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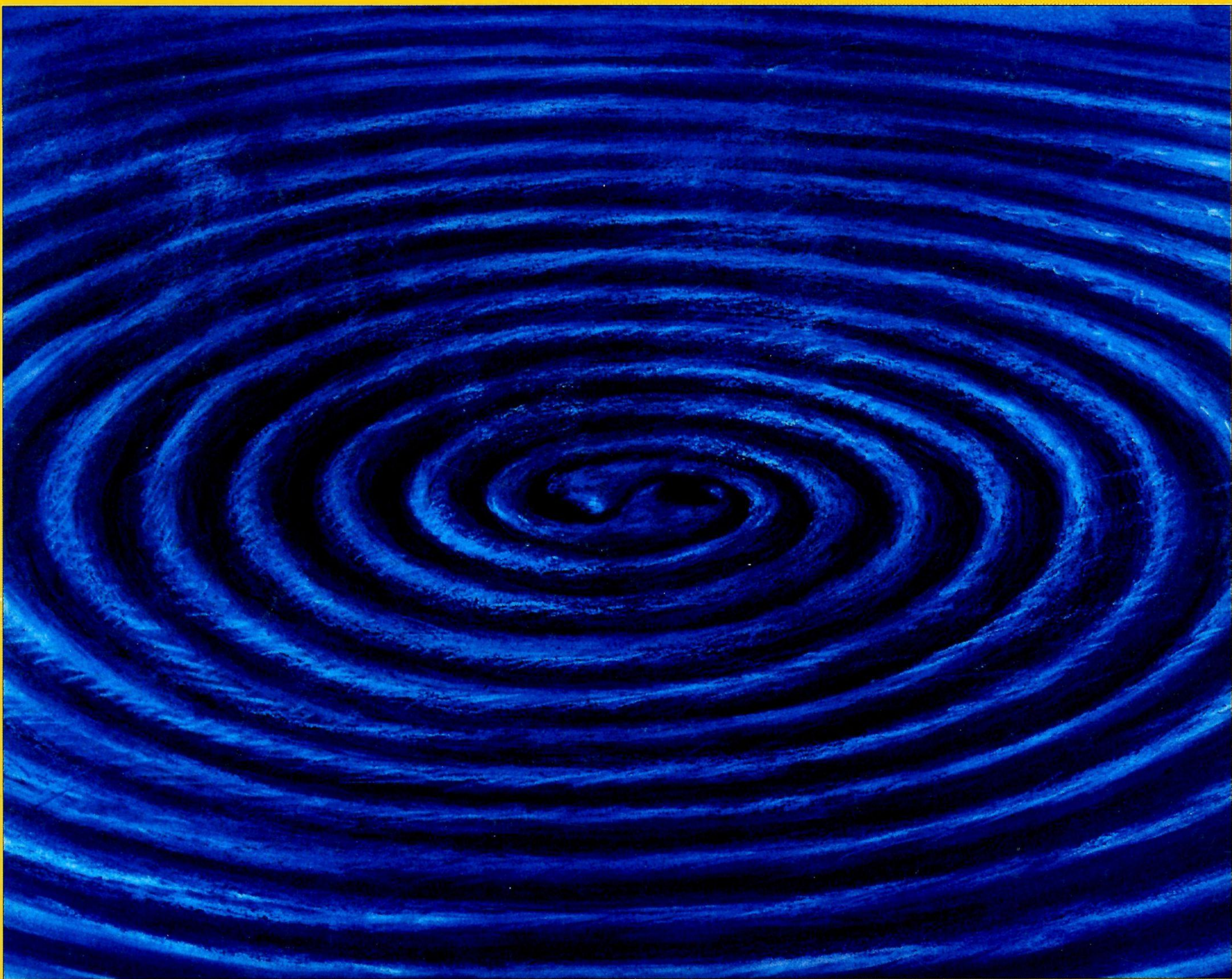
CERN COURIER

VOLUME 39 NUMBER 2 MARCH 1999

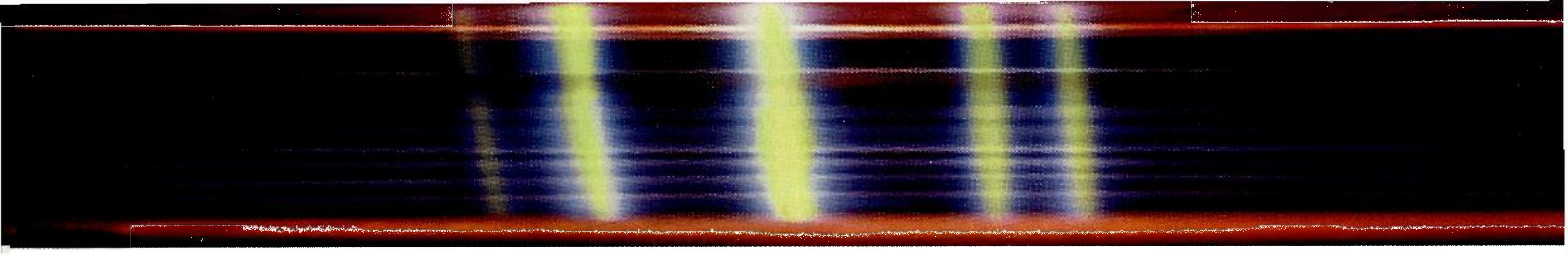


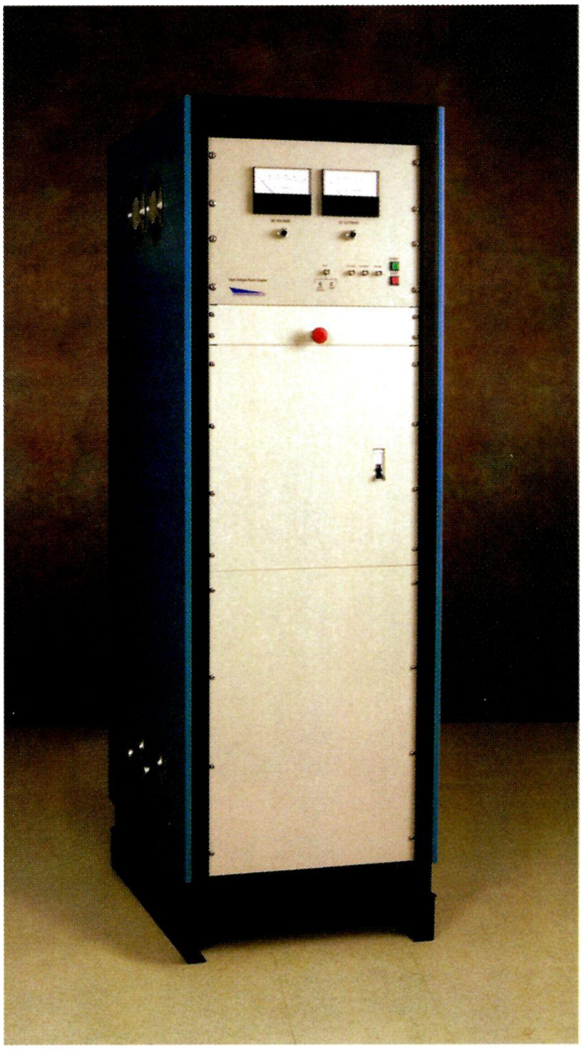
Searching for gravitational waves

A LONGER HISTORY OF TIME
Was the Big Bang really the beginning of the universe?

MAKING TRACKS FOR THE LHC
How the research masterpieces for the next millennium will be recorded

RELIC NEUTRINOS
Looking for primordial particles and assessing their role in evolution





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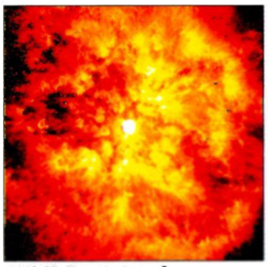
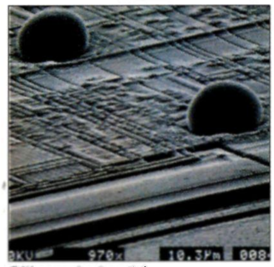


A Wolf-Rayet star p9



Silicon pixels p14

Luciano Maiani p46

Cover: Inspiral – a simulation of the gravitational waves emitted by two coalescing neutron stars. See "The quest for gravitational waves" page 10.

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

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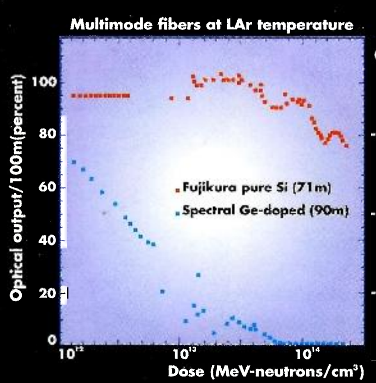
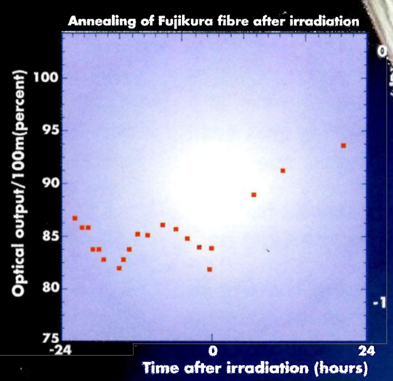
Radiation Hard Optical Fibres and Connectors

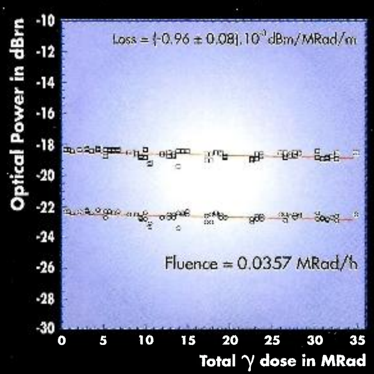
Fujikura's range of Silica based step-index singlemode and multimode fibres are especially designed for use in high radiation environments allowing high data transmission rates in optical links. Other types of application specific optical fibres and MT connectors requiring high radiation resistance are also available. Typical levels of neutron radiation for the 50/60/125 fibres after radiation exposure at levels of $2x10^{15}n/cm^2$.



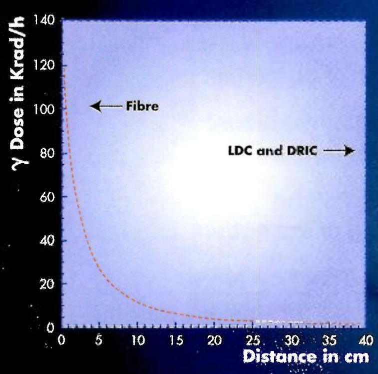
Transmitted light in multimode fibres during neutron irradiation in LAr.



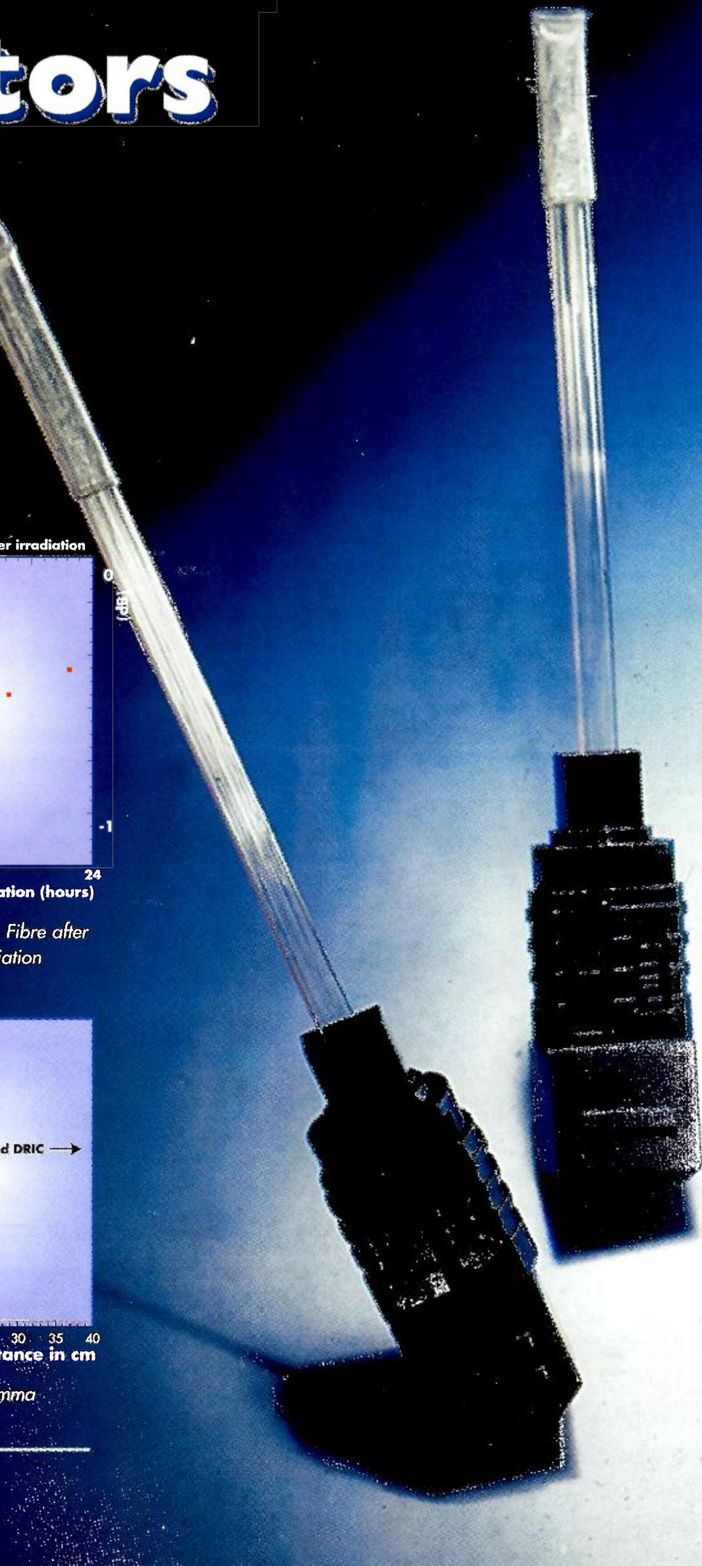
Annealing of Fujikura MM Fibre after end of neutron irradiation



Behavior of LDC and DORIC chips (up to 3 MRaD) (PS file)



Spectrum of the gamma source station



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Pakistan creates national centre for physics

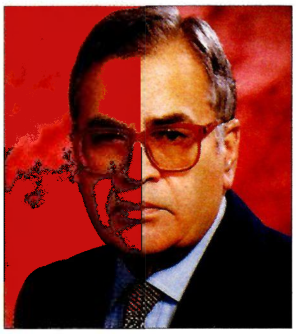
To promote research in physics and strengthen university capability in Pakistan, a National Centre for Physics (NCP) has been established at Quaid-i-Azam University, Islamabad. The director is distinguished theorist Riazuddin and the scientific activities formally began with a one-day symposium on 28 January.

The NCP will try to attract world-class physicists to the Centre throughout the year. Its basic mode of operation will be based on distinguished visiting scholars for periods ranging from a week up to a year.

The NCP will be a permanent focus for workshops, colleges, schools, conferences and seminars covering physics, mathematics and related subjects, and will encourage joint efforts in the relevant departments, institutions, and organizations in Pakistan.

The NCP will also enter into collaborative arrangements with institutions abroad, like CERN and the Abdus Salam International Centre for Theoretical Physics in Trieste.

The strong influence of the late Abdus Salam endowed Pakistan with a distinguished tradition in theoretical physics, and many Pakistani theorists hold important positions in overseas universities and research centres. Recently this tradition has extended to cover also the experimental sector, where Pakistani physicists are involved in the CMS experiment for CERN's LHC proton collider.



Distinguished theorist Riazuddin is director of the new National Centre for Physics (NCP) at Quaid-i-Azam University, Islamabad.

The NCP will also try to use effectively expatriate Pakistani physicists by appointing them as "reverse" associates to enable them to spend some time every year at the Centre.

