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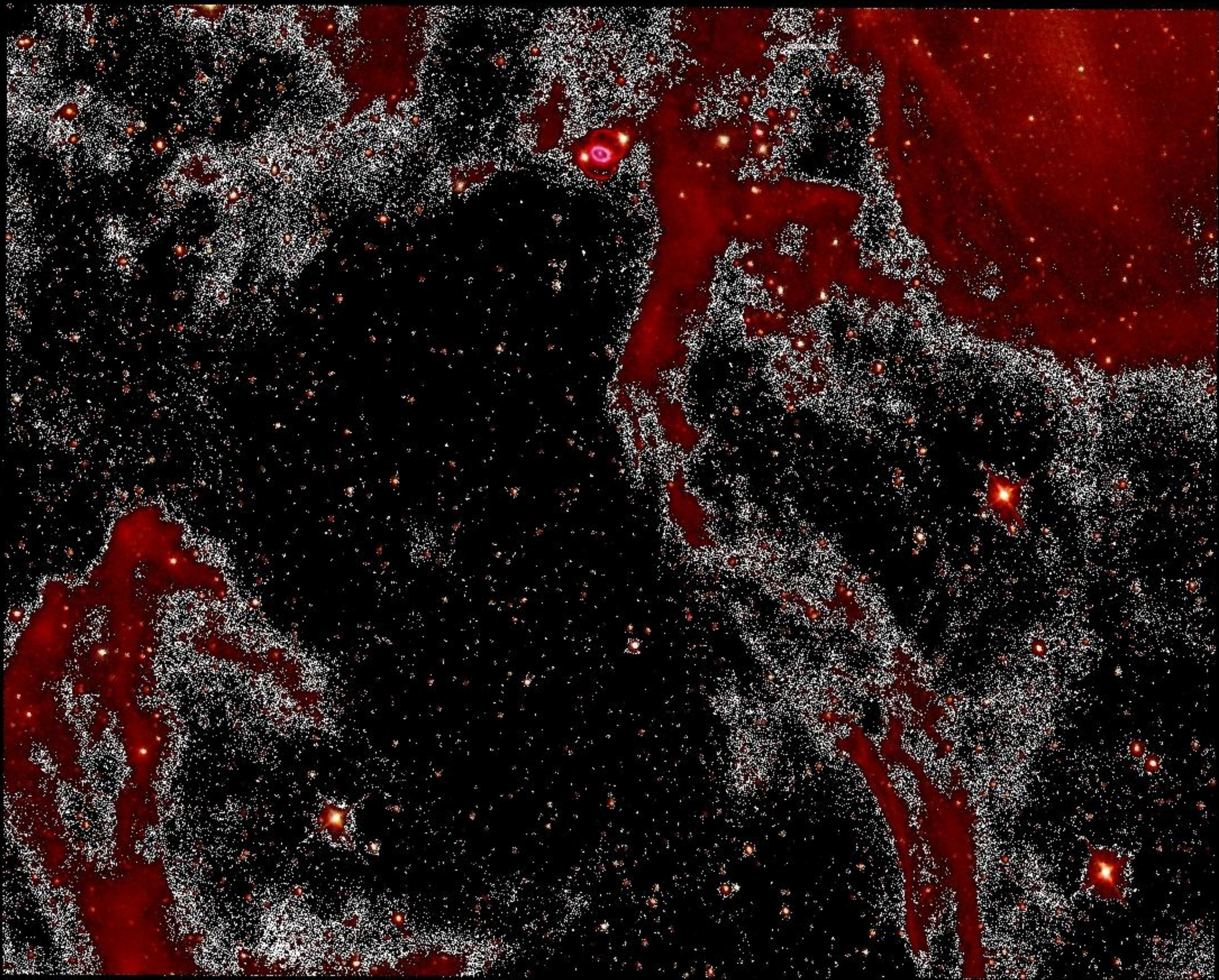

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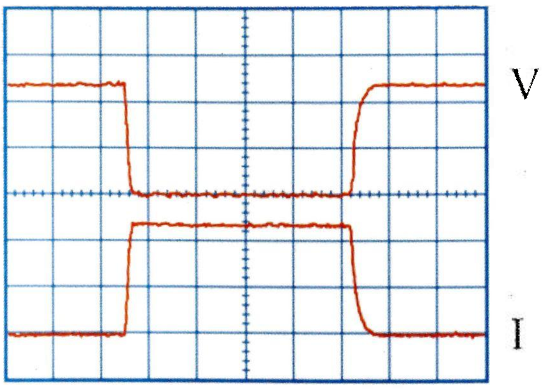

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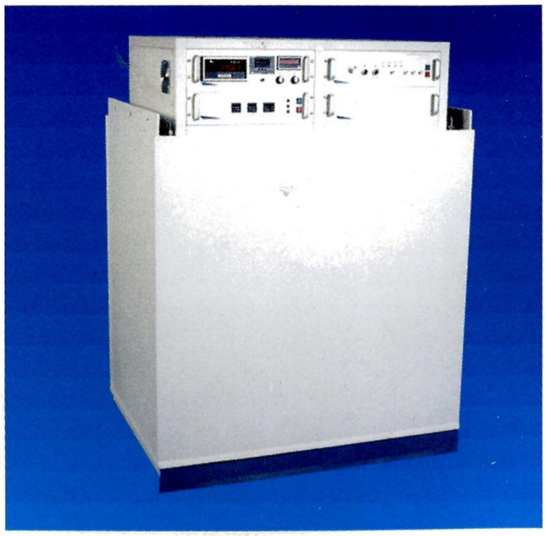

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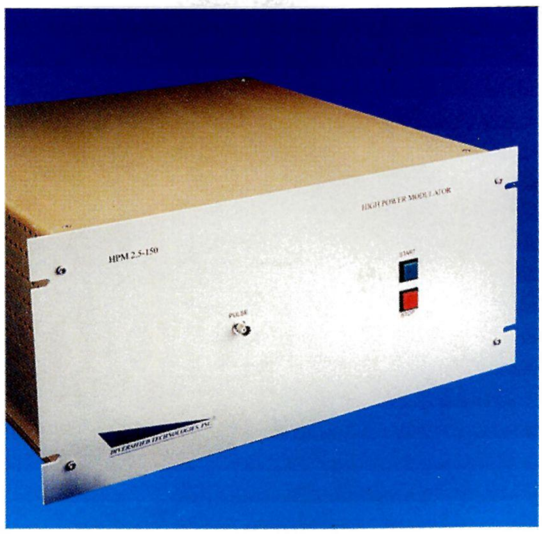

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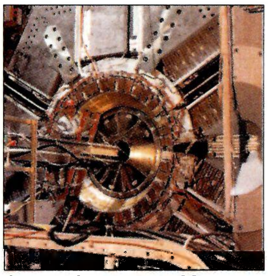


Cover: Glittering stars and wisps of gas create a breathtaking backdrop for the self-destruction of a massive star, supernova 1987A, in the Large Magellanic Cloud, a nearby galaxy. This supernova was a turning point in the study of these cosmic explosions. For the latest implications of these studies see p13. In this NASA Hubble Space Telescope image, the supernova remnant is surrounded by a forest of ethereal, diffuse clouds of gas. This three-colour image is composed of several recent pictures of the supernova and its neighbouring region. In a few years the supernova's fast-moving material will produce a new series of cosmic fireworks that will offer a striking view for more than a decade. (photo: Hubble Heritage Team.)

Edited by Alison Wright

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

DNA acts like a semiconductor

Scientists at Basel have demonstrated that DNA can conduct electricity – a property that could lead to an effective way to repair a DNA helix after radiation damage.

DNA in water was dropped onto a gold-coated carbon foil punctured with an array of 2 µm holes. Blotting paper removed most of the liquid, leaving ropes of DNA molecules spanning the holes in the foil.

Inside an ultrahigh vacuum chamber (10^{-7} mbar), the ropes were broken using a mechanical point. This was watched using a low-energy electron point source microscope (a coherent beam of 20–300 eV electrons), which produced holographic images.

The point was then used to create a potential difference between the loose end of the DNA rope and the foil, to which the other end of the rope was attached. Current flowed along the molecules and a linear variation of the current with voltage, obeying Ohm's Law, was measured in the ±20mV range. The DNA had a resistivity of about 1 MΩ/cm – equivalent to that of a good semiconductor.

The details of the conduction mechanism are not understood, but the fact that DNA chains of up to several tens of milimetres can easily be made means that DNA is suited for use as quantum wires in mesoscopic devices (larger than 1 nm but smaller than 1 µm).

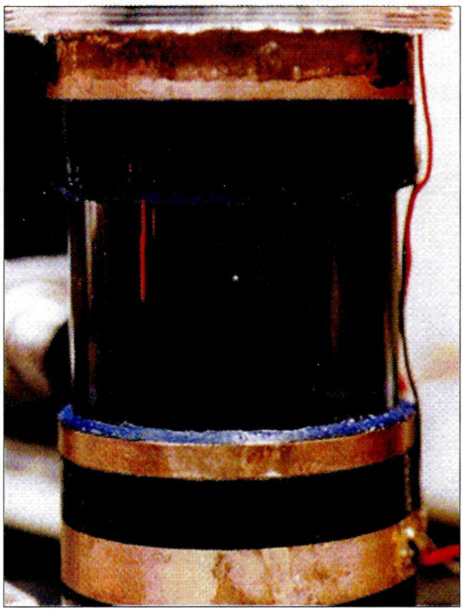
Is sonoluminescence solved?

Gas bubbles trapped in a liquid and excited by sound waves expand then collapse, emitting an intense burst of light – a process known as sonoluminescence. Typically, a bubble can expand by up to 50 µm before collapsing, usually within 50 µs, to a radius of less than 1 µm, but remain stable.

This had never been fully explained, but now a team of scientists from Harvard, Marburg in Germany and Twente in the Netherlands has proposed a model to explain the bubble's stability and the light emission.

New features include the dependence of the bubble's temperature on its radius and an allowance for the small emissivity of the weakly ionized noble gas inside the bubble (after recent experiments demonstrated that all molecules other than noble gases diffuse from the bubble).

The team has suggested that the light is emitted by radiation from the ionized gas (thermal bremsstrahlung) and by the recombination of ions within the bubble.



Lawrence Crum, University of Washington

In sonoluminescence, a gas bubble in a liquid-filled cell is excited using sound waves, causing it to expand before collapsing and emitting a visible flash.

Science conference

A conference on science and its role in society will take place in Budapest in June. Organized by UNESCO and the International Conference on Science, the World Conference on Science will bring together representatives of government, education, research and industry, as well as the media and the general public, to assess the achievements of science and the challenges to be faced in the 21st century.

A preparatory meeting on the future of physics has already recommended that public awareness and the training of good science teachers should be priorities, and it pushes for a declaration affirming the vital importance of basic physical science and the need to protect and support curiosity-led physics.

Laser makes antimatter

Experiments with the Petawatt laser at Lawrence Livermore National Laboratory have created antimatter – something that is usually the preserve of high-energy physics.

The laser (1 petawatt in a 1 fs pulse) was focused on a thin gold disc, ripping electrons from the gold atoms and accelerating them to several mega-electronvolts. The electrons collided with other atoms, producing X-rays with enough energy to release neutrons and induce fission in a sample of uranium metal.

However, the researchers also observed positrons being created – more than 100 from a single laser shot and consistent with the expected rate of electron–positron pair production by X-rays. *AIP*

Atomic laser

Several steps towards building an atomic laser have been made by groups in the US, Japan, Israel and Germany. By firing two laser beams into a Bose–Einstein condensate, a highly directional beam of sodium atoms of well defined momentum has been extracted. A pulsed laser pushing atoms out of the condensate in wave packets, which then start to overlap, produced four-wave mixing – a method familiar in nonlinear optics but demonstrated in matter waves for the first time. Meanwhile, a continuous beam of rubidium atoms has been produced for a record 0.1 s.

Late news: CERN's LEP electron–positron collider supplies 100 GeV beam (story next month).

Space Shuttle experiment reveals

A spaceborne particle physics experiment has come up with new information on the distribution of cosmic-ray particles.

On 2–12 June 1998, the primary payload of NASA's Space Shuttle Discovery in orbit, 400 km above the Earth, was the Alpha Magnetic Spectrometer (AMS), a sophisticated detector of the type that is normally used in high-energy physics laboratories.

During the 10 day voyage, the AMS recorded the tracks of millions of cosmic particles. It was the first time that such a sophisticated physics detector had been deployed in space and the first time so much information on cosmic particles had been collected.

After careful analysis, the data now reveals that subnuclear particles in outer space behave in unexpected ways, especially in how they react to the variation of the Earth's magnetic field with latitude. They behave as though they are confined in a large magnetic toroid around the Earth's equator.

Outer space is filled with cosmic-ray particles, the debris being released by subnuclear explosions in distant stars. Viewing these particles from the Earth is difficult because of the shield of the Earth's atmosphere (the particles are transformed as they crash into atmospheric nuclei). With the AMS, for the first time a major physics experiment was able to view cosmic rays above this atmospheric barrier.

The particle tracks recorded by the AMS show how different cosmic particles respond to the magnetic field of the Earth. In orbit, the AMS was able to scan cosmic rays arriving at different latitudes as the Earth moved. According to previous mappings, this magnetic field was expected to repel less energetic particles arriving around the equator. This terrestrial magnetic repulsion becomes weaker at higher latitudes, so that more particles of lower energy would be seen nearer the North Pole and South Pole.

From the recorded data, the AMS finds an unexpectedly high level of lower energy protons at almost all altitudes, and particularly near the equator. This first deployment of an experiment equipped with a powerful magnet above the Earth's atmosphere reveals that the distribution of cosmic particles 400 km above the Earth is more complex than had previously been thought.

Even more surprising is that, for protons at less than 6 GeV and in an equatorial arc extending over 4000 km at an altitude of 400 km, the AMS detector sees as many particles moving upwards (away from the Earth) as coming down. It is as though, at this energy, cosmic protons are constrained

Major agreement made with China

Chinese National Natural Science Foundation vice-president WANG Naiyan and CERN research director for collider programmes Roger Cashmore sign a new agreement, bringing participation worth 4.8 million Swiss francs from Chinese institutes for the LHC CMS experiment. Funding for these projects comes from the Chinese National Natural Science Foundation and the Academy of Sciences. Peking University president CHEN Jia-er was involved in negotiations with National Natural Science Foundation President ZHANG Cun-hao, vice-president WANG Naiyan and academy general-secretary ZHU Xuan.

Underlining the worldwide involvement in the programme at CERN's LHC collider, a milestone agreement brings funding from Chinese bodies for the LHC CMS experiment.

Chinese physicists have long participated in CERN's programme, notably in the L3 experiment. The new agreement includes the Chinese National Natural Science Foundation, the Institute of High Energy Physics (IHEP) in Beijing, and the universities of Peking and of Science and Technology in Hefei.

A major CMS contribution from China will be the endcap support "carts" for the magnet yoke, which will be made by Chinese industry. A protocol allowing production to begin was signed last year between CERN, acting on behalf of CMS, and the Chinese National Academy of Sciences.

The Chinese will also contribute detector parts, largely via a collaboration between IHEP and Fermilab. A similar collaboration involves Fermilab and the St Petersburg Nuclear Physics Institute in Russia. They will produce cathode strip chambers (CSCs) for the CMS muon-detection system. Fermilab will equip the other institutes with the raw materials and tooling to produce the 648 CSCs. The detector will cover more than 1300 sq. m.

Also covered by the new Chinese agreement is a project involving Peking University that will make a major contribution to resistive-plate chambers (RPCs) for the CMS muon-detection system in collaboration with other institutions, in particular from Italy. RPCs respond rapidly to passing particles and trigger the data acquisition system to read out the detector when interesting collisions occur.

China is also building electronics for the CMS muon detector through a collaboration between Chinese and Italian institutes.

unexplained particle behaviour

around the Earth inside a magnetic toroid.

A similar effect is seen with cosmic electrons and their antiparticles – positrons – except here the energy is approximately 3 GeV. These electrons and positrons are also not primordial – they are continuously produced by high-energy cosmic radiation. This should produce as many cosmic positrons as electrons. However, in the equatorial band, the AMS sees about four times as many positrons as electrons! This discrepancy is not understood.

Another puzzle is that in the equatorial toroid, AMS also finds the rare isotope helium-3 rather than the more common helium-4.

The advertised goal of the AMS was to search for signs of cosmic antimatter. In a universe created from a Big Bang that presumably created matter and antimatter in equal amounts, there should be signs of this primordial antimatter, with antinuclei built of antiprotons and antineutrons.

Crewpatch of the NASA Space Shuttle mission that carried the AMS experiment.

However, our universe appears to be built up entirely of matter and no experiment has ever detected any primordial antimatter. The AMS set out to look for antinuclei above the screen of the atmosphere, but a sample of almost three million cosmic helium nuclei arriving from outer space revealed not one helium antinucleus. AMS sees no primordial antimatter.

AMS, led by Sam Ting of MIT, is a major international collaboration. Important contributions came from groups led by Roberto Battiston in Perugia, Maurice Bourquin in Geneva, Hans Hofer at ETH Zurich, Klaus Luebelsmeyer in Aachen, Antonino Zichichi in Bologna, Shih-Chang Lee in Taipei, Jean-Pierre Vialle in Annecy, Carlos Mana in Madrid, Gaspar Barreira in Lisbon, Jarmo Torsti in Turku and Hesheng Chen in Beijing.

DAFNE and KLOE's kaons

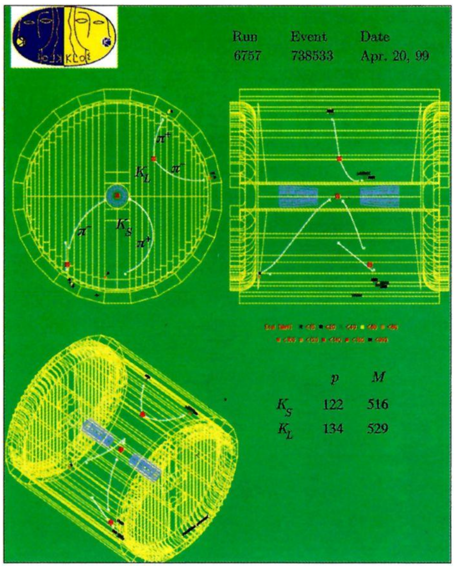
The DAFNE electron–positron collider at Frascati and its KLOE detector are flexing their muscles. On 14 April, during the first DAFNE tune-up using two beams and with the KLOE superconducting detector solenoid in operation, a luminosity of 1.2×10^{29} per sq. cm/s was reached in single bunch mode with 11 mA in the positron beam and 7 mA for electrons, corresponding to some 70% of the expected luminosity for this current.

The first electron–positron scattering events were seen in the KLOE detector. A preliminary estimate of the event rate is in agreement with indications from the machine luminosity monitor.

DAFNE operates at the phi meson resonance (1020 MeV). The ensuing scan of the phi peak produced the first CP-violating decays of long-lived kaons. Such decays will provide more information on the mystery of CP violation, through which nature is able to discriminate between matter and antimatter.

