INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

VOLUME 40 NUMBER 7 SEPTEMBER 2000

A new X-ray eye in the sky

ANTIMATTER ASYMMETRY
Exploring a new route to CP violation p5

TAU NEUTRINO
The most elusive particle of all turns up p6

DISAPPEARING NEUTRINOS
Over 250 km, neutrinos slip off the map p8

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

CERN Courier is distributed to Member State governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly except January and August, in English and French editions. The views expressed are not necessarily those of the CERN management.

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Produced for CERN by Institute of Physics Publishing Ltd
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E-mail jo.nicholas@ioppublishing.co.uk
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Published by: European Laboratory for Particle Physics, CERN, 1211 Geneva 23, Switzerland. Tel. +41 (22) 767 61 11
Telefax +41 (22) 767 65 55

USA: Controlled Circulation Periodicals postage paid at St Charles, Illinois

Printed by: Warners (Midlands) plc, Bourne, Lincolnshire, UK

ISSN 0304-288X

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VOLUME 40 NUMBER 7 SEPTEMBER 2000


OWL telescope project p15


LHC report at EPAC 2000 p26


First Wiik prize winners p36

Cover: A new X-ray eye in the sky – the European Space Agency's X-ray Multi-Mission XMM-Newton. (Photo ESA.) p17.

CP asymmetry moves to new setting

The year 2000 sees the debut of a new kind of precision physics. It formally began with the opening plenary talks at the International Conference on High Energy Physics, the biennial particle physics jamboree, held this year in Osaka.

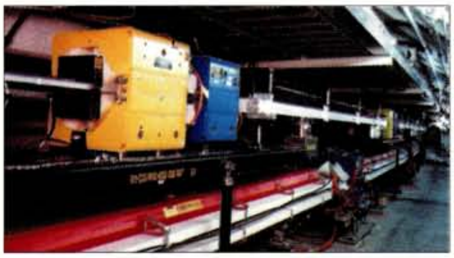
On 31 July the initial plenary speakers at Osaka – David Hitlin of Caltech and Hiroaki Aihara of Tokyo – presented the first physics results from the BaBar and BELLE detectors respectively. A small but paradoxically important effect called CP violation has now been seen and measured outside its traditional hunting ground, which had been limited to studies of neutral kaons.

BaBar and BELLE operate at new electron–positron colliders – BaBar at the PEP-II machine at SLAC, Stanford, and BELLE at KEKB at the Japanese KEK laboratory. These colliders started operating for physics in 1999 with the aim of achieving high luminosities (collision rates) to mass-produce B mesons – particles containing the fifth "beauty" quark, hence their name "B factories". The commissioning of both machines has been impressive, and they are routinely delivering luminosities in excess of $10^{33}/cm^2/s$ – figures previously unheard of.

Physicists think that the delicate charge-parity (CP) violation effect, or matter-antimatter asymmetry, played a major role in shaping the particle scenario that emerged from the Big Bang. The initial explosion that created the universe presumably produced equal amounts of matter and antimatter. The convention is that CP violation then moulded the universe so that it eventually emerged with antimatter apparently erased from the map.

For CP symmetry the physics of left-handed particles is the same as that of right-handed antiparticles. In 1964, physicists discovered that, in the decays of one of the neutral kaons (the long-lived variety), CP symmetry is respected only 99.997% of the time. This tiny violation is enough to define which is positive and which is negative electric charge – the positive–negative assignment is not just convention.

Subsequent precision experiments (May p6) have probed CP violation in depth, revealing even smaller effects that operate at the quark level. At a few parts per million, these effects are difficult to see and even harder to measure, and it has taken some 20 years for experiments to approach a consensus.



One B Factory – the PEP-II ring at SLAC...

...and another – the KEKB collider in Japan.

Quarks transform into each other under the action of the weak force, and the various possible quark transformations have been studied extensively and documented in the Cabibbo–Kobayashi–Maskawa (CKM) matrix of quark coupling strengths. According to these numbers, CP violation in the decays of B mesons should be easier to see than in the neutral kaon case.

The results

At Osaka it was announced that PEP-II has delivered an impressive 16 inverse femtobarns of accumulated luminosity since last May, of which the BaBar team has 14 on tape. The collider is running well and is already exceeding the design goal of 135 inverse picobarns per day. For the measurements presented at Osaka, BaBar uses only this year's data, corresponding to about 10 inverse femtobarns.

The CP violation measurement uses B decays into J/psi and a short-lived kaon, with several different kaon decay modes, and into psi prime and a short-lived kaon. A total of 120 reconstructed events are used to determine the $\sin(2\beta)$ CP violating parameter. The Babar result is $0.12 \pm 0.37 \pm 0.09$. For a check, CP asymmetries of channels that should not have any CP violation, for instance J/psi and a positive kaon, are consistent with zero.

The PEP-II plan is to extend this year's run until October, collecting 25 inverse femtobarns (BaBar aimed for 30 inverse femtobarns, so they are right there from the start).

BELLE at KEKB uses the full data sample since the start-up, corresponding to 6.8 inverse femtobarns. The luminosity reached so far is 2.04×10^{33}. The decay channels used for the determination of the $\sin(2\beta)$ CP-violating parameter include, in addition to those used at PEP-II, B decays into chi-c1 and decays giving long-lived kaons. (BaBar has about 89 of these but doesn't include them yet.) A total of 98 events enter the final BELLE CP fit.

For J/psi Ks events only, the BELLE result is $\sin(2\beta) = 0.49 + 0.53 - 0.57$. Combining this with a result from other events yields $\sin(2\beta) = 0.45 + 0.43 - 0.44 + 0.07 - 0.09$. Statistically, this is within one standard deviation of previous determinations/expectations. BELLE checked that decay channels not expected to show CP asymmetry give a null result. Plans are for BELLE to resume running with higher currents in October until summer 2001.

The upshot

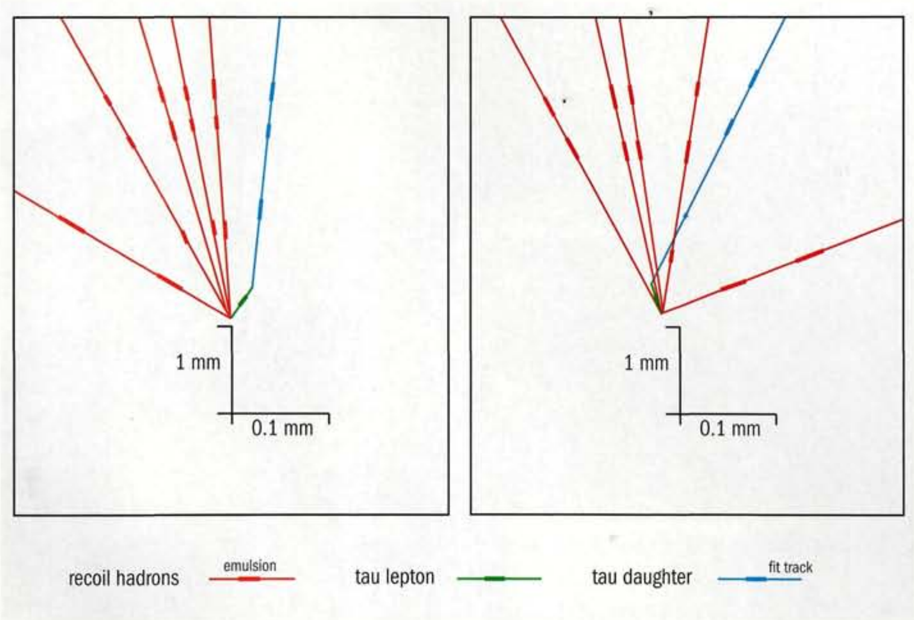
The first results from BaBar and BELLE show that CP violation happens in B decays. Forget briefly about comparing the results with predictions. The fact that the effect can be measured for B particles so soon after the debut of two innovative machines and two challenging new experiments is a major achievement and bodes well for the continued vigour of this new branch of particle physics.

It look a long time before all of the CP violation parameters in neutral kaon decay were known with confidence. The B sector will probably consolidate much faster.

Fermilab's Tevatron proton–antiproton collider is also a prolific source of B particles, and the CDF experiment there made an earlier brave attempt to measure CP violation in B decays. This environment is cluttered and the signal difficult to measure, but an effect was almost certainly there. With the advent of the PEP-II and KEKB B factories, the study of matter-antimatter asymmetry enters a new era. For the longer-term future, other experiments are setting their sights on B physics – HERA-B at DESY, Hamburg, BTeV at Fermilab and LHCb at CERN's LHC collider.

With reporting from Ariane Frey, CERN.

DONUT comes to neutrino town



The tell-tale sub-millimetre tracks left by tau particles (from tau neutrino interactions) in the DONUT emulsion detector at Fermilab.

DONUT spokesman Byron Lundberg, Fermilab, with the DONUT detector.

A neutrino experiment at Fermilab has seen the first direct evidence for the tau neutrino, the most elusive of the 12 particles that make up the Standard Model picture of the fundamental structure of matter.

Using the intense neutrino beam from Fermilab's Tevatron, the DONUT (Direct Observation of the Nu Tau) experiment has seen four examples of neutrinos producing slightly kinked tracks, the tell-tale sign that an unstable tau particle has been produced.

According to the Standard Model, all of the matter we know in nature can be explained in terms of six quarks – the ultimate constituents of nuclear matter – and six other particles (leptons). The quarks are arranged in three pairs – up and down, heavy strange and charm, and still heavier beauty and top. The six leptons are also arranged in three pairs – three electron-like particles; the electron, the muon and the tau; and three ghostly neutrinos – each associated with one of the electron-like particles.

The Standard Model quarks and leptons can thus be arranged in three "families" of four: the first contains the up and down quarks, the electron and the electron neutrino; the second contains the strange and charm quarks, the muon and the muon neutrino; and the third contains the beauty and top quarks and the tau and tau neutrino.

It has been known for a long time that the Standard Model contains these 12 particles, but initially not all of them had been seen. In 1995, experiments at Fermilab's Tevatron collider saw evidence for particles containing the long-awaited sixth "top" quark. Now, with the evidence for the tau neutrino, all of the direct evidence for the 12 particles is finally in place.

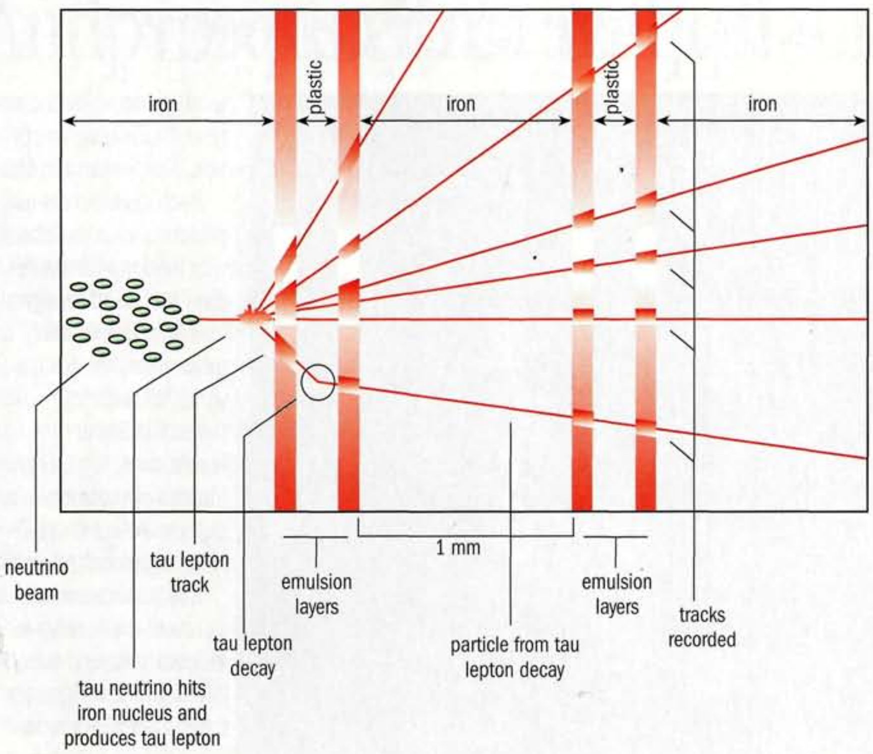
For the DONUT experiment, Fermilab's 800 GeV proton beam (effectively the highest energy in the world) is slammed into a huge target or "beam dump", which produces a dense fog of highly unstable secondary particles. One of these is a D meson, containing both strange and charmed quarks (the D_s particle), which can decay to produce tau neutrinos. (Conventionally, neutrinos are produced by the decay of secondary pions and kaons. However, with a beam dump, many of these are otherwise absorbed by the surrounding material before they have a chance to decay and produce neutrinos. The fraction of the neutrino content produced via other decays is therefore increased.)

After the beam dump, an obstacle course of magnets sweeps away charged particles, while thick shielding absorbs many of the rest. However, the ethereal neutrinos continue almost unaffected.

Downstream of the magnets and shielding is the DONUT detector, a sandwich of iron plates and photographic emulsion. In this target, one in a trillion tau neutrinos hits an iron plate, releasing an unstable tau lepton.

The tau leptons (which like the electron carry electric charge) leave a sub-millimetre track in the emulsion before decaying. The DONUT experiment set out to look for these tiny track stubs. Of the 100 or so tau neutrino collisions, just four track stubs have been unearthed so far. Isolating these signals from the mass of accumulated data is a triumph of painstaking analysis. Emulsion technology developed at Nagoya plays a major role in this work, and the Nagoya team handles DONUT's crucial emulsion analysis.

When CERN's LEP electron-positron collider came into operation in 1989, one of its first results was to show that particle decays allow for three, and only three, kinds of neutrino. The first of these had been seen by Clyde Cowan and Fred Reines in a reactor experiment in 1955, and for this the latter received the Nobel Prize for Physics in 1995 (Cowan died in 1974). In the 1950s, seeing the neutrino (in this case the electron-type particle) was con-



DONUT schematic: how to see the elusive tau neutrino. Of one trillion tau neutrinos crossing the DONUT detector, scientists expect about one to interact with an iron nucleus.

sidered a major accomplishment.

Soon the decay patterns of the muon suggested that the neutrino had to come in two different kinds, one preferring to associate with electrons, the other with muons. In 1962 an experimental team led by Leon Lederman, Mel Schwartz and Jack Steinberger at Brookhaven revealed muon tracks emerging from neutrino interactions. For this discovery the trio received the 1988 Nobel Prize.

In 1975 Martin Perl at the SPEAR electron-positron collider at SLAC, Stanford, discovered the third lepton, the tau. Before this discovery only two families of fundamental particles had been known. Perl's breakthrough suggested that there are three. For the tau discovery he was awarded the 1995 Nobel Prize, sharing it with neutrino pioneer Reines.

For the tau to fit into the picture it also had to be accompanied by its own neutrino. Physicists learned to live with the elusiveness of this particle, and could infer its existence directly. For example, in 1987 the UA1 experiment at CERN's proton-antiproton collider studied decays of the W particle, the electrically charged carrier of weak interactions, which was discovered at CERN four years previously. Setting to one side the W decays producing electrons and muons, they found 29 decays that could be designated as candidate decays producing a tau (and a tau neutrino). Although the neutrino could not be seen, energy-momentum accounting revealed "missing energy, showing that an invisible particle - the tau neutrino - had escaped in the W decays".

Tau physics, with the tau neutrino playing an essential but invisible role, went on to become a precision science in the hands of experiments at electron-positron colliders - LEP at CERN and CESR at Cornell (January p20).

The recent Chorus neutrino experiment at CERN also used Nagoya emulsion technology. This study (and the companion Nomad experiment) explicitly set out to look for the transformation of muon neutrinos into tau neutrinos (neutrino oscillations). These experiments used a conventional neutrino target rather than a beam dump. At the lower proton energies available at CERN, few D_s particles containing heavy quarks are produced directly. The experiments did not see any tau neutrinos, either through oscillations or via direct production.

DONUT is a collaboration between the US, Greece, Japan and Korea. For further DONUT information, see "http://fn872.fnal.gov/".

Energen has a winning plan

Energen magnetostrictive actuators - award-winning material.

Energen of Billerica, Massachusetts, has been selected as winner of the WPI Venture Forum's 7th Annual Business Plan Contest.

Energen's winning business plan details the company's strategy to provide high-force superconducting magnetic smart (magnetostrictive) actuators to the particle accelerator industry.

As a primary component of the radiofrequency cavity tuners in particle accelerators, Energen's actuators improve the accuracy of the particle beams and increase the reliability of the particle accelerators while reducing design and construction costs.

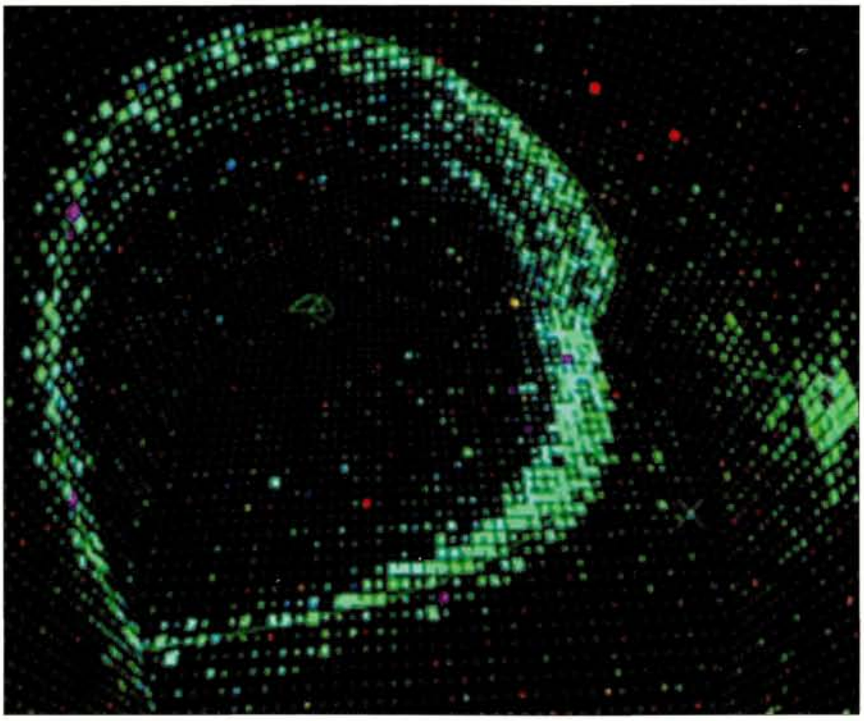
The WPI Venture Forum aims to promote and serve technology-based entrepreneurial activity and economic growth in the New England region of the US by increasing the business and financial knowledge of the participants through the sharing of experiences with entrepreneurs as well as with area business, financial and educational leaders.

The WPI Venture Forum's Business Plan Contest is an annual event open to all entrepreneurs in the New England area with business plans involving a technology-based venture.

Energen develops, manufactures and markets precision actuators based on magnetic smart materials technology for precision positioning, robotics and active vibration control.

More information about Energen is available at "http://www.energeninc.com".

Synthetic neutrinos appear to disappear



Typical neutrino event seen in the K2K long-distance neutrino beam experiment in Japan. Neutrinos generated by a proton beam at the Japanese KEK laboratory are directed towards the Superkamiokande underground detector 250 km away. In the detector, 22.5 kilotons of water are monitored by sensitive photomultipliers to pick up the tiny flashes of light produced by particle interactions in the target volume. Fewer neutrino counts are seen than expected, implying that something happens to the parent neutrinos en route.

Announced at the recent Neutrino 2000 meeting in Sudbury, Canada, were the first results from the K2K long-distance neutrino beam experiment in Japan. For the first time, synthetic neutrinos made in a physics laboratory are seen to disappear.

In the K2K study, neutrinos (of the muon-like variety) generated at the Japanese KEK laboratory are directed towards the Superkamiokande underground detector 250 km away. In the detector, 22.5 kT of water are monitored by sensitive photomultipliers to pick up the tiny flashes of light produced by particle interactions.

The experiment, which began running last year (October 1999 p5), was able to announce at Sudbury that 17 neutrino counts had been picked up. The pulses of parent protons at the source accelerator can be used to clock the arrival of the neutrinos, so the results are essentially free of spurious background.