The Centre is also a natural development of the International Nathiagali Summer College, established in 1976 at the suggestion of Salam and which has been held annually ever since. The twin topics of this year's school are CERN's LHC collider and its research programme, and Non-Conventional Energy Resources.

NCP Director Riazuddin took his first research steps under Abdus Salam at Lahore and in the UK, obtaining his PhD in 1959 at Cambridge. After positions in Pakistan and in the US, in 1966 he became founding director of the Institute of Physics at the then new University of Islamabad, which gave Pakistani physics a research base in its own country. The institute is now a department of Quaid-i-Azam University. In 1982 he joined King Fahd University, Dhahran.

Neutrons in time

A new limit on the electric dipole moment of the neutron comes from an experiment using ultra-cold neutrons at the research reactor at the international Institut Laue-Langevin, Grenoble, France. For many years, the team has been refining its techniques to push the limit progressively lower.

Viewed as an electrically neutral particle, the neutron should have no electric dipole moment, but an effect could arise due to its constituent electrically charged quarks.

An electric dipole moment (the product of spin and electric field) violates time reversal symmetry (T), and any non-zero value for the neutron electric dipole moment would signal a dependence on the arrow of time.

This would be no surprise to physicists. The neutral kaons violate the combined CP reflection which changes particle to antiparticle as well as producing a mirror image. Because the combined CPT has to be good, T symmetry has to be broken in sympathy.

This "natural" level of T violation should give a value for the neutron electric dipole moment of some 10^{-30}. Meanwhile, imaginative physicists have proposed models which predict a larger value. The latest measurement of 6.3×10^{-26}, although still a long way from the naturally expected value, does start to restrict theoretical speculation.

Symmetry violation in a new setting

The CDF experiment at Fermilab's Tevatron proton–antiproton collider has produced heroic new evidence for the violation of "CP" symmetry, a hypothetical operation which takes a particle into a mirror image of its antiparticle.

Although a tiny effect in particle physics, CP violation could be the cause of the matter–antimatter asymmetry of the universe – a Big Bang which presumably produced equal amounts of matter and antimatter resulted in a universe populated entirely by matter.

So far, the only quantitative evidence for this subtle violation has been in the decays of neutral kaons, at a few per mil. CDF now sees tentative evidence for CP violation in the decays of neutral B mesons, in which the strange quark of the neutral kaon is replaced by a heavy b-quark. CDF looks at B decays producing a J/psi and a short-lived neutral kaon.

The vital parameter is measured to be 0.79 ± 0.44, a non-zero value indicating CP violation. While CP violation is not completely understood and therefore cannot be predicted from scratch, the measured value is in line with expectations based on the interconsistency of many Standard Model measurements. Several months ago, CDF published an analysis based on a subset of its B decay sample. The new result uses its full available sample.

With a new generation of electron–positron colliders hoping to open up this area of B physics, we plan to publish more on these initial B–CP violation pointers soon.

DEP and PSL sign distribution agreement

Photodetector supplier Delft Electronic Products (DEP), now in its 30th year of manufacturing for the worldwide image intensifier market, has signed a distributor agreement with Photonic Science Ltd (PSL) for the UK, Eire and France.

PSL, established in the UK in 1985, and with a French office since 1995, specializes in high-technology detector systems, covering imaging applications from X-ray diffraction to night vision. PSL incorporated specially-developed DEP intensified tubes into a unique design for what is claimed to be the world's smallest high-resolution intensified camera.

CERN: Circular solution to the enigma of nucleon spin

Over half the nucleon's spin is unaccounted for, but circularly-polarized photons could soon reveal where it is. Physicists working on the new NA59 experiment at CERN aim to study the production of high-energy circularly-polarized photon beams using crystals. If they are successful, such beams could be used to probe directly the contribution to nucleon spin carried by gluons, answering a question first posed by a European Muon Collaboration experiment in 1988 which found that quarks contribute less than half the nucleon's spin.

Circularly-polarized photon beams are traditionally produced from polarized electron beams. But the sort of physics NA59 has in mind would require much higher electron energies than are currently available. The solution proposed by NA59 is to start with unpolarized electrons and produce circular polarization in a two-step process using a pair of crystals. The first crystal would generate a linearly polarized photon beam, the second would act as a "quarter-wave plate", converting linear into circular polarization. Quarter-wave plates are frequently used to analyse polarized light – a feature which makes the work of NA59 potentially interesting to prospective builders of future high-energy electron–positron colliders. Quarter-wave plates might also be used to measure beam polarization in such machines.

The first step has already been demonstrated by the earlier NA43 experiment which demonstrated that linearly polarized light can be produced by firing a high-energy unpolarized electron beam into a crystal. The degree of polarization, however, was not determined. Measuring it will be the first goal of NA59 during a three-week run in 1999 using a 180 GeV electron beam. A second experiment to produce circularly-polarized light is planned for 2000 if the 1999 results are encouraging.

Circularly-polarized photon beams are not the only way to measure the gluon contribution to nucleon spin. The COMPASS experiment at CERN will soon begin to attack the question using a high-energy muon beam. The photon route, however, offers an attractive alternative with the advantage that for photons of 70 GeV and above, the experimental signature is particularly clear. In a polarized nucleon target, photons fuse with gluons to produce charm–anticharm quark pairs. Measuring the asymmetry between production rates for opposite polarizations of the target gives the gluon contribution to the nucleon's spin. This means that despite the large attenuation of the beam caused by passing it through two crystals, the final measurement would still be competitive with alternative approaches.

ISAC produces first ion beam at TRIUMF

On 30 November 1998 the new ISAC (Isotope Separation and Acceleration) facility at the Canadian TRIUMF laboratory in Vancouver produced its first ion beam with short-lived exotic isotopes.

Low-energy beams of potassium (atomic mass numbers 37 and 38) were transported from a proton-bombarded target through a high-resolution mass-separator system to the first experimental station. This milestone was achieved more than a month ahead of initial estimates. The first experiment will investigate weak interaction symmetries in the decay of optically trapped potassium isotopes.

ISAC uses ISOL (on-line isotope separation) to produce short-lived exotic nuclei through a reaction between the primary proton beam and a thick target. Additional experiments measure precise lifetimes of exotic nuclei.

While this first beam was created with only 0.5 μA of proton current on the production target, over the next few years the current on target will gradually be increased to 100 μA.

A nuclear magnetic resonance station using polarized lithium 8 for condensed matter studies and a low-temperature nuclear-orientation station are scheduled to begin operation this autumn. Completion of this first phase of the facility (ISAC-I) is expected in late 2000 when accelerated beams up to 1.5 MeV/nucleon become available for nuclear astrophysics measurements.

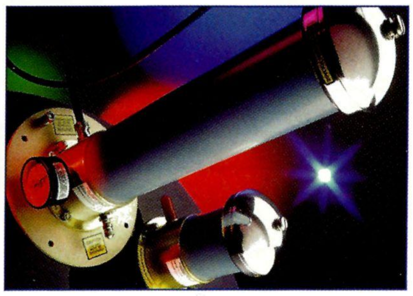
HV SOURCE

Space saving power supplies from Glassman pack more punch - *Full story below*

Glassman launches MORE new products to celebrate 21 years at top

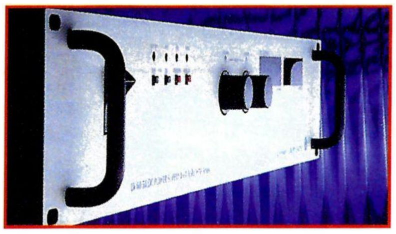
High Performance Dividers

Ross compact and lightweight base-mounted HV dividers handle maximum operating voltages from 3kV to 1000kV DC or PK AC, or up to 1350kV impulse.
Offering high accuracy and bandwidths to over 20MHz, models are available in compensated resistance-capacitance types or uncompensated resistive or capacitive types, for indoor and outdoor use.



High Power, Low Profile

The new LV series high-voltage power supply from Glassman provides high efficiency and high power in a compact enclosure.
Available in 1kW (0 to 600V) or 3kW (0 to 300V) supplies, all units are standard 19" rack mounting. 1kW models are only 1.75" high, and 3kW models 3.5" high.
Overvoltage protection and thermal shutdown are standard. Units carry a full three-year parts and labour warranty.



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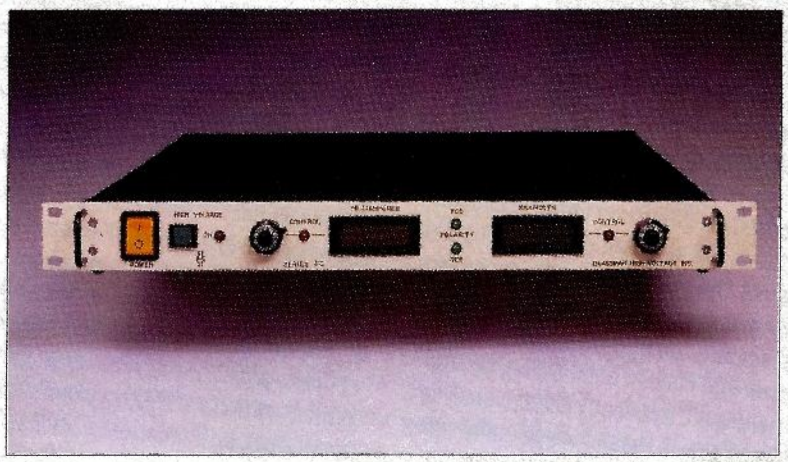

Glassman's new FC series regulated high voltage DC power supplies offer 120W performance in a unit with half the panel height of competing 100W devices. There are 16 output ranges from 1kV to 60kV.
The compact, lightweight package has a panel height of only 1.75", and like other models in the Glassman range, it uses air as the primary dielectric medium for easy serviceability.
Automatic crossover from constant-voltage to constant-current regulation provides protection against overloads, arcs and short circuits. All models in the FC series are fully CE compliant. Advantages include low ripple, low stored energy and excellent voltage/current regulation performance. A full three year parts and labour warranty is included as standard.

AC Supplies from DC Specialists

High-specification Chroma 6400 series AC power supplies offer full frequency programmability from 45 to 500Hz - including the 400Hz standard for aerospace applications.
Now available from Glassman, the 6400 series includes five models, offering 375VA, 800VA, 1500VA, 2000VA and 3000VA output power, for optimum versatility over a broad applications range. Features include optional GPIB, RS232C and analogue programming interfaces.

GLASSMAN europe

Next Issue...
NEW ML Series HV Power Supply launch

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Edited by Emma Sanders

Gas reveals secrets of universe evolution

New observations using the ROSAT X-ray telescope endorse a "bottom-up" model of the evolution of the universe.

Most ordinary matter in the universe is in the hot gas that makes up the intergalactic medium. ROSAT observed X-ray emission from this gas, both in small groups of galaxies (where it has a temperature of around 10 million degrees) and in large clusters (around 100 million degrees). The gas in the small groups contained more energy than expected. This extra energy comes from galaxy formation, and modelling the evolution of the system showed that it had to be injected before the group formed. This supports a "bottom-up" picture, with small objects being formed, then clustering together.

This is the first time that such energy comparisons have been made. Observations are difficult because the intergalactic gas is so thin. The result has important implications for cosmology and may help to explain why we see no galaxies forming today. The original phase of galaxy formation heated up the intergalactic gas so much that it is too energetic to collapse and form stars.

The ROSAT satellite is a collaboration between Germany, the UK and the US. After eight years in orbit and recording 20 times more X-ray sources than had been seen before, ROSAT ceased to function in December 1998.

Stars seeing stars

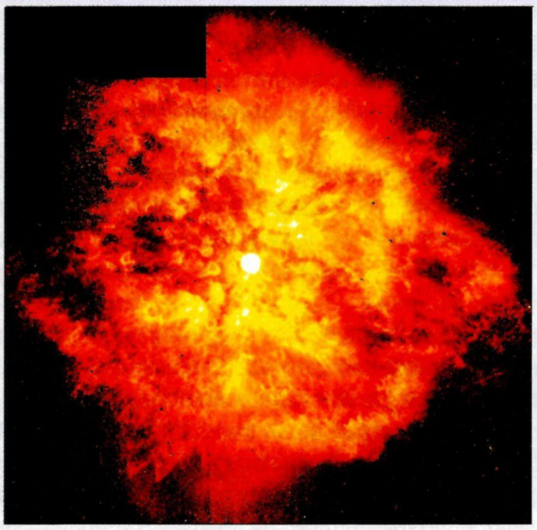
Subaru, a new Japanese telescope, saw first light in January. It joins the UK infrared telescope, the Dutch, UK and Canadian James Clerk Maxwell Telescope and the US Keck Observatory on the 4000 metre Mauna Kea site in Hawaii.

As well as its connotations for the motor industry, "Subaru" means "to bring together" in Japanese and is also the Japanese word for the Pleiades star cluster.

The 8.3 metre primary mirror is composed of 44 one-ton glass hexagons and its surface is polished to an accuracy of two hundred billionths of a centimetre.

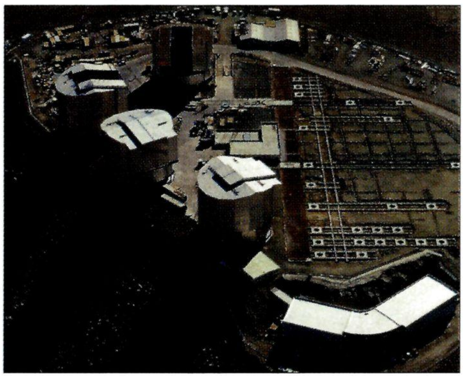
The telescope will be optimized for near-infrared observations, where it will have a resolution of 0.06 arc-seconds. This is three times as great as the resolution of the Hubble Space Telescope.

Picture of the month



This Hubble Space Telescope image shows a Wolf–Rayet star ejecting its outer atmosphere. Hot clumps of gas, some 100 billion kilometres wide, are thrown into space at speeds of more than 100 000 kilometres per hour. All massive stars will eventually evolve through a Wolf–Rayet phase. (Pic: NASA.)

Top telescopes



The VLT site, 2650 m above sea level in the Chilean Atacama Desert. (Pic: ESO.)

The European Southern Observatory inaugurates its new observatory at Paranal, Chile, during the first week of March. Two of the four 8.2 metre telescopes that will make up the Very Large Telescope (VLT) are now complete. The third will follow this autumn.

Construction of the subterranean laboratory, where light from the telescopes will be analysed, is well under way. The first interferometric images are expected next year. The VLT will be the world's most sensitive telescope.

Cluster rides again

The Cluster 2 mission has been given the go-ahead by the European Space Agency review board and is scheduled for launch by two Russian Soyez rockets in mid-2000. The four satellites will, for the first time, study the solar wind and the Earth's magnetosphere in 3-D.

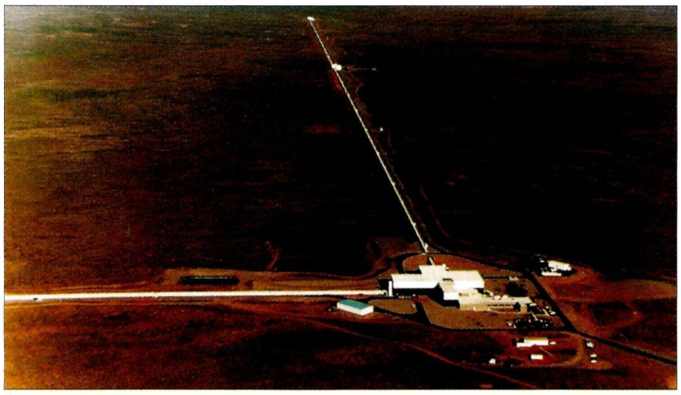
Scientists are particularly interested in the coupling of the Sun and Earth's magnetic fields. This phenomenon, called magnetic reconnection, occurs in large-scale plasmas. Without it, the Sun and Earth's magnetic fields would not mix and the stream of electrons and ions in the solar wind would not be channeled into the Earth's ionosphere.