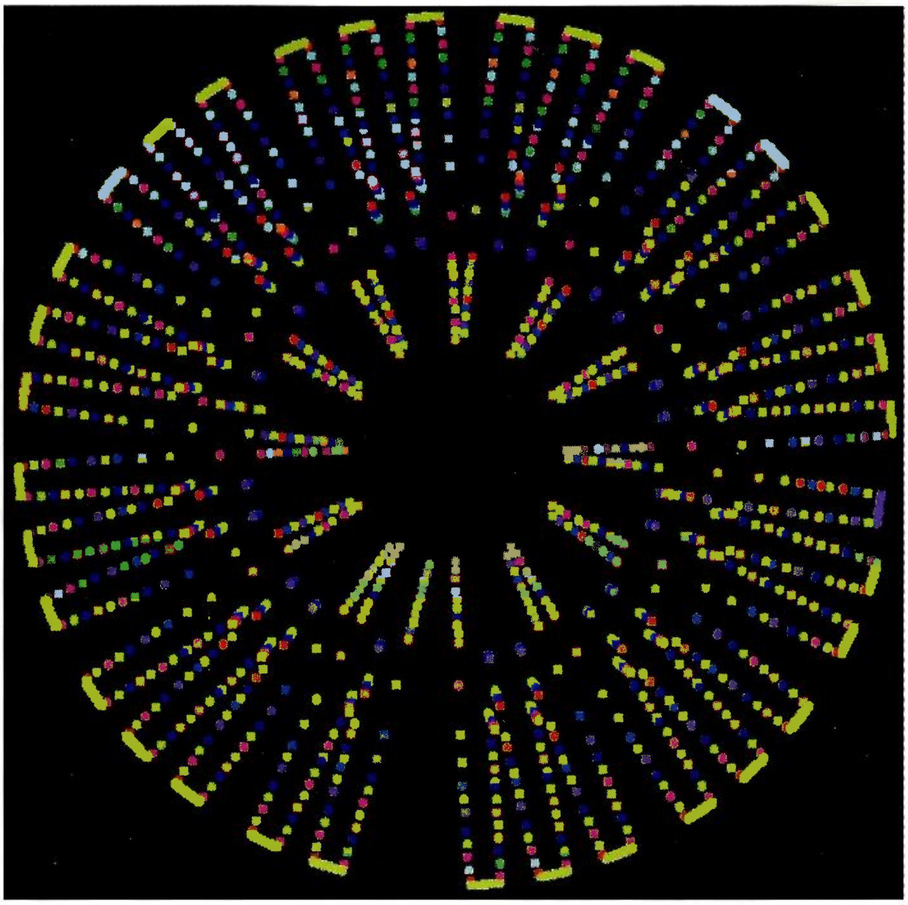
The phi is only slightly heavier than a pair of neutral kaons (498 MeV each), and kinematically this decay is very constrained. At first sight, phi decay via a rho meson (770 MeV) and a pion (140 MeV) should be easier. However, the phi prefers to decay into two kaons, which produces strange results.

The phi meson was first seen in bubble chamber experiments at Brookhaven in 1962. Its decay behaviour motivated George Zweig, who was then at Caltech, to propose his model of "aces", which paralleled the invention of quarks by Murray Gell-Mann (see the story next month, and more news of DAFNE commissioning).



Kaons at KLOE. The new DAFNE electron–positron collider at Frascati operates at the phi meson resonance (1020 MeV). This shows a phi decay into a short-lived and a long-lived kaon. Both kaons decay into two charged pions (the red boxes indicate the kaon decay vertices). A long-lived kaon usually decays into three pions, and a decay into two pions violates CP symmetry. The study of these decays provides more information on the mystery of CP violation, which enables nature to distinguish matter from antimatter. Phi decays produce pairs of neutral kaons as a short-lived and a long-lived kaon, which, owing to their different lifetimes, are clearly tagged by the position of the decay points, the short-lived one close to the central collision point and the long-lived one further away. The KLOE detector's central drift chamber must be large (3×4 m) to intercept the long-lived kaon decays.

Countering the beam-beam effect



How to fill CERN's LHC proton collider with protons. A view of the arrangement of 2835 proton bunches in one beam of CERN's LHC proton collider. This shows how the bunches can be grouped into classes that "see" a given sequence of interactions with bunches of the opposing beam.

A theme that is common to many new particle colliders is the determined push to extend the physics reach by boosting the collision rate (luminosity).

In a particle collider ring, the counter-rotating beams are able to "sense" the electromagnetic effects of each other even before the particles collide. This infamous "beam–beam effect" is complex and can have all kinds of results, sometimes unexpected. These can include decreased collision rates through beam blow-up, and orbit distortions and instabilities.

With CERN's LHC proton collider aiming for very high collision rates (luminosity), such effects could easily degrade performance. To boost the particle supply and the collision rate, today's colliders use ingenious bunched beams that interlace as they collide.

To minimize deleterious beam–beam effects, new colliders using many bunches make them cross each other at an angle rather than colliding head-on. However, ▷

Mirabelle's 30th anniversary celebrated in Russia

Last year marked the 30th anniversary of the inception of the scientific research programme of the Mirabelle liquid-hydrogen bubble chamber, which was a joint effort between the Institute for High-Energy Physics in Protvino, Russia, CERN and CEA-Saclay in France.

A superb technological achievement in its time, Mirabelle was at that time the largest electrophysics structure of its kind in the world. Measuring 11 × 5 × 14 m, representing about 3000 tons of instrumentation and a useful volume of 6 m^3, it was designed, prepared and experimented on by a Saclay research team under the leadership of Pierre Prugne.

Nicknamed "the little prune", the chamber became the apple of Prugne's eye. In 1970–1971 it was installed on the 70 GeV ▷

Pierre Prugne (left), the "father" of the Mirabelle bubble chamber, receives an honorary doctorate from Nicolai Tyurin, First Vice-Director of the Institute for High-Energy Physics, Protvino, Russia. At a time when such contacts were difficult, Mirabelle helped pioneer East–West scientific collaboration.

even a few long-range effects can couple all circulating bunches.

For the LHC, progress was summarized at an LHC99 Beam-Beam workshop at CERN in April. The discussions were organized in two working groups. The first was on incoherent or weak-strong beam-beam effects and was chaired by Eberhard Keil of CERN. The other was on coherent or strong-strong beam-beam effects and was chaired by Kaoru Yokoya of the Japanese KEK laboratory.

A vital part of this work is to decide on an optimal beam bunch scenario to fill the LHC rings with particles. With beam-beam effects being hard to predict, experience as new machines explore new energy regimes is extremely valuable. For the LHC, the new working conditions at Fermilab's Tevatron proton-antiproton collider, which is also striving for very high collision rates, will provide valuable input. Further experience will come from another new collider – Brookhaven's RHIC. Like the LHC, this uses two beam pipes.

Experimental data from the PEP-II electron-positron collider at SLAC, Stanford, US, which uses head-on collisions, and from the KEKB electron-positron collider at KEK, Japan, which uses a beam-crossing angle, will also be highly relevant. Complementary input comes from simulation program, which try to predict beam-beam effects. This work is not easy, but different approaches seem to be converging.

proton beam accelerator at Protvino, which was at that time the most powerful accelerator in the world.

The fast ejection system and, in particular, the particle beam separator for Mirabelle were created at Protvino with the assistance of specialists from CERN . The first photographs were obtained in June 1971. From then on, physicists from Protvino, Saclay and CERN carried out investigations into photon and meson interactions.

Recently at Protvino, specialists from Saclay (many now pensioners), members of their families and their Russian colleagues celebrated Mirabelle's 30th anniversary. At the official ceremony, Pierre Prugne received the honorary degree of doctor of science.

As a souvenir, the chamber's cold piston – which was the heart of the Mirabelle chamber – was symbolically erected in the town centre, in a square that was appropriately renamed Mirabelle Square.

Understanding deconfinement

Participants at the Trento workshop on understanding deconfinement in QCD at the European Centre for Theoretical Studies.

Simulating the immediate aftermath of the Big Bang, strongly interacting particles at high temperature or density are expected to produce weakly interacting "deconfined" quarks and gluons – the famous quark-gluon plasma.

Existing experiments using high-energy beams of heavy ions at CERN's SPS synchrotron – CERES/NA45 (electron-pair production in high-energy heavy-ion collisions) and NA38, NA50, NA51 (muon production in high-energy heavy-ion collisions) – have achieved results that may indicate that the plasma has already been observed (May p8).

In a new energy domain, the Relativistic Heavy Ion Collider at Brookhaven will begin its search later this year and, looking further ahead, understanding the plasma is a primary focus of heavy-ion physics at CERN's LHC.

Awaiting definitive observation and measurements, more work is necessary to develop a theoretical understanding of the plasma's properties and to provide unambiguous signals of its production. In quantum chromodynamics (QCD), the field theory of quarks and gluons, which is the framework for this understanding, complementary tools are provided by numerical simulations of QCD on spacetime lattices and by QCD modelling.

A workshop at the European Centre for Theoretical Studies (ECT), Trento, Italy, followed a 1998 meeting in Bielefeld and attracted interested theorists. The SPS experimental collaborations were also represented.

ECT funding covered the bulk of participants' local expenses. Members of the lattice-QCD community benefited from the European Union's Finite Temperature Phase Transitions in Particle Physics training and mobility network.

Proceedings will be published by World Scientific. Information is available at "http://www.mpg.uni-rostock.de/udq99.html".

Edited by Emma Sanders

Galactic record set

Astronomers using the Hubble Space Telescope have discovered the most distant, and therefore the youngest, object ever observed. The galaxy existed when the universe was only 5% of its present age (redshift 6.68). Stretched by the expansion of the universe, the wavelength of its light is shifted to the red. This redshift is a measure of age. The previous record holder was 1% older.

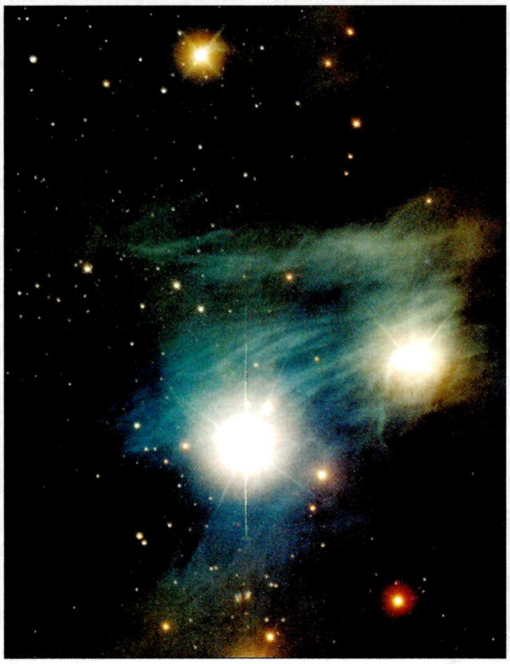
The galaxy emits strongly at ultraviolet wavelengths, indicating a high star formation rate. This suggests that early galaxies had much greater star formation rates than galaxies today. Information can also be gleaned about the intergalactic medium. Absorption of the blue light by intergalactic hydrogen along the line of sight is nearly 100% – much more than light from galaxies slightly closer to home. This might be because at early epochs the intergalactic medium was mainly neutral hydrogen, which later became ionized over a relatively short period when active galaxies started pumping out radiation.

The HST imaging spectrograph is currently a unique tool for discovering faint objects. These new results augur well for observations at the European Southern Observatory's VLT (see picture of the month), which will have even greater sensitivity than the HST. A systematic study of very distant galaxies will provide new information on the origin and formation of galaxies – essential for cosmological theories.

Water, water everywhere

The third mission in NASA's small explorer programme was launched last December. The Submillimetre-Wave Astronomy Satellite (SWAS) is designed to study the chemical composition of interstellar clouds. Submillimetre radiation in the 487 to 556 GHz range is emitted by water, molecular oxygen and atomic carbon and cannot be detected from the ground owing to atmospheric attenuation. So far, results from the satellite show an unexpectedly large abundance of water in the star-forming regions observed.

Picture of the month



This image, which was taken with the Antu telescope, shows the Chameleon I complex of bright nebulae and hot stars. Antu is one of two telescopes that are now operational at the European Southern Observatory site in the Chilean Atacama desert. Antu and Kueyen were named in the local Mapuche language: Antu means the Sun and Kueyen means the Moon. By the year 2005, four telescopes will form the Very Large Telescope (VLT) interferometer. (European Southern Observatory.)

Cosmic-ray detector is under way

The Pierre Auger Observatory "under construction" in Argentina's Mendoza province. (James Cronin, Pierre Auger Project.)

Work has now started on the Pierre Auger Southern Observatory in Argentina's Mendoza province. When completed in the year 2003, it will be the world's largest cosmic ray observatory and will have 1600 detectors spread over 3000 sq. km – an area about 10 times the size of Paris. A complementary observatory is planned for the northern hemisphere.

The detectors consist of water tanks that are equipped with photomultipliers, which detect Cherenkov radiation emitted by the passing particles. On dark nights, sensitive light sensors will also pinpoint the origin of showers by observing the faint fluorescence that is caused by collisions with air molecules in the atmosphere.

Direction, energy and mass measurements will be more accurate than those that are achieved by current cosmic-ray detectors, and the large detector will provide better statistics for rare high-energy events.

The highest-energy cosmic rays ever detected have been seen by the Fly's Eye cosmic-ray detector in Utah and AGASA (Akeno Giant Air Shower Array) in Japan. Their energy, which is greater than 10^{20} eV, is more than a hundred million times as great as that of particles produced in accelerators.

Auger Project collaborators, from 53 institutes in 19 countries, hope to begin southern Hemisphere observations in the year 2001.

The quintessence of cosmology

The most striking recent development in cosmology has come from supernova studies, which reveal how the expansion rate of the universe changes with time. Rather than slowing down, the universe is expanding faster as time goes by. *Pedro G Ferreira* of CERN explains how theorists are faced with the dilemma of living with the controversial cosmological constant or having to postulate a new form of matter.

With no ruler in the sky, astronomers have to locate visible cosmic milestones to help them to measure distances. These distance indicators can be visible objects, such as stars or galaxies, or effects, such as explosions, gravitational lensing or the thermal scattering of background radiation in cluster cores.

As the light from these distant milestones rushes towards us, its wavelength is stretched (redshifted) by the expansion of the universe. In the classic picture this expansion was thought to be decelerating owing to the pull of gravity.

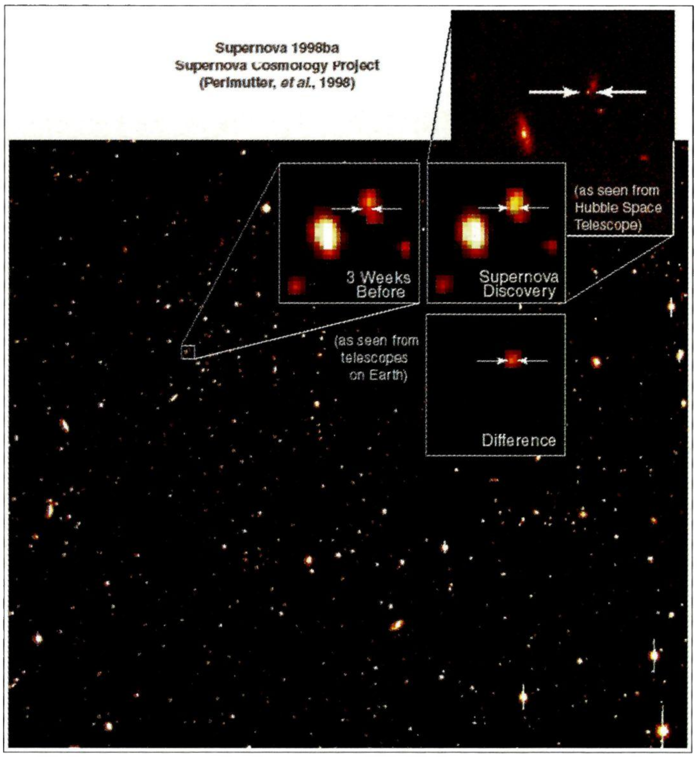
In 1929 Edwin Hubble showed that the redshift and distance of nearby galaxies obeyed a linear law. From the assumption that the universe was expanding, one could show that Hubble's comparison gave a direct estimate of the expansion of the universe and, as a consequence, a measurement of its age.

The difficulties of these measurements are reflected in the result that Hubble obtained: the universe was only a thousand million years old – younger than most astrophysical objects. Current measurements lead to a generally accepted age of 15 gigayears, although different methods still give different values.

Cosmic fireworks

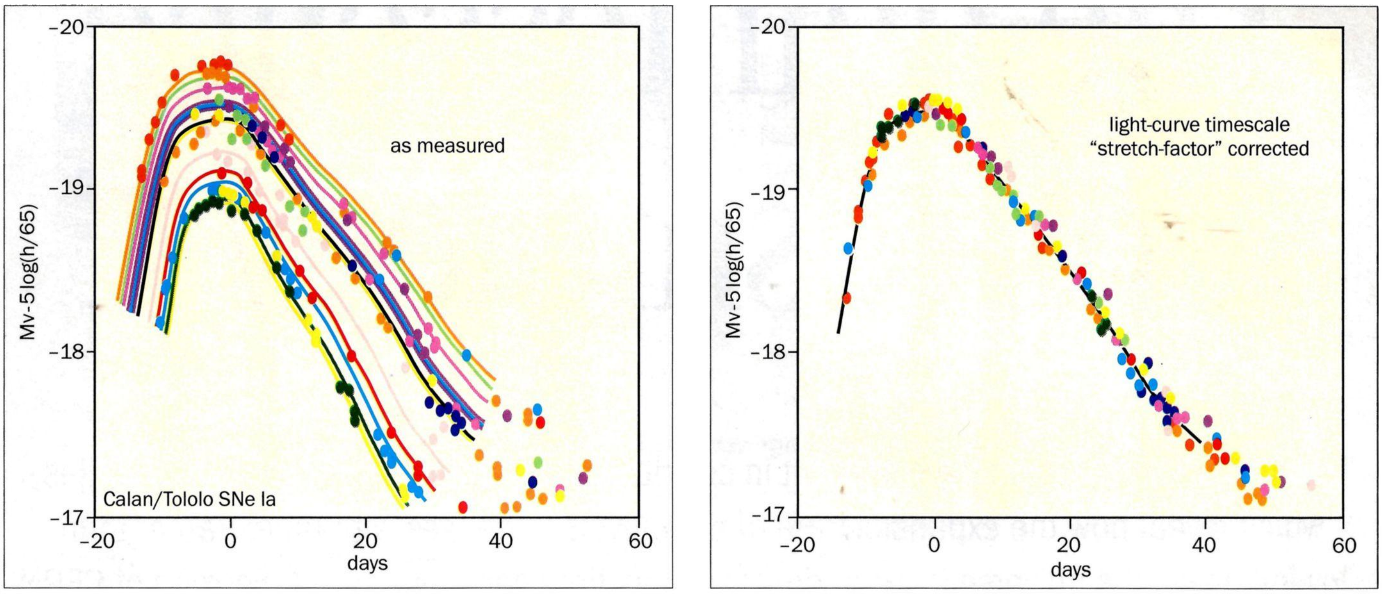
Massive stars are doomed to a violent death as supernovae. The immense gravitational crush inside such a star heats up their core, tripping new thermonuclear switches to release fusion energy. When its nuclear fuel is spent, the star can no longer resist the remorseless pull of gravity and so it implodes, cooking a stew of heavy nuclei and compressing its component atoms into mere neutrons.

Like a rubber ball that has been squeezed, the remnant of the star springs back in a huge shockwave that flings nuclear residue far out into space and releases a characteristic light in the sky. The duration and brightness of nearby supernovae is well known, so by comparing the observed variation in brightness (the light curves) of distant supernovae to those that are closer gives accurate measurements of their distances.



Before-and-after pictures (and Hubble Space Telescope picture) of a high-redshift supernova discovered by the Supernova Cosmology Project in March 1998. Supernovae are valuable benchmarks for the distant universe.

The drawback in this method is that these events are rare. Only a



The characteristic "light curves" (variation in intensity) of nearby supernovae. The vertical axis is absolute magnitude (a logarithmic measure of the inverse absolute brightness).

few supernovae occur every thousand years in a typical galaxy, so finding them means looking at large numbers of galaxies at a time.

The Supernova Cosmology Project and the High-Z Supernovae Project have developed a method to look for and then follow supernovae explosions. These groups carefully scan large patches of the sky for sudden supernova flashes, then carefully monitor their evolution with optical telescopes, obtaining accurate measurements of the light curve and spectra.

In January 1998 the Supernova Cosmology Project presented its 1997 harvest – the analysis of 42 newly discovered distant supernovae. To everyone's surprise, these supernovae looked dimmer than expected in the standard, decelerating model of the universe. Instead of slowing down, the expansion of the universe appeared to be speeding up. The results were confirmed by the rival High-Z Supernova team and have become an essential ingredient of current cosmological model building.

The systematic analysis of these results has been thorough, but there a few sceptics still remain. Two main criticisms are raised: first, distant supernovae could look dimmer because intervening dust scatters the light. Second, are we completely sure that these distant supernovae explode in the same way as those that we see closer to us?

Both groups have set up campaigns to understand supernovae better, and results at different wavelengths will map out the characteristics of intergalactic dust with great precision.