About 29 neutrino counts were expected, assuming the neutrinos despatched from the KEK laboratory arrived unscathed at Superkamiokande. Such a deficiency, if it continues to be seen, implies that something happens to the particles along their 250 km flight path.

This is not a surprise. In 1998, initial results from Superkamiokande on muon signals generated by neutrinos produced via cosmic-ray collisions in the atmosphere showed that the signal from muon-like neutrinos arriving from the atmosphere directly above the detector was very different from the signal arriving from below.

This is not a result of absorption in the Earth – 99.9999...% of neutrinos pass through the Earth as though it were not there. The effect was interpreted as neutrino metamorphosis – "oscillations" – as the particles passed through the planet.

Neutrinos come in three varieties – electron, muon and tau – according to the particles that they are associated with. For a long time, physicists thought that these neutrino allegiances were immutable – a neutrino produced in an electron environment could remain an electron-like neutrino for ever.

However, this is only so if the neutrinos have no mass and travel at the speed of light. If the particles do have a tiny mass, they can, in principle, switch their electron/muon/tau allegiance en route. The 1998 atmospheric neutrino effects seen in Superkamiokande provided the first firm evidence for such neutrino oscillations. These Superkamiokande data have now been consolidated, while other evidence has also appeared.

With neutrino oscillations, neutrinos of a certain type are more likely to change into neutrinos of another type than to interact with matter. If the viewing detector is sensitive only to neutrinos of a certain type, then some neutrinos disappear from view.

Such neutrino disappearance also correlates with the long-observed dearth of neutrino signals from the Sun, where measurements using a variety of detectors (including Superkamiokande) give only a fraction of the number of expected electron-type solar neutrinos (July p17).

The Superkamiokande detector is sensitive to electron-like and muon-like neutrinos. However, if the parent KEK muon-like neutrinos change into tau-like neutrinos, Superkamiokande would not see them. This is the interpretation of the initial deficiency logged by the experiment in Japan. However, these are only the first results to appear from the K2K experiment, and it usually takes a long time to assemble reliable neutrino data.

The transmutation of muon-like into tau-like neutrinos is good news for long-distance neutrino experiments now under construction. The MINOS experiment in the US will send neutrinos 730 km from Fermilab to a detector in the Soudan mine, Minnesota, while neutrinos from CERN will be despatched towards new detectors in the Italian Gran Sasso underground laboratory, also 730 km distant (January p5). The detectors in these projects hope to pick up signs of tau-like neutrinos not present when the beams left the parent laboratories.

Because of the scant affinity of neutrinos for matter, intercepting them in a detector is always a challenge. The DONUT experiment at Fermilab recently presented possible evidence for the production of tau-like neutrinos in particle interactions (see p6).

The K2K experiment is a collaboration involving Japan, Korea and the US.

Antiprotons come with all the trappings

Installing the ATRAP experiment at CERN's antiproton decelerator. Trapping antiprotons using electromagnetic fields provides a cost-effective way of exploiting precious antiprotons.

Now coming into action for physics is CERN's new Antiproton Decelerator (AD), opening another chapter of CERN's tradition of physics with antiprotons. With the AD, the focus switches from exploiting beams of antiprotons to capturing the precious nuclear antiparticles.

When CERN's low-energy antiproton ring (LEAR) was closed in 1996 after more than 10 years of operation, it had supplied 1.3×10^{14} antiprotons – enough to supply about 10 000 particles to everyone on the planet, but representing a theoretical accumulation of only 0.2 ng of antimatter.

Although LEAR slowed down the particle beams supplied by CERN's antiproton factory from 26 GeV by a factor of about 10 (itself no mean feat), its antiprotons were nevertheless still moving extremely fast. A particle with 100 MeV momentum corresponds to a temperature of billions of degrees.

Of all LEAR's antiprotons, just a few were privileged to be selected and eventually cooled down to temperatures approaching absolute zero. The techniques learned in this work opened up substantial economies for antiparticles – probably one of the rarest, and therefore most expensive, commodities in the world.

Cooling antiprotons is a tricky business. They quickly annihilate with ordinary matter such as liquid helium, the conventional ultra-refrigeration medium. Instead, antiprotons have to be supercooled by a gas of electrons (negatively charged antiprotons can peacefully coexist with electrons).

In this way the TRAP Bonn–Harvard–Seoul collaboration was able to stack several thousand ultracold antiprotons at a time. Antiprotons cooled to such a low energy by the electrons were locked in a shallow trap using electric and magnetic fields to contain the valuable antiparticles. Meanwhile a large electromagnetic well was opened alongside to receive a fresh batch of antiprotons, which were then similarly cooled. The energies of the individual antiparticles were then just one ten-millionth of what they were in LEAR.

Interesting antiproton physics thus became feasible using a less ambitious antiproton source. This is the motivation behind CERN's new AD, which supplies antiprotons to several experiments – ATRAP (son of TRAP at LEAR), ATHENA and ASACUSA.

One ultimate physics objective at LEAR was to isolate a lone antiproton and study it carefully. Gradually reducing the electromagnetic "depth" of its snare, the TRAP team spilled out excess antiparticles until just a single antiproton survived.

Like any other captive electrically charged particle, an antiproton orbits in a magnetic field – the principle of the cyclotron. Comparing the frequencies of this rotation for an antiproton and a proton gives a direct comparison of the masses of the particle and its antiparticle.

The TRAP team at LEAR was able to ascertain that the proton and antiproton masses are equal with increasing precision, eventually to just one part in 10 billion. Making a measurement to such astonishing accuracy is equivalent to fixing the position of an obect on the surface of the Earth to within a few millimetres.

This is by far (a factor of a million) the most incisive comparison yet of proton and antiproton properties. According to the fundamental theorems of physics, a particle and an antiparticle should be exactly equal and opposite so that their scalar quantities, like mass, are the same, but quantum numbers, like electron charge, should have opposite signs.

The major objective of ATRAP and ATHENA at the new AD is to synthesize and study antihydrogen – the simplest electrically neutral atoms of antimatter, each made up of a positron orbiting a lone antiproton.

Antihydrogen was first produced by experiment PS210 at LEAR in 1995. Synthesizing atomic antimatter was a major achievement, but no measurements were made – the antihydrogen was too hot and dissociated quickly into its component positrons and antiprotons.

Using electromagnetic traps, ATRAP and ATHENA aim to collect supercold antihydrogen that can be stored for further study. Comparing the properties of this antihydrogen with hydrogen under the same conditions will provide a much more stringent test of whether matter and antimatter behave in exactly the same way.

ASACUSA uses antiprotons for collision and annihilation studies, particularly to form exotic atoms, in which the negatively charged antiproton is captured in a target atom, replacing the electron of everyday atoms.

Extreme cryogenics keeps LHC cool

When it comes into operation in 2005, CERN's Large Hadron Collider (LHC), which will use thousands of superconducting magnets operating at superfluid helium temperatures, will also be the largest cryogenic system of its kind in the world. The LHC has to operate below 2K to achieve the strong magnetic fields required to hold protons in orbit in the confines of CERN's existing 27 km tunnel. Supplying all of this liquid helium is a major cryo-engineering challenge.

One of three 112 m test cells for CERN's Large Hadron Collider (LHC) cryogenic distribution line (QRL). End-boxes close the interconnections that will eventually join QRL cells together and the service modules that will connect the QRL to the LHC's magnet cryostats. One service module is visible here at the near end of the test cell.

Pre-series test cells for the LHC cryogenic distribution line (QRL) went on test at the laboratory at the beginning of June. Made by three European industrial groups, the test cells have been produced following a 1995 decision to separate the accelerator's cryogenic distribution system from the magnet cryostats.

The original design for the LHC included the machine's cryogenic distribution system in the same cryostat as the magnets. This was abandoned in favour of the present solution to avoid unnecessary complexity for the magnet cryostats, their interconnections and the commissioning of the cryogenic system.

This choice had already been successfully adopted for the HERA collider at Germany's DESY laboratory. In the present system, eight cryogenic plants distributed over five access points around the LHC ring will feed the superconducting magnets via eight approximately 3.2 km long QRL sectors, each of which will operate independently.

Helium at different temperatures and pressures will be supplied to the magnets via service modules joining the accelerator's cryogenic components to the QRL every 107 m within the accelerator's bending arcs, a distance that corresponds to a single LHC cell of six dipole and two quadrupole magnets. Elsewhere the interconnections will be at varying distances.

Each of the three test cells currently being put through its paces at CERN is a section about 112 m long in which two service modules are joined by a pipe module made up of several straight pipe elements. Cryogenic supply infrastructure and a number of so-called end-boxes made at CERN complete the test set-up. Two end-boxes close the interconnections that will join units of the final cryogenic distribution line together. A further two cap the service modules where connections to the magnet cryostats will be made. The whole test set-up is extensively instrumented to allow the thermal and mechanical measurements necessary for the technical validation of the system to be made.

Owing to the huge scale of the LHC – some 25.6 km of cryogenic distribution line involving about 200 km of piping needing thousands of welds, around 3300 bellows and 1700 control valves at low temperature – a combination of precision stainless steel piping experience and cryogenics expertise is required from contractors.

Moreover, the finished system will not only be very large and technically challenging but will also be required to operate with unfailing reliability for 6600 h a year over the LHC's projected 20 year lifespan.

When a market survey was launched in 1996, the results revealed few companies with the relevant expertise in both areas, so industrial consortia were sought. Seven groups were invited to tender in 1997, five replied and three were retained. They are France's Air Liquide, the German consortium Linde-Babcock and a larger consortium headed by Switzerland's ABB Alstom Power (the other members are Nordon from France, Kraftanlagen Nukleartechnik, Messer Griesheim and Alcatel Kabel from Germany).

The LHC cryogenic team is careful to stress that the modules currently at CERN are pre-series test cells and not prototypes. The technology is known and the challenge is the large-scale series production of sophisticated cryogenic transfer line components to produce a reliable cryogenic distribution system.

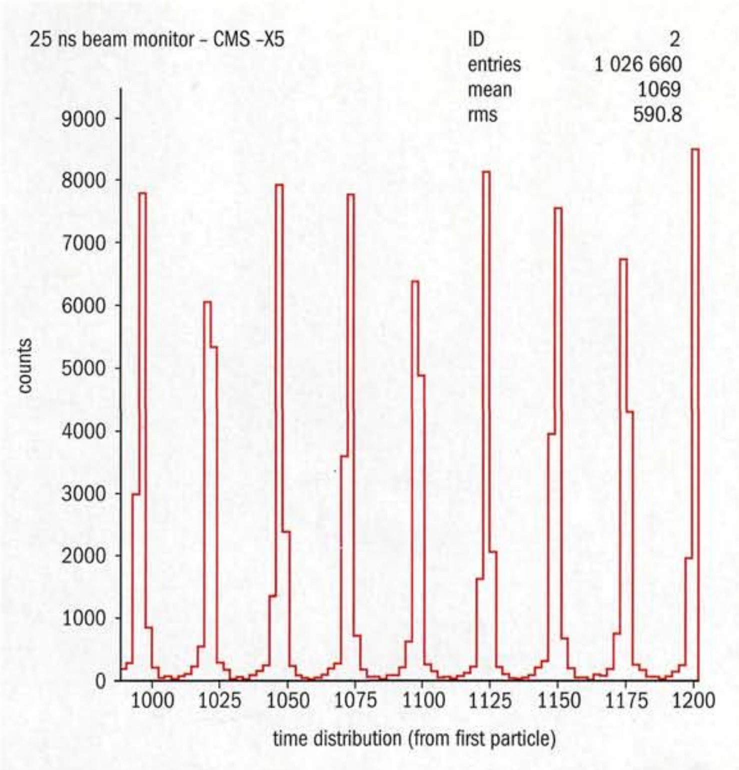
The QRL is four times as long as any existing system and requires the lowest heat inleak ever demanded. Altogether this makes stringent quality control a key issue. The three test cells at CERN are therefore being used not to demonstrate a completely new technology but to qualify the chosen design and test its thermal and mechanical performance before a final call to tender for full-scale production is launched.

A healthy spirit of competition is being maintained between the three suppliers, each of which will be bidding to build the eight sectors of the final system, or a share of it. Final contract adjudication is expected next year. Installation and commissioning of the cryogenic distribution line, which precedes installation of the magnets, is scheduled to run from mid-2002 until summer 2004.

First test beams are delivered for the LHC

The experiments being prepared for CERN's Large Hadron Collider (LHC) received their first beams in May and preliminary results are expected soon. No, the LHC, scheduled to begin operations in 2005, hasn't been brought forward by five years, but with LHC-type test beams being delivered from the SPS synchrotron, the project to upgrade CERN's existing accelerator complex to supply the LHC is well on course.

The upgrade was required because bunches of particles travelling around the LHC will be just 25 ns apart. This is a lot closer together than bunches in the Large Electron Positron (LEP) collider and has been chosen because the phenomena that LHC experiments will be looking for are extremely rare. A 25 ns bunch spacing will give the experiments as many collisions as possible without swamping them with data.



The collaboration for the CMS experiment at CERN's LHC collider used scintillators with fast read-out to measure the 40 MHz rate (25 ns bunch spacing) of CERN's newest test beam.

The Booster was the first of CERN's synchrotrons to be upgraded. It had its radiofrequency system changed and its maximum energy was "boosted" from 1 to 1.4 GeV to provide the high beam brightness required for the LHC.

With a beam energy of 26 GeV, the veteran Proton Synchrotron (PS) is the best place to group particles into short intense bunches before sending them on to the larger accelerators. This is done using new radiofrequency cavities. A cavity operating at 40 MHz produces bunches spaced by 25 ns by applying a rapid change in voltage.

Bunch lengths are also measured in nanoseconds – the time it takes a bunch to pass a fixed point – and this procedure squeezes the bunches down to just 10 ns. If every note in Beethoven's *Fifth Symphony* were that short, the music would be over in a fraction of a second. Nevertheless, it is still not short enough because the next accelerator in the CERN chain, the Super Proton Synchrotron (SPS), operates at 200 not 40 MHz. This means that SPS bunches must be 5 ns long at the most; 10 ns bunches from the PS would be too long.

To overcome this problem, more particle gymnastics are performed by the 40 MHz cavities working together with more new cavities operating at 80 MHz. This squeezes the bunches to less than 5 ns – short enough to transfer into the SPS.

The new 40 and 80 MHz cavities for the PS are one of the first joint ventures resulting from the Canadian contribution to the LHC. Essential elements of the cavities were built in collaboration with the Canadian TRIUMF laboratory. Their installation began in 1996 and the PS was ready to hand over its first LHC-type beams to the SPS in 1997. Two years of fine-tuning and optimization ensued to prepare realistic test beams for the LHC experiments.

The PS celebrated its 40th birthday in 1999 and, to mark the occasion, an optimized LHC-type beam was accelerated and handed over to the SPS on 27 October. That provided the cue for the SPS team to ready itself for the LHC. With modifications to the PS being tailored to fitting in with the existing configuration of the SPS, the modifications to the larger machine were less extensive.

By the end of the year an LHC-type beam had been steered around the SPS and extracted towards the tunnel that will eventually take beams into the LHC. By May this year the SPS was ready to provide its first LHC-type test beams for the experiments.

The goal of this year's tests, carried out by the ATLAS, CMS and LHCb experiment collaborations, was to test electronics and detector prototypes in realistic LHC conditions – a milestone required by the LHC committee. The ALICE collaboration, whose lead-ion beams will come together at the relatively sedate rate of once every 125 ns, did not use the new test beam.

ATLAS tested its semiconductor (SCT) and pixel trackers, and its transition radiation tracker (TRT) systems. CMS tested its silicon tracker and its resistive plate chamber (RPC) muon trigger system. LHCb tested its fast (40 MHz) front-end electronics read-out system based on the response of its calorimeter.

All three experiments report encouraging preliminary results. The ATLAS SCT group, for example, used the tests to investigate the efficiency of its electronics at associating hits in the detector with the correct beam bunch, and to see how well the electronics could keep track of hits from several bunches in the electronics pipeline at the same time.

CMS took the opportunity to test prototype silicon tracker modules with the full electronics read-out chain. The results showed that the detector and electronics are up to the task of operating under the stringent timing constraints imposed by the LHC's 40 MHz bunch-crossing frequency. The LHCb system also proved itself capable of distinguishing clearly between adjacent bunches.

More LHC-type test beam running is foreseen for the coming years, with the goal of testing final electronics and several sub-detector prototypes together.

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PHYSICSWATCH

Edited by Alison Wright

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The hole truth comes to the surface

A group of physicists from Germany, Spain and the UK have solved a long-standing problem in surface science – namely the discrepancy between experimental and theoretical values for the lifetimes of "holes" in metal surfaces. The holes are left when electrons are excited to higher energy bands in the surface. Until now the experimental data and theoretical predictions differed by as much as a factor of seven.

In fact, the researchers have improved both the experiment and the theory. Previous data from photoelectron spectroscopy could not take account of defects in the metal surface, which are known to reduce lifetimes by coupling the surface state electrons to bulk states in the metal.

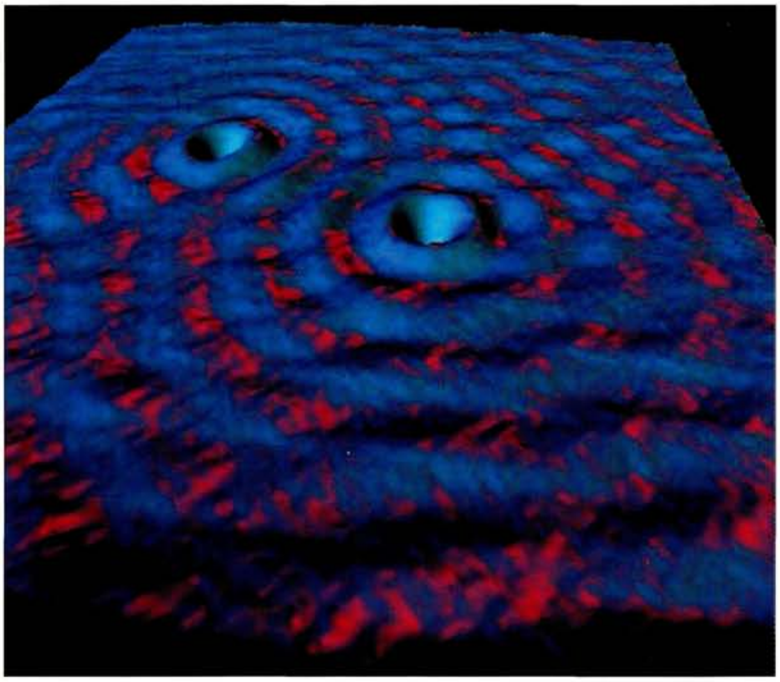


Image from a scanning tunnelling microscope, revealing two point defects on a copper (111) surface. The defects (possibly impurity atoms) scatter the surface state electrons, thereby causing circular standing wave patterns. (IBM.)

The group's new set-up uses a scanning tunnelling microscope (STM) operating at 4.6 K, which first identifies a defect-free area of the metal surface (silver, gold or copper). Then the tungsten tip of the STM measures the differential conductance (dI/dV) within that region, effectively measuring the density of electronic states at the surface. A steep rise in dI/dV indicates the presence of surface states and the hole lifetime for the metal can be directly calculated from the width of this onset.

Meanwhile the researchers also set about refining the theoretical description. Two processes limit the lifetime of holes: coupling between electrons and phonons (quantized vibrations of the metal lattice), and inelastic electron–electron scattering. Previous estimates of the latter assumed that the holes would be filled by interband transitions involving bulk electrons near the surface – a "three-dimensional" decay channel. However, the new treatment takes account of surface effects as well as band structure – the competing "two-dimensional" intraband transition significantly increases the contribution from electron–electron scattering.

The new calculations are in good agreement with the STM data. "For the first time," said the researchers, "a consistent account is found for hole lifetimes." They expect to extend their approach to studying adsorbed atoms, alloys and thin films, thereby promising new insight into surface and interface electronic structure.

How to tell left from right

Physicists and chemists are familiar with the concept of chirality or "handedness". The influence of chirality is also felt in biology, where scientists have long sought to discover the reason why the amino acids that make up the proteins in the human body are all left-handed. A new clue to the "homochirality" of life has now been offered by researchers in Grenoble.