The process is also important for star formation, where magnetic pressure would otherwise stop the star from condensing. However, despite its crucial role, little is known about magnetic reconnection.

Cluster 2 is almost identical to the original Cluster spacecraft, which was lost when the first Ariane 5 flight was destroyed in an explosion in June 1996.

The quest for gravi

Simulation of the gravitational waves emitted by two coalescing neutron stars.



Aerial view of the Hanford (Washington state) LIGO site. Clearly visible are the two 4 km arms stretching across the desert to the end mirror stations. The surface "tunnels" use sections of reinforced concrete U-profiles covering the 1.2 m diameter vacuum pipes.

The search for gravitational waves – gravitational perturbations in transit – remains a major objective for the start of the next century. But with such a feeble force the waves are extremely difficult to detect amid the cacophony of noise on the Earth's crust.

The gravitational waves emitted by accelerated masses were predicted by Albert Einstein's General Theory of Relativity as long ago as 1916, but so far remain undetected. One piece of indirect evidence affirming their existence came in 1974 when Joseph Taylor and Russell Hulse studied PSR1913+16, a system of two compact neutron stars – one of which is a detectable pulsar – orbiting each other in a slowly decreasing eight-hour period. The orbital frequency acceleration was observed to be in perfect agreement with that expected from the energy loss corresponding to their calculated gravitational wave emission. For their accomplishment, Hulse and Taylor were awarded the 1993 Nobel Physics Prize.

Unfortunately these twin stars are presently emitting gravitational waves too feebly to be detectable on Earth, a condition that will continue until the end of their pas-de-deux inspiral some 350 million years hence. Still, from the density of observed binaries, a few such inspiral events are expected per century in our galaxy.

Since the theoretical prediction of gravitational waves, scientists have searched for ways of directly detecting them. To date, efforts have been unsuccessful because the extreme weakness of the postulated signals places them below the detection threshold currently available, and as yet no unexpectedly strong signal has graciously decided to assert itself.

The quest to detect gravitational waves started in earnest in 1965, with the pioneering work of J Weber on resonating bars. These are basically high-quality bells designed to be rung by transient gravitational waves. From this beginning, a small gravitational wave detection community has arisen and thrived, continuing to improve on the original idea. The main effort is directed towards noise reduction by introducing ever lower cryogenic temperature and ever more sensitive displacement sensors, to improve detector sensitivity and ultimately reveal a signal. Many more bars, progressively sophisticated, have been built. One in particular, the Explorer, has been quietly functioning at CERN since 1989.

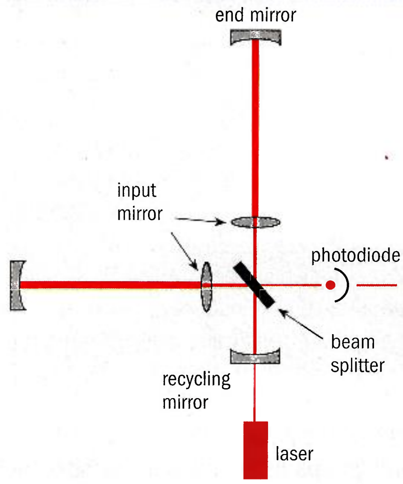
Drawback

Despite their great potential sensitivity, the primary drawback of resonant bars is that they are, by definition, resonant. They are sensitive mainly to signals with a frequency corresponding to the bar mechanical ringing frequency, of the order of 1 kHz. A bar would respond to the hammer blow of an asymmetrical supernova explosion by simply ringing at its own bell tone, and would be excited by a twin neutron star inspiral only in that brief instant when the two stars chirp up through the bell tone frequency.

Recent advancements in laser interferometry have cleared a path to discovery with a new wide-band detection technique. This technique is capable of following a star inspiral from the time it starts generating a distinguishable signal above the clutter of gravitational noise produced by the microseismically vibrating Earth's crust (a few Hz for inspirals in our galaxy), to the time when the two neutron stars actually merge and stop emitting gravitational waves as point-like

tational waves

The interferometric gravitational wave detection scheme



Sketch of the interferometric gravitational wave detection scheme. All mirrors are suspended by wires so as to be free to be jerked by incoming gravitational waves. The Michelson is tuned to keep the detection photodiode in the dark fringe so that only sideband power, modulated by the gravitational waves, reaches the photodiode. All the injected power is then reflected towards the laser, where a recycling mirror bottles all injected energy into the interferometer. Recycling the laser power makes the 10–20 W laser appear like a kW class laser. The two arms – 3 or 4 km Fabry-Perot resonators – further contain the laser beam power fed by the beam splitter. Standing powers of several kW must be maintained in these cavities. Displacement sensitivities well below 10–18 m are achievable using this technique.

masses (a few kHz). The whole process is calculated to last for a fraction of an hour above 5 Hz, and for only about a second above 100 Hz.

Detection would be via very long Michelson interferometers. Inside them, light is modulated by its reflections between mirrors, suspended from wires, free to be jerked by any incoming gravitational wave. The technique has initial sensitivity sufficient to reveal inspirals occurring in neighbouring galaxies, thus allowing detection of some inspiral gravitational wave signals within a physicist's lifetime. Further advancement in lasers, mirrors, seismic isolation, and phase detection techniques must be achieved to get longer reach, up to the full potential of this technique, and reduce the expected time between detectable events to months or even days.

Small effects

Even a strong gravitational wave signal coming from, say, our own galaxy is expected to induce a space strain of the order of 10^{-21}, an unbelievably small effect, which would jerk masses spaced at 1 km by a mere 10^{-18} m - one thousandth of the diameter of a proton!

It seems almost preposterous to hope to measure so small a signal, with light having a wavelength of about 10^{-6} m, and using mirrors made with atoms 10^{-10} m in diameter, and against a ground

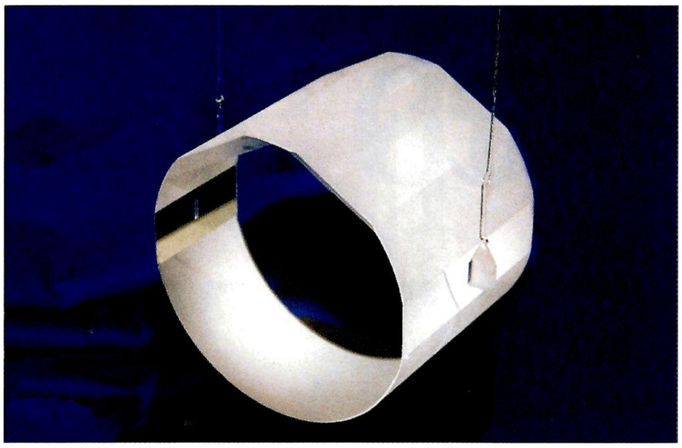
One of the LIGO mirrors which achieves parts-per-million losses.

microseismic activity of the Earth's crust of some 10^{-6} m/Hz$^{-1/2}$. Still it is theoretically possible, and this is reason enough to try!

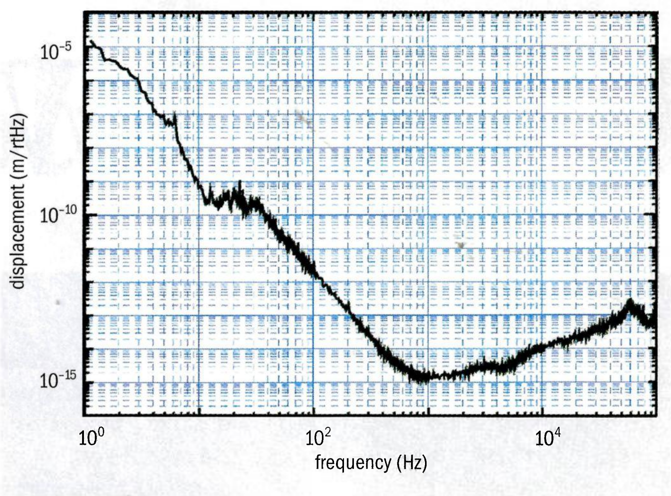
Gravitational wave scientists have assembled a combination of techniques to overcome these daunting problems. To achieve the goal, laser phase sensitivity and seismic noise rejection mechanisms exceeding 10^{-12} must be achieved. Also, the surface of the mirrors must be stationary when compared with the amplitude of the signal and, beware, mirror surface stability is limited by the thermal activation of the drum modes of the mirror surfaces. These and other problems are being addressed.

The Michelson interferometers must have kilometric arms, constituted by "high finesse" Fabry-Perot cavities to trap the light for long periods and increase the sensitivity. Laser standing powers measured in kW will be stored within the cavities. Beam losses at the level of 10^{-6} per passage are required. Mirrors must be 20 or 30 cm in diameter just to hold diffraction losses in check, and coatings with parts per million reflection losses have been developed. Vacuum pipes with diameters of the order of a metre are necessary just to contain the diffraction-limited laser beams, and a vacuum exceeding 10^{-9} Torr is required to prevent the introduction of spurious signals by refraction index fluctuations.

Construction of several detectors has started around the world. They have two characteristics which make the quest for gravitational waves a truly global affair. First, while a single detector may on its own register an incoming signal, more than one detector must be built - at the largest possible separation - to confirm detection through coincidence. Secondly, at least three detectors separated by the maximum possible lever arms are necessary to triangulate on the signal source. In addition gravitational wave detectors must run continuously to be sure of catching the fleeting instant of an inspi-



Fused silica mirror of 2.8 kg mass hung by silica fibres – prototype for the final stage of the suspension system in GEO-600. The all-silica mechanics permitted 2.5×10^7 quality (Q) factor, unthinkable with metallic components. Parts per million optical losses have been achieved by different groups using mirrors of this kind.



First full-interferometer displacement noise spectrum from Tama. Although still orders of magnitude above the target sensitivity, Tama scientists have demonstrated the feasibility of long-arm interferometric gravitational wave detectors.

ral or other pulsed source. As no single machine has a 100% duty cycle, the quest requires several detectors.

An interesting additional twist is given by the fact that gravitational wave emission may be accompanied by neutrino or gamma-ray bursts. The gravitational wave detectors will then work in coincidence not only with themselves and gravitational wave bar antennas, but also with conventional high-energy physics detectors like the underground neutrino experiments and the orbital gamma-ray burst monitors.

Presently six interferometric gravitational wave detectors are under construction around the world. They are (in order of size):

- the two LIGO 4 km arms Michelson in the United States at Hanford, Washington and Livingston, Louisiana, as well as a 2 km Michelson sharing the same vacuum envelope at Hanford;
- the 3 km Virgo instrument near Pisa, Italy;
- the 600 m GEO-600 detector near Hanover, Germany;
- the 300 m Tama-300 at NAO in the Tokyo suburbs; and
- a still undefined-length instrument near Perth, Australia, called AIGO.

The various laboratories have focused on different aspects of the problems in a somewhat complementary way.

The small GEO group leads development of ultra-high mechanical quality factor, all-quartz mirror suspensions. The achieved suspensions have pendular oscillation (Q) factors of tens of millions corresponding to swinging lifetimes measured in years. It is easy to understand that a pendulum requiring years to dissipate its oscillation energy will need the same time to be excited by the seismic motion of its support points thus effectively isolating the mirror from perturbations. The same principle is used in the isolation chains to keep ground perturbations away from the detection band of the instrument.

The Virgo group has contributed a long-standing effort to producing low-frequency mechanical filters to suitably attenuate, across the entire detection band, the seismic activity observable in the Earth's crust. The Virgo group has built impressive 8 m attenuation towers in which seismic noise is progressively filtered to acceptable levels. Construction of these towers posed interesting problems, such as the study of acoustic emission of metals under stress. The slippage of two steel grains under stress frees enough energy to shake the mirror by 10^{-12} m, a million times more than the sought-after signals themselves!

Mirrors of suitable dimensions and parts per million (ppm) losses had to be produced. Several groups have achieved the specified loss levels and Virgo, in collaboration with Heraeus, achieved sub ppm/cm absorption levels in the fused silica mirror substrates.

Lasers with sufficient power and stability to feed the interferometer cavities had to be designed. The kilometric, 1.2 m diameter vacuum tubes of the Michelson arms will be by far the largest ultra-high vacuum volumes ever built, dwarfing even the LEP and LHC combined, with the 9000 m^3 of each interferometer. Techniques have been developed to achieve this at an economically acceptable price.

Infrastructure

Construction of both the infrastructure necessary for these large experiments, and of the experiments themselves, is well under way.

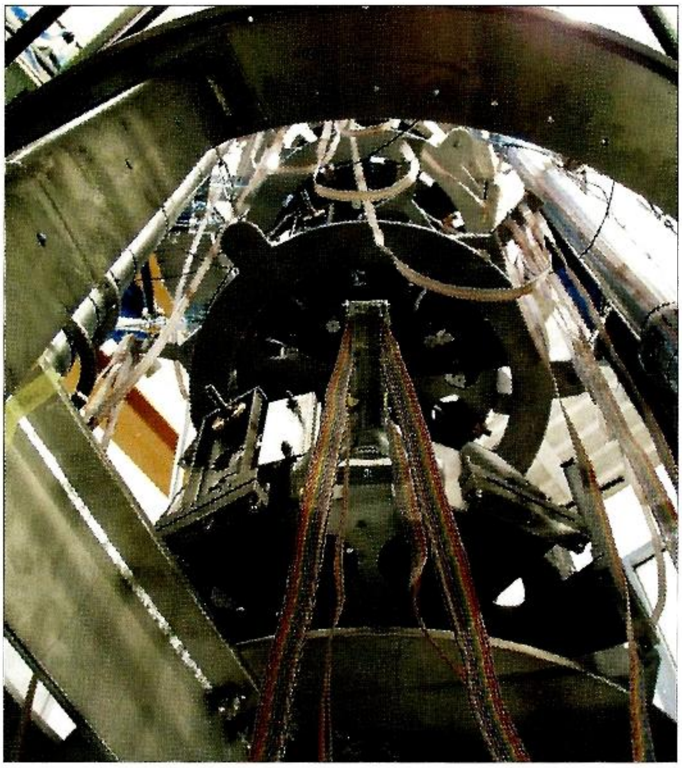
The small Tama-300 detector is virtually complete. It has already achieved stored beams, and breaks ground for the entire community. Tama physicists have measured initial sensitivity curves and are honing the system towards achievement of the design parameters. Tama-300 is probably too small to detect any relevant signal, so the Japanese scientists are applying for funds and approval for a kilometre interferometer.

GEO-600 construction is well under way, with both arms already built and mirror suspensions under test.

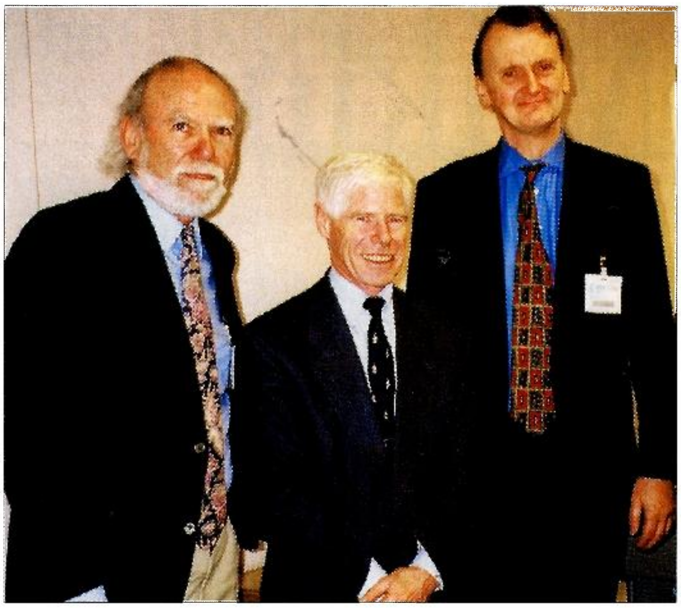
Infrastructure of the two LIGO sites in the US is virtually complete. Already, both LIGO observatories have their 4 km vacuum vessels pumped down. Optics installation has started.

Virgo has ended construction of the central station, where physicists are installing a short interferometer to test the seismic attenuation towers concept. Civil construction of its two 3 km arms is beginning.