Accelerating universe

With an accelerating universe, physicists had some explaining to do. The acceleration or deceleration is dictated by the sum of the energy density of the matter in the universe, and the pressure exerted by the matter in all three directions. If this sum is positive, the universe decelerates; if it is negative, the universe accelerates (the energy density is always positive).

For example, for a universe consisting mostly of ordinary massive §particles, the pressure is essentially negligible. Meanwhile, for a universe dominated by photons or massless neutrinos, the pressure is equal to one-third of the energy density. For both types of matter the pressure is not negative. Therefore, if they are dominant, the universe will decelerate.

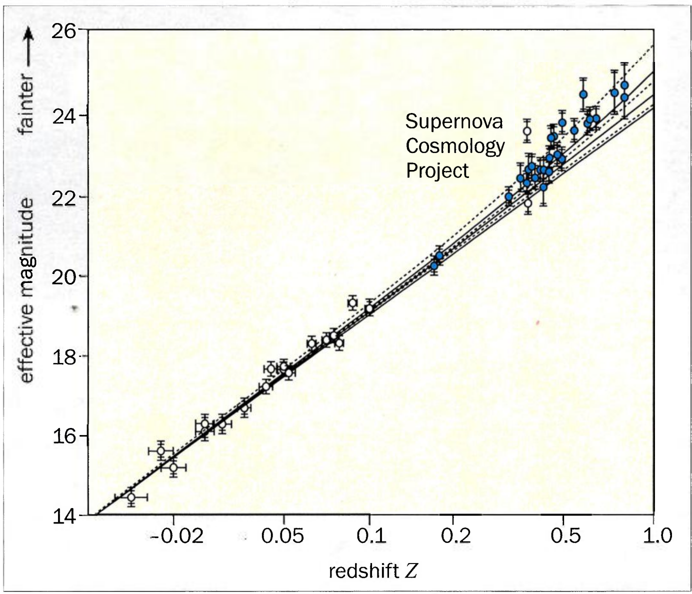
An accelerating universe needs a negative pressure to counterbalance the energy density. The standard ploy is the cosmological constant. Introduced by Einstein in his general theory of relativity to counterbalance the pull of gravity and therefore lead to a static universe, the cosmological constant has been on the one hand a convenient fix for the Big Bang cosmology when the theory doesn't fit the data, but on the other hand one of the major conceptual problems in particle physics and cosmology.

The problem has been stated many times: if we add up the vacuum fluctuations from all of the various quantum fields we know of, we naturally obtain a cosmological constant with an energy density of $10^{29}eV^4$. With such a large value, Einstein's theory would essentially predict that our universe is flying apart with absolutely no possibility of forming galaxies, stars or planets.

This was always an embarrassment for theorists, but if the cosmological constant were zero, there was always the hope that they had "nothing" to worry about.

There have been many attempts to get rid of the cosmological constant. One of the more promising possibilities is that supersymmetry – an as yet unobserved symmetry between bosons and fermions – may lead to an exact cancellation between all of the various contributions to the vacuum energy density. Suggestions abound, but a compelling model has yet to emerge that could explain why the cosmological constant is so small.

A highly speculative possibility relies on a particular feature of the quantum theory of gravity. Fluctuations in the fabric of spacetime modify the local topology, creating a quantum foam of holes and handles (wormholes). The overall effect is to drive the cosmological constant to zero.



The accelerating universe. As the light from distant stars rushes towards us, its wavelength is stretched (redshifted) by the expansion of the intervening universe. This expansion was thought to be decelerating with time – slowing down with the pull of gravity. Not any more! This diagram shows the variation in redshift with brightness (magnitude) for samples of nearby (data points on the left) and distant (right) supernovae. The vertical axis is the apparent magnitude; larger values correspond to dimmer objects. The upwards deviation of the more distant supernovae from a straight line shows that the expansion of the universe is accelerating as time goes by (Supernova Cosmology Project).

The problem of how to incorporate the cosmological constant into a sensible theory of matter remains unresolved and, if anything, has become even harder to tackle with the supernova results. Until now an exact cancellation was needed so that one could argue that some fundamental symmetry would forbid it to be anything other than zero. However, with the discovery of an accelerating universe, a very special cancellation is necessary – a cosmic coordination of very big numbers to add up to one small number. If we are indeed measuring a constant energy density with the supernova results, it is more at the level of 10^{-3}eV^4.

The new quintessence

To save the situation, an idea put forward by physical cosmologists in the early 1980s has recently been resurrected. This uses a type of matter – "quintessence" – that has a negative pressure, doesn't cluster on small scales and could come in various forms and guises: in general it is considered to be a scalar field like the Higgs particle, but with incredibly weak interaction with the rest of the standard model particles.

In the same way that the original quintessence, or fifth element, was an extension to fire, water, earth and air, the new quintessence should be added to the usual cosmological family of baryons, radiation, neutrinos and WIMPS (weakly interacting massive particles – a form of cold dark matter).

For many cosmologists the accelerating universe has come as a blessing. The Big Bang cosmology postulates a completely uniform protouniverse. To account for the observed structure of galaxies and clusters, the protouniverse had to contain gravitational seeds that would grow into observed structure.

The favoured explanation for the origin of large-scale structure in the universe assumes a scale invariant, Gaussian distribution of perturbations on large scales and a well defined mixture of the four cosmological fluids. Known as the standard cold dark matter model, it has fared poorly in comparison with observational data: if one attempts to fit the distribution of galaxies on small scales, it underpredicts the amount of structure on large scales.

There have been many attempts to fix it, by considering different mixtures of the matter content (by considering, for example, massive neutrinos or decaying dark matter particles), or by reducing the amount of gravitationally clustering matter in the universe. One of the options is to postulate the presence of a cosmological constant, Λ, or quintessence, which can alleviate the large-scale structure problem by boosting large-scale fluctuations.

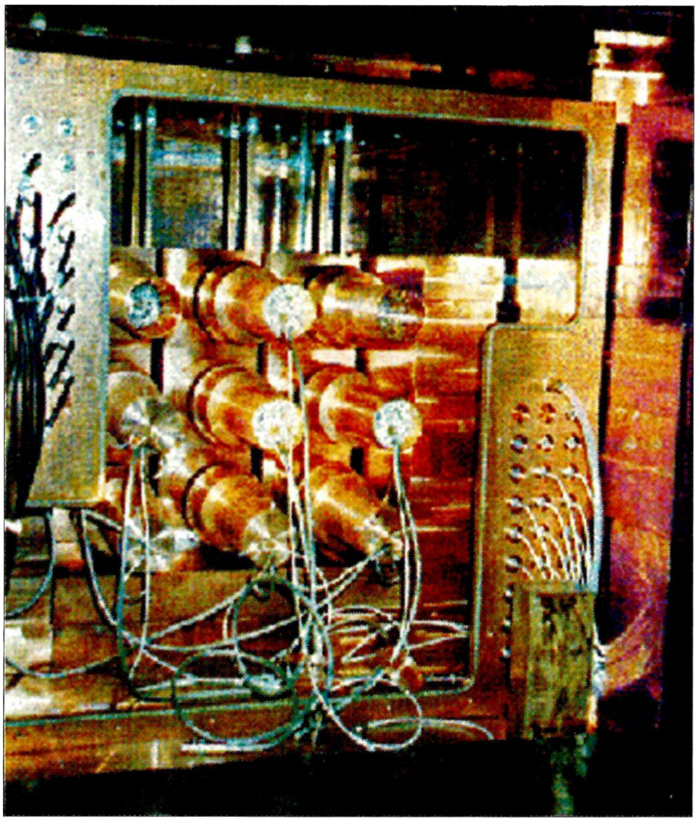
The supernova results have given this model the observational edge over the rival candidates, and Λ-CDM, as it has become known, is the current benchmark against which all other models of structure formation must be compared.

Pedro G Ferreira, *CERN.*

Searching for signals from the dark universe

At the Italian Gran Sasso National Laboratory, a novel experiment that is in search of signs of the invisible dark matter that pervades our universe reports an intriguing result.

A large part of the dark matter that seems to dominate the universe is expected to be in the form of relic particles. This "dark universe" could be a unique window through which we will be able to look for new physics. The DAMA experiment at the INFN Gran Sasso National Laboratory is investigating this new frontier and sees an annual variation, which is suggestive of the Earth's motion against a background "wind" of particles.



The DAMA experiment in the Italian Gran Sasso underground laboratory is searching for signs of WIMPS as a component of the invisible dark matter of the universe. The apparatus contains 100 kg of NaI(Tl).

Particles from the dark universe

Measurements of luminous matter (stars) lead to the conclusion that the universe does not contain enough stellar matter to halt the residual Big Bang expansion. Without enough such gravitational braking, the universe will continue to expand forever. However, many experimental observations suggest that luminous matter is not the end of the story. To account for the observed motion in the cosmos, gravitational fields much stronger than those attributable to luminous matter are required – more than about 90% of the mass in the universe should be the result of invisible dark matter.

This conclusion is further supported by simulations using cosmological models that point out the necessity for large numbers of relic particles – weakly interacting massive particles (WIMPs) – from the early universe.

This scenario implies that our galaxy should be completely embedded in a large WIMP halo. Our solar system, which is moving with a velocity of about 232 km/s with respect to the galactic system, feels a continuous WIMP "wind".

The quantitative study of this wind would provide information on the evolution of the universe and investigate new physics possibilities. The lightest neutral particle (the neutralino) expected by the supersymmetric extension of the Standard Model is the best WIMP candidate.

How to catch a WIMP?

Direct detection of WIMPs is very difficult because they rarely interact. WIMP searches should be shielded from cosmic rays and operate in an environment of very low radioactivity. The detectors should be built using low-radioactive materials.

DAMA's home is deep underground in the INFN Gran Sasso National Laboratory in Italy. The collaboration (involving the University and INFN-Roma2, University and INFN-Roma, IHEP-Beijing) is mainly devoted to the search for WIMPs in the same mass and cross-section region as accelerator experiments, and several results have already emerged.

Thus high-atomic-number target nuclei, such as iodine (in the form of NaI(Tl)) and xenon (in the form of a liquid xenon scintillator) are used. The search mainly focuses on WIMP–nucleus elastic scattering from the target-nuclei part of the detector, which would show up via nuclear recoil energies in the kilo-electronvolt range.

To help to isolate a possible WIMP signal from the background, the main feature of the WIMP wind is its annual modulation. As the Earth

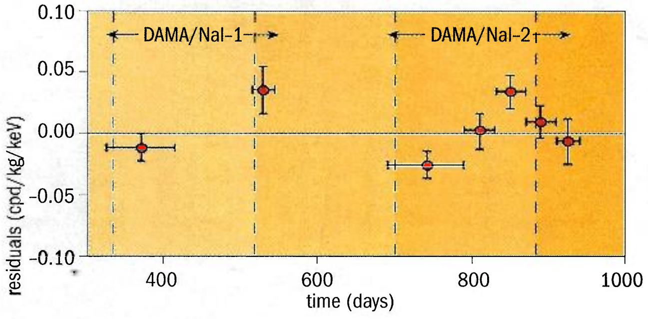


Fig. 1: The DAMA experiment sees an annual variation, suggestive of the effect of the Earth's motion against a background "wind" of dark matter particles. The model-independent residual rate in the lowest energy interval seen by the DAMA experiment is shown as a function of the time elapsed since 1 January of the first year of data taking. The expected behaviour of a WIMP signal is a cosine function with the minimum roughly at the dashed vertical lines and with the maximum roughly at the dotted lines. The complete time and energy correlation data analysis is a similar modulation.

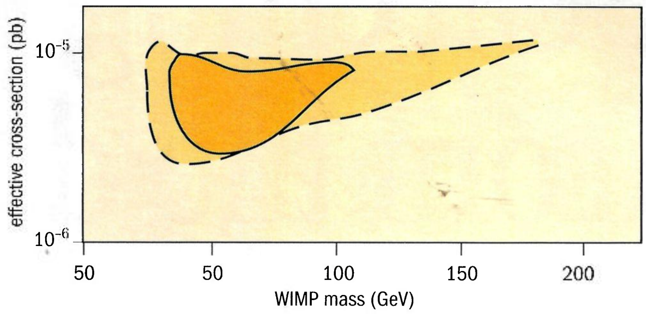


Fig. 2: DAMA sees a subtle variation in the annual count rate. Complying with many criteria (see text), it can be interpreted as being as a result of a relic neutralino. The vertical axis is the WIMP–nucleon cross-section multiplied by the WIMP local density in 0.3 GeV/cm^3. The solid line contour is the combined analysis of the annual modulation DAMA data considering standard values for the local and escape velocities of the galaxy. The dashed line contour comes from varying these velocities around their mean values: between 170 and 270 km/s for the local velocity and between 450 and 650 km/s for the escape velocity.

rotates around the Sun, it would be crossed by a higher WIMP flux in June (when its rotational velocity is in the same direction as that of the solar system with respect to the galaxy) and by a smaller one in December (when the two velocities are subtracted). The fractional difference of the rate is some 7%.

To see such modulation requires heavy, stable detectors with appropriate features and stability control. The 100 kg highly radiopure NaI(Tl) DAMA set-up is an example. Clear signatures overcome the difficulties of comparing different experiments and techniques.

The 100 kg DAMA NaI(Tl) set-up

DAMA uses highly radiopure NaI(Tl) scintillators that are produced in collaboration with the CRISMATEC company. All of the materials and the crystal growth and handling procedures have been studied carefully. A major effort has gone into optimizing the detectors and the electronics to give a relatively high number of photoelectrons per kilo-electronvolt and a low noise level.

The low background photomultiplier tubes employed in the experiment (two for each detector, working in coincidence at a single photoelectron threshold) have been developed by Electron Tubes Ltd. The materials were preselected by the company and their radioactivity was measured deep underground.

The other main parts of the experiment are the passive shield (to exclude environmental contributions to the counting rate), which surrounds the copper box housing the detectors, and the glovebox placed on the top of the shield for calibration. The whole of the apparatus is kept in highly pure nitrogen with slight overpressure with respect to the atmosphere in order to keep out radioactive radon gas.

The materials of the shield have been selected and monitored for low radioactivity. The upper glovebox is used to insert radioactive sources to calibrate the detectors in the same experimental conditions as those occurring during the production measurements.

This set-up is mainly devoted to studies of WIMP annual modulation, therefore particular care has been taken in the stability and monitoring of the running condition parameters, such as the operating temperature, the high-purity nitrogen flux, the glovebox overpressure, the total and single hardware rates above single photoelectron threshold, the environmental radon level and so on. All of the information related to these parameters is continuously recorded with actual data.

The experiment is taking data from a single photoelectron threshold to several mega-electronvolts, although the hardware conditions are obviously optimized for the lowest energy region. Pulse shape information is recorded over a period of 3250 ns for the lowest energy events.

Searching for annual modulation

Any annual modulation of the WIMP–nucleus differential energy spectrum should have all of the following features attributable to WIMP interactions:
- a modulation varying as a cosine function;
- a period of exactly one year;
- a proper summer-winter phase;
- only seen in a defined low-energy region;
- single "hit" events;
- a modulated amplitude below 7%.

Single-hit events with only one detector firing are the ones of interest in WIMP search, the probability of a WIMP interacting in more than one detector being negligible.

After checking the monitored parameters, the time-dependent component of the rate is extracted from the collected data by grouping the events in cells of one day, 1 keV and one detector. The number of events in each cell is then compared by applying a maximum likelihood analysis with the expectation from the standard WIMP model. The limit on the neutralino mass (the most favoured WIMP candidate) achieved at accelerators is taken into account.

The analysis of a first dataset suggested the possible presence of a signal compatible with the features of a neutralino with dominant spin-independent interaction. A second year of data taking with larger statistics has underlined this possibility. The signal modulation is shown in figure 1 and the neutralino interpretation in figure 2.

The combined analysis of these two years of data (total statistics: 19511 kg/day) provides a confidence level of 99.6% for a neutralino mass of 59 GeV (+17/–14) and a proton cross-section of 7.0 (+0.4 /–1.2) 10^{-6} pb in the frame of the standard WIMP model.

Possible systematic effects and alternative explanations have been investigated, as discussed for example at the 3K Cosmology International Conference in Rome last October. None of the effects considered could simulate all six of the criteria for the annual modulation signature and provide the observed modulation.

Despite this the collaboration has been very cautious – mindful of the difficulties of dealing with rare events – and has increased its efforts to investigate all aspects of this intriguing result.

The region singled out by DAMA is consistent with the hypothesis of a relic neutralino as a dominant component of the cold dark matter in the galactic halo, as has been pointed out by a Turin group, which also says that some properties of the relevant supersymmetric particles should be accessible at present accelerators and in WIMP indirect searches.

The inclusion of these relic neutralinos in supergravity models hs also been considered by American physicists. A group from Rome and Moscow suggested that the effect could be the result of a heavy neutrino. Finally, the effect of the uncertainties on the dark halo local density and on the WIMP velocity distribution has been examined recently with the conclusion that the relic neutralinos possibly involved in the annual modulation effect would have a mass in the 30–130 GeV range with an upper bound extending to some 180 GeV when possible bulk rotation of the dark matter halo is introduced.

Perspectives and plans

The analysis of further statistics is in progress as well as further data taking and an upgrade of the apparatus. If new research for the improved radiopurification of NaI(Tl) is successful, the active mass could be increased to 250 kg.

A final result would mean reproducing the effect over several annual cycles, including all tof he consistency checks.

● More information is available from "http://www.lngs.infn.it/lngs/htexts/dama/".

Rita Bernabei, *Rome.*

A tale of three regions

The impact of CERN, particularly with regard to technology transfer and industrial spin-offs, shows an interesting three-fold pattern that reflects the very different geographical and political regions around the laboratory.

When CERN was established in 1954 to provide European nations with forefront facilities for scientific research, its site was Meyin, a burgeoning satellite city near Geneva, and Switzerland was its sole host state.

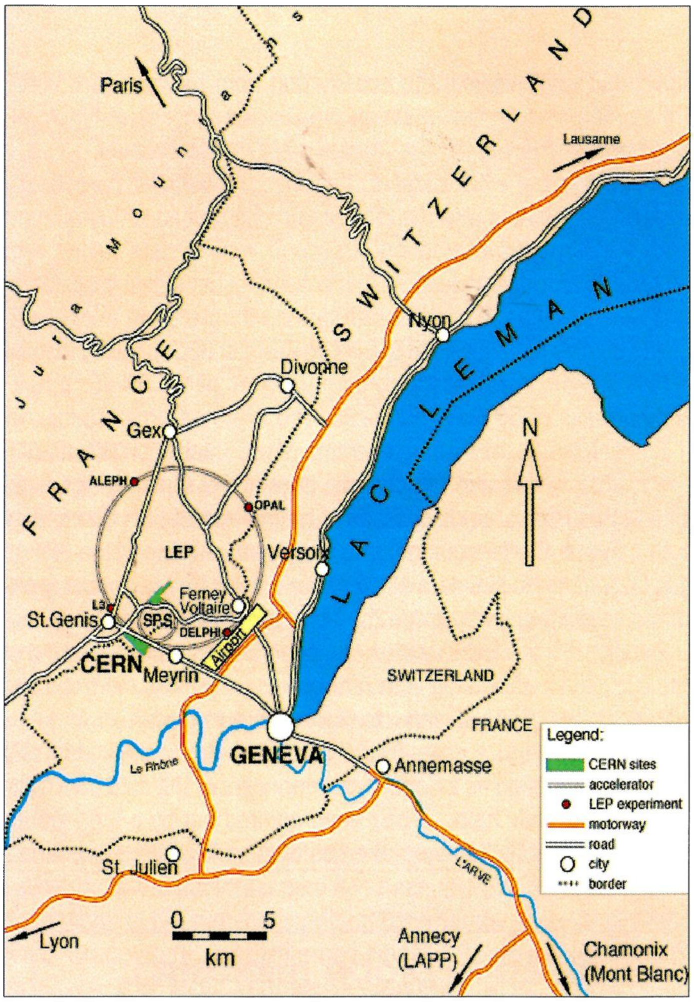
In the 1960s, construction of the Intersecting Storage Rings (ISR) extended CERN's site into France, but only in a limited sense. The land for the construction of the ISR was in France but was linked to the existing Swiss site and the boundary fence was simply extended. The only access to the French ISR territory was via the CERN main gate in Switzerland.