Following a prediction in 1982, the team were the first to demonstrate, in 1997, the phenomenon of magnetochiral dichroism, whereby light is absorbed differently by a solution of chiral molecules according to whether the light beam travels parallel or antiparallel with an external magnetic field. The difference in absorption is independent of the polarization of the light and works even with unpolarized light. The effect represents a subtle interplay of the natural optical activity of chiral molecules and the induced magnetic optical activity.

Now the researchers have exploited their discovery to bias a chemical process in favour of one of two mirror-image products (left- or right-handed molecules, called enantiomers). They studied a complex chiral molecule that spontaneously disassociates and re-associates in solution: at equilibrium there are always equal amounts of left-handed and right-handed molecules. If the sample is illuminated, the rate of disassociation increases. Unpolarized laser light travelling parallel with an applied magnetic field produced and maintained an excess of one enantiomer in the solution. Reversing the magnetic field direction produced an equal concentration of the mirror-image enantiomer.

Now the definition of chirality goes beyond the original static mirror-image idea of Kelvin to allow for motion-dependent effects. Magnetochirality is therefore akin to polarized light and the electroweak interaction in its ability to select a certain handedness, and it thus merits consideration as an explanation for homochirality. *Nature*

Palimpsest returns

The *Archimedes Palimpsest* has re-appeared. This 10th-century manuscript bears seven works by Archimedes, in particular the only known rendition of "Method", in which Archimedes outlines his procedure for using physics to derive mathematical results. In the 12th century, parsimonious Greek monks recycled the paper and wrote the text of a prayer book over the original.

Only in 1906 was the significance of the document realized. The manuscript disappeared in the aftermath of the First World War and resurfaced in 1998, when it was sold at auction for $2 million. The palimpsest has now been made available for research and publication. *Physics Today*

A section of Archimedes's treatise On Floating Bodies *(vertical) is barely visible beneath the 12th-century text of the prayer book (horizontal). (© Christie's Images, New York.)*

Cricket chirp rate indicates temperature

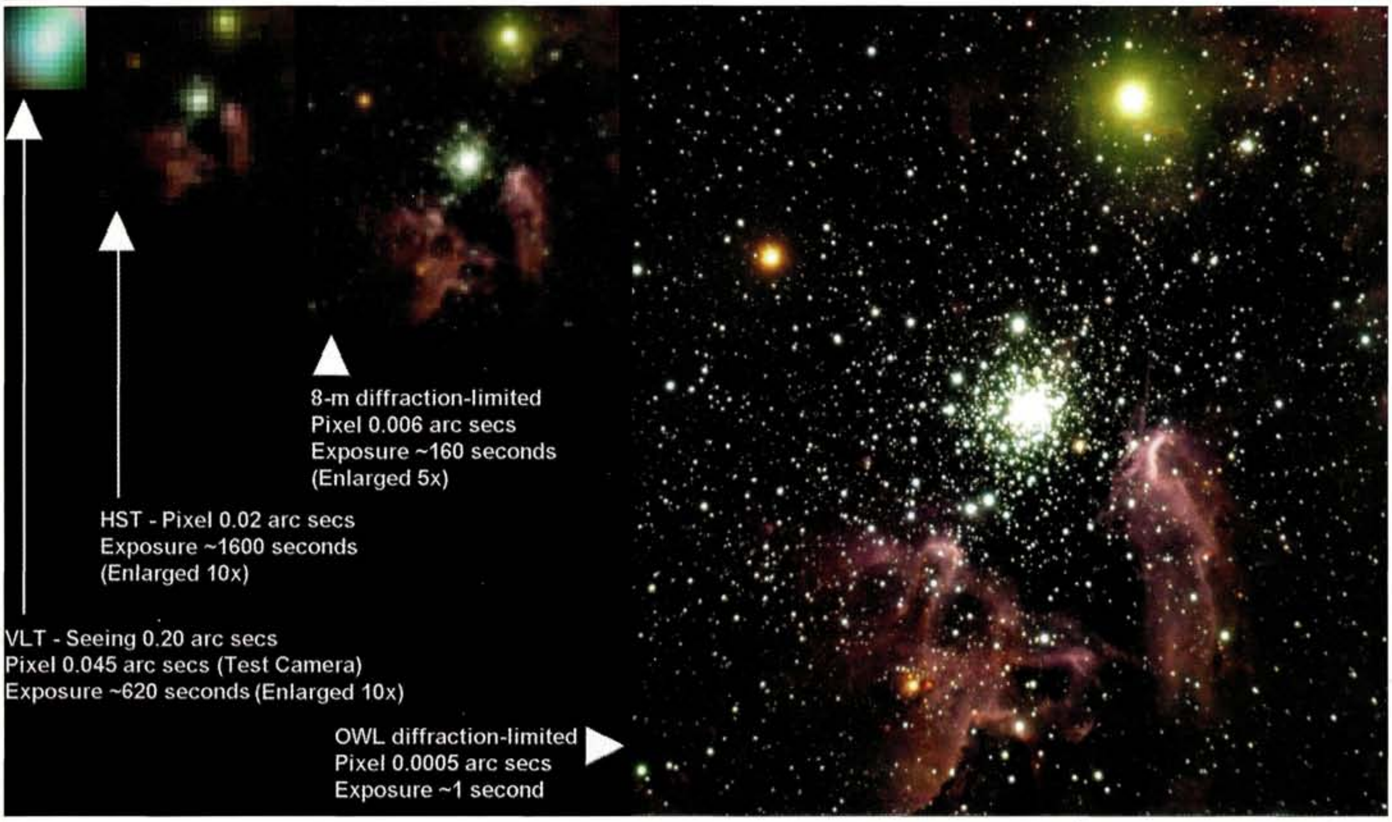
As autumn approaches, take advantage of the balmy evenings to measure the atmospheric temperature from cricket song. Count the number of chirps a minute, add 50 and divide by 9 to get the ambient temperature in degrees celsius. Tests with the Snowy Tree Cricket *Oecanthus fultoni* suggest that the chirp rate is regulated by the insect's metabolism, which is related to its absolute temperature by the Arrhenius equation, deduced in 1889 by the Swedish chemist of the same name. *New Scientist*

Matrix makes total transformation

A loss-less transformer could be the result of research in the Barcelona Xerox Laboratory. Researchers have prepared a new nanocomposite material, composed of 5–10 nm crystals of iron oxide dispersed in a polymer matrix. Usually this solid displays magnetic behaviour just like any other nanoscopic magnetic material. However, by subjecting the material to a special annealing process using alternating magnetic fields, its magnetic characteristics are changed significantly.

Testing the magnetization of the sample with varying magnetic field and temperature revealed that the magnetic nanoparticles inside the polymer matrix can rotate completely freely in response to an applied magnetic field – with no friction, no hysteresis and almost no magnetic or electrical losses. This lightweight, insulating material is also expected to have novel acoustic thermal and optical properties. *AIP*

Edited by Emma Sanders



The OWL telescope would give much better resolution than the Hubble Space Telescope or the Very Large Telescope. (NASA/ESA/ESO.)

The future looks bright

A new class of extremely large telescope is on the drawing board. The European Southern Observatory (ESO) is funding a feasibility study for a ground-based, fully steerable, 100 m optical telescope christened OWL (Over-Whelmingly Large) for its keen night vision.

The project, the brainchild of ESO astronomer Roberto Gilmozzi, uses segmented primary and secondary mirrors and integrated active optics. "OWL owes much of its design characteristics to features of existing telescopes," said ESO engineer Philippe Dierickx.

Indeed, recent breakthroughs in cost-effective optics and mechanical support structures, together with the knowledge gained of active optical control (e.g. at the VLT, Gemini and Subaru), have encouraged astronomers to dream of bigger things.

A 100 m telescope would mean major advances. Imagine measuring the Hubble constant unencumbered by local effects. OWL could measure "standard candles", such as Cepheid variables, as far away as the Virgo cluster; supernovae could be seen up to a redshift of 10 and beyond; and with a large light-collecting area, observations of rapidly varying sources become possible and faint objects, such as planets, can be imaged directly. There is even talk of looking for planetary biospheres.

However, the OWL study is still in an early phase. ESO's activities are currently focused on the completion of the Very Large Telescope and the ALMA project – an array of submillimetre antennae to be installed on Chajnantor in the Chilean Altiplano. "OWL could materialize at the horizon beyond ALMA," said Dierickx. "There is indeed very strong interest in the scientific community to pursue efforts towards such extremely large ground-based telescopes." Current estimates suggest that OWL would cost around a thousand million Euros with a construction time of 11–12 years.

Pulsars are looking their age

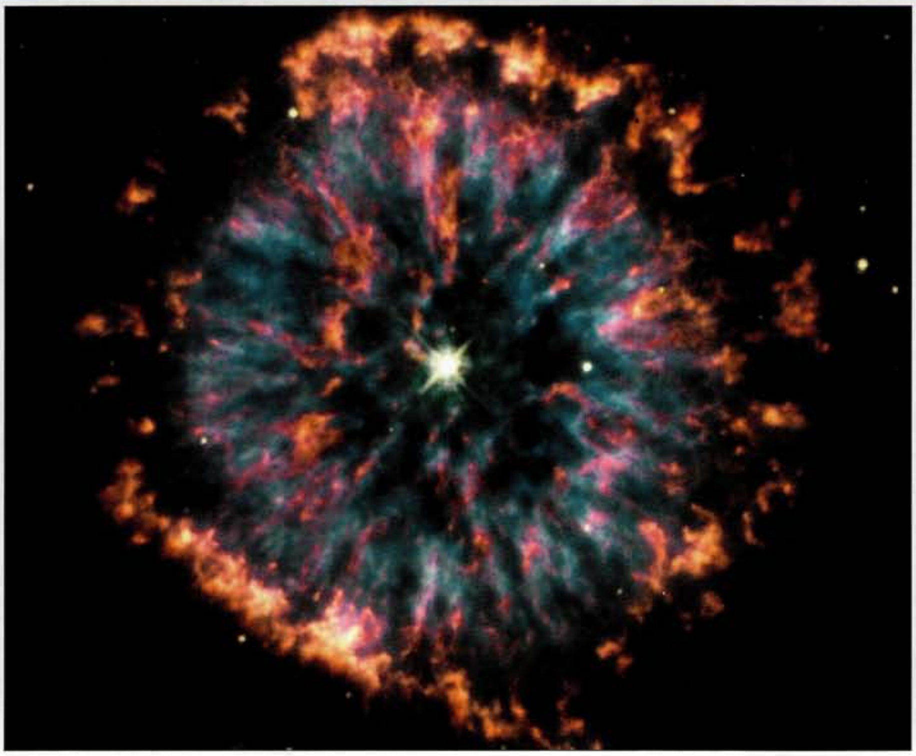
New pulsar observations could lead to a drastic reappraisal of pulsar ages and evolution.

Pulsars, which "blink" regularly like powerful cosmic lighthouses in the depths of galaxies, are understood to be caused by beamed emission from rapidly spinning neutron stars, born in supernova explosions. If so, a pulsar would be expected to be accompanied by other remnants of the explosion.

As pulsars blast out tremendous amounts of energy, their observed pulse rate gradually slows down, and this "spindown" is used to determine the pulsar's age. However, one paradox is that these age estimates do not always tie in with the ages of their associated supernova remnants.

Now new observations by Gaensler (MIT) and Frail (US National Radio Astronomy Observatory) of the motion of Galactic pulsar B1757-24, relative to its physically associated supernova remnant, show that this pulsar, 15 000 light years away, is about 10 times as mature as would be expected simply from its observed spindown rate.

Picture of the month



This cloud of gas was ejected several thousand years ago from the hot star visible in the centre. The loss of the star's outer, gaseous layers exposes the hot stellar core. The strong ultraviolet radiation from the core makes the ejected gas fluoresce in a so-called planetary nebula. This image of planetary nebula NGC 6751 was taken using the Hubble Space Telescope. Blue regions mark the hottest glowing gas. Our own Sun is predicted to eject its planetary nebula some 6 billion years from now. (NASA/ESA.)

XMM-Newton measures the hot universe

A new generation of X-ray observatories is under way to study the hottest parts of the observable universe. Among them the European Space Agency's X-ray Multi-Mirror Mission (XMM – now named XMM-Newton) will play a key role.

A universe made of silent stars and galaxies peacefully drifting through the vast emptiness of space and time – the awe-inspiring view through an optical astronomical telescope has, over recent years, been enlarged by impressions of a much more violent and dynamic universe: that of extremely hot plasmas and high-energy particles.

Ever since the first X-ray telescopes succeeded in observing astrophysical objects above the blanket of the atmosphere, they have found ubiquitous plasmas at temperatures above a million degrees, often accompanied by particles (electrons and ions) in the mega-electronvolt range and higher. In most cases the origin of the large amount of energy, often released in explosive events, is unknown. The considerable diagnostic power of these processes deserves detailed study and has been the motive for several space missions for a quarter of a century.

X-ray observatory: artist's view of XMM-Newton in orbit. The openings on the front are the three mirror systems; the detector systems are located at the far end. The satellite is almost 11 m long, with a total solar-panel wingspan of 16 m. (ESA.)

The Einstein and EXOSAT satellites were among the pioneers in the 1970s and 1980s, revealing a great variety of cosmic X-ray sources. The ROSAT satellite, together with a few further missions launched in the 1990s, provided the first comprehensive view of X-ray phenomena in the universe, detecting more than 150 000 sources across the sky. So far we know of X-ray emission from stellar atmospheres (such as the Sun), star-forming regions, accreting neutron stars and black hole environments, supernova remnants, the interstellar gas, external galaxies and gas in galaxy clusters. Quite unexpectedly, even small brown dwarf stars, planets and the envelopes of icy comets have recently been added to the list of prolific X-ray emitters.

What has been missing in X-ray astronomy is a class of major observatories, equivalent to the Hubble Space Telescope. Such missions, conceived in the 1980s with great foresight, are now in orbit for the first time. NASA's Chandra X-ray observatory was successfully launched in July 1999 and has already sent back a series of breathtaking pictures and spectra. The European Space Agency's (ESA) X-ray Multi-Mirror Mission (XMM) followed on 10 December 1999 with a picture-perfect launch on an Ariane 5 rocket (January p13).

A new view of the X-ray universe

Both missions will reach new frontiers. For the first time, high-resolution spectroscopy is routinely performed in the X-ray range. Chandra's fine mirror optics increase the image sharpness by a factor of 10 over the best previous missions, with an angular ▷

resolution (0.5 arcseconds), thus competing with large ground-based optical telescopes.

XMM's strength, in contrast, is its vast collecting area and therefore its sensitivity to both imaging and high-resolution spectroscopy. This is possible thanks to new technologies in mirror fabrication. In contrast with optical light, X-rays are focused through hollow hyperbolic/parabolic mirror shells by grazing reflection at the entrance of the telescope. Instead of using one or a few such mirrors (four in Chandra's case), XMM carries three telescopes, each consisting of 58 concentrically nested mirrors that provide more collecting area than all previous X-ray satellites added together (July 1999 p13).

The three telescopes observe in parallel so that three independent imaging charge-coupled device (CCD) European photon imaging cameras (EPIC) and two reflection grating spectrometers (RGS) can be fed simultaneously. These detectors are located at the far end of the telescope, approximately 7.5 m from the mirrors.

A further unique advantage of XMM is its complementary optical telescope that, despite its small diameter of 30 cm, competes with large ground-based telescopes in its brightness limits. It addresses important scientific questions, because many high-energy sources emit not only X-rays but also ultraviolet and optical photons after reprocessing within the source.

Altogether, XMM is a huge observatory measuring more than 10 m in length and 4 m in diameter, and weighing nearly 4 tons. It constitutes the largest scientific satellite that ESA has ever built and is one of the key projects of Europe's astrophysics science programme.

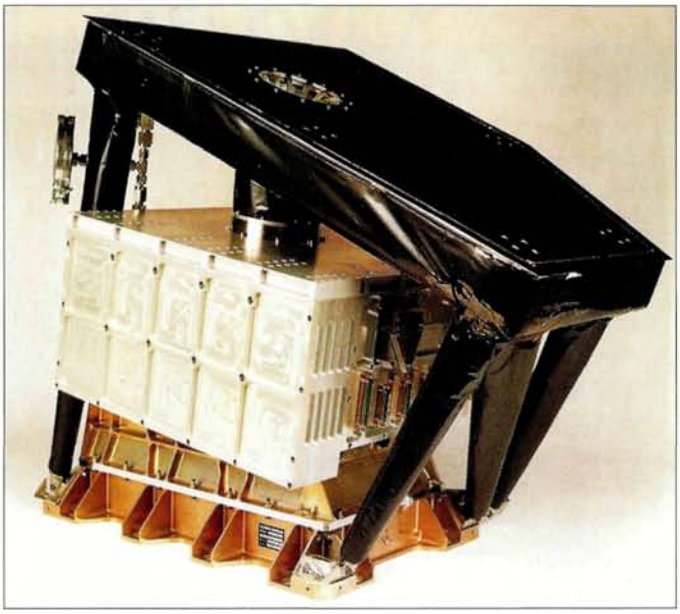
Novel X-ray instrumentation

All XMM detectors are based on CCDs. These not only allow for fine imaging with the EPIC cameras but also provide sufficient intrinsic energy resolution in the X-ray range to resolve broad spectral features and to model plasma temperatures and chemical abundances across the field of view. The latter is approximately 30 arcminutes in diameter (about the diameter of the full moon), which is ideal for the efficient mapping of large astrophysical structures (e.g. star-forming regions or supernova remnants). One of the cameras (the so-called EPIC pn) has been optimized for extremely rapid read-out through new technology down to a time resolution of 30 μs.

The converging X-rays from two of the three mirror systems pass through a reflection grating assembly – a system of numerous thin-grooved plates that disperse half of the incoming light into a high-resolution spectrum. The latter is then recorded by a CCD strip within the RGS detector system. The CCDs are cooled to –80 °C for optimum operation.

Dispersive systems such as the RGS are ideal for isolated point sources (e.g. stars and quasars), although some of the convolution between source geometry and spectral energy distribution can be disentangled through the modelling of extended sources as well. The energy resolution ($E/\Delta E$) of the RGS detectors reaches 800 – sufficient to separate all important atomic emission lines in the range of sensitivity (0.35–2.5 keV), in particular the lines of the iron L-shell. The EPIC cameras will complement the spectroscopy up to 15 keV, albeit with much lower resolution.

The combination of the X-ray and optical/ultraviolet detectors with various filters makes XMM an efficient multiwavelength observatory that simultaneously obtains X-ray images with moderate energy resolution, high-resolution X-ray spectra of selected objects within the field of view, and a variety of optical and ultraviolet photometric and spectroscopic measurements, all with fine time resolution.



One of XMM's two reflecting grating spectrometer (RGS) modules. The prominent dark radiator is mounted on the detector box. (ESA/ESTEC.)

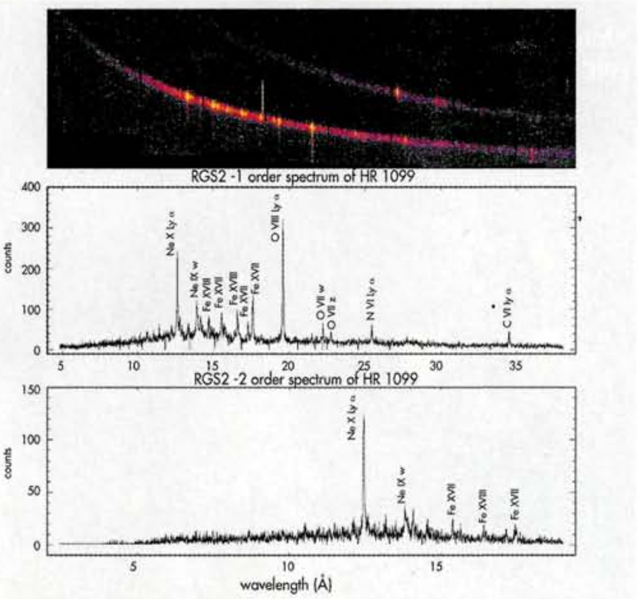
Astrophysical X-ray spectroscopy is a relatively new field that nevertheless provides the key for the understanding of many hot cosmic sources. Optically thin plasmas, with temperatures exceeding a million degrees, radiate much of their energy in spectral lines due to atomic transitions in trace elements such as carbon, nitrogen, oxygen, neon, magnesium, silicon, sulphur and, in particular, iron.