AIGO, despite severe financial problems, is starting construction of its central station at a site capable of accepting 4 km arms.



Trying to untangle the tiny signals due to gravitational waves from a seismic cacophony. Bottom view of a prototype sesimic attenuation tower assembled at the Pisa INFN laboratory for the Virgo gravitational wave experiment showing three of the five filters connected by a single central wire. The chain provides a mechanical attenuation factor of 10^{-11} for large signals in the frequency range 4–30 Hz. The structure will eventually operate in an ultra-high vacuum. Even the slippage of two steel grains under stress produces a vibration amplitude a million times more than the sought-after signals!



The search for gravitional waves brings particle physics and space science closer together. Roger Bonnet (centre), director of the European Space Agency's scientific programme, addressed a recent meeting of ESA's Fundamental Physics Advisory Group, chaired by former CERN Theory Division leader Maurice Jacob. Also attending were (left) Barry Barish of Caltech and a member of IUPAP's PaNAGIC (Particle And Nuclear Astrophysics and Gravitational International Committee – see February, page 4) and Ian Halliday, Chief Executive of the UK Particle Physics and Astronomy Research Council.

Overall, the worldwide effort has already attracted hundreds of dedicated physicists, a small number compared with the thousands working in high-energy physics, but still enough to qualify as "Big Science".

There are of course considerable problems still to be solved. One is to control thermal excitation of the mirror modes presently expected to be the main sensitivity limitation at mid-range frequencies. Another is to control the gravity gradient problem that limits the sensitivity at low frequency, and the development of higher power lasers to depress the shot noise sensitivity in the high frequency region.

Lower frequency detection is possible only in space, a goal aimed for by the LISA joint project of NASA in the US and the European Space Agency, ESA, for the year 2010 and beyond. LISA is only sensitive to super-slow signals, orbital periods of many seconds or longer, from black holes falling into super-massive galactic black holes, and addresses a frequency band below the minimum achievable on the Earth's crust.

However, LISA will start being sensitive at frequencies lower than 0.1 Hz at best, while Virgo will respond only at frequencies higher than 6–8 Hz at best. Thus even the construction of both ground and solar orbit experiments will leave a wide frequency range uncovered. At present nobody knows how to bridge this gap, which ironically corresponds to some of the most interesting gravitational wave astronomy.

The new millennium will be greeted by a small but powerful army of experimenters, wielding their high-tech detectors, doing combat with the forces of extraneous noise, and hoping to capture from behind enemy lines the long-sought-for prize of a gravitational wave signal.

Even after the interferometers come on-line, they will have to follow the long trek of progressive noise reduction. At start-up noise levels, the expected wait for a detectable signal could be many years, perhaps even decades. This period can be dramatically reduced by depressing the noise floor, and reaching out to progressively feebler signals from increasingly distant sources. Extending the search to larger expanses of the universe would reduce the expected wait time to mere months and permit significant statistics to be collected within a physicist's career.

Only a large reduction of readout noise will allow for real gravitational wave astronomy. This, along with the networking of many interferometers at large separations, will grant us at long last a peek into the optically dense regions of the universe (as, for example, the core of our own galaxy) where most of the mass resides. We will glimpse too into the infinitely small confines (from our vantage point) of gravitationally driven stellar collapses or dense star mergers and collisions. The quest, like so many others, begins with an elusive goal fleetingly imagined. But with industry, intelligence and perseverance, it may produce a significant scientific trophy.

Riccardo DeSalvo *Senior Scientist, California Institute of Technology, Pasadena, California and Istituto Nazionale Fisica Nucleare, sezione di Pisa, Italy.*

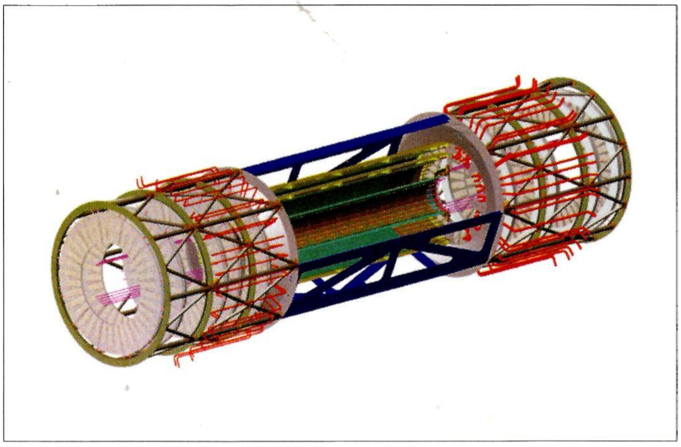
Making tracks for the LHC

Pictures ultimately provide the most graphic record of of particle interactions. For CERN's LHC collider, sophisticated electronic "eyes" at the heart of the big ATLAS and CMS detectors will pick up the tracks left by the particles fleeing from the collisions and search for masterpieces to hang in the next century's gallery of research art.

Whatever means are used to record the result of high-energy collisions, it is still important for physicists to have "pictures" of the tracks left by the emerging particles. In middle of the century, these tracks were captured photographically in mechanically-operated cloud and bubble chambers, whose annals provided a dramatic photo album of physics progress. These chambers have been superseded by sophisticated electronic detectors in which the particles produce signals in successive layers of sensors surrounding the particle collision site. A computer-driven pattern recognition system disentangles a cloud of discrete points, joining together related signals to reveal the tracks and provide an electronic snapshot of the collision. For CERN's LHC collider, it is the inner tracking systems of the big ATLAS and CMS detectors that will illustrate the research albums for the beginning of the 21st century.

The Technical Design Reports for the ATLAS pixel detector and CMS Tracker have now been formally approved and become subject to stringent scheduling and monitoring to ensure commissioning in the year 2005.

ATLAS pixels



The support structure of the inner ATLAS pixel detector.

The heart of the mighty ATLAS detector being constructed for CERN's LHC proton collider will record the sprays of particles emerging directly from particle collisions at energies never before explored. This core "vertex detector", a direct descendant of the old bubble chamber, will track the fine central lacework of these complicated processes. These innermost signals will be vital for the subsequent layers of detector to follow the particles emerging from each LHC interaction.

The technique being used is semiconductor pixels, a technology pioneered at fixed-target experiments and previously used in vertex detectors at the Delphi and SLD experiments respectively at CERN's LEP and Stanford's SLC electron–positron colliders. Pixels – tiny diodes implanted on semiconductor wafers – pick up the ionization produced by charged particles and offer high spatial resolution in two directions, fixing where particles have passed to within ten microns.

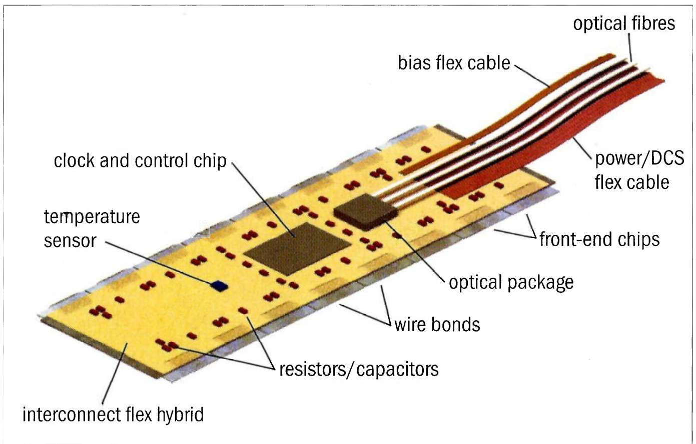
ATLAS pixels will be arranged in three layers in a central barrel of 80 cm length immediately around the collision point, supplemented by five discs either side in the beam direction. The barrel sensors will overlap to ensure that there are no cracks through which particles can escape undetected. The key innermost barrel layer (radius 4 cm) will use 200 micron sensors, while the remainder will use 250 micron thickness. Together with their readout electronics, these will form 1508 barrel modules and 720 disk modules. Although mounted on different structures, the barrel and disk sensors are the same.

Particle bombardment

Using pixels for ATLAS brings new challenges. Firstly, the semiconductors will have to be able to withstand the intense particle bombardment close to the interaction point, with several collisions every 25 nanoseconds each producing hundreds of secondary particles. This could easily spoil the semiconductor properties of the detectors.

Secondly, pixel readout has always needed sophisticated electronics, but in this case the problem is exacerbated by the torrent of data emerging, equivalent to about 100 Megabytes per second.

Thirdly, the substrate of each semiconductor element has to be reliably fixed (bump-bonded) to its support and connections, and



A module of the ATLAS pixel detector

finally the array of pixels has to be mechanically supported without interfering too much with the emerging particles, and with adequate cooling. All this for about a hundred million pixels.

The baseline sensor choice is n+ implants on n-type substrate, with individual sensors isolated either via high-dose p-implant surrounds, or by spraying the whole n-surface with medium dose p-implant which is overcompensated by the high dose pixel implants of the sensors themselves. Both techniques show encouraging results and both are being pursued prior to making a final design decision. 4 inch wafers containing two sensor tiles have been fabricated by industry in Germany and in Japan, using both types of isolation in each wafer.

Readout electronics

Readout electronics is a real challenge. With highly irradiated sensors and thin layers, pixel front-end electronics will have to cope with very small signals. In addition, readout of the few thousand pixels hit during a bunch crossing requires sophisticated architecture with lots of task parallelism and data compression. All the electronics has to be built using radiation-hard components, however, initial design and prototyping will be accelerated by using rad-soft electronics. Data is transmitted via optical fibres.

For the integration of sensors and electronics, bump bonding using indium and solder are both being evaluated using test beams at CERN, with a microstrip telescope fixing tracks to 5 microns.

For the mechanical support, a key element is the thermal management tile (TMT), each one of which has to support 13 modules and drain off about 15 kW of heat produced by 2 m^2 of integrated electronics. This is done via a cooling tube, supported by an omega-shaped backbone framework. Sensors have to be maintained at –6 °C. Several TMT solutions are being investigated.

Having taken the plunge to go for semiconductor pixels, initial tests are progressing well. Several design decision still remain, but the heart of the ATLAS detector is on schedule to begin pumping for the first LHC collisions in 2005.

Information from **Leonardo Rossi**, *Genoa.*

The CMS Central Tracker

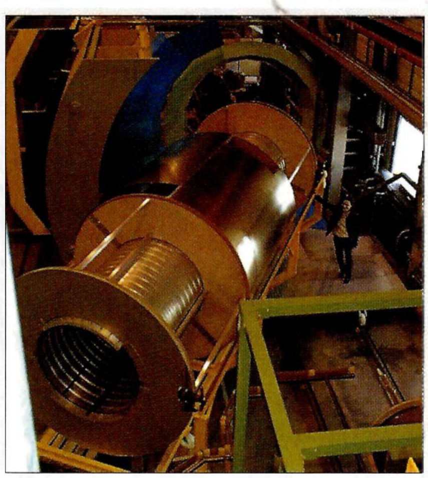


Fig. 1: Full-scale mock-up of the CMS tracker during installation exercise.

The tracking detector for the Compact Muon Solenoid (CMS) is one of the most ambitious LHC projects. The design must be robust and versatile to cope with the full range of accessible physics, while the search for new particles and the study of quark and gluon interactions at an unprecedented energy scale require exceptional track and vertex reconstruction.

The detector reconstructs isolated muons and electrons with efficiencies higher than 98% and 95% respectively. The high track densities inside jets of particles can be studied by measuring the non-isolated hadrons with an average efficiency higher than 90% and down to very low track momentum.

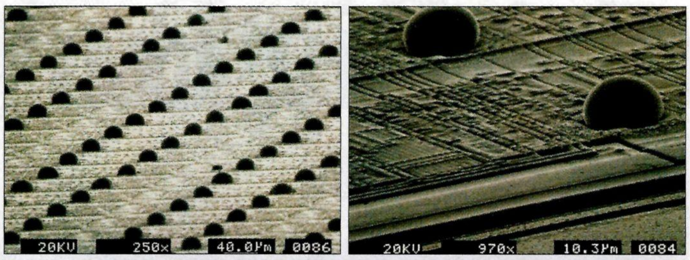
Long-lived particles produced in heavy quark reactions can be identified by precision measurements of their distance of approach to the interaction point and by reconstructing the decays. Typical identification efficiency of 60% can be achieved at the price of about 1% contamination. Finally, excellent momentum resolution will allow for detection of narrow resonances and effective background suppression.

Design constraints

The detector will be operated in a very complex environment. At the LHC design luminosity, 1000 soft tracks due to secondary charged particles will illuminate the detector for each bunch crossing (every 25 ns). In addition, a mass of signals will be generated by low-momentum particles forced into helical trajectories by the 4 T CMS solenoidal magnetic field. A "typical" event will generate more than 40 000 hits in the detector.

The need for efficient two-track resolution and high-precision momentum measurement has pointed the selection of detectors to high granularity and precision and fast response time.

Performance must also be unaffected by the severe radiation due to the flux of secondary particles – detector and electronics will have to survive megarad radiation doses. Special radiation damage R&D studies have shown that detectors based on silicon crystal technology will have to be operated continuously at a temperature as low as –10 °C. This, for sensors dissipating many kilowatts of power over about 7 m^3, is a serious technical challenge.



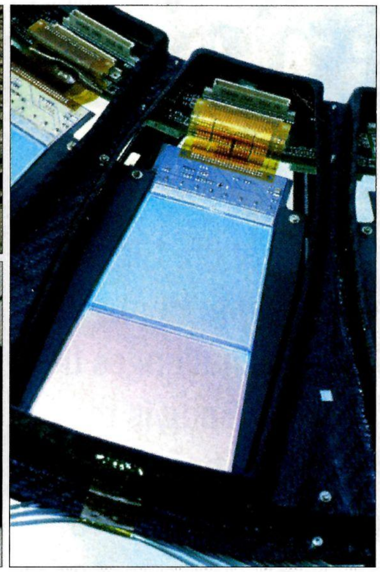


Fig. 2 (top left and centre): Indium bumps connect the radiation-hard CMS readout chips to the silicon pixel sensors. The bump diameter is about 20 microns. (Photo: Paul Scherrer Institut, Villigen, Switzerland.)

Fig. 3 (left): Silicon detector prototype module for the CMS tracker endcap. The active area is 12 × 7 cm.

Fig. 4 (bottom left): CMS Micro Strip Gas Chamber prototype module. The active area is 25 × 10 cm.

In addition, heavily ionizing nuclear fragments (created when high-energy particles hit the detector infrastructure) will pose serious constraints on the operation of gas detectors at the highest luminosity, and will require a careful choice of operating point. Extensive tests have been carried out. An additional constraint is to keep the detector material budget as low as possible, to optimize the combined performance of the tracker and the high-resolution CMS electromagnetic calorimeter.

The CMS tracker has an overall length of 6 m and a diameter of 2.5 m (figure 1). All detector elements are arranged in cylindrical coaxial layers in the barrel region, while the endcap region uses discs normal to the beam direction. The total sensor area amounts to about 300 m^2 with a granularity of about 45 million readout channels.

Detector technologies

Three detector technologies are used, each best matched to the stringent resolution and robustness requirements in the regions handling high, medium and low particle fluxes - Silicon Pixels, Silicon Microstrip and Micro Strip Gas Chambers (MSGC) respectively.

To achieve reliable track identification, the detector segmentation is such that typical channel occupancies are between 1 and 2% in the whole tracker. All three detectors are fast, thus limiting event pile-up to a single bunch crossing in the solid-state sensors and to little more than two in the gas detectors.

The Pixel system occupies the radial region between 7 cm and 20 cm from the interaction point. The 150 × 150 micron cells are connected via an indium bump to the readout chip (figure 2). Sensors are arranged tangentially to cylindrical surfaces so that the strong magnetic field drifts the charge cluster over neighbouring cells, yielding a position resolution of better than 15 microns.