CERN extended into France in a major way with the construction of the 7 km SPS synchrotron in the early 1970s. Initially there were two CERNs: the original CERN I (including the ISR) on the Meyrin site and the new CERN II 3 km away in France at Prévessin. France also became a CERN host state.

Subsequent construction work for the underground 27 km LEP electron–positron collider and the LHC collider enlarged the footprint of CERN both in France and in Switzerland.

With staff levels currently just less than 3000, with some 1000 industrial support staff and about 7000 migratory researchers all over the world who visit periodically, CERN makes a big impact on the local region, simply for day-to-day needs like housing, schooling, shopping, transport and leisure.

In addition is the industrial impact – supplying the equipment and services that make CERN work. These contracts are now subject to strict rules that aim for a balanced return for all of CERN's 19 member states, and local concerns not to enjoy any particular advantage for purchasing requests and calls for tenders.



The Geneva area (canton) is almost totally surrounded by France, joined to the rest of Switzerland by a neck of territory only a few kilometres wide to the north-west of Lac Leman. The dotted line shows the frontier. To the north of the River Rhône, nearer CERN, the neighbouring French territory belongs to the pays de Gex, département de l'Ain, which is bounded by the Jura mountains. To the south, away from CERN, is the département of Haute Savoie. The map also shows the footprint of CERN's 27 km LEP ring, which "touches" Geneva airport, and the four LEP experiments, which are equidistant around the ring.

Impact on Geneva

During the first 15 years of CERN's existence, Geneva and Switzerland were the laboratory's front door. Geneva is a major city with its own commerce, banking, industry and university. The home of the international Red Cross since 1863, its importance increased after the First World War with the establishment of the headquarters of the League of Nations, which in 1946 became the European headquarters of the United Nations (UN) and led to the implantation of several major UN agencies in Geneva.

Throughout its history, Geneva has been a natural crossroads, and

With staff levels currently just less than 3000, with some 1000 industrial support staff and about 7000 migratory researchers all over the world who visit periodically, CERN makes a big impact on the local region

this is underlined today by a major airport with excellent links to all major European cities. While many airports are now constructed far from the towns they serve, every visitor to CERN is aware that the airport is only a few kilometres away.

In the 1960s, major international electronics and telecommunications specialists set up regional offices in Geneva. Although this was not directly because of CERN, the laboratory soon benefited. In the 1970s, Geneva established the ZIMEYSA (Zone industrielle ` Meyrin-Satigny) industrial park on CERN's doorstep. Meyrin, the airport and the availability of land were the main factors behind this move, but the impressive vista of CERN across the valley undoubtedly helped to attract tenants.

The direct impact of CERN on Geneva is difficult to measure, but the spin-off benefits are huge, and the city is undoubtedly proud of its prestigious resident. On arrival in Geneva by road or by air, signs underline CERN's presence.

Neighbouring France – north of the Rhône

CERN's extension into France was in the pays de Gex. Cut off from the rest of France by the river Rhône and the Jura mountains, this area has always naturally looked towards Geneva, even though from 1815 Geneva became part of another country. The pays de Gex (département de l'Ain) remained largely rural until relatively recently, when the arrival of first the SPS and then LEP provided a new focus.

Building on these developments, the local authorities set up a new technology park, this time at CERN's back door. Although a number of firms that had received CERN contracts came in, the authorities were conscious that CERN's balanced return policy meant that these suppliers would not automatically benefit from increased business. Proximity to Geneva and its communications were the greater attraction.

Today some 60 companies employing some 1000 people work in this park. Only half of these have any relationship with CERN.

Neighbouring France – south of the Rhône

Looking at the map, the Geneva administrative area (canton) appears almost totally surrounded by France, joined to the rest of Switzerland by a neck of territory only a few kilometres wide. To the north of the Rhône, nearer CERN, the neighbouring French territory belongs to the pays de Gex. To the south, away from CERN, is the département of Haute Savoie. While the pays de Gex remained rural, Haute Savoie had a significant industrial tradition, with major towns and prestigious universities nearby at Chambery, Grenoble and Lyon.

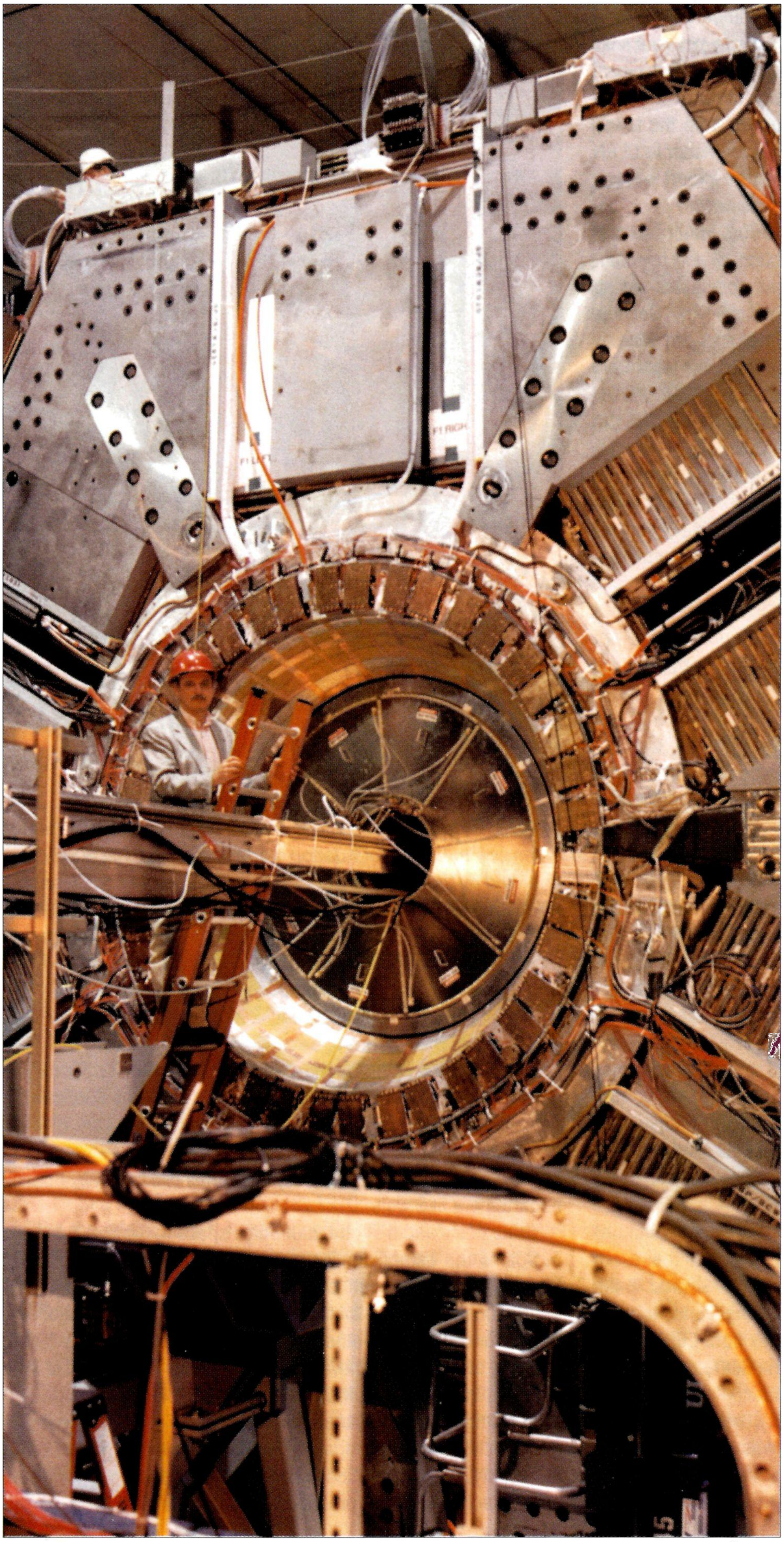
An early development as a result of CERN was LAPP, the particle physics laboratory at Annecy, the administrative capital of Haute Savoie, which was set up to exploit both the proximity of CERN and the significant industrial and academic potential of the region.

CERN director-general Luciano Maiani speaks at the official ceremony to lay the foundation stone of a new CERN building, financed by the Département de l'Ain, in which CERN's French territory lies, as part of France's special contribution to the LHC collider project. The building will be used as an assembly hall for LHC equipment prior to its installation in the 27 km underground tunnel. The French special LHC contribution comprises four components that were granted by the central government, the Rhône-Alpes regional authority, the Département de l'Ain and the Département de Haute Savoie. CERN's other host state, Switzerland, also makes a special contribution to LHC.

Annecy became home to university departments of the neighbouring département of Savoie.

Rising costs and a shortage of office space in Geneva led in the 1980s to the establishment of the Archamps Business Park in France, immediately south of the city, but from the start a university-level educational dimension and high technology were major features. However, on the other side of Geneva to CERN, the recent opening of a major Geneva ring road linking Haute Savoie with Geneva's international airport has been a major improvement.

CERN regularly participates in several Archamps educational programmes. Although the impact of Archamps in Haute Savoie is hard to quantify, its concentration of computer expertise led to local secondary schools being prominent among the first to establish Internet use in France.



In hot ... of CP v...

The subtle effects of CP violati... our understanding of the univers... is difficult to measure. *Gerry* ... CP violation and points out how a... the phenomenon in a new setti...

Long, long ago, in a far, far different universe, there were equal amounts of matter and antimatter. At least, this is the most popular conception. Why only matter remains has been a nagging question for decades.

We normally think of antimatter as a sort of inverted matter behaving the same way as matter does but with reversed properties, such as electric charge. How nature could choose matter over antimatter is puzzling. A seemingly obscure violation of a symmetry principle, called CP, may hold part of the key. As we approach the close of the millennium, laboratories around the world are poised to enter a new era by studying this phenomenon in a new sector – B-mesons, particles containing the fifth quark, variously denoted as "beauty", "bottom" or simply "b".

Symmetry principles

A major theme in particle physics for the last half-century has been symmetry relations. These came to the fore in the mid-

The B particles seen by the BaBar detector at the PEP–II electron–positron collider at SLAC, Stanford, will soon provide a new window on CP violation.

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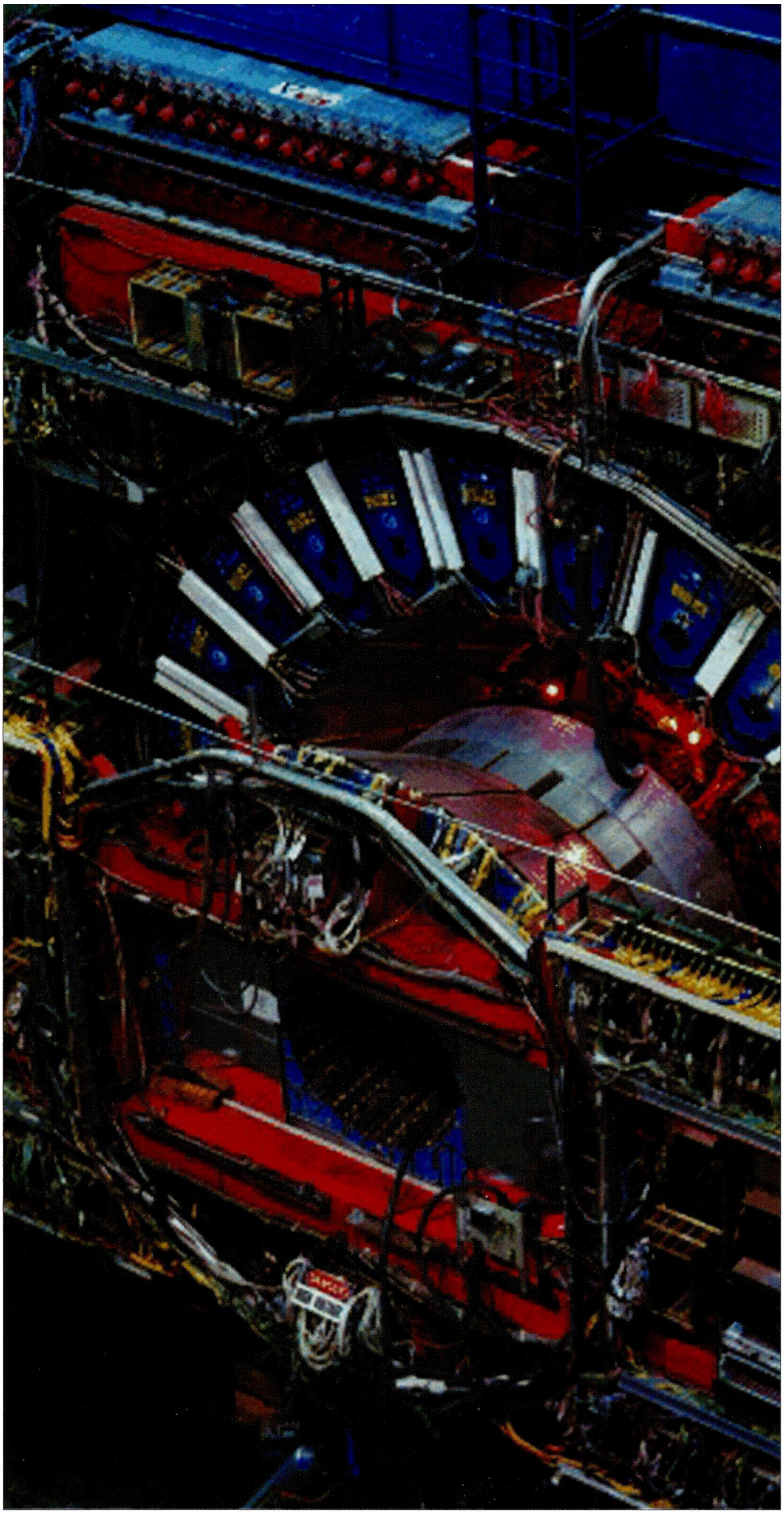
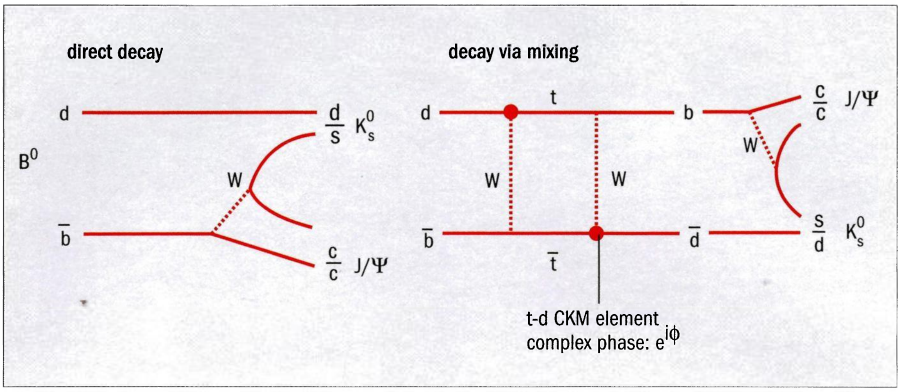


1950s when "parity" violation was discovered. Parity conservation is the apparently innocuous proposition that the laws of physics are the same, or symmetric, when spatially inverted (the parity operation, P), as in a mirror-image world.

Prompted by the realization of T D Lee and C N Yang that there was no experimental evidence that weak interactions conserved parity, C S Wu and collaborators discovered in 1957 that weak interactions do not conserve parity in the radioactive decay of cobalt-60. A stunning development was that weak interactions depend on the specific "handedness" of particles. In modern terms, this is because the charged W carrier particle only couples left-handedly.

The realization soon followed that another symmetry – charge-conjugation (C) – was violated too. This is the operation of switching particles to their antiparticles, and vice versa. However, C violation occurred in such a way that the combined operation of charge-conjugation and parity (CP) restored the symmetry. Thus the decays of mirror-inverted cobalt-60 anti-

The CDF detector at the Fermilab Tevatron sees B particles produced via proton–antiproton collisions.



The decay of neutral B-mesons into a J/psi and a neutral kaon goes via two mechanisms: one (left) where the B decays directly and the other where the neutral B first "oscillates" into its antiparticle via quark transitions before decaying. Note the involvement of the top quark, which introduces an interference term between this mechanism and the direct decay. This results in different decay rates for the two neutral B-mesons, thereby violating CP symmetry.

nuclei, for example, should behave the same way as those of cobalt-60.

Although P and C are not always good symmetries, the combined CP operation was respected by nature. CP was a consolation prize for physicists. At least it seemed so until 1964. Less than a decade after the fall of parity symmetry, physicists were jolted again when CP invariance also fell by the wayside. A landmark experiment, led by James Cronin and Val Fitch, saw a rare neutral K-meson decay that should be prohibited if CP is a perfect symmetry. The effect is small: 1 in 500 decays.

Parity violation could be attributed to an intrinsic feature of weak interactions, but CP violation was a mystery. The effect was very small and hard to study. Was it a feature of weak interactions alone, a sign of a new type of interaction or something completely different? While the origin of CP violation remained a mystery, within a few years it was realized by the renowned Soviet physicist Andrei Sakharov that CP violation was a necessary ingredient for an eventual explanation of how an initially matter-antimatter symmetric universe could evolve into a matter-dominated one.

It took some time for Sakharov's suggestion to be appreciated, but, in the end, CP violation went from being an unpleasant wart on the face of weak interactions to a critical component of an explanation of why we exist.

Quark mixing?

Of the many ideas offered to explain CP violation, one remarkably bold proposition was based on quark mixing. In this hypothesis, which was proposed by N Cabibbo in 1963, the quantum states of quarks with definite mass are mixtures of the states that the weak interaction "sees".

With only four quarks, the rotation matrix that transforms one set of quark states into the other is restricted to real numbers and cannot accommodate CP violation. In 1972, eight years after the discovery of CP violation, M Kobayashi and T Maskawa proposed that quark mixing be generalized to cover three generations of quark pairs. With six quarks, the rotation matrix, now known as the Cabibbo-Kobayashi-Maskawa (CKM) matrix, can have a physical phase that is a complex number, and this could account for the CP violation observed in neutral K-mesons.

The bold proposal did not attract much attention. After all, only three quarks were known at the time. There was speculation about a fourth quark, but even the quark model itself was regarded with some lingering suspicion. Kobayashi and Maskawa were advocating not one new quark but three.

The picture began to change quickly in 1974 when the J/psi was discovered and the second quark generation completed. In a surprisingly short time, Kobayashi and Maskawa's third generation was also exposed: the tau lepton appeared in 1975, and then the b-quark surfaced with the upsilon discovery in 1977. The wait was long, however, before its partner, the top quark, definitively showed itself in 1995.

Quark mixing became an integral part of the Standard Model of particle physics, and the hypothesis of Kobayashi and Maskawa became a leading candidate to describe CP violation in the only place it has so far been observed, neutral K-mesons.

Desperately seeking CP violation

One of the main objectives of B physics has been to complete the mapping of the CKM matrix. The B-mesons are analogous to K-mesons: the strange quark is simply replaced by a b-quark. Just as neutral K-mesons proved to be a powerful tool, the spotlight is now on the neutral B-mesons.

Studies with neutral B-mesons are particularly useful because results are sensitive to CKM elements related to top quarks as well (even though the top quark is not produced physically). This is especially the case for the mixing of neutral B particles and antiparticles, where tremendous progress has been made during the last decade at high-energy colliders like LEP at CERN and the Tevatron at Fermilab.

Despite these advances, a nagging question is that of CP violation: a tiny effect only observed in neutral K-mesons. After 35 years of delicate experiments with K-mesons, progress has been limited. The good news is that not only do B-mesons offer a new arena to study CP violation, but, according to the CKM model, there should be many manifestations of the violation and the effects should in some cases be large. The problem is to produce enough B-mesons, and even LEP falls short.

The need for more B particles has resulted in an armada of new facilities around the globe. These include HERA-B at DESY (wire target in a proton beam), performance upgrades of the venerable CESR electron-positron ring at Cornell, new dedicated electron-positron "B-factories" at KEK (Japan) and SLAC (Stanford), the Tevatron proton-antiproton collider upgrade with the new main injector and, ultimately, the LHC at CERN.