Plasma probes

These emission lines are excellent diagnostic probes of the plasma conditions. Their strengths and ratios can be used to deduce temperatures, chemical abundances and emission characteristics. "Forbidden" lines of highly ionized helium-like ions contain information about electron densities and are therefore used to deduce plasma pressure. The RGS spectral resolution is also sufficient to allow the observation of plasma motion or turbulence through wavelength shifts or line broadening, when the velocities exceed 100–200 km/s – quite common in astrophysical plasmas. Absorption features and continua provide further information on the state of the plasma.

XMM has been designed to address a range of astrophysical problems, including:

- the origin of cometary X-rays, possibly related to fluorescence or scattering of solar light;
- coronal heating in magnetic stellar atmospheres and of magnetic fields on low-mass brown dwarfs;
- the importance of magnetic accretion to spin-down of young stars and to the ionization of their immediate environments;
- the determination of the metallicity (composition), distribution



"First light" RGS spectra of the magnetically active binary star HR 1099. Top: intensity is plotted as a function of wavelength (x-axis) and photon energy detected by the CCD (y-axis). The lower band contains the first-order spectrum and the upper the second-order spectrum. Middle: extracted first-order spectrum showing emission lines of various iron, oxygen, carbon and nitrogen charge states. Bottom: second-order spectrum. (ESA.)

and energy budget of the hot interstellar gas with implications for galactic evolution;

- the spatial and spectral study of supernova remnants to understand the chemical evolution in their progenitors, the expansion of their shells into the interstellar space and therefore the chemical enrichment of the galaxy;
- the measurement of accretion phenomena on neutron stars and towards black holes in binary systems to infer the geometry of these systems or the role of magnetic fields;
- the observation of direct and reprocessed radiation from accretion disks around massive nuclei of active galaxies;
- the measurement of the radial variations of the density, temperature and metallicity of the gas in galaxy clusters, to deduce their mass composition and to study elemental enrichment due to supernova ejecta.

Using XMM's capabilities

Unravelling the mysteries of cosmic sources often requires us to disentangle a variety of parallel processes; the luxury of well defined physical states familiar to laboratory physicists is rarely available. In a good example of this complexity, the heating of cosmic plasmas is poorly understood, even if large source samples are at hand. Almost half of the observed X-ray sources are stars that are surrounded by magnetically enclosed, structured and highly dynamic atmospheres (coronae) heated to several million degrees. The heating mechanism is unknown, but it may be related to explosive energy releases – so-called flares – that transform free magnetic energy into heat.

A popular theory holds that unstable magnetic fields reconnect and accelerate electrons and ions. The particles travel along the magnetic field lines towards the denser but much cooler gases near the stellar surface. Collisions with the ambient cool gas provide signatures of non-thermal X-rays, perhaps marginally detectable by the sensitive EPIC cameras at 15 keV. Subsequent prompt heating of the cool layers produces a first light flash in the ultraviolet regime – the domain of the XMM optical monitor – thus providing an important measure of the energy and of the involved surface area.

As the high-energy particles lose their energy in the target through thermalization, a rapid temperature increase to tens of millions of degrees makes the plasma radiate X-rays, and new diagnostic emission lines show up in the RGS. The time profile, sensitively recorded by the EPIC cameras, depends on the incoming energy, radiative losses and conductive losses. The pressure build-up drives the plasma along the magnetic field lines away from the star at approximately the speed of sound. Spectral lines become Doppler-shifted in the early phase, or broadened through turbulence – signatures that may become measurable in the RGS spectra.

Fractionation of elements (elements with a low first ionization potential appear to be preferentially lifted into the atmosphere) can now be determined through ratios of lines from the different elements available from X-ray spectroscopy.

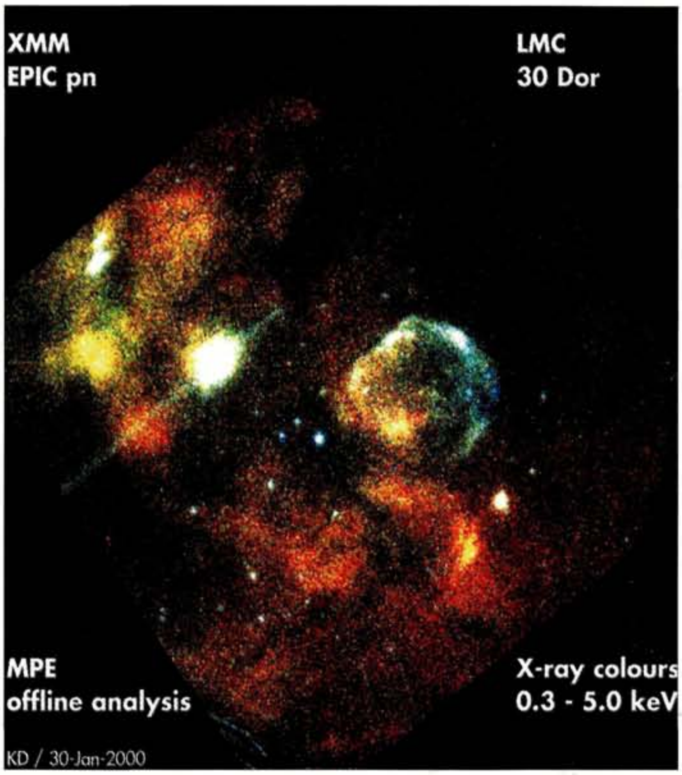
As the pressure in the closed magnetic fields builds up, forbidden atomic lines become suppressed: several of the easily observable lines in the high-resolution spectra thus provide ideal barometers. Rapid heating may drive the plasma out of ionization equilibrium for some time, and cooling plasma may eventually absorb some of the X-ray emission. Again, spectroscopy provides unequivocal information about such processes.

Powerful tool

Given that only simplistic models are to hand and many details are not yet understood, the combined analysis of all datasets will provide a powerful tool to refine models and to help us to understand cosmic plasmas. Solving the mysteries in the above example alone would help greatly in the understanding of explosive plasma heating mechanisms in many astrophysical sources. It would also help to reveal the source of solar and stellar winds (of importance to the understanding of solar-terrestrial physics), which are pivotal in star formation and stellar evolution. In addition it would help us to understand the physics of mass accretion from accretion discs to forming stars, explain parts of the diffuse X-ray background seen in our, and external, galaxies, and perhaps even contribute to a modelling of the origin of low-energy cosmic rays. In-depth observations of many other types of object will further contribute to our understanding of the high-energy universe.

XMM science observations are organized mainly in two sections:

- Guaranteed Time has been allocated for the instrument Co-Investigator research institutes. This provides a unique opportunity for these institutes to define large, fundamental astrophysical projects within international expert teams. It also guarantees an appropriate scientific return for the instrument-contributing institutes and countries.
- The Guest Observer Programme for the first two years is the ▷



This "first light" X-ray image made with the EPIC camera onboard XMM-Newton shows a star-formation region in the Large Magellanic Cloud (a companion galaxy to the Milky Way) where new stars are being born. Also visible are remnants of supernova explosions (centre and upper left). (ESA.)

outcome of projects submitted by astronomers worldwide and selected in the autumn of 1999 by expert panels. It contains typically shorter projects to be worked out later by the proposing teams.

XMM's launch on board the fourth Ariane 5 was a great success for both the Ariane programme and for XMM. After a flawless countdown, a precise launch carried XMM into a high orbit with a period of 48 h. The orbit injection was so accurate that enough fuel was left on board to extend XMM's lifetime by up to 20 years.

An extensive commissioning phase culminated in the release of the first pictures and spectra on 9 February as a foretaste of more science to come. On the same day XMM was renamed XMM-Newton, in honour of the great physicist and inventor of spectroscopy, a science that has now made its way into X-ray astrophysics.

Manuel Güdel, *Paul Scherrer Institute.*

• *The Swiss Paul Scherrer Institute (PSI) is one of the Instrument Co-Investigator institutes for the reflection grating spectrometer, together with the Mullard Space Science Laboratory (MSSL), UK, and Columbia University, under the leadership of the Space Research Organization of the Netherlands. Dr Güdel is also observing principal investigator of several observing programmes in the Guaranteed and Guest Observer sections, to be undertaken with these instruments, and devoted to magnetized stellar plasmas and hot stellar winds, including star-formation regions.*

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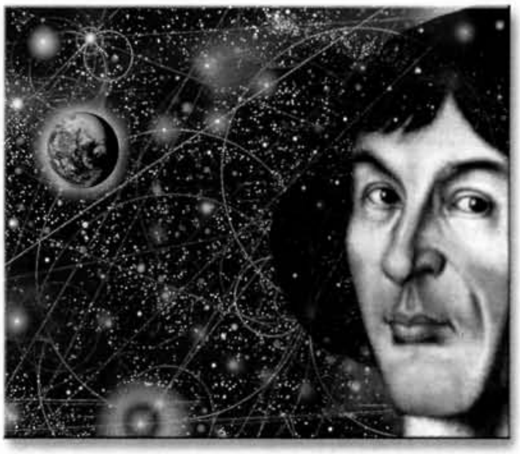

It is the second time when I have the honour and pleasure to announce the opening at CERN of the exhibition of the Polish industry and technology oriented towards the CERN programmes. Through this exhibition we try to demonstrate the ability of Polish firms to meet the standards required by CERN projects and to prove that the industry in our country is aware of innovative role of CERN and its scientific programmes in the field of modern technologies.

Prof. Jerzy Niewodniczański *- President, National Atomic Energy Agency*

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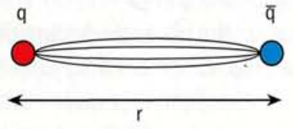
THE EXHIBITION IS ORGANIZED UNDER THE AUSPICES OF THE NATIONAL ATOMIC ENERGY AGENCY.

Mapping quark confinement by exotic particles

According to our increasing understanding of quark physics, more kinds of particle should exist than are currently known. New experiments at the Jefferson Laboratory are setting out to search for these particles.

In the early 1970s, evidence that the masses of strongly interacting particles increased with their internal angular momentum led the Japanese theorist Yoichiro Nambu to propose that the quarks inside these particles are "tied" together by strings. Today the string theories that emerged from this idea are being examined as candidates for the ultimate theory of nature.



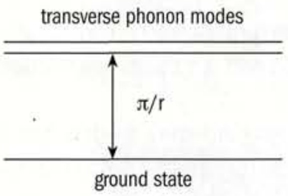


Fig. 1. (left) In quantum chromodynamics, a confining flux tube forms between distant static charges. This leads to quark confinement – the potential energy between (in this case) a quark and an antiquark increases linearly with the distance between them. Fig. 2. (right) Model-independent spectrum of the glue (flux tube) of figure 1. r is the quark–antiquark separation.

Meanwhile, we have learned that the strong interactions are instead described by quantum chromodynamics (QCD), the field theory in which quarks interact through a "colour" force carried by gluons. Although it is therefore not fundamentally a string theory, numerical simulations of QCD ("lattice QCD"; July p23) have demonstrated that Nambu's conjecture was essentially correct: in chromodynamics, a string-like chromoelectric flux tube forms between distant static colour charges. This leads to quark confinement – the potential energy between a quark and the other quarks to which it is tied increases linearly with the distance between them. The phenomenon of confinement is the most novel and spectacular prediction of QCD – unlike anything seen before.

The ideal experimental test of this new feature of QCD would be to study the flux tube of figure 1 directly by anchoring a quark and antiquark several femtometres apart and examining the flux tube between them. In such ideal circumstances, one of the characteristics of the gluonic flux tube would be the model-independent spectrum shown in figure 2. The excitation energy is π/r because the flux tube's mass is entirely due to its stored energy. There are two initially excited longest wavelength vibrations with identical energies because the motion of the flux tube is in the two symmetrical dimensions perpendicular to its length.

Particles with gluons

Such a direct examination of the flux tube is, of course, not possible, so in reality we must be content with systems in which the quarks move. Fortunately we know both from general principles and from lattice QCD that an approximation to the dynamics of the full system that ignores the impact of these two forms of motion on each other works quite well – at least down to the mass of the charm quark.

To extend the flux tube picture to yet lighter quarks, requires models, but the most important properties of this system are determined by the model-independent features described above. In particular, in a mass region around 2 GeV/c^2 a new kind of particle must exist in which the gluonic degree of freedom of mesons is excited.

The smoking gun characteristic of these new states is that the vibrational quantum numbers of the string, when added to those of the quarks, can produce a total angular momentum, J, a total parity (or mirror-inversion symmetry), P, and a total charge conjugation (or quark–antiquark interchange) symmetry, C, not allowed for ▷

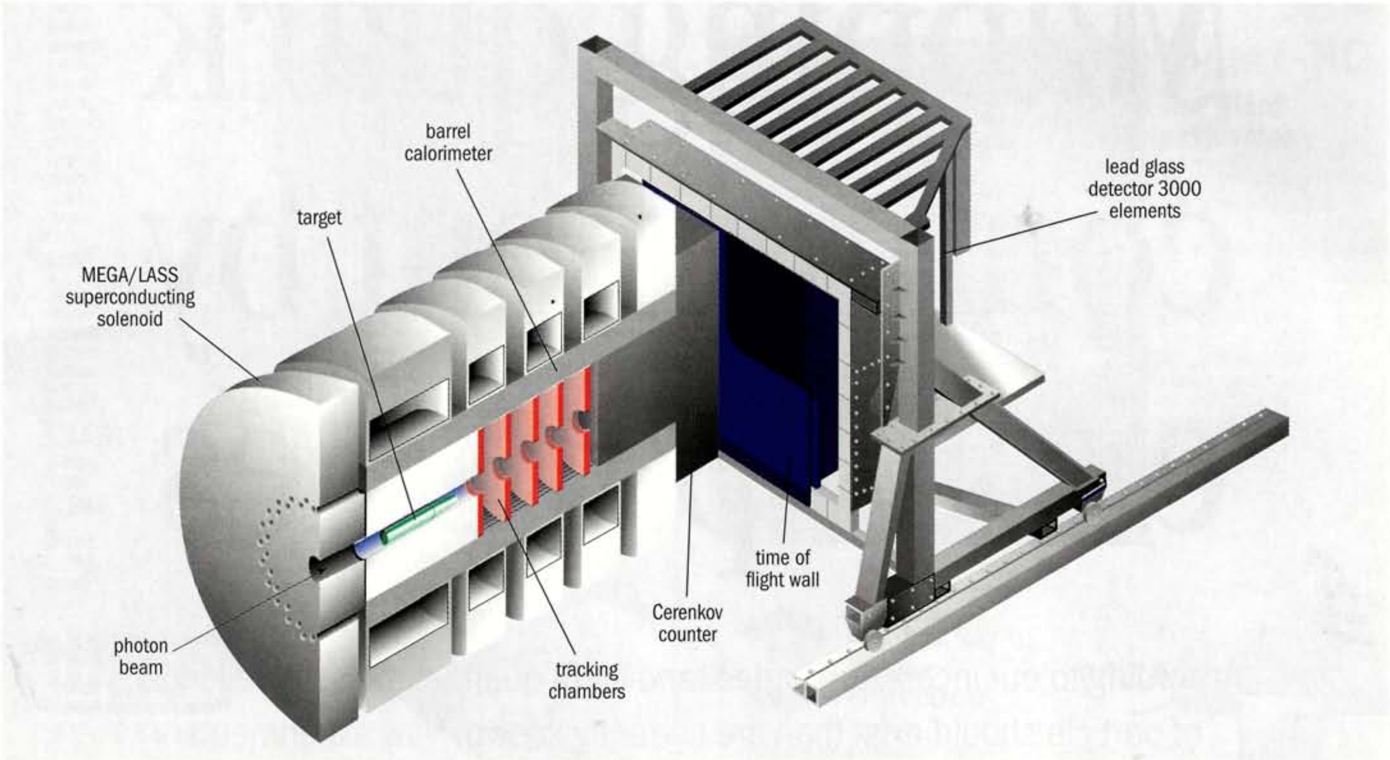


Fig. 3. The Hall D Spectrometer at the Jefferson Lab, Newport News, Virginia. A conceptual design of the proposed detector to study the photoproduction of mesons in the mass region around 2 GeV/c^2.

ordinary quark-antiquark states. These unusual J^{PC} combinations, like 0^{+-}, 1^{-+} and 2^{+-}, are called exotic and the states are referred to as exotic hybrid mesons.

Not only general considerations and flux tube models but also first-principle lattice QCD calculations require that these states are in this mass region, while also demonstrating that the levels and their orderings will provide experimental information on the mechanism that causes the colour flux tube to form. Moreover, tantalizing experimental evidence has appeared over the past several years for exotic hybrids as well as for gluonic excitations with no quarks at all (glueballs).

For the past two years a group of 80 physicists from 25 institutions in seven countries has been working on the design of the definitive experiment to map out the spectrum of these new states required by the QCD confinement mechanism. This experiment is part of the planned 12 GeV upgrade of the CEBAF complex at Jefferson Lab, Newport News, Virginia.

Looking for exotic hybrids

Photon beams are expected to be particularly favourable for the production of the exotic hybrids. The reason is that the photon sometimes behaves as a vector meson (a quark-antiquark state with the quark spins parallel, giving a total quark spin of S = 1). When the flux tube in this S = 1 system is excited to the levels shown in figure 2, both ordinary and exotic J^{PC} are possible. In contrast, when the quark spins are antiparallel (S = 0), as in pion or kaon probes, the exotic combinations are not generated.

To date, most meson spectroscopy has been done with incident pion, kaon or proton probes. High-flux photon beams of sufficient quality and energy have not been available, so there are virtually no data on the photoproduction of mesons below a mass of 3 GeV/c^2. Thus experimenters have not been able to search for exotic hybrids precisely where they are expected to be found.

The detector in Jefferson Lab's new Hall D is optimized for incident photons in the 8–9 GeV energy range in order to access the desired meson mass range. A solenoidal spectrometer allows for the measurement of charged particles with excellent efficiency and momentum determination, while at the same time containing the shower of unwanted electron-positron pairs associated with the photon beam.

Photons will be produced using the "coherent bremsstrahlung" technique, whereby a fine electron beam from the CEBAF accelerator is passed through a wafer-thin diamond crystal. At special orientations of the crystal its atoms can be made to recoil together from the radiating electron, boosting the emission at particular photon energies and yielding linearly polarized photons.

With the planned photon fluxes of 10^7/sec and the con-

When the spectrum and decay modes of these gluonic excitations have been mapped out, we will have made a giant step forward in understanding one of the most important new phenomena discovered in the 20th century – quark confinement.