Silicon-strip detectors occupy the intermediate region extending up to 60 cm radius. Thanks to an active sensor thickness of only 300 microns, the fine readout pitch (about 100 microns) and their radiation hardness, silicon-strip detectors are especially suited to the medium occupancy region. Position resolutions ranging between 15 and 35 microns will be obtained in the r-phi direction. The orthogonal coordinate will be measured in about 60% of the hits by sensors with strips at a small angle to the beam direction.

A prototype detector module is shown in figure 3. In the outer region, extending up to 120 cm, the lower expected count permits lower granularity. The MSGCs are a very performant answer to the specifications. Due to gas diffusion, hit resolutions as good as 40 microns can be achieved with a readout pitch of 200 microns. The strip length will vary between 12.5 cm and 25 cm to match the decrease of occupancy with radius. These chambers will be operated at room temperature, thus simplifying the system. For about 50% of the hits the orthogonal coordinate too will be measured using stereo detectors. A prototype detector module is shown in figure 4.

The electronics will provide analogue data readout in radiation-hard technology. Care will be taken to minimize power consumption and material. Electronic noise immunity and robustness have driven the system design. High-speed signal processing and identification of individual bunch crossings needs to be guaranteed. Main components are the front-end circuit, an analogue optical link, the front-end driver and the control system. The front-end chip amplifies detector signals, stores them in a pipeline and multiplexes, after some analogue signal processing, to the counting room using the optical link. The link technology relies on edge-emitting lasers operating at 1300 nm illuminating single-mode fibres.

The control system will distribute clock, trigger and commands via the digital communication links and a control chip serving each group of modules. Pulse heights are received by a photodiode amplifier on the front-end driver which digitizes and processes the signals and stores results in a local memory for higher level data acquisition.

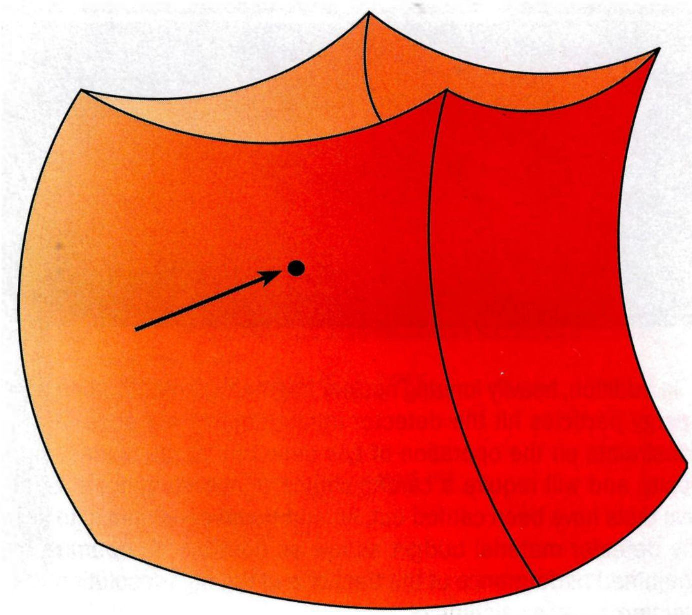
With the recent formal approval of the technical design report by the research board, the CMS tracker collaboration has passed one of its major milestones. The collaboration represents a multinational team with members belonging to more than 40 institutes from 12 countries. They are looking forward to the construction of the final prototypes and the testing of a pre-production series of detectors by the end of this year. Mass production of detectors is planned for next year.

Horst Breuker and Alessandra Caner, *CERN.*

Challenging the Big Bang

Conventional dogma says that the Big Bang was the beginning of everything. Here, *Gabriele Veneziano* of CERN challenges this view. He believes that the Big Bang is the biggest thing that the universe has seen, but that it did not take place at time zero.

The idea that the universe, and time itself, originated from a primordial explosion – the Big Bang – has transcended the boundaries of scientific knowledge to become a key part of modern culture. But is this belief completely justified? An alternative explanation, suggested by recent developments in theoretical physics, holds that the Big Bang was just one of many transitions in the history of the universe, though possibly the most dramatic. In this new scenario, a long prehistory slowly prepared the Big Bang in much the same way that long periods of steady evolution precede the collapse or explosion of stars. But what is wrong with the traditional dogma?



Cosmological chance. To account for our universe using standard cosmology, the initial conditions must have been very specific, corresponding to an absurdly small subset of all possible combinations.

Singularity

Standard cosmology, based on Einstein's Theory of General Relativity, states that some 10 billion years ago the universe was just a mathematical point. As such, not only did it have exactly zero size, but physical quantities, such as temperature, energy density, pressure – and the resulting curvature of space-time – were all infinite. Indeed, the Big Bang is the most dramatic example of a phenomenon that is often encountered in field theories like General Relativity, when the predictive powers of the theory break down. The phenomenon is known as a singularity. Asking what happened before that singular instant, which is conventionally defined as time zero, doesn't make any sense. There was no "before". At least, that's what we are told.

When hard pressed, cosmologists admit that extrapolating the equations of General Relativity back to time zero is not justified. Even the most optimistic will agree that what happened around and before 10^{-43} seconds was greatly affected by quantum effects that General Relativity happily ignores. (10^{-43} seconds is the so-called Planck time: the timescale first constructed by Max Planck out of the speed of light, Planck's constant and Newton's constant of gravitation. At accelerator energies, the gravitational force between two elementary particles is much weaker than the other forces of physics. However, at the Planck scale the effects become comparable.)

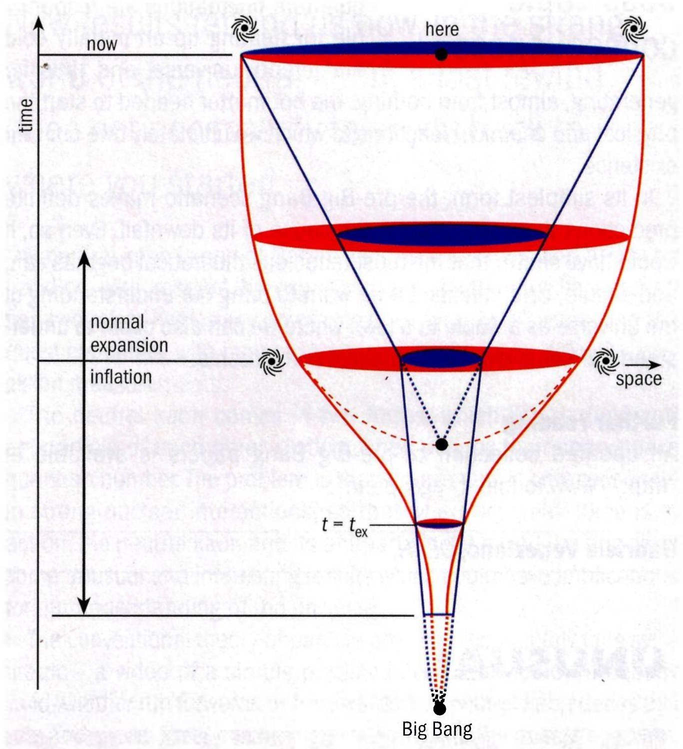
Thus, to be on the safe side, we should ask how the universe would have looked not at $t = 0$ but, say, at $t = 3 \times 10^{-43}$ seconds, possibly a bit later. The answer turns out to be quite embarrassing. According to General Relativity, the many-billion-light-year universe that we observe today was then only one millimetre across. This size, though tiny compared with the present dimensions, was huge compared with the other relevant distance at the time: the distance travelled so far by light: 10^{-32} centimetres.

Cosmological puzzles

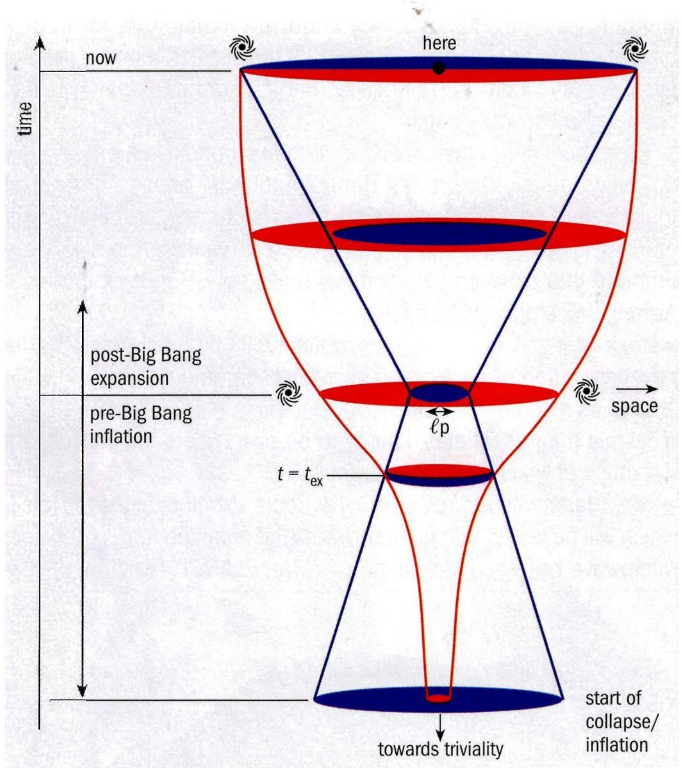
The enormous ratio of these two scales, 10^{31}, is both a mystery and the source of many unsolved cosmological puzzles (the so-called homogeneity, entropy and flatness problems). These problems have been nicely summarized by Roger Penrose in an illustration in his compelling book *The Emperor's New Mind*, in which God selects with unimaginable care the initial state of the universe. In particular, this initial state had to contain a huge amount of matter/energy distributed in a very orderly fashion. This was as improbable as finding, at one moment, all of the molecules of the Earth's atmosphere above the North Pole, and nowhere else.

Whenever similarly odd situations are encountered in physics, the obvious question to ask is: "Can we understand them as the result of an evolution from something more 'natural'?" However, if we assume that the Big Bang was the beginning of everything, there is simply no "past" available to us for assuming those more natural initial conditions. The standard solution to these cosmological puzzles is to invoke the hypothesis that something new – a relatively long period of extremely rapid expansion of the universe, inflation – took place

ga longer history of time



Two wineglass-like scenarios for the universe. In the classic Big Bang picture (above) the universe must at some early stage have expanded faster than a light ray (shown in blue). This requires the additional mechanism of "inflation". Only in this way could galaxies appearing today on opposite sides of the sky have "known" of each other's existence and endowed the universe with its remarkable smoothness.



In the new pre-Big Bang picture, the universe begins its evolution before the Big Bang, and the necessary causal contact is made beforehand. A different kind of inflation is required and the origin of the universe becomes less mysterious.

after the Big Bang and cured its deficiencies. Unfortunately, even after some 18 years of hard work, inflation still lacks a deep theoretical understanding and contains a large degree of arbitrariness, and is therefore difficult to test.

Alternatively, one should appeal to processes that happened around or at the Planck time, but then, as was mentioned earlier, one has to include sizable quantum effects. Indeed, it looks quite plausible that the singularity problem and the puzzles of standard cosmology should somehow be related, and should be simultaneously solved by quantum effects. However, until recently, there has been no way of dealing with these kinds of question. There was no scheme combining General Relativity and quantum mechanics into a consistent theory of quantum gravity.

This situation changed some 15 years ago with the advent of superstring theory, which was itself a re-elaboration of a model developed at CERN about 30 years ago. The way in which strings cope with the problems met by the conventional approach is subtle, but not difficult to describe. In string theory, conventional point-like particles are replaced by small, one-dimensional objects called strings. The typical size of a string, which is dictated by quantum mechanics, defines, through the speed of light, a characteristic timescale that turns out to be about an order of magnitude larger than the Planck time: $t_s = 10^{-42}$ seconds.

An infinite past

As one tries to describe the early universe in string theory, one finds, not surprisingly, that conventional General Relativity has to be substantially modified at shorter timescales than t_s. Because of their intrinsic scale, strings do not allow density, temperature and curvature to exceed a (large but finite) maximal value and become infinite. Having thus "disposed" of the troublesome singularity, string theory allows us to look back in time, beyond $t = 0$. The universe becomes more and more cold, empty, flat and non-interacting as time becomes more and more negative, until it reaches complete emptiness and triviality in its asymptotic past.

The universe would thus obey a principle of Asymptotic Past Triviality, emerging from the simplest possible kind of initial states.

This is a kind of Copernican Revolution, in time rather than in space, when the Big Bang loses its historical meaning of initial time to become a more modest, though still important, turning point in the history of the universe. The Big Bang was the moment of maximal (yet finite) density, temperature and curvature. Furthermore, the pre-Big Bang turns out to be automatically inflationary, thus solving the problems of standard cosmology in a natural way.

Although it is very rewarding to explain the origin of the universe without having to invoke a very contrived initial state for it, or a bizarre inflationary phase to correct its "bad start", the new pre-Big Bang theory would be science fiction if it had no experimentally observable consequences.

This is not, in fact, the case. Quantum fluctuations are enormously amplified during the pre-Big Bang inflationary phase. Throughout the standard post-Big Bang epoch, these fluctuations generate irregularities in the universe, thus giving rise to a wealth of physical phenomena that today open a window on the pre-Big Bang universe. Among these phenomena are:

- stochastic gravitational waves, which could be measurable by the new generation of gravitational wave interferometric (LIGO, VIRGO) as well as resonant (antenna-like) detectors (see page 10);
- cosmic magnetic fields, known to be everywhere in galaxies, but the origin of which is still mysterious;
- new, characteristic sources of large-scale structure in the universe, which will be tested through future satellite measurements of cosmic microwave background anisotropy (MAP, PLANCK) or through precise determinations of galaxy and galaxy-cluster distributions;
- new kinds of weakly interacting relic, which could provide the long-sought missing (dark matter) component in the energy budget of the universe.

The new pre-Big Bang theory would be science fiction if it had no experimentally observable consequences.

At a more conceptual level, these quantum fluctuations are responsible for heating up an initially cold and empty universe, and thus for generating, almost from nothing, the hot matter needed to start the physical and chemical reactions to which we ultimately owe our own existence.

In its simplest form, the pre-Big Bang scenario makes definite predictions that may soon be the cause of its downfall. Even so, it would have shown that the most tenacious theoretical dogmas can, and should, be challenged if we want to bring our understanding of the universe as a whole to a level where we can also claim to understand the behaviour of its smallest constituents.

Further reading

An updated collection of pre-Big Bang papers is available at "http://www.to.infn.it/~gasperin".

Gabriele Veneziano, *CERN.*

The ratchet of time

New results remind us how, in the strange world of the neutral kaon, a fast rewind does not necessarily take you back to where you started.

The CPLEAR experiment at CERN's LEAR low-energy antiproton ring looked at the time evolution of neutral kaons produced in proton–antiproton annihilation.

The neutral kaon is one of Nature's trickiest particles and has to be handled with respect by experimenters. Measuring its detailed behaviour has kept many physicists busy for over 30 years, and the quest continues, with major experiments still to make definitive precision measurements.

The neutral kaon comes in two forms, which are particle and antiparticle of each other, distinguished only by their strangeness quantum number. The problem is that strangeness is only conserved in strong nuclear interactions, so that when the weak force is in action, the neutral kaon and its antiparticle get mixed up. This gives some unusual and interesting results which could have implications for our understanding of the universe.

The conventional theory of particle physics is completely time symmetric – a video of a simple particle interaction would be equally valid whether run forwards or backwards. The neutral kaon defies this rule and shows there can be a one-way valve in the passage of time.

This delicate asymmetry could help explain how a universe created in a Big Bang that was matter–antimatter symmetric has evolved into one that contains no antimatter at all. Perhaps time is the arch-enemy of antimatter.

How Nature is asymmetric

In 1956 the world of physics was startled to discover that the weak force looks very different when viewed in a mirror. Weakly-interacting particles have a definite "handedness". If nuclear beta decay is reflected in a mirror, a right-handed particle becomes left-handed, and the physics scenario is not the same. In the trade, such a mirror reflection is called a parity operation, P. Parity is violated in weak interactions.

The parity violation blow was quickly followed by another. Physicists also discovered that the weak force scenario also changes if particles are switched into antiparticles and vice versa. This "charge conjugation symmetry", C, is also violated in weak interactions.

