresistible, but a "shop window" journal of a numerate profession should resist. In British terms, a batsman hasn't scored a century till he successfully completes his hundredth run.
David Lewin, Rutherford Appleton Lab, UK.

CERN Courier *replies:*
Having no year zero separating "negative" BC and "positive" AD must have caused a lot of confusion for the computers of the time. However, this YOK dilemma has had ample time to sort itself out. On 1 January 2000, 100 years had passed since 1 January 1900 and a thousand years (give or take a few days because of changes to the calendar) had elapsed since 1 January 1000. For most people, that was a significant enough milestone. Party poopers, who wanted to wait an extra year, had to step back as the millennium express thundered through.
Gordon Fraser, editor CERN Courier.

Erudition

After decades of castigation by Europeans for our (read US physicists') use of the unit "fermi" to mean 10^{-13} cm, I am delighted to cry, "shame on you" for perpetuating that usage. On p8 of the November 1999 issue of *CERN Courier,* per cubic fermi occurs three times and 1 fermi is defined as 10^{-13} cm, "which is the 'diameter' of a proton." The proper SI unit is, as even the Particle Data Group now agrees, the femtometer, abbreviated conveniently as fm, and is 10^{-15} m. It was Leon Rosenfeld in Copenhagen who got femto put on. Femten is the number fifteen in Danish. The charge radius of the proton is roughly 0.8 fm, so diameter is a bit wrong as well as being patronizing.
Dave Jackson, Berkeley.

A long read

I recently visited Longyearbyen, a small city with 1200 inhabitants, in Spitzbergen. From there it is only 1000 km to the North Pole. The city has an airport, a university, a hospital and a public library, which displays *CERN Courier.*
Dieter Notz, DESY.

NEW PRODUCTS

The Channel Photomultiplier: a new method to detect extremely low light levels

A compact design – ultra-high-sensitivity optical detector from Heimann Optoelectonics of Wiesbaden.

Heimann Optoelectonics of Wiesbaden, a subsidiary of Perkin-Elmer and a specialist in vacuum electronic components, has developed a new, ultra-high-sensitivity, optical detector. The key part of the Channel Photomultiplier (CPM) is a channel electron multiplier that exhibits a very high secondary-emission multplication. As a result, the CPM guarantees a very high anode sensitivity, up to 107 A/W with a gain exceeding 108, and a fast response. The extremely low noise level of, typically, 3 pA at a gain of 106 improves the dynamic range. In addition the low noise shows extreme stability over time.

Heimann offers a choice of window materials and photocathodes to cover the spectral range from 115 nm (ultraviolet) to 850 nm (near infrared). For applications in high-energy physics the tubes can be coupled with scintillator crystals. The CPM can be used in analogue-DC or single-photon counting mode.

The high performance of the detector and the very compact design, with a diameter of 10.6 mm, offer fundamental advantages in: analytical instrumentation, life science products, and industrial and medical equipment as well as many physical applications including particle physics and basic research.

The product range will be extended to include complete photon-counting modules with TTL output signal, and multichannel devices such as linear or area detectors.

For further information contact Alfred Herke, Heimann Optoelectronics, Wiesbaden, tel. 49 (611) 492 330, fax 49 (611) 492 159 or e-mail "alfred_herke@perkinelmer.com".

Nanoflash: a new high-intensity short-pulse source

Nanoflash, a low-cost alternative to high-power, pulsed lasers and flashlamps, is now available from Electron Tubes Limited. Researchers in high-energy physics and astrophysics will find this versatile optical source useful for a range of applications, including exciting fluorescence and calibrating photomultiplier systems.

Nanoflash emits subnanosecond pulses containing up to 10^{12} photons. The output flash can be subdivided, using a fibre optic bundle, to give many independent signal channels, which provide excellent long-term signal stability.

Nanoflash is available with eight, interchangeable, light-emitting heads, covering the ultraviolet to infrared range. These compact heads, 25 by 40 mm, can be operated remotely and are easily incorporated into existing measuring systems.

For further information contact Tony Wright, Electron Tubes Limited, tel. +44 (0) 1895 630 771, fax +44 (0) 1895 621055 or e-mail "pmt@electron-tubes.co.uk". The Web site is at "www.electron-tubes.co.uk".

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