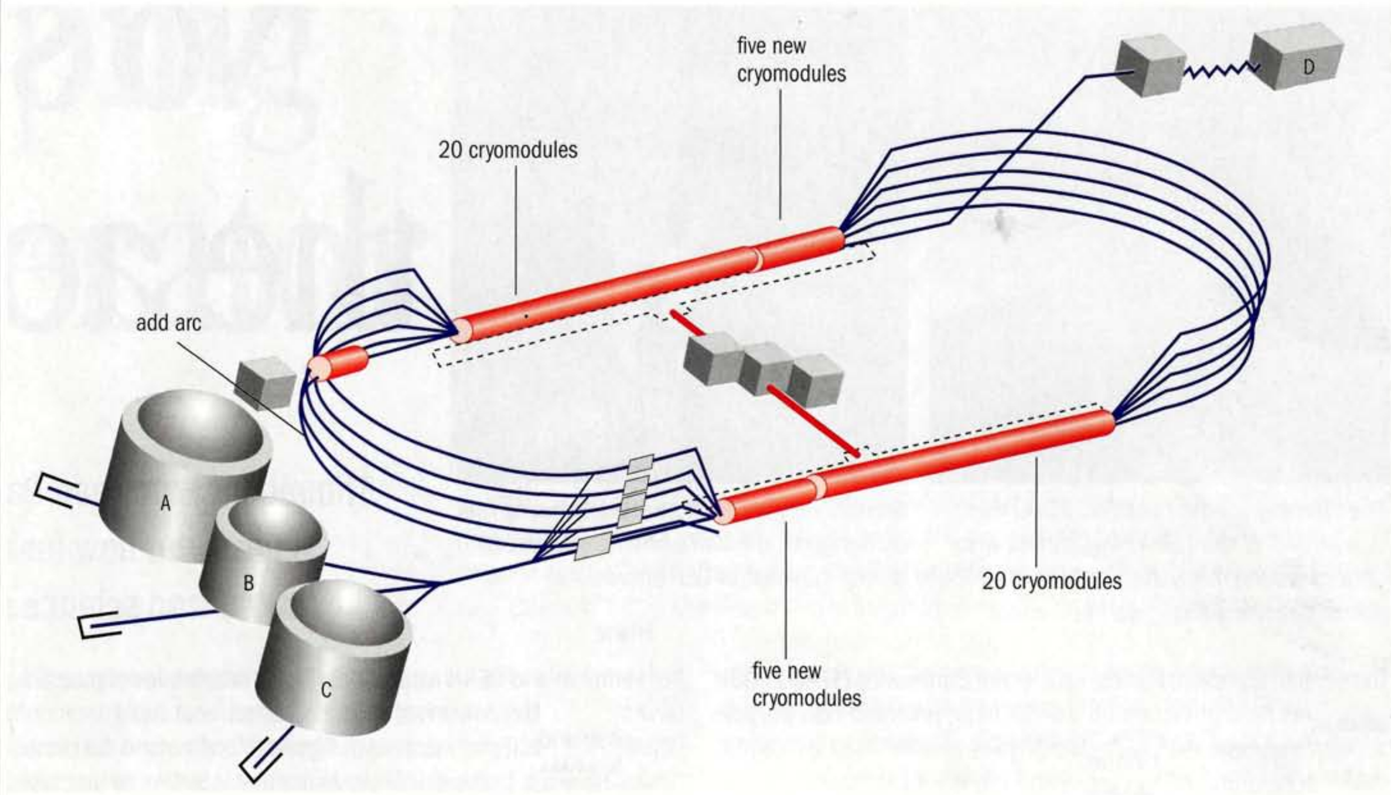


Fig. 4. The current CEBAF multipass electron machine at the Jefferson Lab, showing the existing three experimental Halls (A, B and C) and the planned Hall D.

tinuous CEBAF beam, the experiment will accumulate statistics during the first year of operation that will exceed extant data with pions by at least an order of magnitude. With this detector, the high statistics and the linear polarization information it will be possible to map out the full spectrum of these gluonic excitations.

A committee chaired by David Cassel (Cornell) and consisting of Frank Close (Rutherford), John Domingo (Jefferson), William Dunwoodie (SLAC), Donald Geesaman (Argonne), David Hitlin (Caltech), Martin Olsson (Wisconsin) and Glenn Young (Oak Ridge) reviewed the project in December 1999. It concluded that the project is "well suited for definitive searches for exotic states that are required according to our current understanding of QCD." They further pointed out that, because of the exceptional quality of the beams at Jefferson Lab, the laboratory is uniquely suited for carrying out such studies.

To achieve the required photon energy and flux with coherent bremsstrahlung a 12 GeV electron beam is required. Figure 4 shows the current CEBAF complex with the existing three experimental halls (A, B and C) and the planned Hall D. The addition of state-of-the-art accelerating units ("cryomodules") in the linear sections of the accelerator, along with upgrading the arc magnets, will increase the electron energy from the current maximum of 5.5 GeV to 12 GeV.

When the spectrum and decay modes of these gluonic excitations have been mapped out, we will have made a giant step forward in understanding one of the most important new phenomena discovered in the 20th century – quark confinement.

Alex Dzierba, *Indiana University, and* **Nathan Isgur**, *Jefferson Laboratory.*

The opening speaker at EPAC 2000 was Ugo Amaldi of the TERA Foundation, who underlined the many applications in which particle accelerators have been used.

Steve Myers of CERN gave an amusing talk on the good, the bad and the unforeseen during 12 years of LEP operations.

No st the acc

The recent European Particle underlined how far and w infiltrated into science and t

The seventh European Particle Accelerator Conference (EPAC 2000), which was held in Vienna on 26–30 June, reflected how particle accelerators have evolved from a physics research tool into a burgeoning applications field covering the sciences, medicine and industry. In his opening talk, Ugo Amaldi of the TERA Foundation underlined the many facets of particle acceleration today, ranging from the history of art through many diverse sciences to the study of the energy frontier in physics.

Then followed the performance reports on the Phi-factory DAFNE at Frascati and the B-factories PEP-II and KEKB at SLAC, Stanford and KEK, Japan, respectively. Here the emphasis was on machine tuning to arrive at design luminosities. This demonstrates a different form of art – the careful diagnostic study of circulating beams linked to feedback control systems that overcome potential instabilities.

Never is the accelerator specialist more elated than when this leads to higher beam currents and greater luminosity for the experimenter – provided, of course, that the detector backgrounds are tolerable. John Seeman of SLAC, who once described this excitement in striking detail in his article "The Tao of Commissioning" (*SLAC BeamLine* **29** 2), was able to report a PEP-II record luminosity of 2.22×10^{33} cm^{-2}s^{-1}, with KEKB not far behind.

At DESY, Hamburg, the electron–proton collider HERA has been shut down for nine months for upgrades that should lead to luminosity gains of up to a factor of five. The last sprint of LEP at CERN is towards higher energy at the expense of luminosity and broken cavities, although there is some benefit from the reduced radiation damping times that accompany the higher beam energies. Steve Myers of CERN used a touch of blarney in his witty account of the good, the bad and the unforeseen in 12 years of LEP operations – recommended reading if it is ever published.

Future machines

Magnet production and testing for CERN's LHC collider represented the forefront of new large machine project work (see box), while looking beyond LHC, the feasibility studies on neutrino factory design were described by Norbert Holtkamp and Helmut Haseroth for Fermilab and CERN respectively. These assemblies of machines and machine components to produce, collect, cool and store muons stretch our abilities as machine designers to and beyond our present limits. Here is a challenge for the future that is similar to that faced in linear collider studies for many years.

This design work was not reported at EPAC 2000 because it is a main component of linac and collider conferences. However, on the last day there was a session devoted to the four main test facilities for linear collider R&D. D Trines of DESY reported on the impressive recent results of the TESLA collaboration in developing nine-cell 1.3 GHz superconducting cavities to withstand gradients of 25 MV/m and single-cell cavities to gradients of 40 MV/m. The surface treatment and assembly of the cavities is now well understood and electropolishing the niobium surfaces is seen as a major factor in pushing up the breakdown limit. Four companies are now able to supply cavities that meet the TESLA design specifications.

The higher-gradient copper cavity linac designs, studied at the NLC Test Accelerator at SLAC and the CLIC Test Facility at CERN,

The biggest of them all

Testbenches for LHC magnets at CERN for 15 m dipoles (background) and a quadrupole (foreground).

At the EPAC 2000 conference, in CERN's 27 km tunnel from L part that industrial collaborati that could reliably reach the d

Three 15 m long prototypes manufacturing errors have bee tender in 2001, according to t

Norbert Siegel of CERN follo collaboration and the variety o proceeding well. The many new whole field of superconducting the acceptance testing.

For LHC as a whole, the shee magnets – pose manufacturin

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Accelerator Conference in Vienna
ide particle accelerators have
echnology. *Colin Johnson* reports.

At EPAC 2000, the EPS-IGA prize for an individual in the early part of his or her career, for making a significant, original contribution to the accelerator field, went to Pantaleo Raimondi, SLAC (left). That for outstanding work in the accelerator field went to Eberhard Keil, CERN (centre). The awards were made by Victor Suller of the Daresbury Laboratory.

also progress by demonstrating their functionality while revealing the need to concentrate on certain technical details. One such detail is the recently discovered damage to the copper surfaces of these cavities when they are pushed to the highest gradients. Both the NLC and CLIC study groups reported that they had found unexpected damage of the internal copper surfaces of their respective large-aperture travelling-wave accelerating structures after conditioning them with radiofrequency power to accelerating gradients of 50–60 MV/m.

Medical applications

Turning to the vast majority of accelerator design and construction projects, it was the medical applications that featured most prominently. Synchrotron light sources were naturally well represented and the third-generation sources are being extended into a fourth generation of ultraviolet, vacuum ultraviolet and X-ray free electron lasers capable of performance in terms of beam brilliance many orders of magnitude above present-day synchrotron light sources.

Carlo Wyss of CERN presented the story of the ongoing collider metamorphosis
P to the LHC. The process started 10 years ago and he stressed the important
n has played in the development and validation of suitably optimized dipoles
sign field of 8.4 T.
re now reliably ramping to more than 9 T. Strategies for correcting
established under strict quality control. The way is now open for a call for
e construction schedule.
ed with an overview of other LHC magnets. The extent of the international
design among the different magnet families was striking. Cold tests are
features that have been introduced and the boost that this must give to the
magnet design attest to the quality of the engineering and the thoroughness of

numbers – 3000 double-aperture magnets and 5000 single-aperture
challenges en route to LHC commissioning, which is scheduled for 2005.

However, it was the proton- and ion-beam therapy units that drew the crowds to their plenary sessions, reflecting their interest for society as well as in science. Eros Pedroni of PSI gave a comprehensive account of the latest developments in proton therapy, followed by Jose Alonso of Berkeley, who reviewed present and future ion-beam therapy.

These and other talks, together with the well attended stand demonstrating the "best possible design" proton–ion medical machine study (PIMMS), were a highlight of the week, but were, in fact, just appetizers for a dedicated post-conference meeting on medical accelerators (see box). The PIMMS CD-ROM was a great success and I had to donate my copy to an interested MD during the rail journey home from Vienna.

Industry

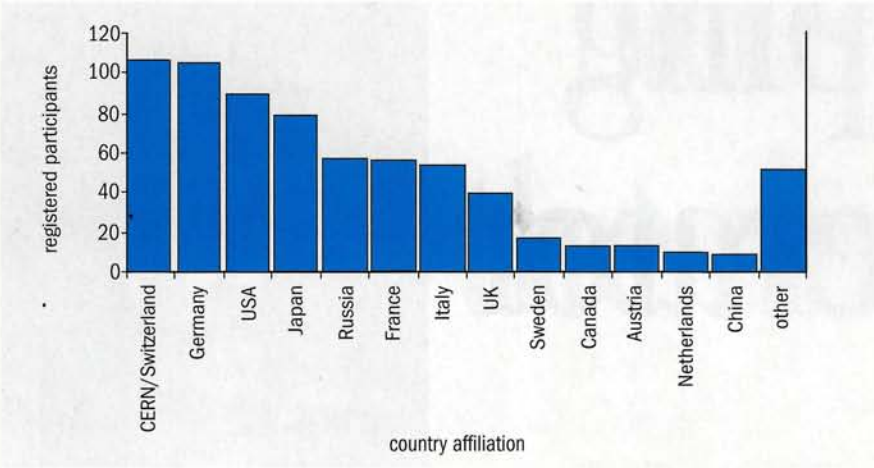
Opening the session for industry, Kurt Hübner of CERN gave an overview of the future construction needs of ongoing and future projects. Many technologies will be needed and some will be pushed to new limits. New materials, cryogenics, radiofrequency and controls form part of a long list.

With around 15 000 accelerators in the world, this field continues to be an important source of technology transfer, and this was the theme of the other speakers in this session. The immediate response from those industrialists present was not so obvious, because there was little interchange during the formal presentations. However, as evidenced by the continued discussion in their booths and over coffee, they preferred to handle the situation by more customary methods.

Prizes

Another highlight of the meeting was the presentation of this year's European Physical Society Interdivisional Group on Accelerators (EPS-IGA) accelerator prizes (May p30). The prize for an individual in the early part of his or her career, having made a recent significant, original contribution to the accelerator field, was awarded to Pantaleo Raimondi of SLAC. The prize for outstanding work in the accelerator field went to Eberhard Keil of CERN. ▷

Meinhard Regler (Institute of High Energy Physics of the Austrian Academy of Sciences) chaired the local organization committee.



EPAC 2000 attendance by country. Despite its name, the conference had a very strong international flavour with entry-level activities in many countries that are grouped together in the attendance chart.

Raimondi described in "SLC – the end game" how, with considerable ingenuity, he was able to use the measurement of the beam-beam interaction at the Stanford Linear Collider to improve the tune and hence the luminosity. Eberhard Keil drew on a recent study of an electron recirculating accelerator at CERN, ELFE at CERN, to illustrate some recent advances in accelerator design methods.

These stimulating presentations were followed by an invited talk, "Vacuum in philosophy, physics and classical music", by Herbert Pietschmann of Vienna. Despite its improbable title and the reference to classical music rather than the empty-headed pop version, this turned out (not unexpectedly, given the speaker) to be a source of great pleasure to the audience and an insight into our concept and use of the void.

High-intensity protons

During the week we were continually reminded of the push towards high-instantaneous-intensity proton machines for neutron spallation sources. In his presentation to industry, Albert Furrer of PSI emphasized the value of these devices by giving several excellent examples of the uses of neutron beams for radiography, tomography, reflectometry, spectroscopy, diffraction and scattering – all techniques applied to the study of materials.

One of the plenary sessions on the following morning was entirely devoted to high-power facilities. The interest in radioactive beam facilities and their relation to astrophysics was presented by Alex Mueller of IPN Orsay. An attentive audience was treated to an excellent account of the challenges to be met in exploring the *terra incognita* of exotic nuclei.

Poster colour

The oral presentations were supplemented by hundreds of posters. It is difficult to make an objective selection – on the whole the quality was excellent. Particular merit should go to the set of KEK/KEKB posters, accompanied by self-service sets of preprints. Unfortunately, many exhibitors offered neither preprints nor a Web address to access their work.

One poster, presented by Kenjii Sato of KEK, Japan, must be selected for special mention. It was the demonstration of acceleration in the world's first proton fixed field alternating gradient synchrotron, albeit at a very modest energy as a proof of principle.

Under the leadership of Yoshiharu Mori, design at KEK started in January 1999 and the first beam was accelerated on 16 June 2000. The fact that these machines use fixed fields allows them to operate at high repetition rates and produce high-intensity beams. The price to pay is large apertures, a larger circumference and consequently massive magnets, which has favoured so far the now classical alternating-gradient pulsed synchrotrons and explains why only electron model machines have ever been built.

However, because of their large momentum and transverse acceptances, these machines constitute a promising alternative to the more conventional approaches to muon collection and acceleration (RF and induction linacs) in a neutrino factory, and an international workshop on this topic was held at CERN immediately after the close of EPAC 2000.

Many posters illustrated the use of new materials, particularly magnetic materials, and a stunning array of new beam diagnostic tools was on display. The latter, coupled with precise numerical simulations, are increasingly used for performance optimization. These appeared in many posters and were the topic of an oral presentation by Frank Zimmerman of CERN. Perhaps, above all else, they reflect the onward direction of accelerator science towards complex machines where instrumentation and beam control will play an increasingly important role.

Attendance

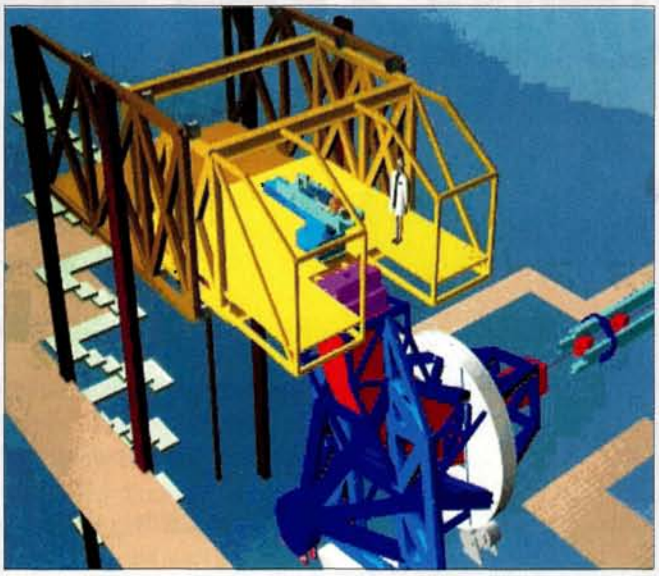
Shortly before the opening date there were 702 registered participants. Further confirmation of the large attendance was the fleet of 18 buses needed for transport to the Viennese Heurigen village for the conference dinner.

Some 86 plenary presentations were spread over five days with two parallel sessions during the middle three days. A session devoted to industrial relations occupied one afternoon and this complemented the industrial exhibition, where 37 companies presented their wares. Almost 900 abstracts were submitted for posters

Accelerator medicine

Among the increasing number of application fields in which particle accelerators are making their mark, medicine is always centre stage. The current status of the field was summarized at IMMAC 2000, a one-day International Meeting on Medical Accelerators, which was held at Vienna's Technical University. Many of the 196 participants had attended EPAC 2000 during the previous week.

At registration, everyone received a pamphlet describing the advantages of hadrons (protons and heavy ions) for cancer therapy and explaining the unique suitability of carbon ions because of their low radiobiological effect (RBE) in the entry channel and high RBE in the Bragg-peak energy deposition region. This was a fitting tribute to the half-century of progress since the late Robert R Wilson's famous paper "Radiobiological use of fast protons" (*Radiobiology* **47** 1946), in which he had the visionary foresight to point out the possible future use of carbon ions.



The "Riesenrad" (after the famous Vienna ferris wheel) is a novel exocentric gantry for handling beams of light ions for tumour therapy.

After a warm welcome by the organizer, Meinhard Regler, the first session reviewed the techniques available to treatment planners. Costas de Wagter of University Hospital, Ghent, described the progress in photon therapy for conformal dose delivery, starting with patient-specific collimators that shadow tumour boundaries and ending with dynamically controlled, multileafed collimators – intensity modulation and multiple-entry channels used in "step and shoot" or continuous rotation regimes.

Costas Kappas of Patras described stereotactic therapy with collimator helmets that direct radiation from some 200 small channels for three-dimensional treatments in the head. The use of hadrons was covered in the third talk by Anders Brahme of Stockholm's Karolinska Institute. In addition to the known advantage of hadrons in depth control by the Bragg-peak behaviour, Brahme proposed an extra degree of freedom to be gained by mixing different radiations.

Brahme first explained how 20–30 daily treatments by photons or protons (low RBE radiations) could eradicate cancerous cells while allowing normal tissue to repair, thus giving a true meaning to the word "therapy". On the other hand, light ions (high RBE radiations) are more efficient at killing cells. The complementarity of these radiations suggests a possible optimization. While treatments would in general be in the "therapy" mode, a booster dose that exploits the spatial precision and high RBE of light ions could be used in the tumour core.

The second session centred on reports from the main hadron therapy centres – PSI (Switzerland) by Eros Pedroni, HIMAC (Japan) by Kyomitsu Kawachi, GSI (Germany) by Jürgen Debus, and the Massachusetts General Hospital by Alfred Smith. The latter emphasized that, beam for beam, proton treatment plans were more accurate than photon plans. Smith's prediction was for a dozen proton centres in the US within a decade, with treatment costs competitive with those of established photon facilities.

In the third session, Jan Ingloff spoke first about the proton gantry from specialist firm IBA that is rapidly becoming a standard for deploying passively spread proton beams. This was followed by an account by Michael Benedikt of PIMMS, hosted by CERN, and a more general talk on gantries and patient-positioning equipment by Giovanni Cairoli of Schär Engineering AG, Switzerland.

Gantries are universally appreciated for their flexibility, but, in the case of carbon ions, the increase in size and power consumption owing to the high magnetic rigidity raises the question of whether such gantries are still practical. To answer this question positively, Stefan Reimoser of CERN proposed a detailed design of a novel exocentric light-ion gantry called the Riesenrad, after the famous Vienna ferris wheel.

In the final session, Hans Hoffmann of CERN spoke on information transfer and called for an open collaboration in the design of medical facilities. Concluding remarks came from Richard Pötter of University Hospital, Vienna.

Philip Bryant, *CERN.*

to be presented in sessions of more or less equal numbers on each of the first four days.

There were few gaps in the long lines of sometimes very colourful illustrations of today's accelerator developments and applications.

Vienna was an excellent and relatively inexpensive conference location with good transport and relaxation within easy reach of the conference centre. Within the Vienna Center, computing facilities were good, but the provision of writing desks and smoke-free areas had been overlooked. However, all in all it was a profitable week to look back on with great pleasure.