If P and C separately are not respected by the weak force, what is? Physicists suggested that perhaps the separate P and C violations compensate for each other, and that the compound CP symmetry would be good. In such a CP mirror, a left-handed particle (such as a neutrino) changes into a right-handed antiparticle (such as an antineutrino), etc.

The next shock came in 1964 when a fraction of a per cent of the decays of the neutral kaon were found to violate CP symmetry. What symmetry would be the next to fall? Powerful theorems said that the underlying formalism should be invariant under CPT – when the compound CP operation is supplemented by time reversal, T. If CPT went, then the underlying formalism would sink and physics would be in deep trouble, as nobody would understand very much any more.

If CPT is to hold good, and CP is violated by the neutral kaons, then the neutral kaons necessarily violate time reversal symmetry – rewinding a "videotape" of a neutral kaon interaction would not take you back to the point of departure.

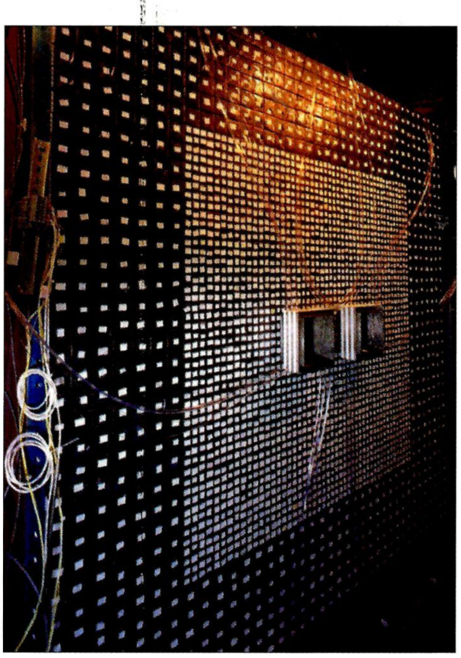
Violation

The traditional description of CP violation by neutral kaons includes two alternatives: CPT good and T violation, and CPT violation and T good. The first evidence for the first alternative was found in 1970 in an experiment at CERN's PS proton synchrotron which looked at the time dependence of neutral kaon decays. This result was of key importance for the understanding of neutral kaon decay. Ever since, physicists have been searching for other glimpses of time symmetry violation.

One of the major experiments continuing to probe neutral kaon physics to provide precision measurements of CP violation is Fermilab's KTEV study, which began in 1996 and is currently churning through the data accumulated so far. Most of the time the long-lived neutral kaon decays into three particles, respecting CP. One rare neutral kaon decay is into two charged pions accompanied by an electron-positron pair, a decay channel only recently seen for the first time. It accounts for only 3×10^{-7} of the total decays, much smaller than CP violation in the mainstream decay channels.

This decay can happen via several mechanisms, some of them CP violating, some not, and these different mechanisms interfere. Several years ago, Lalit Sehgal at Aachen realized that because of this subtle quantum mechanical interference, the angle between the plane of the two pions and that of the electrons is sensitive to the arrow of time. If such a decay were run backwards, momenta would be reversed, but the "resultant" involvement of the neutral kaon would not always correspond to the original process.

The cesium iodide crystals of Fermilab's KTEV experiment. Using a previously unexplored neutral kaon decay channel has revealed how the passage of time can be directional.



Asymmetry

From some 1800 such decays, the KTEV experiment reports an asymmetry of some 13%, in line with the prediction. This time asymmetry is much larger than the usual levels of CP violation, seen in the dominant neutral kaon channels, and shows how a rare decay channel, once found, can be a rich source of information.

Also studying this decay process is the big NA48 experiment at CERN, which began gathering precision data in 1997. Its major objective is to measure the elusive parameters of the more usual examples of CP violation.

Another example of T violation comes from the CPLEAR collaboration, which studied CP violation physics at CERN's LEAR low-energy antiproton ring from 1990 until LEAR was closed in 1996. CPLEAR looks at the many different particle combinations emerging from proton–antiproton annihilation.

Among them are two interesting quantum opposites: a positive kaon, a negative pion and a neutral kaon; or a negative kaon, a positive pion and a neutral kaon antiparticle. Whether the annihilation produced a neutral kaon or its antiparticle is "tagged" by the electric charge of the associated kaon.

This contrasts with the situation in experiments using secondary beams of neutral kaons, which are particle–antiparticle mixtures.

Once formed in the initial strong interaction annihilation, the CPLEAR kaons or antikaons are then free to decay under the weak force. Comparing these decays with the original strangeness tags from the annihilation process shows whether a kaon has subsequently transformed into an antiparticle, or vice versa. If time reversal is good, as many kaons will change into antikaons as antikaons into kaons.

CPLEAR finds a mismatch between the two rates. The time asymmetry is measured at 6.6×10^{-3} and is compatible with the observed levels of CP violation. The arrow of time is broken, but in such a way that the master CPT symmetry is good.

More work to do

The major experiments probing CP violation in with neutral kaons – NA48 at CERN, KTEV at Fermilab and KLOE at Frascati's DAFNE electron–positron collider – still have a lot of work to do before these effects are measured definitively.

But the big mystery remains. Why is CP, and therefore time reversal symmetry, violated at all? To answer this question, physicists will probably have to use the longer CP violation (and therefore T violation) lever expected with B particles containing the fifth, beauty, or "b" quark.

Gordon Fraser, *CERN.*

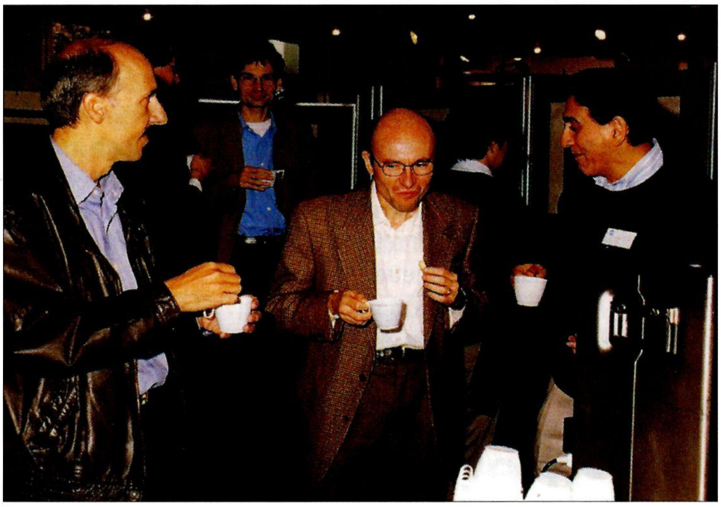
Directions beyond the Standard Model

The annual theory workshop at the German DESY laboratory in Hamburg traditionally focuses on a burning physics issue. The latest event, exploring "Directions beyond the Standard Model", tried to peer beyond the physics horizon.

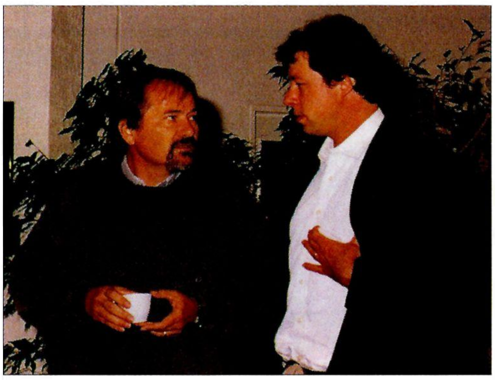
While the Standard Model (SM) of strong, weak and electromagnetic interactions is healthy and keeps surviving experimental tests, motivations to go beyond it are primarily based on theoretical considerations in the quest for a unified theory of all fundamental forces. Leading candidates at the moment are supersymmetric field theories and string theories.

On the experimental side, traditional high-energy physics experiments have tested the SM to a high degree of precision and strongly constrain many new theoretical ideas. However, the 1998 harvest of new results on atmospheric neutrinos, together with the accumulated data on solar particles, might provide the first sign of physics beyond the Standard Model. Other more indirect arguments for physics beyond the SM might come from cosmological considerations, like the question of the baryon asymmetry or the nature of dark matter in the universe.

The status of the "Search for new particles at high-energy colliders" was covered by P Zerwas of DESY. Most notably the searches at LEP at CERN and the Tevatron at Fermilab have pushed the mass threshold for new particles to higher and higher values. He then went on to explain how CERN's LHC proton collider or, looking further ahead, an electron–positron linear collider (TESLA, NLC, JLC) might help shed new light on the physics beyond the Standard Model. This will not only give information about particle spectroscopy, but will also allow us to study the Higgs mechanism and distinguish between specific models. The design parameters of such a linear collider might play a crucial role for these future precision experiments.



Searching for directions beyond the Standard Model (left to right): I Antoniadis ("Phenomenology of string- and M-theory"), A Masiero ("Flavour changing neutral currents and CP-violation in SUSY") and Q Shafi ("Inflation, baryogenesis and neutrino dark matter").



Looking far beyond the Standard Model at the DESY Theory Workshop: H Verlinde (right, who spoke on "Black holes") explains them to organizing committee chairman H P Nilles.

Supersymmetry

S Pokorski of Warsaw reviewed the supersymmetric extension of the Standard Model and its comparison with electroweak precision experiments. While many of the superpartners have to be quite heavy, the prediction of a light Higgs boson in the supersymmetric models seems to be consistent with available data.

On the theoretical side, string theory (a generalization of quantum field theory to one-dimensionally extended objects) has been revolutionized in the past few years. Various unexpected symmetries, called "dualities", relate different string theories to each other. This leads to the conjecture that all string theories are interconnected via dualities, and unified in what is called M-theory. Apart from strings, such theories would then also contain higher dimensional objects ("p-branes"), as was explained by S Theisen (LMU Munich).

P Mayr from CERN reported on "Insights into field theory from string theory". He explained how many results in quantum field theory can be derived by embedding these theories in higher dimensional string theories. Parameters in field theory, like gauge coupling constants, then become geometric objects with extra dimensions in string theory. S Yankielowicz (Tel Aviv) explained the origins of the new Maldacena-conjecture which suggests a deep conceptual connection between string and field theory.

Black holes

H Verlinde of Amsterdam linked these results to progress in the understanding of black holes and quantum gravity, including the celebrated "holographic principle", originally introduced in an attempt to unify general relativity and quantum mechanics.

That such developments could have an impact on possible generalizations of the SM was emphasized by I Antoniadis (Paris) and L Ibanez (Madrid). "New aspects in string phenomenology" appear as a result of string dualities, including some results concerning non-perturbative aspects in the effective low-energy supergravity theories, as Ibanez explained. Antoniadis concentrated on currently popular models where the string scale (usually identified with the Planck scale, 10^{18} GeV) is lowered to the TeV range. Such models would be tested at future collider experiments, as well as experiments probing the structure of gravity in the sub-millimetre range, which could reveal deviations from Newtonian gravitation at distances smaller than a millimetre.

Generalizations of the Standard Model often link to cosmology and astrophysics, and observations in these fields would then test particle physics theories. M Drees (Sao Paulo) concentrated on supersymmetric candidates for cold dark matter and the experimental efforts to find signals in direct detection of so-called WIMPs (Weakly Interacting Massive Particles). Other "Astronomical probes of new physics", like ultra-high-energy cosmic rays, the cosmological constant and density perturbations in the cosmic microwave background, were discussed by S Sarkar of Oxford.

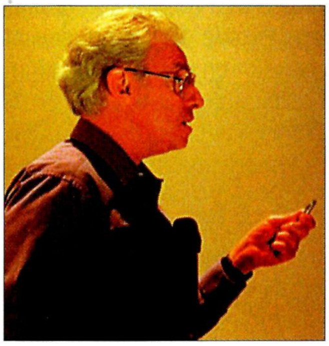
C Wagner (CERN) described the possible generation of a baryon asymmetry of the universe during the electroweak phase transition. Such a mechanism (not possible in the SM) might be operative in the MSSM with a relatively light Higgs boson. Q Shafi (Delaware) considered models of an inflationary universe and its predictions for the large-scale structure of the universe to test the nature of non-baryonic dark matter, including neutrinos. This brought the focus back to neutrino oscillations. The implications of the new experimental results on grand unified theories were analysed by T Yanagida of Tokyo.

The final talk came from M Koshiba (Tokyo) who recounted the landmark history of Kamiokande and Super-Kamiokande and looked forward to new insights in particle physics and neutrino astronomy.

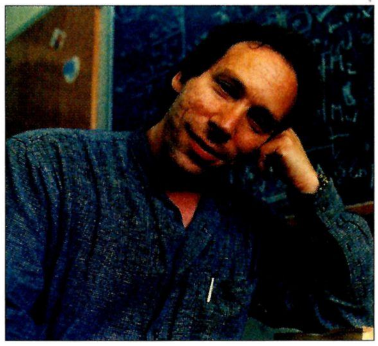
Hans-Peter Nilles, *DESY.*

Relic neutrinos, a challenge for the next millennium

Neutrinos created in the first seconds after the Big Bang could hold vital clues about the evolution of the universe. A workshop in Trieste looked at a wealth of intriguing possibilities.



Gary Steigman – neutrino involvement in Big Bang nucleosynthesis.



Lawrence Krauss – detailed studies of spectral distortions and possible time variations are needed to determine neutrino parameters.

Neutrinos are probably one of the most abundant components of the universe. As well as the 3K microwave background radiation, the universe is filled with a sea of relic neutrinos that decoupled from the rest of the matter within the first 10 seconds after the Big Bang. These relic neutrinos may have played a crucial role in nucleosynthesis, structure formation and the evolution of the universe as a whole. They may also contain clues about baryogenesis – the formation of nuclear matter.

Relic neutrinos, their role in Nature and their possible manifestations were the focus of a workshop entitled the Physics of Relic Neutrinos, which was organized at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy, last September by ICTP and the Italian INFN.

A non-zero neutrino mass can dramatically change the properties of the relic neutrino sea and its role in the evolution of the universe. A special session looked at the evidence for neutrino masses and consequent mixing from the studies of atmospheric and solar neutrinos. E Lisi (Bari) showed that all data on atmospheric neutrinos (including the latest SuperKamiokande data and the old results from Kamiokande) can be well described by maximal muon–tau neutrino oscillations with a squared mass difference of some 5×10^{-3} eV^2.

Muon neutrino oscillations into non-interacting "sterile" neutrinos can also give a good fit of the data (O Peres, Valencia). A majority of alternative explanations of the atmospheric neutrino problem, like a neutrino decay, reviewed by S Pakvasa (Hawaii), still imply non-zero neutrino masses.

Although the solar neutrino data give a strong hint of neutrino mass we are still far from reaching a conclusion, and progress (in Lisi's opinion) will be slow. Detailed studies of spectral distortions and possible time variations (L Krauss, Case Western) are needed to determine the neutrino parameters.

Neutrino mass spectrum

Reconstruction of the complete neutrino mass spectrum from present data is of great importance both for particle physics and cosmology, as discussed by M Fukugita (Tokyo), F Vissani (DESY) and R Mohapatra (Maryland). One of the most interesting recent suggestions is the bimaximal mixing scheme with degenerate neutrinos in eV mass range (Vissani). Attempts to accommodate all of the existing data and/or to explain large mixing lead to the introduction of sterile neutrinos (reviewed by Mohapatra). Their existence would have enormous consequences for astrophysics and cosmology (Z Berezhiani, Tbilisi).

Several talks looked at a possible relationship between properties of the relic neutrinos and baryogenesis. One of the favoured mechanisms (reviewed by E Roulet, La Plata) is an initial lepton asymmetry, converted to baryon asymmetry through electroweak sphalerons. (The electroweak vacuum has two topologically distinct classes. Sphalerons can connect these different vacua.)