> We normally think of antimatter as a sort of inverted matter behaving the same way as matter does but with reversed properties, such as electric charge. How nature could choose matter over antimatter is puzzling

Two paths to decay

The centrepiece of these studies is to look for an asymmetry between the decays of the two neutral B-mesons (which are a particle and an antiparticle of each other) into a J/psi particle and a short-lived K-meson. This "golden" mode is ideal in several respects: the resulting state has well defined CP properties; the relationship between the decay asymmetry and CKM parameters is not plagued by theoretical uncertainties, as is the case for some other decays; and, experimentally, the decay is easy to identify when the J/psi subsequently decays into a pair of leptons. It also has a relatively large rate, but still fewer than one neutral B in a thousand will decay in this way.

The CP violation manifests itself via the unequal decay rates of neutral B particles and antiparticles. This effect should be starkly exposed because of subtle interference effects from neutral B mixing. A neutral B can decay directly, or it may oscillate into its antiparticle before decaying (see figure). These two different paths are expected to have a slightly different phase, and the interference between them produces an asymmetry.

Whereas the classic CP violation in neutral K-mesons amounts to approximately one violation in 500 decays, the expected asymmetry in the new case means that, at the times of maximal interference in the neutral B oscillation cycle, the difference in decay rates is one out of eight.

If observed, such CP violation will not be an obscure subtlety. Although a massive attack on this problem is about to commence with the ongoing start-up of the B-factories, the opening salvos have already been fired. Last year the OPAL experiment at LEP was the first to publish results of an investigation of CP violation with a sample of about a dozen golden mode decays. Taking advantage of the clean LEP environment and powerful "tagging" techniques to distinguish neutral B particles from their antiparticles, the experiment obtained an asymmetry of 3.2, but with an error of ±2. Mathematically, such an asymmetry must lie between −1.0 and 1.0. Furthermore, the errors are large compared with this allowed range. It was none the less intriguing to obtain such a large number, as it is somewhat unlikely for the measurement to fluctuate to so high a value if CP is conserved. Overall, this was an impressive achievement given so few events.

Hot on OPAL's heels was CDF at the Fermilab Tevatron. The advantage of a hadron collider is the much larger B production rate. From existing data samples, CDF was able to muster several hundred golden mode decays. Last summer, CDF announced a measurement of CP asymmetry of 1.8 ±1.1 using a single method to separate neutral B particle and antiparticle events. Again, this is an unusually large positive asymmetry, but with half of the uncertainty of the OPAL result. Is a pattern emerging?

In February, CDF released results from an expanded analysis using all available data and tagging methods to squeeze the uncertainty. The preliminary asymmetry result was 0.79 ±0.43 – large and physically possible. This result is strikingly close to the expected asymmetry of about 3/4 from experimental constraints on the CKM matrix. The limit excluding no asymmetry is only a little better than before, but the uncertainty is halved. This is still too large to claim that CP violation has finally been observed outside the K-meson system, but it is tantalizingly close. The uncertainty shrinks: the evidence mounts.

Prospects look bright for the new generation of B experiments to look for large CP violating effects. In a matter of months we can hope for new signs of CP violation, especially from the new B factories at KEK and SLAC; and next year the Tevatron experiments will return to the hunt where CDF left off.

In the years to come, an extensive array of measurements around the globe will study various manifestations of CP violation in B-mesons and stringently test the CKM model. This will hopefully enable us to move beyond the phenomenological CKM description and unveil some of the mystery surrounding the emergence of a matter-dominated universe that is so convenient for our existence.

Gerry Bauer, *Massachusetts Institute of Technology.*

Meetings highlight boom in accelerator developments

New projects and important upgrades are under way in many laboratories, while technological progress and continual ingenuity augur well for the future.

High-energy accelerators in the spotlight
An initial report from the recent Particle Accelerator Conference (PAC) in New York was published last month (p7). The PAC parallel sessions spanned a range of accelerator activities, which are summarized here. The complete PAC programme is available at "http://pac99.bnl.gov/Pac99/Program/PMenu.html".

Magnets Most of the PAC magnet session covered the status and progress on the research and development for superconducting magnets.

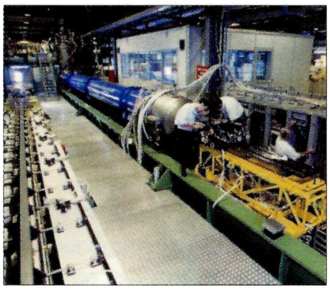
For CERN's LHC collider, a large effort is devoted to the optimization of the dipole for series production. C Wyss presented the updated version of the dipole parameters, featuring stainless steel collars and six-block coils. He also discussed the aim and status of the short model and full-size prototype dipole programmes and the schedule for series manufacture.

D Tommasini described in detail the scope of the 20 short models, some of which have been rebuilt in different variants, with more than 35 versions already having been tested. The aims are to compare the five-block and six-block coil geometry, training behaviour, temperature margin, mechanical stability and magnetic field quality.

In the US the post-SSC period has seen a renewed interest in high-field dipole development. R M Scanlan presented an extensive review of the activities in various laboratories, including Brookhaven; Fermilab; KEK, Japan; LASA/INFN, Milan; Berkeley; Texas A&M; and Twente, the Netherlands. He stressed the common requirement to exceed 10 Tesla – the practical limit for niobium-titanium superconductors.

Potential applications include a Very Large Hadron Collider (VLHC), a Muon Collider and upgrades to the LHC. The cosine theta coil-winding approach is replaced in recent work by block coil designs, which may be more compatible with the brittle superconductors and high Lorentz field stresses that are inherent in high-field magnets.

The new block designs include the "common coil" designs that are being explored at Brookhaven and Berkeley, as well as a segmented block design with reduced winding stresses at Texas A&M. In addition to magnet design work, several new superconductors are being developed for use in high-field accelerator magnets. These include niobium-aluminium as well as the high-temperature superconductors in both tape and cable configurations.



The first 15 m superconducting dipole for CERN's LHC collider was developed by the Italian INFN in collaboration with CERN and with Ansaldo Energia as main contractor. International collaboration is vital to the LHC machine.

S Gourlay and A Zlobin gave more details on the dipoles proposed at Berkeley and Fermilab respectively. At Berkeley, a prototype niobium-tin superconducting magnet, utilizing a racetrack coil design, has been built and tested. This was constructed with coils wound from conductor developed for the ITER fusion project, limiting the magnet to a field of approximately 6 Tesla. Subsequent magnets will utilize improved conductor, culminating in a design that is capable of approaching 15 Tesla. The simple geometry is more suitable for the brittle superconductors that are needed to reach high fields.

At Fermilab, high-field magnets of between 10 and 12 T are proposed in view of the VLHC. The main aims are to exploit the relatively small machine circumference and emittance damping owing to synchrotron radiation and still be able to accommodate the radiation power absorbed in the beam tube.

Recent progress in the development of niobium-tin superconducting strands makes it possible to design cost-effective accelerator magnets based on a cosine-theta coil geometry above 10 T. A 1 m high-field dipole model with 10–11 T nominal field in a 50 mm bore is being developed at Fermilab in collaboration with Berkeley and KEK as part of the effort for a VLHC.

P Lee presented the prospects for the use of high-temperature superconductors (HTS) in high-field accelerator magnets. In the short term the most promising high-field magnet application is 2212. However, HTSs are still at an early stage of development and continued improvement over the next 10 years should reveal other HTSs for accelerator application.

The Bi-2212 recipe appears to have the greatest potential today, because it can be made in round wire form with a reasonably high critical current, thus permitting access to the cabling technology of low-temperature materials.

A dipole is being made at Berkeley using round wire Bi-2212. Among other recipes being explored, Bi-2223 and YBCO are both largely committed to wide-tape designs, for which cabling is a significant challenge. G Foster described the Transmission Line Magnet – a dual-aperture warm-iron superferric magnet, built around an 80 kA superconducting transmission line. He pointed out that the large inventory of surplus cable manufactured for the defunct Superconducting Supercollider could be used for the construction of a VLHC injector with an energy up to 3 TeV.

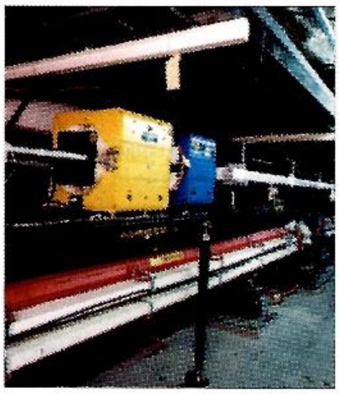
R Goupta described the tuning shims technique that is used in the interaction region quadrupoles of Brookhaven's Relativistic Heavy Ion Collider (RHIC) to obtain much lower field errors. Measurements have shown that both systematic and random error harmonics have been reduced to several parts in 100 000 instead of a few parts in 10 000 at two-thirds of the coil radius. The ultimate field errors are now limited by the "changes" in harmonics after quenching and thermal cycling rather than measurements, design or magnet construction errors. These changes appear to depend on the details of the magnet.

J Plueger was one of the few to describe high-technology warm magnets. He presented an overview of an insertion designed for the next generation of free flectron faser (FEL) synchrotron light sources using the principle of self -amplified spontaneous emission. Very long undulators are needed to reach saturation, easily exceeding 100 m for the X-ray FELs. To minimize the total length and maximize output, an optimum overlap must be foreseen between electron and laser beam, as well strong external focusing fields to keep the electron beam size small over the whole undulator length.
Walter Scandale.

Current and future machines Many PAC papers covered machines that are under construction or undergoing major upgrades (p29). News of the RHIC heavy ion collider at Brookhaven and the PEP-II and KEKB electron–positron collider B-factories was included in our PAC preview last month (p7).

Design studies for the next generation of colliders – linear electron–positron colliders, muon colliders and very large hadron colliders – were well covered. R Brinkmann of DESY talked about technology and challenges of linear colliders. The session chairman J Peoples paid tribute to B Wiik (April p41), who had been scheduled to give this talk. T Raubenheimer of SLAC covered the accelerator physics challenges of linear colliders; M Pekeler of DESY the experience of superconducting cavity cperation in the TESLA test facility; and J P Delahaye of CERN the CLIC study of a multi-TeV linear collider. K T McDonald of Princeton reported on the status of research and development and future plans relating to muon colliders, mentioning that 40 PAC papers were related to muon colliders. G Dugan of Cornell described reseach and development work for Very Large Hadron Colliders. Quite a few posters also treated various aspects of these machines.

Radiofrequency technology Striking in the PAC radiofrequency sessions was the remarkable and encouraging progress made in the maximum hold-off voltage in superconducting cavities. A reliable technique to attain the necessary accelerating gradient of 34 MV/m is of paramount importance for the TESLA approach. Electropolishing (EP), jointly studied at KEK in Japan and CEA-Saclay in France, is a clear candidate. Tests on three sample cavities showed an increase of the maximum accelerating field from 25 to 33 MV/m (in one case a record 37 MV/m was attained), at full TESLA pulse length.



Impressive radiofrequency. The PEP-II electron–positron collider at SLAC, Stanford, with the higher-energy (electron) ring below and the lower-energy (positron) ring above.

It is interesting that, in contrast with the established methods of high-pressure rinsing and chemical polishing (CP), EP does not seem to act on the residual resistance ratio. Once this is high enough, EP pushes the maximum gradient right up. Even a cavity with bad initial performance attained 33 MV/m. The fact that these cavities turned "bad" again when doing CP after EP can be considered as a validation of the EP approach.

Even though ideas on photonic bandgap (PBG) structures were already presented in PAC three years ago, they now appear interesting for future multi-TeV electron–positron colliders. Of primary concern in these accelerators are the transverse wakefields – fields that are left behind in the accelerating structure by the passing bunches, which, in turn, can kick subsequent bunches so violently that they eventually get lost before the collision point. The damping and detuning of these detrimental transverse modes are the techniques deployed and investigated until now to alleviate this serious problem. (See MOBC2, THAL6 on the PAC Web site. The URL is given at the beginning of this article.)

The PBG structure now sheds light on accelerating structures from a different viewpoint The cell of a PBG structure consists of a transverse periodic lattice of metallic rods between a pair of metal plates. Thus it can be described like a two-dimensional crystal, the central beam hole being a "defect" in this lattice.

If the fundamental, accelerating mode frequency lies in the bandgap of the PBG structure, it cannot propagate transversely and thus remains well confined around the defect. The structure can, however, be made so that it is (transversely) transparent to all higher-order modes, which in turn can quite easily be damped by absorbing material at the periphery, a few lattice constants from the central beam hole. (See MOP72, MOP73.)

For anyone who thought that vacuum tubes were history, the development of high-power RF tubes, especially for modern accelerator applications, would prove them wrong. High-power klystrons will be needed in large numbers for future accelerators. For gridded tubes, the technology is still advancing.

Efficiency and high average power at moderate anode voltages and good operational stability are of increasing importance. For klystrons, this leads to multibeam devices, like the one being developed at Thomson Tubes (TTE) for TESLA (seven beams, 10 MW, 1.5 ms, 1.3 GHz).

An interesting novel device being developed at Communications and Power Industries (formerly Varian Electron Device Group) is higher-order mode inductive-output tube (HOM IOT), which has been around since 1982 under the name klystrode (i.e. a gridded input, klystron type output device). Its promising design data aim for 1 MW continuous wave at 700 MHz with (only) 45 kV anode voltage, and with an efficiency of 73% (THBL3).

An impressive gridded tube was on display at TTE's stand in the industrial exhibit. The company's Diacrode is a tetrode with optimized current distribution, which allows for larger surfaces compared with the wavelength, and thus with higher power. This tube has now been built and tested, producing 1 MW in continuous wave, 4.1 MW for 1 ms pulses, both at 200 MHz.

Leaving high-power RF, an impressive realization of a modern low-level RF system is that of the asymmetric B factory PEP-II now being commissioned at SLAC, Stanford. Since the advent of feedback in accelerators in the 1970s, many systems have been realized that are conceptionally similar, but this is a beautiful example of feedback at work in a modern environment - the VXI(VME)-based, completely digital control system. Both storage rings are longitudinally unstable, but, as if this were not enough trouble, the control system has to handle heavy transient beam loading. The beam is a more powerful source of induced voltages in the cavities than the power amplifier - and "transient" refers in this case to the ion-clearing gap - the ring is not homogeneously filled, but the beam current changes drastically during a single turn.

Many interwoven control loops are necessary to handle this nightmare situation, the fastest having a group delay of less than 500 ns, 150 of which are contributed by the klystron alone. Another loop deploys digital comb filters. Its signal is fed back exactly one turn later to control the longitudinal vibration of particles in exactly the same bunch where they were detected.

Since the control systems have to have such a hard grip on the beam, some amplifiers risk saturation. This is prevented by learning algorithms for the creation of reference signals. In addition, a fibre-optic system distributes the signal of yet another control loop - longitudinal multibunch feedback - to the different RF stations around the rings.

Network analysers are integrated in the part of the control (see THBL1).

Erk Jensen.

Control systems

The ability to exploit fully a particle accelerator is the job of its control system and instrumentation, and the performance requirements of modern accelerators demand the use of advanced and advancing technologies.

At PAC99 it was clear that techniques, such as the application of digital signal processors, the use of a large distributed multiprocessor system and high-speed networks based on reflective memory and fibre optics, are now mature. For example, they have provided the high bandwidth and fast response that are essential for the development of sophisticated feedback systems.

Feedback systems are now indispensable for the stable operation of a linear collider, such as the SLC at SLAC, Stanford, providing a cost-effective method for relaxing otherwise tight tolerances. At the SLC, feedback controls beam parameters such as trajectory, energy and intensity throughout the accelerator.

Looking to the future, for the Next Linear Collider, extensive feedback systems are planned as an integral part of the design. The manpower cost of developing individual control systems has long been a bane, and attempts to minimize the effort have led to fruitful collaboration between laboratories around the world.

One of the particle accelerating structures in the Next Linear Collider Test Accelerator at SLAC, Stanford. A major international collaboration, the NLC includes feedback systems to control, among other things, the intensity, energy, steering and collision of its electron and positron beams. The indispensability of such feedback systems has been proven with great success at SLAC's SLC electron–positron collider.

Standards such as the Experimental Physics Industrial Control System attempt to provide a common basis for development. It is also hoped that the power of object-oriented programming techniques will make it possible for accelerator designers to develop independently different software components that can work together.

With this in mind, there have been a number of eager attempts to harness such languages as C++ and Java, resulting, in the limit, in Web-based accelerator control.

Joint projects, such as the planned Spallation Neutron Source at Oak Ridge, provide the need for a Collaboratively Developed Distributed Control System, posing technical and organizational challenges in a development involving four different institutions.

On the computational front, powerful resources are now available to accelerator designers. Using new programs, they will be able to simulate complex three-dimensional components and systems on a scale that is orders of magnitude larger than is possible with existing software packages. Multiprocessing and the use of parallel techniques are providing the resolution that is needed to solve the challenging problems in next-generation accelerators.

In theory the use of object-oriented techniques will improve the maintainability, reusability, and extensibility of the parallel code being developed. As participants in the development of new technologies, accelerator laboratories are among the first to attempt to harness them. This could lead to a perplexing plethora of applications of these techniques, the effectiveness of which may sometimes be brought into question. What was clear from PAC99, however, in the fields of control and computing at least, was that people are enjoying themselves trying.

Mike Lamont.

Sources and Injectors

Much progress was reported at PAC for sources of polarized electrons and negative hydrogen (H^-) ions. Electron guns with photocathodes are able to deliver continuous-wave mode currents of more than 100 μA with 80% polarization. Cathodes can provide 10 000 C/sq. cm before the quantum efficiency becomes significantly reduced (Jefferson Lab).

With optically pumped (laser) sources (TRIUMF (Canada)/

Brookhaven/Institute for Nuclear Research, Moscow), H^- currents of 1 mA over some 100 μs have been achieved. This has encouraged source designers to project a source with a current of 20 mA over 50 μs, which is just what DESY's HERA electron-proton collder would need.

Like the CERN Linear Collider Test Facility, the TESLA Test Facility at DESY uses an RF gun with a photocathode. At DESY, one aims at electron bunches of 8 nC with a bunch frequency of 1 MHz in bunch trains of 800 μs, at a repetition frequency of 10 Hz. An alternative, which is to increase the bunch frequency by a factor 9, where one bunch carries 1 nC, is envisaged. With, for safety reasons, reduced operating conditions (1 Hz, 50 μs), this source has worked in the 8 nC mode over one full three-month running period with uptime close to 100%.

Most accelerator laboratories with ion beams use slectron cyclotron resonance (ECR) sources. From the modest ion current of some 1 μA DC of light ions in early days, ECRs have been improved to deliver currents hundreds of times as high. In a pulsed mode – the so-called afterglow mode – ion currents of 1 mA of a single charge-state are in reach.

Experts talk of the third generation of ECRs, where previous magnetic and RF fields of 1–2 Tesla at 10 GHz to confine and heat the ions are increased to 4–5 Tesla, 25–30 GHz by applying superconducting magnets and gyrotrons. An ECR at Cantania, Italy, with superconducting magnets, already running at 2.8 T at 18 GHz, is planned to be upgraded to run at 28 GHz.

In ECR pulses, the particle beam is stretched out over pulse lengths of too many single turn injection periods of circular accelerators. An alternative to the resulting multiturn injection with its unavoidable particle losses is to inject a high current pulse over just one turn. This is studied in a collaboration involving CERN/ITEP (Moscow)/TRINITI (Moscow/Troitsk). The heart of such a source is a high-energy laser, bombarding targets to produce ions of the desired charge state. The goal of the ongoing experiment at CERN is to generate about 10^{10} lead 25^+ ions in 5 microseconds, every second. This would lead to a source able to fill the LHC.

For lead 22^+, already 25% of the desired number of ions per pulse, once in 30 s, has been achieved. Upgrading of the laser facility's energy, laser pulse form and repetition rate is under way at ITEP and TRINITI.

The generation of radioactive ion beams (RIB) and their acceleration at isotope separators on line (ISOL) is of major interest (23 RIB facilities are in operation or construction, with REX ISOLDE at CERN).