Colin Johnson, *CERN.*

Wolfgang Pauli: ne

This year marks the 100th anniversary
on 25 April 1900 and died in Zürich on
several events that have been a

Wolfgang Pauli with his mother in 1901.

Wolfgang Pauli – long the "conscience of physics" – was professor at ETH-Zürich for 30 years, from 1928 to 1958, except during the Second World War, when he was at Princeton at the Institute for Advanced Study. To honour his centenary, the ETH Library organized a special exhibition, which was first presented at ETH Zürich in April and May.

The exhibition, which beautifully illustrates Pauli's life, has now moved to CERN where it is on display in the Main Building from 17 August until 26 September. A ceremony in the Council Chamber on Monday 11 September at 4.30 p.m. will include short presentations from Maurice Jacob (chairman of the Pauli Committee), Konrad Osterwalder (Rektor of the ETH Zürich), Luciano Maiani (director-general of CERN) and Charles Enz (University of Geneva) on Pauli's life and legacy.

It is natural that CERN honours in this way one of the greatest physicists of the past century. Pauli acted as custodian of intellectual integrity while the field underwent tremendous development. He discovered the Exclusion Principle, which he formulated in 1924 and for which he was awarded the Nobel prize in 1945. He predicted the existence of the neutrino in 1930. However, he first became known through the publication of his famous 1921 review on relativity, when he was a student of Arnold Sommerfeld's. Many physicists, including Einstein, much admired this article, later reprinted as a book.

After the centenary exhibition, the next Pauli milestone will be the publication of the authoritative biography by Charles Enz. This should be complete in 2002, "in phase" with the completion of the Herculean task of publishing Pauli's scientific correspondence.

Pauli and CERN

Wolfgang Pauli left an imposing scientific correspondence. At a time when private correspondence, rather than preprints and e-mail, was instrumental in discussing and maturing ideas, his advice was often solicited and given on many key issues. Pauli maintained a prolific correspondence with the greatest physics minds of his time – Einstein, Bohr, Heisenberg and many others – amounting to several thousand letters.

This correspondence is a mine of information on the development of theoretical physics and is of great value both to physicists interested in history and to historians interested in modern physics. Most of the letters deal with topical physics questions, but they also reflect Pauli's great interest in philosophy and psychology.

After her husband's death, Mrs Franca Pauli, helped by Charles Enz, Pauli's last scientific assistant, began to sort out and administer this scientific legacy and invited friends and colleagues of Pauli to send copies of scientific correspondence. Mrs Pauli relied on the advice and help of Victor Weisskopf, who had been one of Pauli's first assistants at ETH Zürich and was soon to become director-general of CERN.

In August 1960 Mrs Pauli made a first deed of gift to CERN on behalf of her late husband's estate. After Mrs Pauli's death in July 1987, all author rights as well as inherent legal financial claims from the scientific work of Pauli were transferred to CERN. A second formal deed of gift was made in November 1971.

Thus, while CERN has the privilege of being the home of the Pauli Archive – scientific books, reprints, correspondence, manuscripts and photographs, as well as his Nobel Prize and other awards – it also has copyright on all hitherto unpublished works of Pauli and had to assume responsibility for publishing the scientific correspondence. CERN signed a contract with Springer-Verlag for the publication of this correspondence.

The Pauli Committee

After Weisskopf's mandate as CERN director-general (1961–1965), the responsibility for the Pauli Archive was assigned to a committee chaired by the new director-general, Bernard Gregory. Responsibility for looking after the collection passed to CERN's Scientific Information Service (including the CERN library).

ver to be excluded

Wolfgang Pauli, who was born in Vienna December 1958. *Maurice Jacob* describes nged to mark the Pauli centenary.

Weisskopf remained a member of the Pauli Committee, chaired by successive director-generals, until Leon Van Hove was mandated by Herwig Schopper to retain chairmanship of the committee after Van Hove left his director-general position in 1981. I succeeded Van Hove as chairman when he retired from CERN in 1989. My successor is Gabriele Veneziano.

The Pauli Committee was reorganized in 1985. Charles Enz from the University of Geneva joined, shortly followed by H Primas of ETH-Zürich and me, as CERN representative. CERN archivist Roswitha Rahmy was nominated to represent the Scientific Information Service and to look after the collection. This task has been inherited by Anita Hollier.

In 1997 Enz and Primas retired from their university posts and left the committee. They were replaced by W Amrein of Geneva and K Osterwalder of ETH-Zürich. K von Meÿenn had then already joined the committee and R Mumenthaler joined more recently to strengthen the links with the ETH library.

The committee has only one formal meeting per year. Until 1997 this took place when Weisskopf returned to the Geneva area for a traditional vacation.

As well as the archive, CERN has its Pauli Room, where many memorabilia and books are kept. Scholars are welcome to use the archive but there are some restrictions on publishing under their name material that includes extensive quotes from unpublished material (see "http://library.cern.ch/archives/pauli.html").

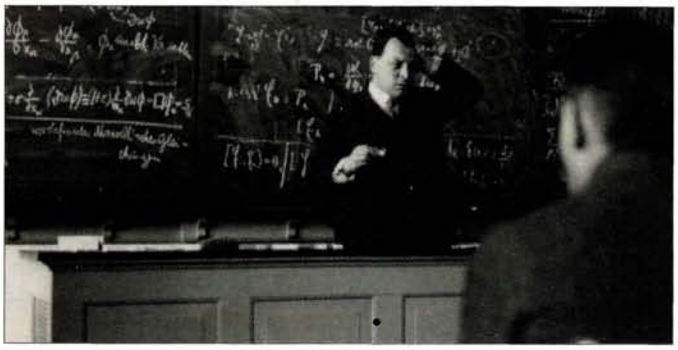
Another important Pauli collection is in the "Pauliana" archive of the ETH-Zürich Library. This too includes much Pauli correspondence, in particular with Markus Fierz, Carl Jung and Marie-Louise von Franz.

Nevertheless, much Pauli correspondence is still scattered and is being patiently located and retrieved by editors. Recently, many letters have been found in the Oppenheimer files at Princeton and in the Jauch files in Geneva.

Volumes of work

The Pauli Committee first concentrated on publishing scientific correspondence. This will eventually consist of four volumes: *Wolfgang Pauli, Wissenschaftlicher Briefwechsel mit Bohr, Einstein, Heisenberg u.a.* (*Scientific Correspondence with Bohr, Einstein, Heisenberg, a.o.*), published by Springer-Verlag.

The letters are printed in their original version, dominantly in German to start with but later with increasing use of English. Volume 1, published in 1979 and edited by A Hermann, K von Meÿenn and V Weisskopf, covers 1919–1929 and brings together 242 letters.



Pauli at Copenhagen in 1929.

During the Second World War, Pauli found a haven at Princeton.

Volume 2, published in 1985 with K von Meÿenn as editor, includes 364 letters from 1930–1939 together with 15 letters from the preceding period, which were subsequently retrieved. Volume 3, also edited by K von Meÿenn, covers 1940–1949. It includes 486 letters together with 67 from the preceding period. Volumes 1, 2 and 3 include more than 1000 letters.

Volume 4, also edited by K von Meÿenn, covers 1950–1958 and will include more than 2000 letters. It was therefore deemed appropriate to publish it as four separate books. The first, covering 1950–1952, appeared in 1996. It puts together close to 450 letters and bears witness to a new trend – about 100 letters refer to questions of psychology. The second book (1100 pages) came out in 1998. Covering 1953–1954, it includes about 450 letters, 50 of them concerning psychological matters. The third (1955-1956) will appear at the end of this year. The impressive editorial work of K von Meÿenn is recognized this year by the award of the Marc-Auguste Pictet medal.

Pauli and psychology

The inclusion of letters dealing mainly with psychology within the scientific correspondence was much debated by the committee. The scientific publications of Pauli are presented in strictly scientific terms and make no reference to any influence of the psyche in theoretical physics. Nevertheless, Pauli was convinced that science ▷

In August 1960 Mrs Franca Pauli made a first deed of gift to CERN on part of her late husband's estate. She is seen here at CERN with CERN director-general John Adams (left) and Council president François de Rose.

was unable to provide all of the answers.

He was deeply interested in psychology and in particular in the significance of dreams. Dreams were precious guides to him. It was therefore considered proper that the publication of his scientific correspondence should reveal the thinker as a whole and not only the physicist, providing clues about how Pauli reached his ideas, as well as articulating and presenting them in purely logical and analytical arguments.

Despite the interest and value of all of this material, sales are limited and a reasonable price for the books does not cover all costs. It was fortunate that the long-time editor, K von Meÿenn, could be supported for many years by the Deutsche Forschungsgemeinschaft, with extra support provided by the Max Planck Gesellschaft. After a stopgap solution provided by CERN, this support has continued, thanks to the Swiss National Fund and then the ETH. Support to cover part of the publication costs was provided by the Swiss National Fund and later by the Deutsche Forschungsgemeinschaft. This help, which we hope will continue until the end of publication of volume 4, is greatly appreciated. It is one of the tasks of the committee to assure it.

Pauli and Jung

The psychological correspondence of Pauli culminated in his long exchange of letters with C G Jung from 1932 to 1958. This reveals an hitherto poorly known facet of Pauli's mind. It is fascinating to follow how these two intellectual giants argue from different sides to find mutual enlightment.

This correspondence has been published as *Wolfgang Pauli and C G Jung – Ein Briefwechsel 1932–1958*. This collection of letters was brought together by C A Meier, with the help of C Enz and M Fierz, and it was first published by Springer-Verlag in 1992. This caters for a rather wider audience and there was no need to engineer additional finance. Sales have even warranted a second print run.

This correspondence is published in the original German, but translations into English (Routledge, London and Princeton University Press), French (Albin Michel, Paris) and Spanish (Alienza Editorial, Madrid) are now available.

He was deeply interested in psychology and in particular in the significance of dreams. Dreams were precious guides to him.

This interest prompted a special symposium, held at Monte Verita, Ascona, in June 1993. Its proceedings include the first publication of a remarkable essay by Pauli in which dreams and physics are intertwined. This is *The Piano Lesson* (*Die Klavierstunde*), a long letter to Mrs von Franz. The proceedings of the meeting – *Der Pauli-Jung-Dialog und seine Bedeutung für die moderne Wissenschaft* – have been published by Springer-Verlag (1995). The editors are H Altmanspacher, H Primas and E Wertenschlag-Birkhäuser.

Pauli's deep and brillant grasp of epistemology and the philosophy of science is clearly displayed in the collection of essays *Aufsätze und Vorträge über Physik und Erkenntnistheorie*, published by Vieweg, Braunschweig in 1961, and in the article "Der Einfluss archetypischer Vorstellungen auf die Bildung naturwissenschaftlicher Theorien bei Kepler", written with C G Jung, which appeared in *Naturerklärung und Psyche*, first published by Rascher Verlag, Zürich, in 1952. The latter shows Pauli's great interest in the archetypes (in the Jungian sense) of Kepler.

Under the auspices of the Pauli Committee, these two publications have been put together in an English translation as *W Pauli, Writings on Physics and Philosophy*, published by Springer-Verlag in 1992, with editorial work by C Enz and K von Meÿenn and a short Pauli biography by C Enz. They benefited from the careful but unused English translation by R Schlapp, which was made during Pauli's lifetime. Translations into French, Spanish and Japanese are in progress. In all cases the Pauli Committee insisted that these translations should follow the German originals and not rely on the more readily available English translation.

A separate publication of correspondence between Pauli and Arnold Sommerfeld is now under way as a Deutsche-Forschungsgemeinschaft project.

The expenses of the archive, referencing and preparation for publication are met by the modest income from translation rights. The committee was also glad to support in this way the publication of a volume bringing together the "Schulrat" papers and minutes related to Pauli's professorship at ETH, once they became publicly available. This *ETH Schulratsakten/Pauli*, published by ETH-Hochschulverlag, is edited by C Enz, B Glaus and G Oberkofler from the University of Innsbruck Archives. The committee could also help with the publication of a booklet associated with the Pauli centenary exhibition.

The Pauli Committee hopes that all of these endeavours will make for a better understanding and knowledge of the many aspects of a great mind that played such a leading role in the development of modern physics.

Maurice Jacob, *CERN, chairman of the Pauli Committee.*

PEOPLE

AWARDS

Vladimir Kadyshevsky, director of the Joint Institute for Nuclear Research, Dubna, near Moscow, has been elected a full member of the Russian Academy of Sciences.

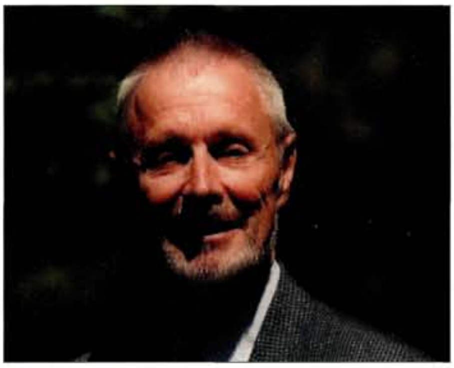
Christoph W Leemann, former associate director of the Jefferson Laboratory, Newport News, Virginia, has been elevated to the newly created position of deputy director. He was the original head of the laboratory's Accelerator Division, having come from Berkeley with the initial nucleus of key people to build Jefferson's CEBAF electron machine.

The Division of Particles and Fields of the American Physical Society has presented a Certification of Appreciation to **Jean Trân Thanh Vân** of Paris XI, Orsay, in recognition of his many contributions to particle physics and international understanding by initiating regular meetings. These include the annual Rencontres de Moriond, established in 1966, the Rencontres de Blois (1989) and the Rencontres du Vietnam (1993). The certificate was presented in Paris on 8 July.

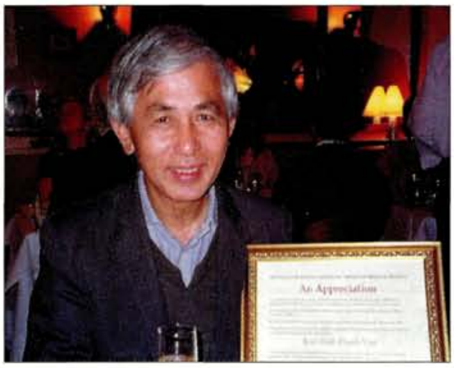
Ghulam Murtaza becomes the first Salam professor of physics at Government College, Lahore, Pakistan. The chair was established to honour Abdus Salam, 1979 Nobel prizewinner and co-architect of the electroweak theory, who was a student and, briefly, a teacher at the college. Murtaza was a student of Salam at London's Imperial College.

CERN physicist **Edwige Tournefier**, who works on the CMS experiment for the LHC, received an "Award for brilliant activity in high energy physics detection techniques" at the Eighth Pisa Meeting on Advanced Detectors held in Elba in May. The award was made for her presentation on CMS's pre-shower detector, designed to identify and reject neutral pions, which fake photon signals in the experiment's lead tungstate calorimeter.

Sven Reiche of Hamburg receives this year's prize from the Friends and Promoters of DESY for the best doctorate work. The title of his thesis is "Numerical studies for a single pass high gain free electron laser".



Christoph W Leemann becomes deputy director of the Jefferson Laboratory.



Jean Trân Thanh Vân receives American appreciation for initiating meetings.

Edwige Tournefier is recognized for her presentation on detection techniques.

MEETINGS

The 2nd Topical Seminar on Global and Local Network for Research and Education will take place at the Certosa of Pontignano near Siena, Italy, on 6–9 November. The seminar is organized by F-L Navarria of Bologna and PG Pelfer of Firenze, and it is sponsored by INFN, Universita di Bologna, Universita di Firenze and Universita di Siena. It is the second in a series devoted to information networks in research and education. The previous one was held in 1994 on The World Wide Web and beyond in Physics Research and Applications.

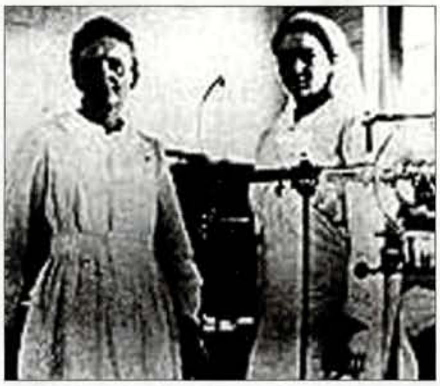
The seminar will address present and future developments and applications of information and communication technologies for research and education in physics and other natural sciences. Special sessions will be dedicated to new information technologies for human and historical sciences.

For further information, e-mail "pelfer@fi.infn.it/kaos@bo.infn.it" or visit "http://www.bo.infn.it/sminiato/sminiato00.html".

An **International Symposium on Nuclear Physics** will be held on 18–22 December at the Bhabha Atomic Research Centre, Bombay, India. For further information see "http://www.barc.ernet.in/barc/isnp2000" or e-mail "kailas@magnum.barc.ernet.in".

A Gordon Research Conference on Nuclear Physics – QCD in Extreme Conditions: High Temperature, High Density and Small-x will take place on 22–27 July 2001 at Newport, Rhode Island. Contact Wit Busza, Bldg 24-510, Massachusetts Instiute of Technology, Laboratory for Nuclear Science, 77 Massachusetts Ave, Cambridge, MA 02139-4307; e-mail "busza@mit.edu".

The 84th Exhibition of the French Physical Society, held on 19–21 September at the Paris Expo, Porte de Versailles, highlights cutting-edge instrumentation technology. Related events running in parallel are devoted to measurement, sensors, optophotonics, etc. See "http://sfp.in2p3.fr/expo" and "http://www.physiquerechercheindustrie.com".



Marie Curie is the subject of a new Web exhibit offered by the Center for History of Physics at the American Institute of Physics. This illustration shows her (left) and her daughter, Irène Curie, with X-ray equipment at a First World War military hospital. After training Irène as a radiologist for a year, Curie deemed her daughter capable of directing a battlefront radiological installation on her own. The exhibit can be viewed at "http://www.aip.org/history/curie".

Dubna plays host to scientific academies

The 10th meeting of the Board of the International Association of Academies of Sciences (IAAS) took place at the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, in June. The IAAS was established in 1993 to unite efforts of the National Academies of Sciences for solving major scientific problems and for keeping and developing traditional and new collaborative ties between scientists.

At present the IAAS includes the Academies of Sciences of all of the CIS countries – Azerbaijan, Armenia, Belarus, Georgia, Kazakhstan, Moldova, Russia, Turkmenistan, Ukraine and Uzbekistan, as well as Vietnam. The JINR is an associate member of the IAAS as well as the Russian Humanitarian Scientific Foundation, the Russian Foundation for Basic Research, the Moscow Physics and Technology Institute and the Belarusian Republican Foundation for Basic Research. The IAAS president is B E Paton, Academician of the National Academy of Sciences of Ukraine. The JINR was also recently the scene of an ATLAS Week – a major meeting of the collaboration building the ATLAS detector for CERN's LHC collider.

The Board of the International Association of Academies of Sciences met recently at the Joint Institute for Nuclear Research, Dubna, near Moscow.

ATLAS Week at JINR, for the first time outside CERN. JINR is a major contributor to several LHC experiments. The ATLAS Week also preceded an international symposium at Dubna on LHC Physics and Detectors.

Bohr's tall story

A physics student at the University of Copenhagen was once faced with the following challenge:

"Describe how to determine the height of a skyscraper using a barometer."

The student replied: "Tie a long piece of string to the barometer, lower it from the roof of the skyscraper to the ground. The length of the string plus the length of the barometer will equal the height of the building."

This answer so incensed the examiner that the student was failed immediately. However, the student appealed on the grounds that the answer was indisputably correct, and the university appointed an independent arbiter to decide.

The arbiter judged that the answer was indeed correct, but that it did not display any noticeable knowledge of physics. To resolve the problem, it was decided to call the student and allow six minutes for him to provide an oral answer.

For five minutes the student sat in silence, his forehead creased in thought. When the arbiter pointed out that time was running out, the student replied that he had several extremely relevant answers but could not decide which to use.

"Firstly, you could take a barometer up to the roof of the skyscraper, drop it over the edge and measure the time it takes to reach the ground, but too bad for the barometer.

"If the sun is shining you could measure the height of the barometer, then set it on end and measure the length of its shadow. Then you measure the length of the skyscraper's shadow, and thereafter it is a simple matter of proportional arithmetic.