The lepton asymmetry can be generated via the CP-violating decay of heavy (10^{10} GeV) right-handed neutrinos. W Buchmuller (DESY) has considered a supersymmetric realization of this possibility. A new mechanism of leptogenesis, via CP-violating oscillations of the right-handed neutrinos with masses 20–50 GeV and very small couplings, was described by E Akhmedov (ICTP). A Pilaftsis (Munich) discussed the enhancement of leptonic CP asymmetries in the decays of nearly degenerate TeV neutrinos. In all of these scenarios the lepton asymmetry is typically of the same order as the final baryon asymmetry. Through the "seesaw" oscillation mechanism these right-handed neutrinos naturally endow light neutrinos with masses in the range 10^{-3}–1 eV, relevant for cosmology and for explaining the solar and atmospheric neutrino data. The leptonic asymmetry can also be produced without right-handed neutrinos in the decays of new triplet Higgs particles (U Sarkar, Ahmedabad).

The neutrino sea was crucial for Big Bang nucleosynthesis (BBN). The present status of the BBN "crisis" – inconsistent values of baryon-to-photon number densities implied by helium-4 and deuterium abundances – was covered by G Steigman (Ohio). This issue is not yet settled, although recent studies indicate a larger He-4 abundance. The problem can be resolved if there were less than three light neutrino species at the time of nucleosynthesis. This can be realized, for example, if the mass of the tau neutrino is a few MeV and it decays with a lifetime of about 5 s (S Pastor, Valencia).

Another solution can be related to a significant leptonic asymmetry. The influence of the leptonic asymmetry on BBN was discussed by R Volkas (Melbourne), X Shi (San Diego) and D Kirilova (Sofia). The general principles of the creation of an asymmetry in oscillations of active to sterile neutrinos in a medium were presented by Volkas. A lepton asymmetry of some 10^{-5} produced at high temperatures may suppress the generation of the equilibrium concentration of sterile neutrinos in oscillations at low temperatures. This could reconcile a possible large mixing of active and sterile neutrinos (as indicated by the atmospheric neutrino data) with the BBN bound. For this to work, the heaviest neutrino has to be heavier than 15 eV (Shi). The production of a lepton asymmetry in neutrino oscillations after neutrino decoupling and its influence on He-4 abundance was discussed by Kirilova.

Structure formation

One of the central themes of the workshop was the role played by relic neutrinos in the structure formation of the universe. Recently the situation has changed dramatically. According to J Silk (Berkeley), no model fits the detailed shape of the power spectrum of density perturbations and satisfies all of the existing constraints. The cold + hot dark matter (CHDM) model with neutrinos contributing 0.2 to the critical Ω parameter gives a better fit than other models. This implies a neutrino mass of about 5 eV and describes the nearby universe well, however (like the other models with $\Omega = 1$ and zero cosmological constant) it is disfavoured by data on early galaxies, cluster evolution and high redshift type IA supernova (J Primack, UC Santa Cruz). A good fit of both the nearby and distant data can be obtained with a cosmological constant and Ω about 0.6, and the presence of large-scale inflationary relics like voids (Silk). As was underlined by Primack and M Roos (Helsinki), the presence of HDM is not necessary in this model, although some amount of HDM is still possible and may be useful for further tuning the data.

The situation can be clarified with new precision measurements of the cosmic background radiation anisotropy made by MAP and PLANCK, and by new galaxy surveys like SDSS. The latter will be sensitive to neutrino masses as low as 0.1 eV.

The properties of neutrinos and the relic neutrino sea are imprinted in the cosmic microwave background anisotropy. The observations by MAP and PLANCK will be sensitive to the effective number of neutrino species to an accuracy of 0.1, so it will be possible to test the existence of sterile (even non-equilibrium) neutrinos in the relic sea, neutrino decays (S Hannestad, Aarhus), and a possible neutrino degeneracy (discussed by S Sarkar, Oxford). Present data admit a rather strong degeneracy. A large lepton asymmetry can modify the history of the universe, leading, for example, to symmetry non-restoration. A large lepton asymmetry can be generated by neutrino oscillations or other mechanisms.

The evolution of the relic neutrino sea (clustering, formation of structures and so on) in the presence of neutrino masses or new interactions is of special interest. As was discussed by N Bilic (Zagreb), self-gravitating neutrino clouds can show "gravitational phase transitions" in the process of contraction and form neutrino stars, the scale of whose sizes would depend on the neutrino mass.

The properties of neutrinos and their reactions in extreme conditions – very dense and hot media, and very strong magnetic fields – are an important issue. These were considered by R Horvat (Zagreb), A Ioannisian (Munich) and D Grasso (Valencia).

Detecting relic neutrinos directly will of course be of fundamental importance, but it would seem to be impossible with present methods. However, we may be able to observe some indirect manifestations of the relic sea even now. D Fargion (Rome) and T Weiler (Vanderbilt) have considered the possibility that the highest energy cosmic rays detected on Earth may have been produced by the annihilation of ultra-high energy neutrinos with the neutrinos from the relic sea. This mechanism implies a neutrino mass of at least a few eV and the clustering of HDM near our galaxy. The relic sea could also be detected if neutrinos undergo a relatively fast radiative decay. Such a decay would explain the ionization of hydrogen in the universe. The present status of this hypothesis was summarized by D Sciama (Trieste). Direct searches for the 900 Å line from this radiative decay are now under way by the UV detector EURD, in orbit since April 1997, and results are expected soon.

Apart from the Big Bang relic neutrinos, the present universe must be filled with relic neutrinos from past supernovae (K Sato, Tokyo) or from collapses of supermassive objects with an energy spectrum in the range 1–50 MeV. Some contribution may also come from the evaporation of primordial black holes (E Bugaev, Moscow). The possibilities for detecting neutrinos from relic and real-time supernovae with existing and new underground neutrino detectors were discussed by D Cline (UCLA), who also described the new project for a supernova burst observatory, where neutrinos will be detected through secondary neutrons emitted by the recoiling nuclei.

The workshop revealed deep connections between a variety of fundamental open questions in cosmology, astrophysics and particle physics. In a sense it outlined a new field of research which has the goal of understanding the properties of the relic neutrino sea and its possible detection. This goal will be one of the challenges for the physics and astrophysics of the next millennium.

Amol Dighe *and* **Alexei Smirnov**, *ICTP Trieste.*

Sterile neutrinos

The neutrinos that we know of do not carry an electrical charge and only interact through the weak force. Traditionally, three distinct varieties of neutrino – electron, muon and tau – couple to the three electrically charged, weakly interacting particles (leptons). However, a rogue "sterile" neutrino may exist that does not even feel the weak force. Such a neutrino would be difficult to detect. It is now generally accepted that neutrinos "oscillate", changing their lepton label as they propagate. If sterile neutrinos exist, it is possible that ordinary neutrinos oscillate into sterile ones and become invisible. Sterile neutrinos may also have been mass produced in the aftermath of the Big Bang. Such particles, although invisible, could have enormous implications for cosmology.

ABSolutely fabulous!

Software is playing an increasingly important role in the tricky business of setting up the beams from particle accelerators. A recent workshop at CERN looked at what has been accomplished so far and what still needs to be done.

The aim of the ABS Automated Beam Steering project is to give accelerator operators a set of software tools to make their lives easier, while improving the quality of the beams that they deliver. The scheme was initiated by Bruno Autin in CERN's Proton Synchrotron (PS) Division. Similar projects are in place in accelerator labs around the world, and on 14–16 December CERN hosted a workshop for 70 accelerator physicists. On the agenda was software sharing to make best use of limited resources, the adoption of a common vocabulary and a look ahead to control systems for future accelerators.

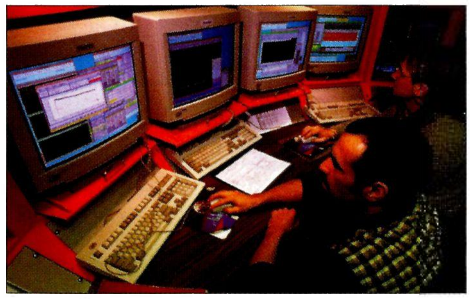
When accelerator physics was young, particle accelerators were set up by hand. Operators would go to the magnets with a voltmeter and a screwdriver and adjust each one. Now, computers display information and allow the magnet-tweaking to be done from a central control room, but the procedure is essentially still manual.

With modern computer technology it was only a matter of time before someone asked if operators are necessary. Could accelerators be controlled by computer? The answer, at least for now, is no. Skilled operators are still needed to ensure the smooth running of these sensitive machines, and so the ABS project was born. After two years of preparation, prototypes written by the PS controls group were tested last year and the new tools will be available in 1999.

ABS is not the first attempt at the partial automation of accelerator controls. The project's origin can be traced to the antiproton source control software designed by CERN's 1984 Nobel laureate Simon van der Meer. Later, at CERN's LEP electron-positron collider, an ABS-type program was written to perform closed-orbit corrections. ABS is, however, the first standardized set of software tools for the purpose. Previous attempts in PS have not been successful because, without a standard interface to the software, operators simply found it easier to continue as they were, rather then learn a new system for each kind of accelerator adjustment. The ABS team's main feature is a generic interface, so whatever adjustment is needed, the program to do it looks the same to the operator.

The ABS backbone is an Oracle database in which every detail of the accelerator can be described. One problem faced by the venerable PS when the project began is that, without a database, vital information was being lost as people retired. Oracle expert Josi Schinzel joined PS in early 1997 to address this problem and has designed a flexible database package that can be adapted easily to new kinds of data as required. Currently it includes all of the information needed to control the accelerator in day-to-day running. In the future it will be extended to include more general documentation of the type frequently carried around only inside experts' heads.

The ABS procedure starts by setting up the accelerator to nominal settings. But, at PS, those settings were defined in the 1950s and were badly dated. So, when the ABS project began, even this step



Test driving the new ABS software for CERN's proton synchrotron accelerator.

had to be redefined. Over the years, parts had moved and new ones had been added, so the first step was to dust off the old nominal model and update it, realigning components that had not been touched since they were installed in the 1950s. However, even the best model is never exact. There are always uncertainties in magnet currents, ground movements are not accounted for, and there are inevitably magnetic inhomogeneities. To optimize, the machine parameters must be tweaked until the beam is as required.

ABS uses the Mathematica package along with minimization software developed at CERN. Dedicated corrector magnets – dipoles or quadrupoles – are then tweaked by the program to produce an optimal beam. In the PS, 40 corrector magnets are under ABS control for closed-orbit corrections alone. Not all are needed to make a correction. For an operator to go through all of the permutations to find the optimal solution would take weeks. ABS can do the job in minutes, thus reducing the arbitrariness of the process.

December's workshop was the first of its kind but is unlikely to be the last. Already, accelerator physicists from SLAC are planning a follow-up in two years' time. About half of the workshop's participants were from CERN; the rest came from accelerator labs around the world, with all of the main particle physics sites being represented.

Summing up the meeting, CERN's Phil Bryant stressed the chance for industry to play a role, citing the ABS system in use at Italy's ELETTRA synchrotron light source as an ideal candidate for a commercial package. This would be a godsend for small labs where resources to develop the software themselves are not available.

ABS is currently applied to the PS, Booster and several associated linacs and transfer lines. At CERN's December workshop, accelerator physicists began sharing their expertise in a bid to extend ABS and similar systems to other accelerator complexes. The net result will be better beams for researchers and a quieter life for operators.

Further reading

CERN has an ABS Web site at "http://www.cern.ch/abs".

ECFA in Poland

In its continual tour of CERN Member States, the European Committee for Future Accelerators (ECFA) visited Poland recently. The venue was Cracow's 600-year-old Jagiellonian University, the oldest institution for higher education in Poland and among the oldest in Europe.

Jagiellonian University's tradition of natural sciences dates back to the 15th century, when its famous student Nicholas Copernicus revolutionized our view of the universe. Another student, five and a half centuries later, was Karol Wojtyla, Pope John Paul II, who had to receive clandestine education during the Second World War.

The ECFA participants were welcomed by the Dean of the Faculty of Mathematics and Physics of the University, Krzysztof Fialkowski, a theoretical particle physicist. The Jagiellonian University has a strong theoretical physics tradition and has some 40 theorists who carefully follow experimental results.

The University is also well known as the organizer of the Annual Cracow School of Theoretical Physics (Zakopane), that had its 38th session this year. Other schools of theoretical physics in southern Poland are the biennial Katowice School of Theoretical Physics and the annual Cracow Epiphany Conference on Particle Physics. These schools play an essential role in keeping Polish theorists at the forefront of knowledge. The international "Rochester" meeting, held in Warsaw in 1996, also helped put the nation on the world physics map.

Polish theoretical particle physics is very healthy, with about 160 tenured staff, with large concentrations in the Cracow and Warsaw regions, working on many different topics such as electroweak interactions, QCD, neutrino masses and mixing, physics at future accelerators, baryogenesis and cosmology.

In the Cracow region, experimental activities are carried out at the Henryk Niewodniczanski Institute of Nuclear Physics as well as at the Faculty of Physics and Nuclear Techniques of the University of Mining and Metallurgy, one of the largest academic schools of technology in Poland. These Institutes take part in several high-energy physics experiments at CERN: ATLAS, DELPHI, ALICE, and NA49 as well as EMU13. Moreover, the Cracow groups contribute to both the major experiments at the HERA accelerator at DESY and are in the PHOBOS Collaboration at RHIC, Brookhaven.

Another major centre for experimental research is Warsaw. The researchers from University of Warsaw, Warsaw University of Technology, the Andrzej Soltan Institute for Nuclear Studies, together with colleagues from Bialystok and Kielce, are contributing to several experiments at CERN: DELPHI, NA48, NA49, and WA98 as well as to CMS and ALICE. At DESY, researchers from Warsaw take part in ZEUS and in the TESLA project for the construction of an electron-positron linear collider.

Cracow – Mariacki Church in the market square.

About 190 Polish experimentalists, engineers and technicians are working at CERN and DESY. Around 50 more are involved in a large variety of experiments elsewhere, the biggest groups among them participating in heavy-ion experiments to be carried out at RHIC and in the Pierre Auger Observatory air-shower project currently under construction.

A characteristic feature of Polish experimental groups has been their rather large number of highly qualified engineers and technicians. Polish scientists have therefore been able to contribute significantly to detector construction, maintenance and operation. Developing software for event simulation and reconstruction is another speciality. In a number of cases, Poles have made outstanding contributions to physics analysis.

Funding structure and academia

Polish universities are funded by the Ministry of National Education. However, to obtain research grants Polish physicists usually have to apply to the State Committee for Scientific Research (KBN), created in 1991. For institutes outside universities, the KBN may also cover salaries. KBN is independent and objective as it has no institutions of its own to finance. The main disadvantage is, however, that it has too little money for the wide spectrum of activities that fall within its responsibility. Polish scientists are unhappy that the percentage of the GNP allocated to research and development has been steadily decreasing, from 0.76% in 1991 to 0.47% in 1998.

A third major source of funding is the National Atomic Energy Agency (PAA) that supervises a number of Institutes in the atomic, nuclear and plasma physics sectors. It is also responsible for signing agreements with organizations such as CERN and DESY. From 1999 this body will be in charge of paying for the Polish participation in the Joint Institute for Nuclear Research (JINR), Dubna, and CERN. Unfortunately state funding has been insufficient: "We are only getting 40% of what we need."

Poles working at DESY have also had resources from the Polish-German Foundation as well as from the German Ministry of Research and Technology, which have made it possible for Polish scientists to work at DESY.

Low salaries

A particularity of the Polish system is that there are practically no fixed-term positions for researchers. A researcher is either a graduate student or is tenured. Low salaries are a major problem. Young people offered a permanent position in the academic sector find it difficult to make ends meet. Graduate students tend to accept hardship for four or five years as an investment in a more profitable future elsewhere. There are also serious difficulties in keeping technical staff. The Warsaw groups, for example, have lost a major proportion of their young and dynamic technical personnel. Another serious problem is that it is expensive to send graduate students to work at CERN.

Some of these points were stressed in a talk by PhD student Anna Stasto. She is a theorist working on QCD, structure functions and neutrino physics. A PhD student earns $200 monthly, about 40% of subsistence level, so many have to find part-time jobs. In spite of this, the number of students has increased. Most of them go on to find jobs at banks, computer and mobile phone companies etc. Only a minority end up as teachers at schools. Some international programmes for student mobility, particularly from Germany and sometimes from national funds, are a boon.