In the past, the "purification" of isotopes, generated via fission in the target and then ionized for post acceleration, was a problem. Multistage resonant laser ionization with its high chemical selectivity, as applied at ISOLDE at CERN and IRIS in St Petersburg are the solution.

Hartmut Kugler.

Report coordinator: **Eberhard Kell**, *CERN.*

Snapshot of high-energy accelerator progress

A major event in the international accelerator calendar is the triennial International Conference on High Energy Accelerators. The seventeeth such event, which was held recently in Dubna, Russia, provided a useful view of the current world scene.

Status reports from leading laboratories accounted for a major part of the programme of the International Conference on High Energy Accelerators, which was held at the Joint Institute for Nuclear Research (JINR) in Dubna near Moscow.

G Jackson described the increased luminosity for Fermilab's Tevatron. An additional ring, the recycler, which utilizes permanent focusing magnets in the main injector tunnel, should be able to triple the antiproton intensity and provide luminosities as high as 10^{33} $cm^{-2}s^{-1}$.

The participation of JINR in international accelerator projects, such as CERN's LHC collider and the TESLA superconducting linear collider, and the most recent results of the operation of the Nuclotron at JINR, was reported by A Sissakian. Deuteron beams from the Nuclotron for experiments with a thin internal target attain 3.2 GeV/nucleon, the intensity of circulating particles being 1.2×10^{10}.

D Trines of DESY covered the HERA electron(positron)–proton collider and the DORIS synchrotron radiation source and their improvements. He reported results from the TESLA international project for a linear electron–positron collider and spoke on future plans for the Tesla Test Facility.

All of CERN's machines set new records in 1998. With a new extraction channel, a beam from the SPS synchrotron could be used for generating neutrinos for an experiment in the underground laboratory of Gran Sasso, Italy, 732 km away from CERN (November 1998 p13).

Record run

J Dorfan of SLAC reported from the Stanford Linear Collider where a record 10 month run had just ended. Investigation of the neutron and proton spin structure continues in the fixed-target SLAC programme. For the future the B-factory based on the PEP II electron-positron collider will open a new physics programme.

The Relativistic Heavy-Ion Collider at Brookhaven, with 100 GeV per nucleon for heavy ions and 250 GeV for protons, is nearing completion, reported S Ozaki. The first experiments with colliding beams (gold ions) will be followed by investigations with polarized beams, beginning in the year 2000.

The Budker Institute of Nuclear Physics operates the VEPP-4 electron-positron collider at 5.5 GeV and a luminosity of 10^{32}, according to A Skrinsky of Novosibirsk. Development continues for the VLEPP linear electron-proton collider. BINP takes an active part in the development of the electron-nucleus collider that is proposed at GSI in Darmstadt.

From Japan, with the operation of the KEKB asymmetric electron-positron collider (8 GeV electrons, 3.5 GeV positrons, design luminosity 10^{34}) imminent, S Kurokawa described experiments for this storage ring and the K2K experiment on the oscillations of neutrinos generated by the 12 GeV beam from the KEK proton synchrotron and using the SuperKamiokande detector 250 km west of KEK.

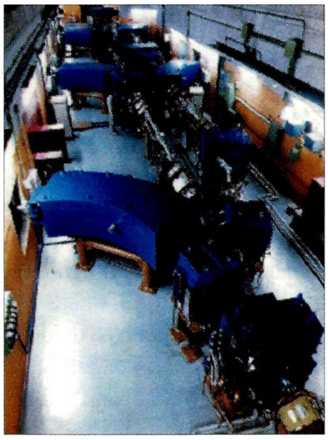
Increased beam intensity

E Troyanov of IHEP reported the main recent results from the 70 GeV Serpukhov proton synchrotron and the status of the Accelerator Storage Complex (UNK). The U-70 accelerator is being upgraded, the ultimate goal being to increase the beam intensity to 5×10^{13} and to prepare the accelerator for an UNK injector. Despite a lack of funds, measures are being taken to maintain 21 km of UNK tunnel, and the manufacture and installation of equipment for the "warm" 600 GeV UNK proton synchrotron is under way.

A Temnykh of Cornell covered the Cornell Electron Storage Ring, which is operating as an electron-positron collider with 6 GeV beams. The available maximum luminosity is 6×10^{32}. The replacement of copper cavities by superconducting ones and vacuum improvement will soon boost its luminosity to 10^{33}.

Progress towards CERN's LHC was reported by P Lebrun. The first full-scale prototype dipole has been built and successfully tested in cooperation with INFN of Italy. Short, straight sections of the ring and their quadrupoles have been designed in co-operation with CEA and CNRS of France. The first prototype magnets for the injection beamline have been designed and manufactured at Budker INP. Other elements of the LHC magnetic system are being designed in co-operation with Canadian, Japanese and US laboratories.

GSI Darmstadt's Electron-Nucleus Collider project was discussed by K Blasche. Its main aim would be to investigate deep inelastic electron-nucleon and electron-nucleus scattering at collision energies of 10-30 GeV. The design luminosity is 10^{33} for electron-proton collisions and 4×10^{32} for collisions with uranium nuclei.



Beam transport system at the Japanese RIKEN laboratory. The MUSES project would considerably extend the laboratory's range of science.

The beginning of work for the MUSES project for a radioactive ion Beam Factory at RIKEN, Japan, was reported by T Katayama. This involves four new accelerating facilities. One, a double storage ring, will be used as an ion-ion and electron-ion collider for ions of 1.5 GeV per nucleon and 2.5 GeV electrons. The calculated luminosity for ions of isotopes with a lifetime of 1 min is 10^{32}.

A Kovalenko of JINR and Fermilab's E Malamud discussed future projects, among them the Very Large Hadron Collider, with beam energies of 2×50 GeV using Nuclotron-type magnets.

Progress for muon colliders was reviewed by R Palmer of Brookhaven.

S Mitsunobu of KEK and DESY's D Proch and W Singer described the development of superconducting cavities for future linear colliders. Accelerating fields could reach 40 MV/m.

Linear colliders based on normal conducting cavities (for which the maximum accelerating field strength is 100-200 MV/m) were discussed by V Balakin of Budker INP.

For CERN's CLIC collider with a maximum energy of 5 TeV and a luminosity of 10^{34}-10^{35}, reported by I Wilson, a new, potentially more effective and cheaper, method uses two-beam acceleration for generating radiofrequency power with the hope of achieving accelerating fields of 150 MV/m (September 1998 p18). The NLC, TESLA/SBLC and JLC collider projects also envisage gamma-gamma and gamma-electron collisions. Photon colliders can appreciably increase the research potential of linear colliders for insignificant extra cost, according to V Telnov of BINP.

The message from the round-table discussion chaired by G Loew of SLAC was that linear colliders are promising tools for high-energy physics.

Another round-table discussion recommended that the Dubna experience should become a model for future conferences in the series, with a relatively small number of leading participants for talks and debates on future projects, and with promising young scientists being invited to present novel techniques and technologies.

Despite a serious economic crisis in Russia, the organization of the conference was assured, thanks to the support of INTAS, IUPAP, the Russian Foundation for Basic Research, the Ministry of Science and Technologies of the Russian Federation, the Ministry of Atomic Industry of the Russian Federation, some businessmen and sponsors from Dubna, and, finally, JINR, despite its own financial problems. Aeroflot proposed special tariffs.

From **A Sidorin** *and* **G Shirkov.**

Neutrinos with a swing

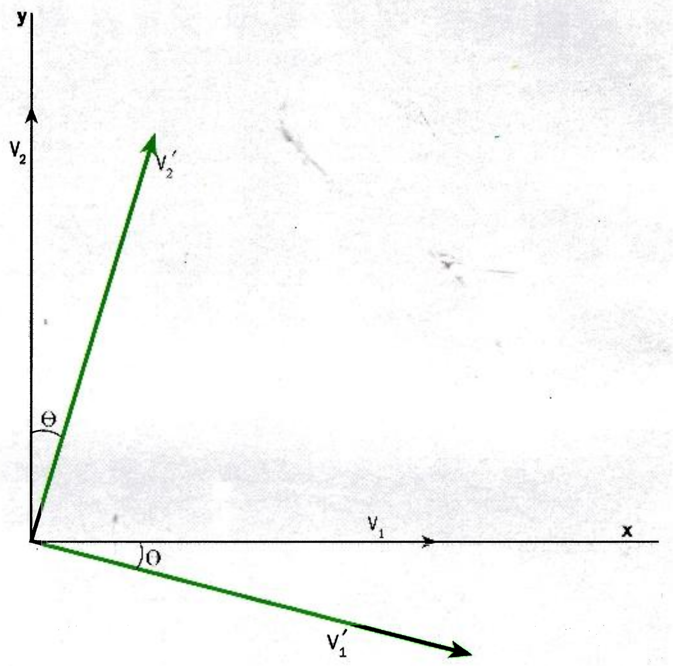


Fig. 1 Coupled pendula. The x *and* y *components of* v'_1 *and* v'_2 *give the relative amplitudes of two coupled pendula in their normal modes. In contrast,* v_1 *and* v_2 *respectively describe the motion of the shorter or the longer pendulum, with the other being at rest. The two sets of vectors are at an angle, θ, with respect to each other.* v_1 *and* v_2 *can be thought of as describing the electron- and muon-neutrino, which participate in weak interactions, while* v'_1 *and* v'_2 *are the neutrino states that travel freely through space.*

New results suggest that types of neutrinos that were once thought to be distinct could mix. Here *Louis Lyons* compares this apparently mysterious mechanism to the behaviour of two simple pendula tied together.

Physicists used to believe that the three types of neutrinos – electrons, muons and taus – were distinct. Then came the claim that neutrinos could "oscillate" – one type can change into another, and then back again – and that, as a consequence, at least one type has a non-zero mass.

Cosmic rays hitting the Earth's atmosphere produce secondary particles, and the new claim was based on observations of the effects of neutrinos produced by cosmic rays. Measured using large underground detectors to record neutrino interactions, the ratio of muon-neutrinos to electron-neutrinos is less than expected.

This is interpreted as being the result of muon-neutrinos changing into a different neutrino type between their production high in the atmosphere and their detection underground. A similar effect is used to explain the fact, known for some 30 years, that the number of neutrinos from the Sun detected on Earth is also smaller than expected from the known solar power output. A third experiment that may have seen oscillation effects was performed at Los Alamos, where some muon-neutrinos produced by an accelerator beam appeared to behave like electron-neutrinos by the time they interacted several metres away.

Oscillations depend on the difference in the mass squared of the two types of neutrinos involved in the oscillation, $\Delta(m^2)$, and a mixing parameter. The physical significance of both of these parameters can be understood in terms of a simple analogy with coupled pendula. With two independent pendula of different lengths, the shorter one swings faster than the longer. The situation changes if the two pendula are joined together, for example by an elastic band, when the elasticity of the band governs the coupling between the pendula. This coupling is usually expressed as a "mixing angle". If the angle is zero, there is no coupling.

For the coupled case, there are special "normal modes" in which the two pendula swing at the same frequency and with constant amplitude. For this to happen, the ratio of the amplitudes must be just right. In fact there are two such modes. In the lower-frequency mode, the pendula swing in phase (if one pendulum is on the left of its equilibrium position at any time, then so is the other), with the longer one having the larger displacement. For the other mode they are out of phase (one swinging to the left when the other goes to the right) and the shorter pendulum has the larger displacement.

Stronger coupling

The relative amplitudes of the pendula in these two normal modes are displayed by the vectors v'_2 and v'_1 in figure 1. x is the amplitude of the shorter pendulum and y is the amplitude of the longer one. For given lengths, as the coupling between the pendula becomes stronger, the two vectors rotate together until the mixing angle, θ, eventually reaches 45°. As the coupling becomes progressively weaker and θ tends to zero, the normal modes correspond to either the shorter pendulum swinging and the longer one being stationary or vice versa.

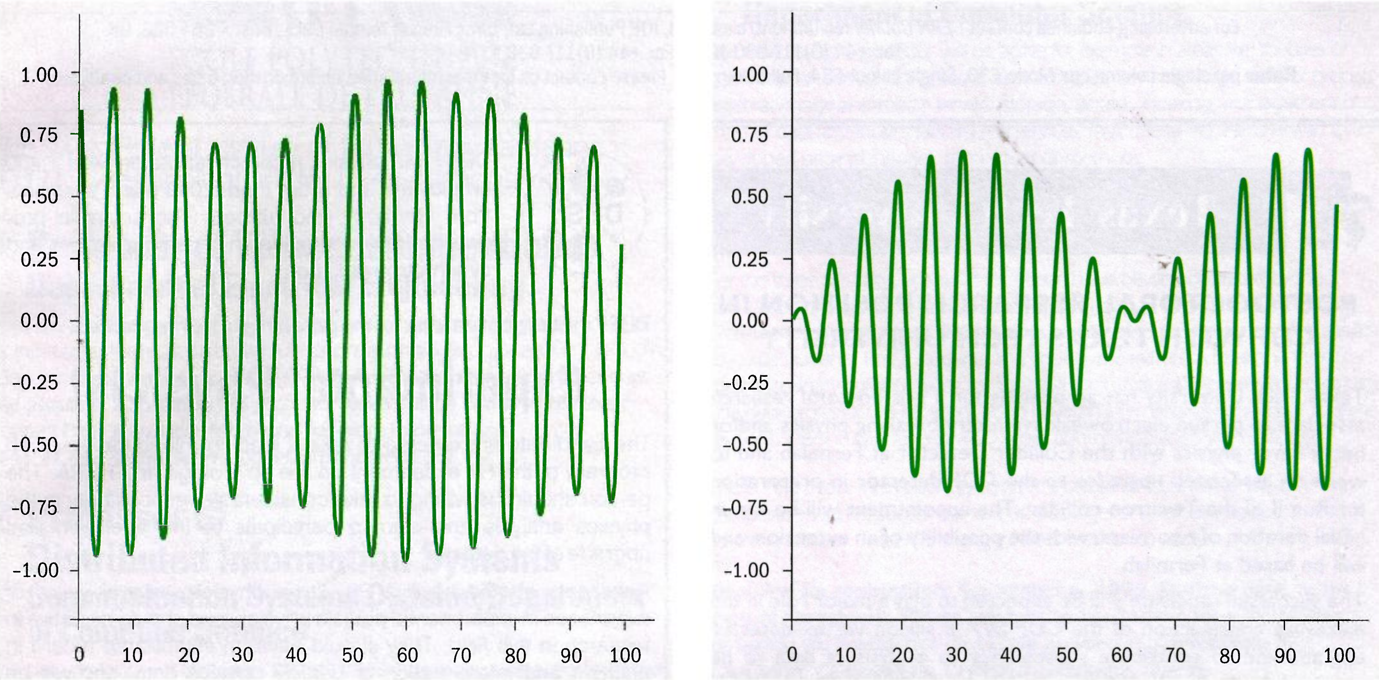


Fig. 2 The displacements of two coupled pendula of unequal lengths. Initially one is displaced and then released. An incomplete exchange of energy occurs between them. The amplitude of the first pendulum (left) decreases from A initially to a minimum of Acos2θ, while that of the second (right) rises to a maximum of Asin2θ. θ is the rotation angle of figure 1. In neutrino terms the displacement can be thought of as the amplitude of neutrinos from the Sun. The frequency of the oscillations between the neutrino types depends on the difference of the squares of their masses. For the pendula, this is equal to the frequency difference of the two normal modes. As the neutrinos travel towards the Earth, the amplitude of the electron-neutrinos initially decreases because of the oscillation, so fewer electron-neutrinos are detected (left), while the muon neutrino signal starts from zero and then initially increases (right).

If we displace just the first pendulum and release it (while the second is in its equilibrium position), it starts swinging with a given amplitude *A*. However, because of the coupling, its amplitude gradually decreases while that of the second increases. The transfer of energy between the pendula is a beat phenomenon, the frequency of which is just the difference in frequencies of the normal modes of the system. For pendula of unequal length, the transfer of energy is not complete (figure 2). The amplitude of the first pendulum goes down not to zero, but only to Acos2θ, where θ is the rotation angle of figure 1, while that of the second reaches Asin2θ.

Beat frequency

Now for the neutrino analogy. The first pendulum corresponds to, say, the electron-neutrinos as produced in the Sun, while that of the second pendulum could correspond to the muon-neutrino. As the electron-neutrinos travel towards the Earth, the natural states for describing the way in which they propagate correspond to the normal modes of the coupled pendula. These are "rotated" by the angle θ with respect to the electron- and muon-neutrinos (figure 1).

The net effect is that the amplitude for the electron-neutrino changes with time, much as in figure 2a, with the result that, when they reach the Earth, it is reduced by a factor of as much as cos2θ. Meanwhile the muon-neutrino component, which was initially absent, has grown by up to sin2θ times the initial electron-neutrino amplitude (figure 2b). Therefore, by the time the solar electron-neutrinos are detected on Earth, their flux is smaller than would be expected simply from the rate of electron-neutrino production in the Sun. The exact flux of electron-neutrinos arriving at the Earth will depend on the time it takes for the neutrinos to arrive, expressed as a fraction of the oscillation period. It also depends on cos2θ.

The possible oscillation of one type of neutrino into another is thus completely analogous to the beat-type phenomenon of the transfer of energy between two coupled pendula. θ is the angle between the neutrino quantum states that participate in the weak interaction (electron- and muon-neutrinos), and the neutrino states that propagate through space. It also appears in the factor cos2θ, which is relevant for the minimum amplitude of the electron-neutrino component as it oscillates backward and forwards into the muon-neutrino.

The beat frequency of the actual oscillations depends on the difference in frequencies of the two neutrino states as they propagate through free space. Because neutrinos are highly relativistic, it turns out that this depends on the difference of the squares of their masses. If both neutrinos are massless, there will be no oscillations. (In the coupled pendula example, if the normal mode frequencies were the same there would be no beats.)

Thus the parameters describing the neutrino oscillations have direct analogies to the case of the two coupled pendula. The coupled pendulum problem provides a useful insight into the mysterious world of neutrinos.

Louis Lyons, *Oxford*

RECRUITMENT

Texas Tech University

POSTDOCTORAL RESEARCH POSITION IN CDF WITH TEXAS TECH UNIVERSITY

Texas Tech University has an opening for a postdoctoral research associate to pursue electroweak symmetry breaking physics and/or heavy flavor physics with the Collider Detector at Fermilab and to work on associated upgrades to the CDF detector in preparation for Run II of the Tevatron collider. The appointment will be for an initial duration of two years, with the possibility of an extension, and will be based at Fermilab.

The successful candidate will be expected to play a major role in the hardware construction of the CDF SVX II silicon vertex detector upgrade and to contribute substantially to analysis of data to be acquired during Run II with the upgraded experiment. Our group at TTU has major responsibilities in the construction of the SVX II, in front end electronics development and testing, and in calibration software development for the CDF upgrade. Our current physics analysis activities are focused on tests of the mechanism for electroweak symmetry breaking, including high-precision methods for measuring the W mass and other related tests of the standard model, and on studies of B physics and quarkonia production. We are also involved in detector development and physics preparations for the CMS experiment at the LHC.

Applicants should send their vitae, a publication list, and arrange to have three letters of reference sent as soon as possible to Prof. Alan Sill, High Energy Physics Group, Texas Tech University, Lubbock, TX 79409-1051, USA. Replies containing the same information will also be accepted by e-mail directed to alansill@ttu.edu.

Texas Tech University is an equal opportunity employer.

RESEARCH ASSOCIATE POSITION HIGH ENERGY PHYSICS THE OHIO STATE UNIVERSITY

The experimental high energy physics group at The Ohio State University invites application for a postdoctoral research associate position with our CLEO/ATLAS program. In the CLEO program, we are involved in both the ongoing date analysis effort in heavy flavor physics and the CLEO III upgrade program where we have major responsibilities for the design and implementation of the silicon vertex detector and the data acquisition system. For the ATLAS program, we are involved in the design and prototyping of the optical electronics and packaging for the pixel detector. Interested candidates should send a letter of application, vitae, list of publications, and three letters of recommendation to **Professor. K. K. Gan, The Ohio State University, Department of Physics, 174 West 18th Avenue, Columbus, Ohio 43210-1106, or email: GAN@ohstpy.mps.ohio-state.edu.**

The Ohio State University is an equal opportunity employer and we actively encourage applications from women and minority candidates.