"If you wanted to be highly scientific, you could tie a short piece of string to the barometer and swing it as a pendulum, first at ground level, then on the roof of the skyscraper. The height of the building can be calculated from the difference in the pendulum's period.

"If the skyscraper has an outside emergency staircase, it would be easy to walk up it and mark off the height in barometer lengths.

"If you wanted to be boring and orthodox, of course, you could use the barometer to measure the air pressure on the roof of the skyscraper and on the ground, and convert the difference into a height of air.

"But since we are continually being urged to seek new ways of doing things, probably the best way would be to knock on the janitor's door and say: 'If you would like a nice new barometer, I will give you this one if you tell me the height of this building'."

The student was allegedly Niels Bohr.

This story ties in well with an anecdote recounted in Abraham Pais' book *Niels Bohr's Times, in Physics, Philosophy and Polity* (Oxford, 1991). In his youth, Bohr played goalkeeper in soccer. On one occasion his team was playing against a German side, and most of the action was taking place in the German half of the field. Suddenly the German team counterattacked, and a spectator had to shout to warn Bohr, who was using the goalpost to write down a mathematical problem.

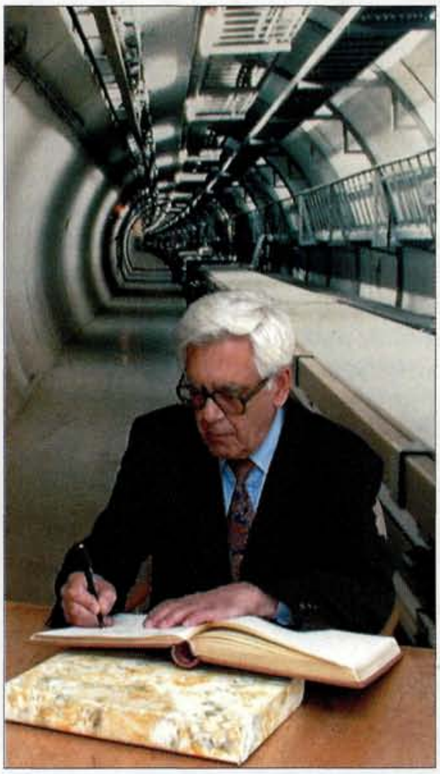
First presentation of the Wiik prize

The first winners of the Bjørn H Wiik prize are Russian scientists (left to right) Mikhail Yurkov, Evgeny Saldin and Evgeny Schneidmiller.

On 15 June Dr Margret Becker-Wiik presented for the first time the Bjørn H Wiik prize, established in honour of the DESY director-general, who died tragically in 1999. The winners are the Russian scientists Evgeny Saldin, Evgeny Schneidmiller and Mikhail Yurkov. The three physicists were awarded the prize for their outstanding contributions to the Free Electron Laser (FEL) project at DESY. Yurkov was one of the speakers at the recent DESY 40th anniversary celebrations (July p6).

In 1994 – shortly after the start of the project – Saldin, Yurkov and Schneidmiller joined the FEL team at DESY's TESLA test facility. Earlier this year the FEL emitted its first laser light (July p26).

In future the Bjørn H Wiik prize will be presented every two years. Financed by donations, it aims to acknowledge outstanding contributions to the advancement of research programmes or technical development projects at DESY.



Bulgarian Minister of Education and Science Dimitar Dimitron signs CERN's VIP visitors book on 21 June. Bulgaria is CERN's newest member state.

Abraham Pais (1918–2000)
A tribute will be published in the next edition.

Pomeranchuk prize

The Pomeranchuk prize for 2000 is awarded to E L Feinberg (Lebedev Institute, Moscow) and J D Bjorken (SLAC).

Evgenii L'vovich Feinberg receives the award for his outstanding contributions to theoretical physics and especially to the theory of inelastic collisions of hadrons. A staff member at the Lebedev Institute and a member of the Russian Academy of Science, he was originally a postgraduate student of Igor Tamm. During his long career his interest has varied from problems of radiophysics and statistical acoustics, and of low-energy neutron physics and neutron spectroscopy, to particle physics and nuclear interactions at high energies. He is the author of more than 100 scientific publications, including "About the external diffractive production of particles in nuclear collisions" (with I Ya Pomeranchuk, 1953); "Propagation of radiowaves along the terrestrial surface" (1961); "Direct production of photons and dileptons in multiple hadron production" (1976); and "Hadron clusters and half-dressed particles in quantum field theory" (1980).

J D Bjorken receives the award for his outstanding contributions to particle physics and quantum field theory, in particular for formulating the scaling law in deep inelastic processes. His most important theoretical research achievements include the development, simultaneously and independent of Johnson and Low, of limiting the behaviour of interaction amplitudes in quantum field theory – the so-called BJL asymptotic limit – and the formulation of the rigorous Bjorken Sum Rules for the difference between spin-dependent scattering amplitudes of polarized electrons from polarized protons and neutrons.

In collaboration with Sheldon Glashow, Bjorken extended the underlying symmetry structure of elementary particles from SU(3) to SU(4) and introduced the "charm" quantum number. Together with Sidney Drell he wrote the famous textbooks *Relativistic Quantum Mechanics and Field Theory*, which have served for many years as standard references for graduate education.

Established in 1998, the Pomeranchuk prize is awarded annually for outstanding achievements in all of the fields of theoretical physics to which Isaak Yakovlevich Pomeranchuk (1913–1966) contributed. Administered by Moscow's Institute of Theoretical and Experimental Physics (ITEP), the prize was awarded in 1998 to A I Akhiezer (Kharkov, Ukraine) and Sidney Drell (Stanford, USA), and in 1999 to K A Ter-Martirosyan (ITEP, Moscow) and Gabriele Veneziano (CERN).

Nominations for the Pomeranchuk prize 2001 should be sent to "pomeron@heron.itep.ru" no later than 1 February 2001. Further information is available via "http://face.itep.ru/pomeranchuk.html".

Alexander Skrinsky (right) presents CERN director-general **Luciano Maiani** with the medal of a foreign member of the Russian Academy of Sciences at the CERN Council meeting on 23 June. Distinguished physicist Valentine Telegdi received the honour on the same occasion.

CERN Council news

At the meeting of CERN's governing body, Council, on 23 June, **Kurt Hübner** was reappointed CERN's director of accelerators from 1 January to 30 June 2001, and **Carlo Wyss** was appointed as director of accelerators from 1 July 2001 to 31 December 2003. **Georgio Goggi** was reappointed leader of CERN's EP Division from 1 January to 30 June 2001 and **Wolf-Dieter Schlatter** was appointed as leader of the division from 1 July 2001 to 30 June 2004. **Walter Majerotto** was re-elected as vice-president of Council for one year from 1 July 2000. **Wilfried Buchmüller** of DESY and **Paolo Strolin** of Naples were elected as new members of the Scientific Policy Committee.

Lazarus Gershon Ratner 1923–2000

Lazarus (Larry) Gershon Ratner, an outstanding and dedicated accelerator physicist who played a major role in developing the acceleration of polarized beams, died on 9 March of pneumonia.

Ratner graduated from Berkeley in 1951. Joining Lawrence Berkeley National Laboratory as a staff physicist in 1950, he initially worked on the 184 inch cyclotron and was involved in the design and construction effort of the Bevatron. He then moved to Argonne in 1960 and became a key member of the team that designed, constructed and commissioned the Zero Gradient Synchrotron (ZGS). After the completion of the ZGS, he was principally responsible for the slow extraction of the proton beam and the tuning of secondary beams.

Lazarus Gershon Ratner 1923–2000.

During this period Ratner joined a Michigan team in pioneer experiments at the ZGS. He also made major contributions to the Argonne-Bologna-Michigan collaboration, which carried out an early proton-proton collider experiment when the CERN Intersecting Storage Rings first operated in 1971.

Next Ratner rejoined his Michigan colleagues as a major collaborator in the pioneering large-angle proton-proton elastic experiments that found large and unexpected spin effects, first using the Argonne ZGS polarized proton beam in 1975-9 and then using Brookhaven's AGS in 1984-90. However, Ratner's major role in the world's first successful effort to accelerate polarized protons to high energy at the ZGS will remain one of his lasting legacies. He was a pioneer in the use of correction dipoles and pulsed quadrupoles to overcome the many depolarizing resonances encountered during acceleration to high energy. The successful acceleration of polarized protons at the ZGS made it possible to conceive of polarized beam acceleration at even higher energies. This is now a very active field of accelerator physics.

After the 1979 shutdown of the ZGS, Ratner joined Brookhaven in 1981 to apply his unique talents and expertise to the construction and commissioning of the polarized proton beam project at Brookhaven's Alternating Gradient Synchrotron (AGS). The AGS's strong focusing fields made the task of overcoming its many depolarizing resonances truly formidable. However, Ratner persevered and in 1988 a polarized beam was successfully accelerated to 22 GeV. Again he played a key role in all aspects of the project – from magnet and power supply design to the design, testing and operation of three polarimeters.

The experience at the AGS, although successful, also demonstrated that new techniques were needed to accelerate polarized protons to even higher energy. In 1975 Derbenev and Kondratenko at Novosibirsk had proposed that inserting local spin rotators called Siberian snakes should eliminate all depolarizing resonances, but the concept had never been tested. Ratner enthusiastically joined the pioneering Michigan-Indiana-Brookhaven-KEK experiment at the Indiana University Cooler Ring, which provided the "proof-of-principle" in 1989.

Then, as co-spokesperson of an experiment at the AGS, he led the effort to design, install and successfully test a solenoid partial Siberian snake. Based on these successful tests, full Siberian snakes are now being built and installed in Brookhaven's Relativistic Heavy Ion Collider (RHIC), which will allow the study of spin effects in 500 GeV proton-proton collisions. Until last year, Ratner remained actively involved with his long-term Michigan colleagues and with the RHIC spin project. His dedication and thoughtfulness continued to serve as an inspiration to all of us. With Larry's passing, his colleagues lost a wise and creative physicist and a good friend.

A D Krisch, Brookhaven, and T Roser, Michigan.

RECRUITMENT

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Two Positions as Heads of Programme

1. Optical materials
2. Plasma and fluid dynamics

As the former heads of the two research programmes have been appointed research professor and head of department, respectively, in the Optics and Fluid Dynamics Department at Risø, the department invites applications for two positions as heads of the two research programmes:

1. Optical materials (OMA). This programme has core competences in polymer optics, laser systems development, optical storage and nonlinear optics. The programme has close contacts with the Danish Polymer Centre and with the Center for Biomedical Optics, which both are collaborative efforts between the Technical University of Denmark and Risø.
2. Plasma and fluid dynamics (PLF). This programme has core competences in fusion plasma physics, nonlinear continuum dynamics and scientific computing. Members of the staff participate in the European programme for the development of controlled nuclear fusion coordinated by Euratom.

Both research programmes have well-developed national and international networks, they partipate in the operation of the Graduate School in Nonlinear Science together with the Technical University of Denmark and Copenhagen University, and they have a number of collaborative projects with both academic institutions and private companies.

Qualifications
Each head of programme will assume the scientific and administrative responsibility for a programme comprising 10-20 scientists and technicians. In addition, both programmes have a number of Ph.D. students and post docs involved in research and development.

The successful candidates can document a significant activity at an international level within one or more of the core competences of the relevant programme. Experience in scientific leadership as well as fund raising ability and contact with industry and academia will be taken into account in the evaluation. The candidates are requested to submit a description of their plans for the programme (max. three pages).

Terms of employment
The terms of employment will be in accordance with those of the Danish scientific staff at Risø National Laboratory. The salary is approximately DKK 445,000 per year including pension scheme (16.6% of the base salary). Depending on qualifications, a higher salary can be negotiated. Based on results defined in an annual performance contract, an additional bonus can be obtained.

A selection committee with external participation will evaluate the qualifications of the candidates.

Information
Further information about the department can be obtained from Head of Department Jens-Peter Lynov (phone +45 4677 4501; e-mail jens-peter.lynov@risoe.dk) and can be found at the website http://www.risoe.dk/ofd.

Application
Three copies of the application written in either English or Danish and marked "163-00-OMA" or "162-00-PLF", including relevant material (CV, list of publications, max. ten recent publications, programme plan, etc.) should be sent to

Risø National Laboratory
Personnel Office, Building 776
P.O. Box 49
DK-4000 Roskilde
Denmark

Deadline for submission of applications is 2 October 2000.

RISØ

Risø udfører naturvidenskabelig og teknisk-videnskabelig forskning.
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Science Serving Society

Experimental Physicist

The Subatomic Physics Group (P-25) seeks an outstanding Experimental Physicist to participate in the BooNE neutrino-oscillation experiment and explore future experiments that draw on the strengths of the Group. The successful candidate will enhance the Group's physics program and participate in a large effort involving institutions from the United States and other countries to develop, coordinate, and mount the next generations of experiments. Examples of areas in addition to oscillations that we are currently investigating include a future neutrino experiment to determine the axial-strange form factor of the proton from neutrino-nucleon scattering and fundamental symmetry measurements with neutrons.

The Subatomic Physics Group at the Los Alamos National Laboratory performs research over a wide range of topics in nuclear, particle, and applied physics. In addition to neutrino physics, the Group investigates heavy-ion collisions (PHENIX), high-energy strong interaction physics (E866/NuSea), the neutron electric dipole moment, quantum computing, and atomic trapping. The Group also performs research and development using hadron radiography and other beam technology relevant to the Science-Based Stockpile Stewardship program. Our experiments are collaborations between national laboratories and universities, and provide a vital link with the academic community. The position requires extensive achievement in physics relevant to neutrino interactions and other fundamental measurements, with a broad knowledge of experimental techniques employed in nuclear and particle physics. Applicants should also have demonstrated capabilities in defining and articulating achievable scientific goals.

For technical questions related to this position, contact Andrea Palounek at aptp@lanl.gov.

Interested candidates should submit a written statement explaining how their qualifications match our needs and attach a resume to this statement. For the full text of this job advertisement, see www.hr.lanl.gov/jobs, and look under the Professional section for Job #995201.

To apply, submit a comprehensive resume and cover letter that addresses the specific required and desired criteria, referencing "CERN995201," to the Resume Service Center, Mailstop MSP286, Los Alamos, NM 87545.

Los Alamos National Laboratory — Science Serving Society

Los Alamos
NATIONAL LABORATORY

Operated by the University of California for the Department of Energy. AA/EOE

www.lanl.gov/jobs

BEAM DIAGNOSTIC PHYSICIST/ELECTRONICS ENGINEER

ISIS, Rutherford Appleton Laboratory, Oxfordshire

ISIS is the world's most powerful pulsed spallation neutron source. It consists of a fast cycling 800 MeV proton synchrotron, delivering 2.5×10^{13} protons per pulse at 50 Hz, to a heavy metal target which produces intense pulses of neutrons. The facility provides a wide scientific community with beams of neutrons and muons that probe, on a microscopic scale, the structure and dynamics of condensed matter, and supports several accelerator based research programmes.

There is a post for a Physicist/Electronics Engineer in the Accelerator Physics and Beam Diagnostics Section of the ISIS Accelerator Division. The postholder is required for the development of Beam Diagnostics and the associated electronics on the ISIS accelerators and beam lines. Work will involve interaction with an interdisciplinary team of Engineers, Physicists and Programmers, and will have potential for development into machine physics related work for those interested.

The postholder will be expected to develop beam diagnostics essential to the operational running of ISIS, and also contribute to designs for future projects. Diagnostics devices include beam position monitors, current monitors, profile monitors and loss monitors - requiring digital, analogue and RF electronics, appropriate data acquisition systems and links to control computer systems. Expertise or potential to develop expertise in analogue electronics is essential, and experience will be considered, along with potential for development. Applicants should have a degree or HNC in Physics/Electronic Engineering.

The salary range is between £14,850 and £21,850 or between £18,620 and £26,600 (2000 pay award pending). A non-contributory pension scheme and a generous leave allowance are also offered. For an informal discussion about the post, please contact Adrian Morris, telephone +44 (0)1235 446275, or e-mail a.morris@rl.ac.uk

Application forms can be obtained from: Operations Group, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) quoting reference VN1956, or e-mail recruit@rl.ac.uk More information about CCLRC and application forms are available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 22 September 2000.

The CCLRC is committed to Equal Opportunities and to achieving the Investors In People standard.

A no smoking policy is in operation.

CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

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 or with the fixed target experiments HERA-B and HERMES. 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 (BAT IIa).

Interested persons, who have recently completed their Ph. D. and who should be younger than 32 years are invited to send their application including a resume and the usual documents (curriculum vitae, list of publications, copies of university degrees) until September 30, 2000 to

DESY
Personalabteilung -V2-
Notkestraße 85, D- 22607 Hamburg

ıey should also arrange for three letters of reference to be sent until the same date to the address given above.

Handicapped applicants with equal qualifications will be prefered. DESY encourages especially women to apply.

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

THE UNIVERSITY OF VIRGINIA POSTDOCTORAL POSITION IN EXPERIMENTAL NUCLEAR/PARTICLE PHYSICS

The University of Virginia invites applications for a postdoctoral position in experimental nuclear/particle physics with an emphasis on developing and operating solid polarized targets. The group (consisting of Profs. D. Crabb, D. Day and O. Rondon) plays a major role in experiments at SLAC and JLAB using solid polarized targets developed here. For the next 18 months we will be running experiments with these targets in Hall B and Hall C at JLAB. Applicants must have a Ph.D. in experimental nuclear or particle physics; experience with cryogenics and familiarity with the operation of polarized targets is highly desirable. The successful candidate will be responsible for the development of dilution refrigerator based solid polarized targets for future experiments and participate in the group effort at JLAB. Opportunities for working on experiments at other laboratories will arise during the term of the appointment.

These are initially one-year positions, with the possibility of extension for one or two more years contingent upon mutual agreement and the availability of funds. The position will be available immediately and will remain open until filled. Applicants should submit a resume, summary of research interests and arrange to have three letters of recommendation sent to: Experimental Nuclear/Particle Physics Positions, University of Virginia, Department of Physics, 382 McCormick Road, P.O. Box 400714, Charlottesville, VA 22904-4714 (ATTN: TAMMIE SHIFFLETT)

Informal inquiries may be addressed to Prof. Donald Crabb (dgc3q@virginia.edu).

The University of Virginia is an Equal Opportunity/Affirmative Action Employer. Women and minorities are strongly encouraged to apply.

Staff Scientist Position

at the

LIGO Laboratory, California Institute of Technology (Caltech).

The Laser Interferometer Gravitational-Wave Observatory (LIGO) Laboratory is seeking to fill a three-year term position for staff scientist at its Livingston, Louisiana Observatory. The position may be converted at a later date to a long-term appointment subject to available funding. The successful candidate will become a member of the observatory staff with primary responsibility to participate locally in the LIGO Laboratory Data and Computing Group activities. Primary responsibilities will include: site support for LIGO Data Analysis System hardware and software; and participation in the scientific data analysis for astrophysical signatures from gravitational waves associated with compact relativistic objects.

Skills we are seeking include: Linux/Solaris administration background; MPI based parallel computational background; training in astronomy, astrophysics or physics; programming experience in C and C++ and/or tcl / tk; knowledge of computer hardware systems, ability to repair computer equipment, install computer equipment, maintain computer equipment. The ideal candidate would have a deep-seated commitment to successfully implement and use the LIGO computational resources for astrophysical research in near real time at the site. He or she should have a can-do attitude that includes openness to learning new skills as they are needed, and the ability to work in a collegial manner with others both locally and remotely.

Letters of interest should be sent to Dr. Albert Lazzarini, California Institute of Technology, LIGO 18-34, Pasadena, Ca 91125, and must include a resume with a minimum of three references listed. Further information may be obtained from Dr. Lazzarini at lazz@ligo.caltech.edu.

Caltech is an Affirmative Action/Equal Opportunity Employers. Women, Minorities, Veterans, and Disabled Persons are encouraged to apply.

DESY

The Deutsches Elektronen-Synchrotron DESY is a national physics research laboratory with 1400 employees and more than 3000 guest scientists from Germany and abroad. The scientific program includes research in particle physics and synchrotron radiation.

In the framework of an international collaboration a Free-Electron-Laser is set up at DESY for wavelengths far below the visible. The project is based on the superconducting TESLA test facility, which supplies the technological foundation for a future linear accelerator for electron-positron collision experiments.Within this framework we search several physicists with Ph.D. for the development, construction and commissioning of sophisticated components of the electron accelerator.

We are looking for a

Scientist or Diplom-Engineer (m/f)

The successful applicants will have responsibility for the coordination of work already in progress and/or for the construction and commissioning of self-developed components.

The qualification should be Ph.D. in physics or electrical engineering and preferrably appropriate experience in accelerator physics and techniques. The ability to coordinate sophisticated technological work in international collaboration is desired.

The contract will be unlimited. The salary will be according to the German Civil Service (BAT).

Interested applicants are invited to send their letter of application and three names of referees to

DESY, Personalabteilung, Notkestraße 85, D- 22603 Hamburg
by September 30, 2000 **Code-number: 64/2000**
phone 040/8998-3617 **www.desy.de**

Handicapped applicants will be given preference to other applicants with the same qualification. DESY supports the career of women and encourages especially women to apply.

Jefferson Lab

Thomas Jefferson National Accelerator Facility

POSTDOCTORAL POSITION

(Position #PT2113)

Thomas Jefferson National Accelerator Facility is a DOE-sponsored laboratory operated by the Southeastern Universities Research Association. Jefferson Lab's primary mission is to study strongly interacting matter with multi-GeV electromagnetic probes. The experimental program includes both high energy nuclear physics and low energy particle physics. The laboratory routinely operates up to 5.5 GeV beam energy.

Jefferson Lab invites applications for a post-doctoral research associate position in the Hall C group. The core Hall C equipment consists of two focussing magnetic spectrometers, high power 1,2H and 3,4He cryogenic targets, and dynamically polarized H and D targets. Flexibility is the key to the Hall C program therefore special purpose detectors and targets are brought in as needed. Operating since late 1995, our publication and Ph.D. production streams are well established. Our experimental program for the next few years includes two measurements of the neutron electric form factor, inclusive measurements on nuclei in the nucleon resonance region, further measurements of the pion charge form factor, and the G0 parity violation experiment. The successful candidate will play a role in the preparation, data-taking, and analysis for these experiments, and assist in the design of future experiments. Leadership roles in already approved and scheduled experiments are possible by mutual agreement with experiment spokespersons.

A Ph.D. in experimental nuclear, particle, or high-energy astrophysics is required. Experience in analyzing data from intermediate/high energy experiments is essential, and a background in lepton-nucleus physics would be a plus. The appointment will be made initially for one year and is renewable. Applicants should send a curriculum vitae, copies of any recent (un)published work, and arrange to have letters from three references sent to: Employment Manager, Mail Stop 28A, TJNAF, 12000 Jefferson Avenue, Newport News, VA 23606.

Jefferson Lab is an Affirmative Action/Equal Opportunity Employer.

ACCELERATOR PHYSICIST

ISIS, Rutherford Appleton Laboratory, Oxfordshire

Applications are invited for a vacancy in the Accelerator Theory and Future Projects Group, which is part of the ISIS Accelerator Division at RAL. The Group is involved with development of the existing ISIS facility and collaborates with laboratories worldwide in theoretical studies for future accelerator projects.

Candidates should have a first degree in Physics or Mathematics and a Ph.D. or equivalent in accelerator theory or a closely related subject. A sound mathematical background and knowledge of computer modelling techniques would be an advantage.

The salary range is between £18,620 and £26,600 (pay award pending). A non-contributory pension scheme and a generous leave allowance are also offered. For an informal discussion about the post, please contact Dr CR Prior, telephone +44 (0)1235 445262, or e-mail c.r.prior@rl.ac.uk

Application forms can be obtained from: Operations Group, HR Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) quoting reference VN1968, or e-mail recruit@rl.ac.uk More information about CCLRC and application forms are available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 29 September 2000.

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CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

POSTDOCTORAL POSITION IN EXPERIMENTAL PARTICLE PHYSICS

The BaBar Group of the Physics Division at the E.O. Lawrence Berkeley National Laboratory has an opening for a Visiting Postdoctoral Physicist. The BaBar detector is fully operational at PEP-II B-factory and has been actively taking data since Summer 1999. The Berkeley group has major commitments in the following areas: Silicon Vertex Tracker (SVT), DIRC particle ID system, trigger, online and offline computing. Physics analysis of the rapidly accumulating data set is a high priority.

Qualified candidates should have a Ph.D in particle physics and demonstrated strong potential for outstanding achievement as an independent researcher. The primary responsibility of this position will be physics analysis as well as some hardware development.

This is a two-year term appointment with the possibility of renewal. The salary range is $3,640-$4,295/month. Applications, including CV, list of publications, description of skills, and three letters of recommendation should be sent via e-mail to gensciemployment@lbl.gov or mail to Lawrence Berkeley National Laboratory, 1 Cyclotron Road, MS 50-4037, Berkeley, CA 94720. Please reference Job# PH011898. E-mail inquiries to gensciemployment@lbl.gov. For more information, please visit our web site www.lbl.gov/CJO. Berkeley Laboratory is an AA/EEO employer.

BERKELEY LAB

DESY

The Deutsches Elektronen-Synchrotron DESY is a national physics research laboratory with 1400 employees and more than 3000 guest scientists from Germany and abroad. The scientific program includes research in particle physics and synchrotron radiation.

In the framework of an international collaboration, DESY is developing a Free Electron Laser for wavelengths far below the visible. After the successful proof-of-principle demonstration in the first phase of the project, a user facility will now be constructed to provide a worldwide community with unprecedented radiation quality. The project is based on the superconducting TESLA Test Accelerator Facility, which provides the technological basis for a future high-energy electron-positron linear collider.

A key contribution to the success of this installation will be the development, construction and commissioning of a number of advanced electron accelerator components.

Within the scope of this activity, DESY Hamburg invites applications for

several Postdoctoral positions in Experimental Physics or Electrical Engineering

The successful candidate will be responsible for coordination of work already under way and/or for construction of components to be designed by him/herself. He/She will find an optimum environment for professional training.

The contract will be limited to 3 years. The salary will be according to the German Civil Service (IIa MTV Angestellte).

Scientists who have recently finished their Ph. D., have experience in this field and are not more than 32 years old, are invited to send their letter of application and three names of referees to

DESY, Personalabteilung, Notkestraße 85, D- 22603 Hamburg
by September 15, 2000 Code-number: 50/2000

Handicapped applicants will be given preference to other applicants with the same qualification. DESY encourages especially women to apply.

Universität Heidelberg

The Kirchhoff-Institut für Physik invites applications for the position of a

Physicist or Electrical Engineer

The position is located at the ASIC laboratory of the faculty of physics and astronomy, in which application specific integrated circuits for various research projects of the faculty are being developed. As the head of the design department, the successful candidate will lead and/or participate in the chip design itself, but also be responsible for the installation and maintenance of the CAD software and design libraries. Additional tasks include the technical support to users in house.

Current developments of the laboratory include digital, analogue, mixed-signal chips and integrated sensors to be used in research projects in the areas of particle physics and medical physics. More information can be found at **http://wwwasic.ihep.uni-heidelberg.de/asic/**.

Applicants should have a surpassing degree in physics or electrical engineering and a profound knowledge in the area of microelectronics or communications engineering.

The salary will be according to the German salary scale BAT.

Letters of application including the usual documents should be sent by October 1st to:

Universität Heidelberg, Kirchhoff-Institut für Physik, c/o Prof. K. Meier, Ref. ASIC-Ingenieur, Schröderstr. 90, 69120 Heidelberg, Germany.

BOOKSHELF

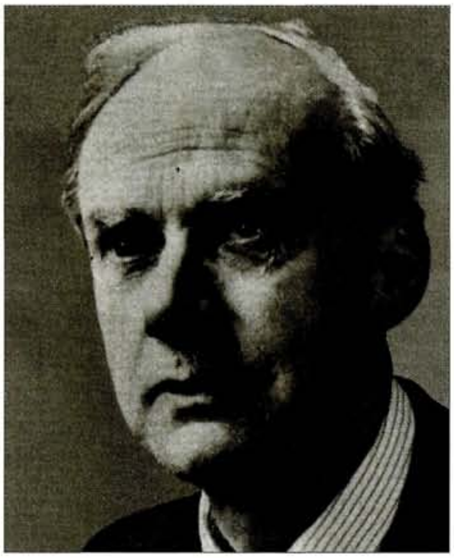
Antimatter – the Ultimate Mirror by Gordon Fraser, Cambridge University Press, 0 521 65252 9, £16.95/$24.95.

The correct prediction of antimatter by Paul Dirac is arguably the most astonishing intellectual achievement of the 20th century. By insisting that quantum theory and special relativity must be consistent, he was able to deduce the generalization of the Schrödinger equation to the Dirac equation. By doing that he was able to give a proximate explanation for spin, and to predict a whole new set of particles, antimatter. That the human mind can discover a previously unknown part of the world is a great achievement. (I largely agree with Antonino Zichichi who argued for Dirac as the most important physicist of the 20th century in *Physics World* in March.) Gordon Fraser's lively and interesting book provides a broad treatment of this story, and the history, science and implications of antimatter.

This is a very nice book, totally accessible to any curious reader, yet with occasional thought-provoking pieces even for experts. Fraser keeps a fast pace, explaining the science well but taking care not to dwell too long on any difficult aspect. In a few places I didn't fully agree with his viewpoint or arguments. I will mention some of these as a service to possible readers, but they do not detract from the value of a successful book.

Publishers are notorious for writing anything they please on book jackets and in publicity. Fraser is not responsible for the remark on the jacket that the book is about how science fiction became fact, which is, of course, the opposite of what happened (the remark is taken from the title of chapter 1, but its meaning is different there), or the charming reference to "Hans van der Meer" in the publicity, mixing up Hans Dehmelt (whose work with traps is described in chapter 11) and Simon van der Meer (who figured out how to get antiprotons in sufficient quantities to make a collider.)

Chapter 1 describes the public excitement about the 1995 discovery of antiatoms, and then begins the history. My impression of one bit of the history differs a little here. Fraser says that at first Dirac thought that the antielectron was the proton. He may be correct, but I have heard over the years that people pushed rather hard on Dirac about where the predicted antielectron was – after all, predicting new particles was not normal then. Dirac defensively remarked that perhaps it was the proton,



Paul Dirac – spiritual father of antimatter.

though he knew that that didn't make sense.

The next chapter introduces the relevant symmetries, charge conjugation, parity and time reversal, and then provides a quick history from Galileo through Newton to Einstein. It includes the Thornhill portrait of Newton without a wig, which I have seen in the Master's Lodge of Trinity College, Cambridge – Newton looks much more like a physicist there than in his usual wigged appearances. Here and later the book has a nice way of giving brief descriptions that capture the essence of people.

Chapter 3 is a history of the acceptance of atoms, and the discoveries of the electron, nucleus, proton and neutron. Next is a more thorough biographical treatment of Dirac, with some of the many anecdotes, followed by the development of quantum theory and the Dirac equation. Chapter 5 describes the positron discovery, including the opposition of R A Millikan. That opposition helped to make European physicists more aware that Carl Anderson's CalTech data could be the antielectron than were the US physicists. There is also a (delightful for a theorist) quote from Rutherford of a sentiment that we still encounter: "It seems to be to a certain degree regrettable that we had a theory of the positive electron before the experiments...I would be more pleased if the theory had appeared after the establishment of the experimental facts."

Fraser then presents a quick discussion of infinities, renormalization and Richard Feynman, and interesting speculations on Dirac and Feynman's distinctive personalities and the strong influences of their fathers as they were growing up. The story moves to the development of accelerators and the discovery of the antiproton, and then to quarks. (A minor point: the wording of a sentence on p108 suggests that quarks have a known size, but in fact there is only an upper limit and quarks are expected to be far too small to measure their size directly.) Next comes further discussion of parity violation and then CP violation, leading up to Andrei Sakharov's statement of the conditions required for an explanation of the mysterious baryon asymmetry of the universe.

Particle colliders, which of course, require expertise in handling antimatter, are brought in and some of their discoveries presented. The only typographic error I found was on p175, where the ratio of the top quark mass to the b-quark mass is about 35, not 300. Chapter 13 is basically on antimatter technology, including PET scans and more. Fraser gets somewhat sensational here, beginning the chapter with a survey of the Reagan era "Star Wars" antimissile programme, and then unfairly relating that to the US plans to build the Superconducting SuperCollider, even seeing a connection to antimatter propulsion proposals and personnel for Star Wars. He also laments the loss of the LEAR antiproton beam at CERN, and perhaps misses an opportunity to discuss the difficulties of doing all science projects in times of limited resources, and of deciding which ones to pursue.

Why the universe is matter and not antimatter is still a mystery. The explanation of the evidence in chapter 14 is very clear. However, there are more approaches that could eventually explain this mystery than the book suggests. The problem is that the calculations are very difficult and the underlying theory is not established. Perhaps most fundamentally, we do not yet know the origin and size of the CP-violating effects that are essential to explain the matter asymmetry. One piece of progress is that we do know now that the Standard Model cannot explain the matter asymmetry of the universe, so new physics must enter. It is likely that the phases that lead to the CP violation needed to generate the matter asymmetry arise when string theories are compactified to three space dimensions and when supersymmetry is broken, but these subjects are not yet well understood. If you think these approaches are somewhat far out, you'll enjoy Fraser's speculations on this issue even more.

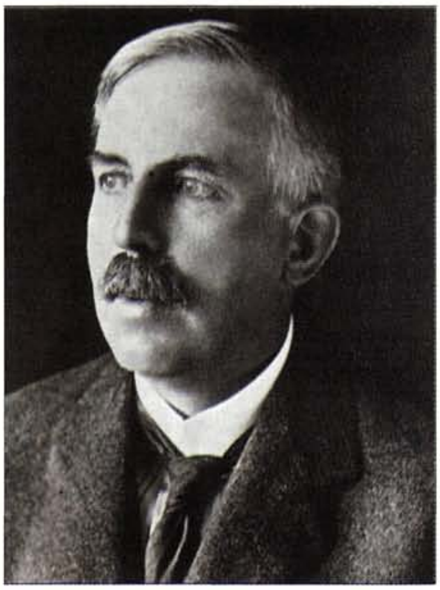
Gordon Kane, Michigan.

Rutherford – Scientist Supreme by John Campbell, AAS publications, 494pp hbk £25/$40 (obtainable direct from the publisher: AAS publications, PO Box 31-035, Christchurch, New Zealand; e-mail "aas@its.canterbury.ac.nz").

Ernest Rutherford towered over the early 20th-century decryption of the atom. At a series of university settings - Cambridge, McGill, Manchester and then Cambridge again - he masterminded a progression of classic experiments that dramatically revealed the nature of radioactivity, and the structure of the atom and its nucleus. Many of those he had chosen to be his research partners - Blackett, Chadwick, Cockcroft, Geiger and Walton, among others - went on to become physics figureheads in their own right. In Manchester, Rutherford inspired Niels Bohr to abandon the theory of electrons in metals and turn to that of electrons in atoms instead.

Rutherford biographies are not scarce, with inspired memoirs and nostalgic reminiscences by several contemporaries - Allibone, Da Costa Andrade, Oliphant - and the 1983 biography *Rutherford, Simple Genius* by David Wilson.

The title of Wilson's book succinctly catches the nature of Rutherford. He was no fiery intellect like many of his central European contemporaries. Instead, his slow but penetrating insight and analysis, and his gift for patient, incisive investigation, isolated key problems and elucidated them.



Ernest Rutherford - scientist supreme.

Rutherford was born in modest surroundings in New Zealand when the country was still being settled. When New Zealand schoolchildren of the late 19th century learned history, they learned British history - there was no New Zealand history. University examination papers were despatched by boat to Britain for marking.

New Zealander John Campbell - he teaches physics at the University of Canterbury - was struck, ashamed even, by the lack of recognition of his nation's premier scientist and he set out to do something about it. He developed a fitting memorial at Rutherford's birthplace in Nelson and embarked on this major biography, which fleshed out Rutherford's New Zealand background. While other epochs in Rutherford's life have been well documented, his youth in New Zealand has until now been largely overlooked. Compared with 50 sketchy pages in Wilson's book, perhaps half of Campbell's book deals with local matters - Rutherford's birth, schooling, early university education and periodic visits throughout his life. During his studies, Rutherford emerged as a gifted student but no precocious childhood genius.

As well as the focus on New Zealand, there is much valuable additional material in the book - anecdotes, the paradox of how the 20th century's foremost experimental physicist never received the Nobel Prize for Physics (even before his historic discovery of the atomic nucleus in 1911, he received the Nobel Prize for Chemistry for his work on radioactivity), several major discoveries that were missed at Cambridge in the early 1930s - the positron, induced radioactivity - and finally the bizarre circumstances of his death at the

Painstaking research

In his Rutherford biography, New Zealand physicist John Campbell has done an immense amount of spadework. Some of this is references in the book, but more complete references are being assigned to public repositories. He says:

"I have filled 10 quarto 120-page record books and three filing cabinet drawers with such notes. These have been willed to the Rutherford Collection at the Alexander Turnbull Library, the historic arm of the National Library of New Zealand. The master manuscript refers to these notes. The biography also draws extensively on the local newspapers of the day, Rutherford family correspondence and the official and unofficial records of the relevant organizations.

"In such a major research, sometimes every paragraph, sentence or even phrase requires a reference or further comment. This is too detailed for most users. In this book only the main points will be referenced due to space considerations.

"A master copy, which includes material edited out of the printed version, will be hand annotated with full references and comments on the sources of every statement. Two years after publication date, thus allowing for the incorporation of any new information which may come to light as a result of the book, I will donate a copy of this master manuscript to public repositories in each country with a Rutherford association. This will make the details more freely accessible to interested people.

"There will be one condition imposed, that for 10 years after the deposition date any person can copy no more than 10 pages per day. After that period copying will be as per the usual custom for the particular archive. During that 10 year period I will invite people seriously interested in Rutherford to purchase their own copy from AAS Publications, PO Box 31-035, Christchurch, New Zealand. Purchasers will be encouraged to donate their copy to any other appropriate public repository."

Repositories of Master Copies:

Alexander Turnbull Library of the National Library of New Zealand
Nelson Provincial Museum
Cambridge University Library (Manuscripts)
National Library of Scotland
Center for the History of Science, Royal Swedish Academy of Sciences, Stockholm
Musée Curie (France)
McGill University Library (Archives)
P L Kapitza Institute for Physical Problems (Moscow)
American Institute of Physics, Niels Bohr Library
National Library of Australia

age of only 66. (Details of Rutherford's death are strangely absent in existing biographies, written when many people still had an upright Victorian attitude.) Rutherford had been influential in key applied research positions in the First World War. What impact would his blustering no-nonsense personality have made in Second World War science and technology?

The book underlines Rutherford's continual push for higher-energy particles. In a 1927 speech to the Royal Society, he said: "It has long been my ambition to have available for study a copious supply of atoms and electrons which have an individual energy far transcending that of particles from radioactive bodies." At Cambridge, industrial techniques were exploited in the search for higher voltages – an early example of technology transfer. This ultimately led to Cockcroft and Walton's accelerator, carried further by Oliphant. However, Rutherford dropped the ball by not acknowledging the arrival of the upstart cyclotron, developed by Ernest Lawrence in the US.

Especially poignant is the description of Rutherford's undemonstrative romance and marriage to the faithful Mary ("May") Newton, whom he met while a student in New Zealand and who eventually followed him to Britain after patiently waiting to be summoned.

Campbell's homely but complete biography of "Ern" is totally in keeping with Rutherford's own bluntness – a valuable addition to the biography of a key scientific figure. It will be particularly appreciated in New Zealand, even if major world publishers did not agree with this antipodean focus. A shorter 250-page version is thus in the pipeline.

Gordon Fraser, CERN.

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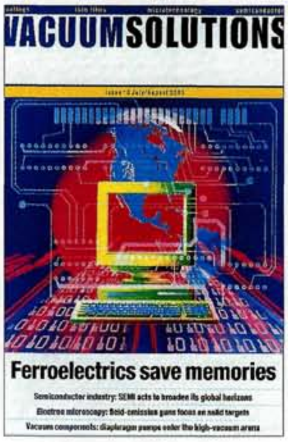

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