DESY

DESY is a physics research laboratory with 1.400 employees and more than 3.000 guest scientists from Germany and abroad. The scientific programme includes research in particle physics and synchrotron radiation.

DESY invites applications for the position of a highly qualified

Experimental Physicist

The candidate is expected to take a leading role in the research program of the H1 experiment on the ep storage ring HERA. The person should be willing to take considerable responsibility in the physics analysis and also to participate in the operation and upgrade of the detector.

Applicants should have a Ph. D. in physics, several years of experience in experimental particle physics, and should be active in research in this field. They should have an established record in analysis and interpretation of particle physics data, and will be expected to work with physicists and technicians of the H1 experiment.

The appointment is to a permanent position with a salary according to federal tariffs (BAT Ib).

Letters of application including a curriculum vitae, list of publications and the names of three referees should be sent to:

DESY, Personalabteilung, Notkestraße 85, D-22607 Hamburg by June 15th, 1999 Code-No. 51/99

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

Centre for Advanced Studies, Research and Development in Sardinia

Engineer or Physicist (Nuclear or reactor physics)

Education: Degree, preferably MSc or PhD in Physics or Nuclear engineering. Good knowledge of English. Knowledge of French would be an advantage.

Experience required: Three years minimum experience in one or more of the following areas:

- Neutronic analysis.
- Montecarlo simulations.
- Scientific programming (Fortran, and possibly parallel programming using MPI).
- Reactor Physics and Engineering.
- Knowledge in the fields of Accelerator Driven subcritical Systems (ADS) and radiation medicine is welcome.

Functions: The candidate (2 years renewable contract) will work under the direction of Prof. Carlo Rubbia. Such work is carried our jointly with ASI and the Universities of Rome and Pavia. The candidate should be prepared to spend some time at CERN, Geneva.

Working Environment: CRS4, located in Cagliari, Italy, is a stimulating environment with more than 80 researchers working on different applied research projects: numerical modelling and simulation, scientific visualisation, education and information technology. The position is available immediately: applications will be accepted until the position is filled. Applicants should send a resume and three letters of reference to:

Marco Rosa-Clot, CRS4, C.P. 94, I-09010 UTA (CA) quoting Reference. CFD.NA1. or by e-mail to simona@crs4.it

For information see http://www.crs4.it/

science serving society

Neutron Science Center
Superconducting Laboratory Team Leader

SUMMARY: Senior-level scientist to lead the effort in superconducting RF cavity technology in Los Alamos Neutron Science Center (LANSCE) Division. Experimentalist to work as a member of the Accelerator Physics and Engineering Group on a variety of novel and intriguing accelerator projects. Primary emphasis will focus on superconducting RF cavity technology in application to high power proton linacs. In this capacity, experimental work in support of linac design efforts will be done, including but not limited to: cavity field-limiting physics, RF structures physics, cavity testing, RF power couplers, mechanical fabrication oversight, and contamination control in overall assembly of cryomodules. Expected to also support RF structures work on normal conducting cavities as well. Supervise technical staff working in the experimental facilities. Work with and provide technical support for design engineers and physicists in LANSCE-1 and other departments.

REQUIRED SKILLS: Experience in RF and microwave engineering from 100 MHz to 25 GHz. Significant experience in the areas of RF superconductivity and resonant cavity physics. Experience in RF structures measurements. Strong experimental background in a laboratory environment. Experience with high vacuum technology. Experience with computer-based data acquisition. Demonstrated ability to achieve hardware deliverables on a timely basis and to work well in a team environment. Above experience and skills must be supported by a strong record of publications, honors, awards, and invitations to speak at conferences and universities and by letters of recommendation.

DESIRED SKILLS: Experience with low-level RF control. Experience with cryogenics and contamination control technology. Familiarity with cavity modeling codes (e.g., SUPERFISH, MAFIA, HFSS). Experience with high-power RF.

EDUCATION: PhD in Electrical Engineering or Physics plus 10 years minimum relevant experience or an equivalent combination of education and experience.

For consideration, please send your resume referencing **"CERN994913"** to **jobs@lanl.gov** (no attachments, please) or mail to: **Human Resources Division, Los Alamos National Laboratory, "CERN994913," Mail Stop P286, Los Alamos, New Mexico 87545.**

www.lanl.gov AA/EOE

Los Alamos
NATIONAL LABORATORY

Operated by the University of California
for the Department of Energy

Rheinische Friedrich-Wilhelms-Universität Bonn

The Faculty of Mathematics and Sciences invites applications for two openings in the Physikalisches Institut:

Professor (C3)
Theoretical Physics (Condensed Matter)
and
Professor (C3)
Theoretical Physics (Elementary Particle Physics)

The activities of the theory group at the Physikalisches Institut include mathematical physics, quantum field theory, condensed matter and elementary particle physics. It is expected that the successful candidates strengthen and expand the research activities in these areas.

The focus of the position in condensed matter theory is modern many body theory (i,e. strongly correlated systems, quantum transport in mesoscopic systems). The position in elementary particle physics in intended to strengthen the research of high energy phenomena (i,e. physics beyond the standard model), Cooperation in existing or planned Research Initiative Programs is desirable.

The candidates are expected to teach regular courses in theoretical physics (Diplom and Teaching Profession Degree (Staatsexamen)) and support graduate education in the respective areas.

Formal requirements are regulated by § 49 UG (NRW). The University of Bonn is an Equal Opportunity Employer and therefore encourages qualified women to apply. Handicapped applicants with equal scientific and teaching standing will be preferred.

Interested persons should submit their application by 8.31.99 to: Vorsitzender der Fachgruppe Physik-Astronomie, Endenicher Allee 11-13, 53115 Bonn, Federal Republic of Germany, http://www.physik-astro.uni-bonn.de.

MAX-PLANCK-INSTITUT FÜR PHYSIK (WERNER-HEISENBERG-INSTITUT)

An unserem Institut is zum 01.09.1999 die Stelle einer/eines

Assistentin/Assistenten der Direktion

zum Aufgabengebiet dieser Position gehören u.a:

- Unterstützung der Institutsdirektion in allen Angelegenheitendes Wissenschaftsmanagements
- Umsetzung und Koordinierung von Direktionsbeschlüssen
- Ausbau der Öffentlichkeitsarbeit
- Kontakte und Verhandlungen mit Ministerien und Großforschungseinrichtungen
- Organisation von Tagungen und Schulungsprogrammen

Einstellungsvoraussetzungen sind eine abgeschlossene Promotion in Physik, experimentelle Erfahrung mit Großprojekten der Teilchen -, der Astroteilchen - oder der Schwerionenphysik sowie praktische Erfahrungen in mindestens zwei aufgelisteten Aufgabenbereiche.

Wir bieten eine tarifgerechte Eingruppierung je nach persönlichen Voraussetzungen bis BAT Ia. Sozialleistungen werden in Anlehnung an den öffentlichen Dienst gewährt. Schwerbehinderte werden bei gleicher Eignung bevorzugt eingestellt.

Die Max-Planck-Gesellschaft will den Anteil von Frauen in den Bereichen erhöhen, in denen sie unterrepräsentiert sind. Frauen werden deshalb ausdrücklich aufgefordert, sich zu bewerben.

Bewerbungen mit den üblichen Unterlagen erbitten wir bis zum 15.06.1999 an das

Max-Planck-Institut für Physik (Werner-Heisenberg-Institut),
z.Hd. Prof.Dr Siegfried Bethke
Föhringer Ring 6,
80805 München

Informationen über das Institut sind unter http://www.mppmu.mpg.de erhältlich

POSTDOCTORAL POSITION IN 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 now installed on beamline at PEP-II and first data-taking will commence in late Spring, 1999. Berkeley has major commitments in the following areas: Silicon Vertex Tracker (SVT), DIRC particle ID system, trigger and computing (on-line, simulation, reconstruction).

The applicant should have a Ph.D in Particle Physics and demonstrate strong potential for outstanding achievement as an independent researcher. Major responsibilities will include physics analysis as well as hardware development.

This is a two-year appointment with the possibility of renewal. The salary is $3530-$4170/month. Please submit a resume together with a publication list and arrange for three letters of reference, to be sent to: **Dr. Morris Pripstein, c/o Personnel Administrator, Job # PHY10431/JCERN, E.O. Lawrence Berkeley National Laboratory, One Cyclotron Road, Mail Stop 50-4049, Berkeley, CA 94720, U.S.A. FAX: (510) 486-6003**. E-mail inquiries to: **SCWilliams@lbl.gov**. Berkeley Lab is an affirmative action/equal opportunity employer committed to the development of a diverse workforce.

BERKELEY LAB

EPFL

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

The Swiss Federal Institute of Technology Lausanne (EPFL) invites applications for a position of

Professor of Electronic Systems

for the Department of Electrical Engineering

This position primarily involves information management in complex industrial systems (hard and software co-design). The post is conceived as integrating knowledge of electronic components and the skill to implement them, whilst respecting the constraints related to technology, reliability, performance and cost. Aptitudes for research will be demonstrated by the publication of scientific articles in international journals and/or by patents.
A taste and talent for multidisciplinary collaborations with industry and within the EPFL are essential, coupled with proven project management ability. Industrial experience is an advantage. Education will constitute an important responsibility; the position requires teaching abilities and the capacity to guide students and young researchers.
Deadline for registration: July 15, 1999. Starting date: upon mutual agreement. Please ask for the application form by writing or faxing to:
Présidence de l'Ecole polytechnique fédérale de Lausanne,
CE-Ecublens, CH-1015 Lausanne, Suisse,
fax nr. +41 21 693 70 84.

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

universität mainz

Johannes Gutenberg - Universität Mainz

Das Institut für Kernphysik im Fachbereich 18/Physik der Universität Mainz sucht zum nächst möglichen Zeitpunkt eine/n erfahrene/n promovierte/n

Beschleunigerphysiker/in

zur Mitarbeit am Ausbau des Mainzer Mikrotrons (MAMI C).

Das Institut für Kernphysik betreibt seit 1990 mit Unterstützung der Deutschen Forschungsgemeinschaft (DFG) den normalleitenden 855 MeV Dauerstrich-Elektronenbeschleuniger MAMI B, bestehend aus einer Kaskade von drei Rennbahn-Mikrotronen mit einem Linearbeschleuniger als Inkjektor, zur Durchführung kernphysikalischer Messungen und zur Erzeugung und Anwendung kohärenter Röntgenstrahlung. Im Rahmen des neu gegründeten Sonderforschungsbereichs SFB 443 "Vielkörperstruktur stark wechselwirkender Systeme" wird, finanziert mit Mitteln der Hochschulbauförderung (HBFG), bis zum Jahr 2003 ein Ausbau von MAMI auf 1.5 GeV Endenergie durch Hinzufügen einer vierten Stufe verwirklicht werden. Diese vierte Stufe wird als sogenanntes Doppelseitiges Mikrotron (DSM) realisiert, eine neuartige Weiterentwicklung des Rennbahn-Mikrotrons, bestehend aus zwei Linearbeschleunigern für 2.45 GHz bzw. 4.90 GHz und zwei 180°-Umlenksystemen.

Aufgabengebiet:

- Flexible Mitarbeit an Enddesign, Aufbau und Inbetriebnahme von MAMI C in den Bereichen Hf-Technik, Strahldynamik, Strahldiagnostik, Computersteuerung, Magnet-und Vakuumtechnologie.
- Anleitung von Ingenieuren, Technikern und Werkstattkräften.
- Verhandlungen mit Industriefirmen und Beaufsichtigung von deren Zulieferungen.
- Einarbeitung in die Bedienung und den Betrieb des derzeit laufenden Beschleunigers; langfristig Nachfolge des Betriebsleiters.
- In begrenztem Umfang Teilnahme am Lehrbetrieb des Instituts für Kernphysik, Anleitung von Diplomanden und Doktoranden.

Voraussetzungen:

- Langjährige Erfahrung an einer Beschleunigeranlage.
- Erfahrung in der Anleitung von Wissenschaftlern und Technikern sowie Umgang mit Industriefirmen.
- Gute Kenntnisse der englischen Sprache.

Die Vergütung erfolgt im Rahmen des Bundesangestelltentarifs nach Ver.-Gr: II a/I b; ein späterer Aufstieg nach Ver.-Gr. BAT I a ist möglich.

Die Johannes-Gutenberg-Universität Mainz ist bestrebt, den Anteil von Frauen im wissenschaftlichen Bereich zu erhöhen. Daher sind Bewerbungen von Frauen erwünscht.

Schwerbehinderte werden bei entsprechender Eignung bevorzugt eingestellt.

Bewerbungen sind bis zum 30. Juni 1999 zu richten an das Institut für Kernphysik der Universität Mainz, z.Hd.Frau Huhn, J.-J.-Becher-Weg 45, 55099 Mainz.

Medical/Radiation Physicist and Medical Physicist

Indiana University Cyclotron Facility

The Midwest Proton Radiation Institute has an exciting opportunity for two medical physicists. We are embarking upon a $20M renovation to add three new proton therapy treatment rooms at the Indiana University Cyclotron Facility – one fixed horizontal beam line and two gantries. We are looking for people who can work independently as well as in a team environment. You will be expected to provide leadership for the medical physics aspects of this project. Current priorities include designing, building, and commissioning the patient treatment systems (treatment nozzles, patient positioners, safety systems, and treatment control system), and choosing and commissioning a 3D treatment planning system. Completion of the first new treatment room is expected in two years, leading to a full clinical and research program.
The ideal candidate will have a M.S. or Ph.D. in medical physics in the area of radiation therapy. Experience with the use of charged particle beams is desirable. ABR/ABMP certification is a plus. Salary will be commensurate with experience.
For information regarding the excellent cultural, academic and recreational activities in Bloomington and its environs, refer to http://www.bloomington.in.us and http://www.indiana.edu/iub. Screening of applications will begin immediately. **Please send CV and contact information for three references to:**
Ms. Moira Wedekind, Indiana University Cyclotron Facility,
2401 Milo Sampson Lane, Bloomington, Indiana 47408.

An Equal Employment Opportunity/Affirmative Action Employer.

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

The Swiss Federal Institute of Technology Lausanne (EPFL) invites applications for a position of

Processor architecture
(assistant, associate or full professor) for the Department of Computer Science

This position is open to candidates with a higher education in computer sciences or electrical engineering. Candidate must have an outstanding research record in the field of hardware architecture (processors or systems). Industrial experience is an advantage.

This position requires a strong personality, teaching talents and the ability to guide students and young researchers. The successful candidate will be talented for interdisciplinary research.

Deadline for registration: 15 August 1999. Starting date upon mutual agreement. Interested applicants can ask for the applications forms by writing or faxing to:
Présidence de l'Ecole polytechnique fédérale de Lausanne, CE-Ecublens, CH-1015 Lausanne, Switzerland, fax nr. +41 21 693 70 84.

For further information, please consult also URL: http://www.epfl.ch, http://diwww.epfl.ch/ or http://admwww.epfl.ch/pres/profs.html, http://research.epfl.ch

The Max-Planck-Institute for Nuclear Physics offers at the earliest possible convenience, a

Postdoctoral Position

for the HERA-B experiment in the group of Prof. Dr. Werner Hofmann. The goal of HERA-B is the study of CP-violation in the decay of B-mesons. The MPI-group is involved in the construction of the complex silicon vertex tracker of the experiment. The successful candidate is expected to be based at DESY and take a leading role in the running and data analysis of the experiment.

The applicant should have a university degree with a Ph.D. in high energy or nuclear physics hardware as well as software experience and aged below 33 years. The contract will initially be for 2 years, with possible extension to 5 years and salary according to the German BAT.

Applications should be sent until June 30, 1999 to "Personalverwaltung des MPI fuer Kernphysik, Postfach 103980, D-69029 Heidelberg".

As the Max-Planck-Gesellschaft aims towards increasing the fraction of female employes, women are especially encouraged to apply. Handicapped applicants will be given preference to others with the same qualifications.

science serving society

Senior Electronics Technician

SUMMARY: Senior Electronics Technician to work as a member of the Accelerator Physics and Engineering Group in the Los Alamos Neutron Science (LANSCE) Division on the characterization of RF resonant accelerator structures, superconducting-RF-cavity technology, and beam diagnostics. Provide technical support for the development, assembly, and testing of normal and superconducting linear-accelerator structures and components. Work in a class-100 clean room environment on the assembly of superconducting-cavity structures. Interact with linac and beam transport physicists, mechanical engineers and designers, and fabrication technicians in the assembly and testing of RF structures. Provide technical support in the maintenance and upgrade of the laboratory facilities. Must have disposition to work in a fully-gowned clean room environment up to 50% of the time.

REQUIRED SKILLS: Significant experience with RF-measurement methodology in the 100-MHz to 20-GHz frequency ranges on resonant cavity structures. Experience with basic circuitry, vacuum systems, and assembly of complex electromechanical systems. Experience in working in a team environment focused on hardware deliverables.

DESIRED SKILLS: Experience with superconducting RF structures, and the associated areas of contamination-control technology and cryogenics. Experience with beam diagnostics and low-level-RF-control methodology. Clean room experience. High-power klystron transmitter experience.

EDUCATION: Minimum of an Associate's degree in Electronics, or an equivalent combination of education and experience.

For consideration, please send your resume referencing **"CERN994912"** to **jobs@lanl.gov** (no attachments, please) or mail to: **Human Resources Division, Los Alamos National Laboratory, "CERN994912," Mail Stop P286, Los Alamos, New Mexico 87545.**

www.lanl.gov AA/EOE

Los Alamos
NATIONAL LABORATORY
Operated by the University of California for the Department of Energy

Theoretical Particle Physics

The Department of Physics, University of Alberta, plans to make a tenure-track appointment in theoretical particle physics, with a potential starting date of July 1, 2000. We specifically seek candidates at the rank of Assistant Professor. We are looking for candidates with research experience in particle phenomenology, and an ability to interact constructively with experiementalists, but all qualified candidates in particle theory will be given consideration and are encouraged to apply. In addition to the ability to maintain an outstanding research program, ability and interest in teaching at the undergraduate and graduate level will be important selection criteria. In accordance with Canadian Immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. If suitable Canadian citizens and permanent residents cannot be found, other individuals will be considered. Applicants should send a curriculum vitae, including a research plan and a teaching profile outlining experience and interest, and arrange for at least three letters of reference to be sent prior to November 1, 1999 to: Theoretical Particle Physics Search & Selection Committee, Dr. John Samson, Chair, Department of Physics, **University of Alberta**, 42 Avadh Bhatia Physics Lab, Edmonton, Alberta, Canada, T6G 2J1. Fax: (780) 492-0714, E-mail: dept@phys.ualberta.ca. Women are especially encouraged to apply as we may be able to increase the number of available faculty positions through the NSERC University Faculty Awards program. The University of Alberta is committed to the principle of equity in employment. As an employer, we welcome diversity in the workplace and encourage applications from all qualified women and men, including Aboriginal peoples, persons with disabilities, and members of visible minorities.

JEFFERSON LAB/NORFOLK STATE UNIVERSITY

POSTDOCTORAL RESEARCH ASSOCIATE EXPERIMENTAL NUCLEAR/PARTICLE PHYSICS

POSITION #PR2140

Jefferson Lab (the Thomas Jefferson National Accelerator Facility) invites applications for a postdoctoral position in experimental nuclear/particle physics. Applicants must have a Ph.D. degree in experimental nuclear or particle physics. The successful candidate will be stationed at Jefferson Lab, and will support the existing group of experimentalists at Jefferson Lab and Norfolk State University which are emphasizing the physics of meson spectroscopy on few-body decays and preparing for the CLAS detector upgrades.
The candidate will initially be working in the partial wave analysis (PWA) of CLAS experiment 99005, and in the prototyping and testing of ultra-compact calorimeters.

This is a two-year term position and is available immediately. Applicants should send a curriculum vitae and arrange to have letters from three referees sent to:

Jefferson Lab-Hall B/NSU Postdoctoral Position
Employment Manager
Mail Stop 28A
Jefferson Lab
12000 Jefferson Avenue
Newport News, VA 23606
Please specify #PR2140 and job title when applying

Informal inquiries may be addressed to:
Dr. Carlos Salgado, Norfolk State University, salgado@jlab.org
or Dr. Dennis Weygand, Jefferson Lab, weygand@jlab.org

Applications will be reviewed on a continuing basis.
Jefferson Lab is an Affirmative Action/Equal Opportunity Employer.

RESEARCH ASSOCIATE POSITIONS

Experimental High Energy Physics

Carnegie Mellon University

The Department of Physics at Carnegie Mellon University invites applications for two postdoctoral Research Associate positions in experimental high energy particle physics. The two individuals who fill these positions will work on our CLEO program at CESR, beginning in September 1999. The successful candidates will be based at the Cornell Synchrotron, in Ithaca NY, and will be expected to play a major role in the successful commissioning of the physics program for the CLEOIII detector. They will also be involved in the analysis of the existing CLEOII data, consisting of 10 million B pairs and extensive samples of charm and tau events. Interested candidates should submit a letter of application, curriculum vitae, and list of publications, and arrange to have three letters of recommendation sent to:

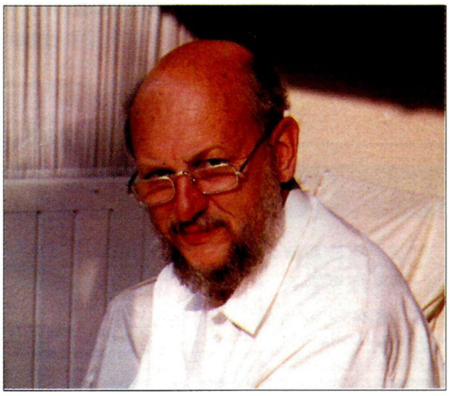
Professor Roy Briere
Department of Physics
Carnegie Mellon University
Pittsburgh, PA 15213, USA
(e-mail: briere@mail.lns.cornell.edu)

The application and recommendations can be sent either by normal or electronic mail. Review of applications will begin on July 1, 1999 and continue until the positions are filled.

Carnegie Mellon is an equal opportunity / affirmative action employer

The American Physical Society (APS) Centennial meeting in Atlanta on 20–26 March, attended by some 11 400, physicists was the largest physics meeting in history. At the event, **Cecilia Jarlskog** of CERN (with microphone), who chairs the Nobel Committee for Physics and Chemistry, opened a photographic gallery of physics laureates. On the right is APS President and 1990 Nobel Prize for Physics winner **Jerome Friedman**.

Klaus Schultze



Klaus Schultze.

Enthusiastic and committed physicist Klaus Schultze died on 8 April aged 67.

After receiving his doctorate at Würzburg with a thesis on the range of electrons in a heavy liquid bubble chamber, Schultze became a CERN fellow in 1962, joining the NPA heavy liquid bubble chamber group. Using the CERN 1 m chamber, he participated in the first successful bubble chamber neutrino experiments. After three years he went to RWTH Aachen, where he set up a bubble chamber group collaborating with the ongoing programme at CERN in the NPA, Gargamelle and BEBC chambers. It was at Aachen that the first event in Gargamelle demonstrating neutral currents in neutrino-electron scattering was observed, and Schultze's group made major contributions to the measurement of structure functions and scaling violations.

Schultze then reoriented the group to participate in the European Muon Collaboration (EMC), which discovered the EMC Effect and was at the origin of the "spin crisis", and the follow-up NMC experiment.

With the advent of LEP, he joined the L3 collaboration, adding to his research career a final chapter of weak interaction physics, where his group has contributed substantially to the central tracking chamber and the measurement of Z parameters.

From the early 1980s, Schultze devoted an increasing part of his time to the responsibility of scientists to society. He participated in studies on the devastating effects of nuclear warfare ("nuclear winter") and became Secretary of the Science and Society Committee of the European Physical Society. Later his concerns shifted to the problems of energy and the greenhouse effect.

Schultze was invited to bodies concerned with environmental and energy policies and was one of the driving forces of the Energy Working Party of the German Physical Society, working on strategies to reduce energy demand in industrialized countries and to introduce renewable energy sources. He passed away during a meeting of that working party.

Meetings

- The Sixth International Wigner Symposium (WigSym6) will be held in Istanbul, Turkey, on 16–22 August as part of the ongoing biennial series of International Wigner symposia. Concentrating on quantum and conformal field theory, strings and quantum groups, the even will be held at Bogazici University on one of the hills of Bosphorus. Internet "http://www.wigsym6.boun.edu.tr". E-mail "wigsym6@boun.edu.tr". For an automated answering service, e-mail "<robot@physics.umd.edu>" with WIGSYM.99 on the subject line.
- The Ninth Lomonosov Conference on Elementary Particle Physics, organized by the Interregional Centre for Advanced Studies, Moscow; the Faculty of Physics, the Institute of Theoretical Microphysics of the Moscow State University; the Joint Institute for Nuclear Research, Dubna; the Instituto Superior Tecnico – CENTRA, Lisbon; the Institute of Theoretical and Experimental Physics, Moscow; the Institute for High Energy Physics, Protvino; and the Institute for Nuclear Research, Moscow) will be held at Moscow State University, Moscow, from 20–26 September. Topics will include electroweak theory, tests of the standard model and beyond, heavy quark physics, non-perturbative QCD, neutrino physics, astroparticle physics and quantum gravity effects. Further information is available at "studenik@srdlan.npi.msu.su" and "ane@srdlan.npi.msu.su".
- The Symposium on Applications of particle detectors in Medicine, Biology and Astrophysics (SAMBA) will take place in Siegen on 6–8 October. Further information is available at "http://www.physik.uni-siegen.de/samba/". E-mail "samba@alwa02.physik.uni-siegen.de".

Bruno Pontecorvo prize

Vladimir Lobashev of the Institute for Nuclear Research, Moscow/Troitsk, received the prestigious 1998 Bruno Pontecorvo prize, awarded by the Joint Institute for Nuclear Research, Dubna, near Moscow, in recognition of his contributions to weak interaction physics.

National Academy of Sciences member

Fermilab theorist William Bardeen has been elected a member of the US National Academy of Sciences.

Bookshelf

• *From Hiroshima to the Iceman: the Development and Applications of Accelerator Mass Spectrometry* by Harry E Gove, Institute of Physics Publishing 07503 0557 6 (hbk £50/$99) 07503 05584 (pbk £15/$27).

Invented some 20 years ago, accelerator mass spectrometry (AMS) is one of the newer success stories in the applications of particle accelerators. It provides a powerful, fast and reliable means of measuring long-lived radio-isotopes using only minute samples.

Radiocarbon-14, which has a half-life of 5730 years, was the first isotope to be measured this way, and AMS radiocarbon dating soon became a powerful tool for determining the age of organic material using small samples. Other isotopes are also suitable for AMS.

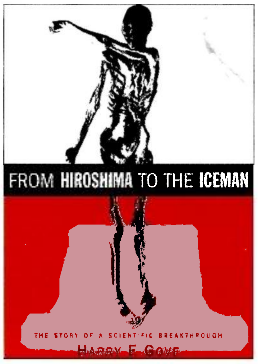
Radiocarbon dating was invented by Willard Libby in the 1940s and brought him the 1960 Nobel Prize for Chemistry. In its original form, radiocarbon dating counted the actual decays of residual carbon-14, requiring relatively large samples of material.

Jolted by news of carbon-14 measurements at a Berkeley cyclotron, Gove participated in pioneer AMS measurements at Rochester in 1977, which dramatically showed how the level of carbon-14 in commercial charcoal and fossil graphite is different, using milligram samples. It is usually no problem to take a milligram sample from even the most valuable relic.

Giving a reliable measurement of the age of a specimen can be vital input in archaeology, history and mineralogy, as well as being a focus of public interest. Such measurements can settle disputes and separate fact from myth.

One of the most spectacular AMS applications is the dating of the Turin Shroud, and Gove's earlier book, *Relic or Hoax?: Carbon Dating the Turin Shroud*, is a scientific account of this work. Multiple AMS measurements gave the origin of the shroud material, widely believed to be of biblical origin, as AD 1325 ±33 years.

In his latest book, Gove casts the AMS net wider, describing the history and instrumentation of the technique, concentrating on electrostatic tandem accelerators, before turning to its application. The analysis examples, described in graphic detail, include radio-relics from Hiroshima and Nakasaki that provided new insights into the mechanisms of radiation damage; North American archaeological remains; modern radioactive waste; the Turin Shroud revisited; Egyptian mummies; "Oetzi", the neolithic iceman discovered in 1991 in the Alps on the Austrian-Italian border; and the Dead Sea Scrolls.



For the dating of the Turin Shroud, one theory mentioned is that bacteria on cloth continue to ingest carbon-14 from the air, making the cloth look younger.

This is a fascinating account of a major particle accelerator application success by an enthusiastic scientist who played a major role in its development. Harry Gove contributed an article on AMS to the special July 1995 Applying the Accelerator issue of *CERN Courier*.

• *Making Physics: a Biography of Brookhaven National Laboratory, 1946-1972* by Robert P Crease, University of Chicago Press 0 226 12017 1 (446pp $38/£30.50).

Crease calls this book a biography because he likens Brookhaven National Laboratory to a community, and a community lends itself to biographical treatment. Crease is a philosopher, but he has absorbed and is faithful to the ethos of the scientific community.

I have been at Brookhaven for 44 years but found much in this book that I did not know about the place. Crease had full access to the laboratory's archives and had interviews with many of the personnel. I found the book fascinating and a good read. He recounts the history of the founding of Brookhaven; the drive by I I Rabi to obtain large physics instruments for the east of the US after the Second World War; the interactions with the Manhattan District of the US Army, which had built the atomic bombs; and the finally successful negotiations with the Federal Government for the establishment of the laboratory at the US Army's Camp Upton site.

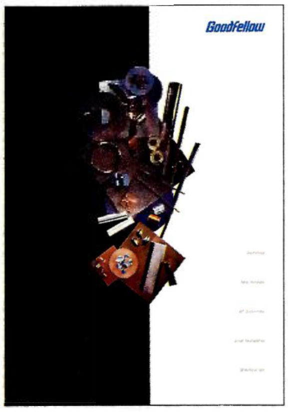
Brookhaven was the first civilian laboratory to have a reactor. Along with the reactor it was decided that accelerators would also be built there. The first two were a Van de Graaff and a 60 inch cyclotron. Both of these machines were built by commercial companies and neither worked properly until significantly altered by laboratory personnel. Rabi was insistent that a large synchrotron should be built at Brookhaven. In a compromise worked out with the funding agency and Berkeley, it was agreed that Brookhaven would build a 2-3 GeV machine and Berkeley a 8 GeV machine with Brookhaven to get the follow-on machine later.

After the Cosmotron was finished, the Brookhaven accelerator builders were informed that a delegation of accelerator builders from a new laboratory, called CERN (modelled to a considerable extent on Brookhaven), would be visiting with plans to build a machine more ambitious than the Cosmotron. Livingston felt that Brookhaven should do more than just show and tell, and organized a study group to brainstorm for improvements on the Cosmotron's basic design. Crease narrates how this study group came up with the ideas for alternating gradient synchrotrons. When the CERN group arrived they were caught up in the excitement, changed their plans and resolved to build what became the PS. Brookhaven built the AGS, which came on line shortly after the PS.

Crease goes into considerable detail about the work done in particle physics, in nuclear physics (both at the reactors and the accelerators) and in solidstate physics. Brookhaven is a multidisciplinary laboratory, and while Crease's emphasis is on physics, there is also information about some of the work in other disciplines, such as medicine, chemistry, instrumentation and biology. He cites the development of Tc99 as used in nuclear medicine. It is the predominantly used radionuclide in the several million nuclear-medicine procedures performed today.

Other fruitful developments include the first treatment for Parkinson's disease and the effect of salt on hypertension. Ray Davis's work on the detection of solar neutrinos was done in the chemistry department with help from the instrumentation department.

Science is made by human beings. Crease emphasizes the human side of Brookhaven, with miniportraits of many of the prominent personalities associated with the laboratory. He describes in some detail its administration, the interaction of scientists with the administration and how scientific policy is set. He describes interactions among strong-willed personalities and how some of this impacts the research done. He explains the science well and made remarkably few errors.
David C Rahm, Brookhaven.



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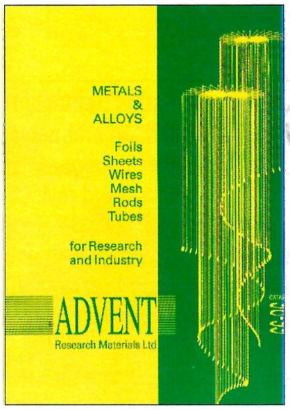

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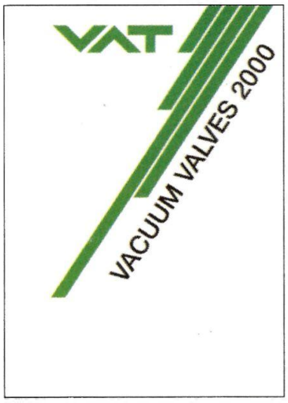

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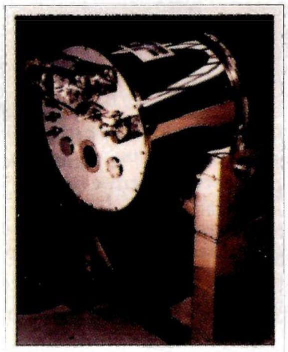

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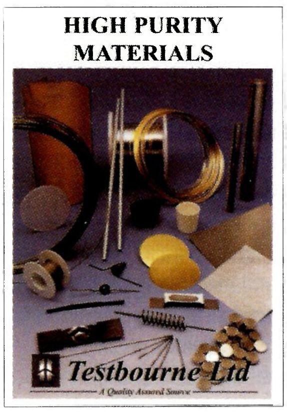

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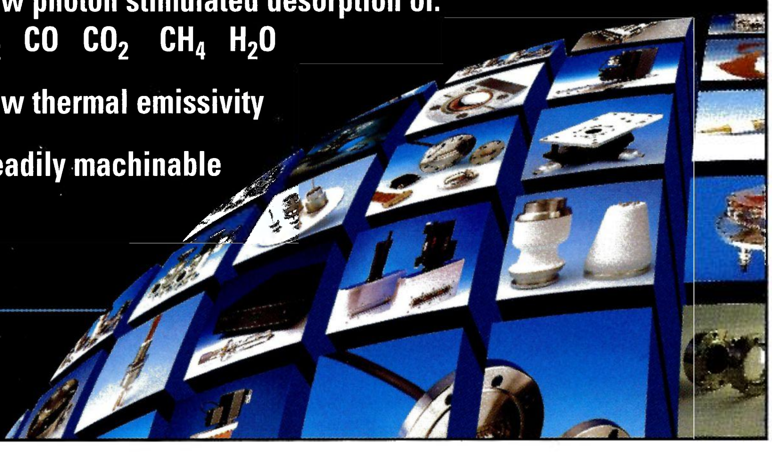

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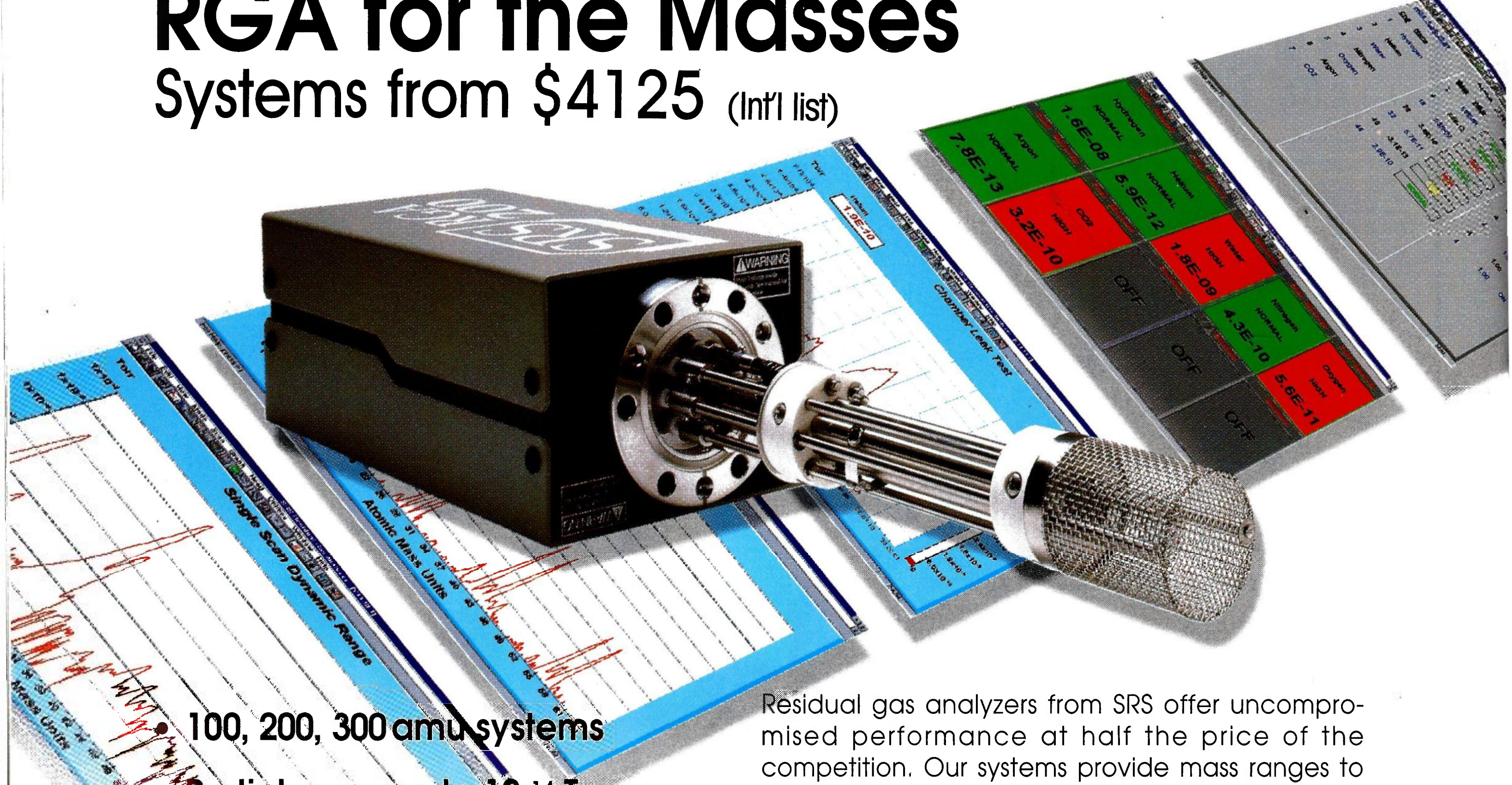

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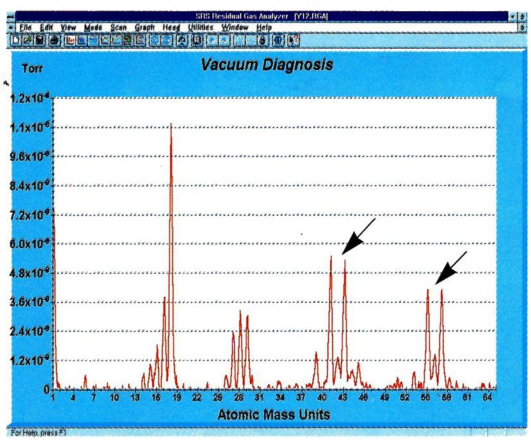

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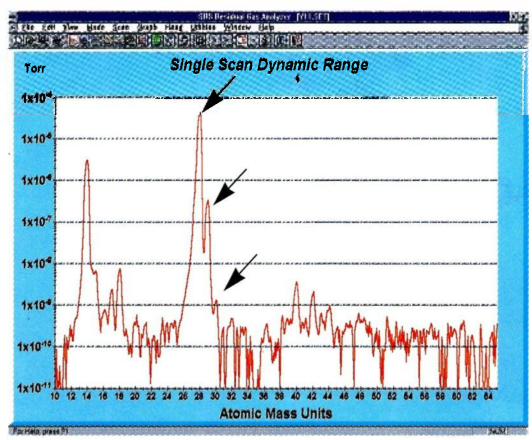

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