Naturally, the international collaboration in high-energy physics has been very important for raising the level of education of young people, including engineers, and for technology transfer.

Experimental work has led to interesting new partnerships. In Cracow, for example, researchers from the Institute of Nuclear Physics are collaborating with faculty specialists in electronics as well as with specialists in physics and nuclear techniques from the University of Mining and Metallurgy.

High-energy physics has also contributed in some unexpected ways. For example, the former Mayor of Cracow contributed to design work for the HI detector at DESY and the Vice-Mayor was responsible for the mechanical construction of the forward RICH detector in DELPHI.

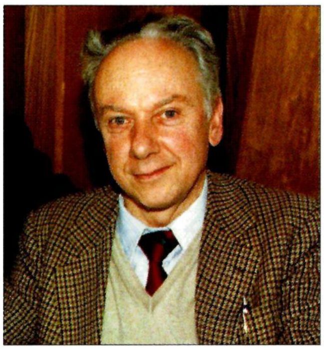
There seems to be a great public interest in particle physics. A CERN Microcosm exhibition, "From Quarks to Stars", organized in Cracow and Warsaw three years ago, was a tremendous success. In Cracow, it was visited by more than 25 000 people. Several leading Polish scientists are actively popularizing particle physics, and such efforts are greatly appreciated.

Curie effect

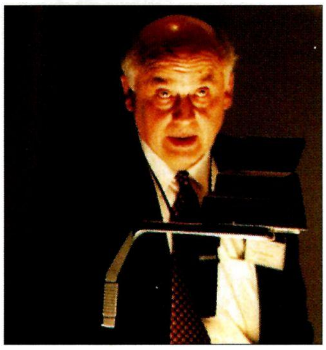
The spirit of Marie Sklodowska Curie (1867–1934) seems to prevail. She was the only person ever to receive Nobel prizes both in physics and in chemistry, in 1903 and 1911 respectively. That was a long time ago, yet Polish women still constitute a large fraction of physicists working in the field of experimental high energy physics – a Curie effect?

Putting a spin on physics

Both theoretically and experimentally, spin physics has always been a challenge. Although many physicists proudly point to an increased understanding, some spin puzzles are still waiting for an explanation. The biennial Spin Physics Conference is always a good barometer for spin.



Giuseppe Fidecaro – the early history of spin experiments.



Erwin Gabathuler – 10 years trying to explain proton spin.

The series of biennial International Symposia on High Energy Spin Physics was initiated in 1974 and, in his opening talk at the recent meeting (the 13th in the series) at the Institute for High Energy Physics, Protvino, Russia, International Committee chairman Charles Prescott pointed out that the symposium venues have established a right-handed rotation about the world axis.

Last year marked the tenth anniversary of the European Muon Collaboration's publication, which launched the nucleon spin problem – the spin of the proton is not the sum of the spins of its individual quarks. E Gabathuler (Liverpool) gave an overview of recent experimental progress. The latest nucleon spin structure measurements were reported by I Savin (SMC, CERN), E Hughes (E155, SLAC, Stanford) and A Bruell (HERMES, DESY, Hamburg).

Progress in this sector means collecting data at smaller Bjorken x (momentum fraction carried by the struck quark) and increased statistical precision. The new high-precision experimental data for the proton and deuteron spin structure functions are consistent with previous measurements and allow better extrapolation to $x = 0$.

The small-x behaviour of the structure is one of the unsolved problems *en route* to a final resolution of the overall nucleon spin puzzle. Others are the important issues of gluon and sea quark contributions to the nucleon spin, and the role of orbital angular momentum.

It is not easy to define the separate components of the nucleon spin in an interacting field theory of quarks and gluons. Different theoretical approaches to the nucleon spin problem in quantum chromodynamics (QCD) are related, to a large extent, to the renormalization and the role of the axial anomaly. These general theoretical problems and recent results were covered by V Petrov (Protvino).

After 10 years, explaining nucleon spin structure remains a problem. A solution could be expected from non-perturbative QCD (for example, lattice calculations). Another possibility, advocated by T P Cheng (Missouri), is a two-stage approach where the first stage uses effective degrees of freedom at large distances (constituent quarks) and in the second stage these effective degrees of freedom are related to the QCD quarks and gluons. Experimentally, the constituent quark idea can be tested by measuring the strange quark content of the proton via parity-violating processes in high-energy electron scattering. Preliminary results from HAPPEX at Jefferson were reported by E Burtin (CEA-DSM/DAPNIA).

The theoretical status of spin effects in hard hadronic reactions was discussed by P Ratcliffe (Milan), while the current experimental results were covered by A Bravar (Mainz). Large spin asymmetries at the level of 30% were reported in inclusive meson and hyperon production. The asymmetries in different reactions have a similar dependence on transverse momentum and Feynman x and tend not to decrease with transverse momentum. However, elastic proton–proton scattering shows increasing such behaviour with increasing transverse momentum.

After G Fidecaro of CERN related the early history of spin experiments, A Penzo (Trieste) surveyed future perspectives for such studies and their role in the resolution of current problems. A key player will be the spin experimental programme at Brookhaven's RHIC collider, described by S Vigdor (Indiana). New physics opportunities at HERA with polarized protons were covered by A De Roeck (DESY), using material from a recent workshop. Perspectives for future experiments depend strongly on the progress in acceleration of polarized beams, and the availability of new polarized targets and sources.

In his plenary talk, A Masaike (KEK) described the role of spin as a probe of symmetry in intermediate and low-energy regions. H Ejiri (Osaka) reviewed the role of spin effects in neutrino-nuclear responses and nuclear medium effects. Reports on workshops sponsored by the International Committee were given by their organizers – D Crabb (Virginia), A Efremov (Dubna) and Yu Mamaev (St Petersburg) – and the meeting summary was given by A Krisch (Michigan).

Despite the enduring puzzles, the Protvino symposium displayed the considerable spin physics progress over the past two years. The next chapter in the story will be reported in Osaka, Japan, in 2000.

The local Protvino organizing committee received support from the International Committee, the Russian Ministry of Science and the Foundation for Basic Research. The proceedings are being published by World Scientific.

Sergey Troshin, *IHEP, Protvino.*

SATURNE's ring at Saclay, France.

The sun sets on SATURNE

After a 40-year career, first as a weak focusing machine and then rebuilt with strong focusing, the French SATURNE synchrotron has exited the physics stage.

The French SATURNE National Laboratory formally ceased to exist on 31 December 1997. The authorities had actually taken the decision to close it down a few weeks earlier when a large area of the roof above the experimental areas collapsed under a heavy fall of snow. This was the sad end of a forty-year-old laboratory which had lived through two clearly distinguishable eras.

The first SATURNE synchrotron built by the CEA (French Atomic Energy Authority) in 1956–58 was a weak focusing machine, mainly supplying 3 GeV protons. Particle physicists used bubble chambers (hydrogen or propane) among other detectors. From the mid-60s higher-energy beams elsewhere attracted away an increasing number of SATURNE users.

At the same time, a core community was becoming more aware of the importance of probes close to the GeV energy range, highly suitable for nucleons. The construction of a large magnetic energy-loss spectrometer, SPES1, showed that while nuclear levels could be measured at 1 GeV, the obsolescent synchrotron had to be replaced.

The outcome was the construction in 1978 of a new strong-focussing and separated-SATURNE (focusing and bending) synchrotron for nuclear physics, SATURNE-2. Its maximum energy, limited by the size of its buildings, remained the same (2.95 GeV for protons). This machine was the result of careful consideration followed by a project undertaken jointly by CEA-IRF and CNRS-IN2P3, establishing the new SATURNE National Laboratory.

Over the years, the Laboratory acquired several particle sources making it possible to supply all light-nucleus beams (up to helium-4) at high intensities (up to 10^{11} per second extracted slowly and without RF). Heavy-ion beams accelerated up to 1.15 GeV per nucleon also became available with the DIONE source and the MIMAS preinjector. Finally, following the solution of the depolarization problem by slow or fast negotiation of depolarizing resonances, SATURNE became capable of supplying the world's most intense GeV-range proton and deuteron beams. The gradual improvement in the intensities and emittances of the HYPERION polarized particle source and the MIMAS preinjector were essential for this.

A national and then an international community built a large array of detectors to exploit these beams. The first were magnetic spectrometers (SPES 1, SPES 2, SPES 3 and SPES 4) with complementary properties (high resolution to separate nuclear levels, large pulse acceptance for the study of large objects and wide excitation energy ranges, operation close to the beam direction etc). An unusual Time Projection Chamber (DIOGENE) was built to study central collisions between heavy ions, resulting in high multiplicities. A station devoted to nucleon–nucleon interactions (elastic scattering) made it possible to polarize the incident beam and the proton target along different axes independently.

More specific devices were also installed: a full solid angle detector (ISIS) for multi-fragmentation studies, cylindrical wire chambers (ARCOLE) for elastic n-p examination, high-acceptance magnetic detectors (DISTO, SPES 4π) recoil polarimeters, photon detection for eta physics (PINOT), proton radiography etc.

Hadron studies

Most of the experiments at SATURNE were devoted to hadrons – their interactions and their behaviour in nuclei. The beams available also made possible a large number of nuclear structure studies, the simulation of the effects of cosmic radiation in the laboratory and a series of spallation neutron measurements with an eye to transmuting nuclear waste, to mention only a few.

The Laboratory made a particularly important contribution to the understanding of the nuclear force by polarization measurements in proton–proton and neutron–proton collisions in an energy range hitherto largely unexplored. It also contributed to research into narrow dibaryonic states consisting of six quarks.

As the wavelength of the proton in the GeV range is nucleon-sized, it is possible to calculate directly the proton-nucleus interaction from the free nucleon-nucleon interaction without going through the intermediary of an effective force. This provides direct access to the properties of the target nucleus. It thus became possible to determine matter radii (in addition to the charge radii studied by electron scattering) and transition densities for many nuclei.

Moreover, the polarization of the deuteron beams made it possible to isolate specific (spin isoscalar) response functions of the nuclei, which it had never been possible to measure before.

The study of systems with a small number of nucleons provided a better knowledge of the reaction mechanisms for a wide variety of processes and energy and momentum transfers. It particularly concerned the role of certain baryonic resonances in meson production and kinematic limits to meson exchange models. A set of mainly pseudoscalar meson production experiments in nucleon-nucleon collisions provided the basic information needed to interpret these processes in proton-nucleus and nucleus-nucleus collisions. The contribution of the polarization was found to be highly important in determining the dominant mechanisms. This applies especially to exclusive hyperon production, one of the laboratory's final major programmes.

A remarkable effect, the highly intense production of eta mesons (over 10^8 a day) at threshold in proton-deuteron collisions provided a tagged eta source for precise measurements of the eta mass and its decay into muon and photon pairs. This high production can also be seen in deuteron-deuteron reactions at threshold and may be interpreted as the first evidence for eta-mesic nuclei.

A particularly important collective phenomenon, the pion mode which characterizes propagation in nuclear media, was demonstrated by charge exchange reactions using light and heavy ions.

The heavy ion beams also resulted in several programmes for the study of macroscopic properties of nuclear systems (multi-fragmentation, stopping power, compressibility).

Two applications-oriented programmes produced important results. Proton and deuteron beams made it possible to examine neutron production by spallation. These data are essential for the validation of the computation programs used in the design of new methods of transmuting radioactive waste. SATURNE's energy range and beams also made it ideal for simulating cosmic rays and the damage caused to instruments exposed to it. With a week of irradiation simulating a million years of exposure, a series of experiments made it possible to trace stellar history.

SATURNE's assets were: the quality of its beams; easy and fast energy changes (half an hour or less); its variety of ions and intensity; stable polarization; and mutiple ejection (two experiments supplied with different energies and intensities). The complementary detectors were another trump card. Last, but by no means least, was the competence and willingness of laboratory staff in finding the best solutions for physics.

A book describing many of these research programmes is being published by World Scientific.

A Boudard, *CEA-DAPNIA-SPhN.*

1999 American Physical Society Prizes and Awards

Among the 1999 American Physical Society Prizes and Awards are:

- The Hans A Bethe Prize to **Edwin Salpeter** of Cornell, "for wide-ranging contributions to nuclear and atomic physics and astrophysics, including the triple-alpha reaction, electron screening of nuclear reactions, charged-current emission of neutrinos, and the form of the stellar initial mass function".
- The Joseph A Burton Forum Award to **Freeman J Dyson** of Princeton's Institute for Advanced Studies, "for his thoughtful, elegant and widely published writings regarding the impact of diverse science and technology developments on critical societal issues and on fundamental questions for humankind".
- The Dannie Heinemann Prize to **Barry M McCoy** of SUNY, Stony Brook, **Tai Tsun Wu** of Harvard and **Alexander Zamolodchikov** of Rutgers, "for their groundbreaking and penetrating work on classical statistical mechanics, integrable models, and conformal field theories".
- The Lilienfeld Prize to **Stephen Hawking** of Cambridge, "for boldness and creativity in gravitational physics, best illustrated by the prediction that black holes should emit black-body radiation and evaporate, and for the special gift of making abstract ideas accessible and exciting to experts, generalists, and the public alike".
- The Nicholson Medal to **Vitaly Ginzburg** of the Russian Academy of Sciences, "for courageously supporting democratic reforms in the former Soviet Union, and for leading the Soviet scientific community in humane directions".
- The Lars Onsager Prize to **C N Yang** of SUNY, Stony Brook, "for fundamental contributions to statistical mechanics and the theory of quantum fluids, including: the circle theorem, off-diagonal long-range order and flux quantization, Bose-Einstein condensation, and one- and two-dimensional statistical mechanical models".
- The George E Pake Prize to **H B G Casimir** of Philips, "for excellence as a leader of industrial research at Royal Philips Electronics and for fundamental contributions to the foundations of quantum mechanics and solid-state physics".
- The W K H Panofsky Prize to **Edward Thorndike** of Rochester, "for a leading role in milestone advances in the study of the b quark with the CLEO collaboration; particularly the discovery and measurement of b semileptonic decay, the b to s Penguin decay process, and the b to u weak transition. In addition, his contributions led to substantial improvements in understanding the flavour sector of the Standard Model and the Cabibbo–Kobayashi–Maskawa matrix of weak quark couplings".
- The Francis Pipkin Award to **Stephen Lamoreaux** of Los Alamos, "for extensive contributions to precision measurements science, especially searches for a permanent electric dipole moment of the neutron and atoms, measurements of atomic parity violation, and tests of spatial symmetries and quantum mechanics, including observation of the vacuum Casimir Effect".
- The J J Sakurai Prize to **Mikhail Shifman** and **Arkady Vainshtein** of Minnesota and **Valentine Zakharov** of Michigan, "for fundamental contributions to the understanding of non-perturbative QCD, non-leptonic weak decays, and the analytic properties of supersymmetric gauge theories".
- The Arthur Schawlow Prize to **Carl Wieman** of JILA and Colorado, "for pioneering work on the production and study of Bose-Einstein condensation in a dilute atomic vapour, which has become a major testing ground for macroscopic quantum phenomena, and quantum statistical mechanics".
- The Robert R Wilson Prize to **Robert Palmer** of Brookhaven, "for his many diverse contributions and innovations in particle accelerator and detector technologies, including superconducting magnets, longitudinal stochastic cooling, bubble chambers and neutrino beam lines, crab crossing in lepton colliders, laser acceleration, and for recent leadership of the muon collider concept".

UK Minister of Science **Lord Sainsbury** (second from right) on a visit to CERN on 15 January hears about preparations for the ATLAS experiment at the LHC collider from ATLAS spokesman Peter Jenni (right). With the Minister were CERN Director General Luciano Maiani (left) and CERN Director for Collider Programmes Roger Cashmore.

DESY Director **Bjoern Wiik** has been made Honorary Professor at the Institute of Nuclear Physics, Krakow, Poland. The celebration took place on 9 January during a special meeting of the Scientific Council during the 5th Cracow Epiphany Conference "On the Electron–Positron Colliders". The new Honorary Professor gave a lecture on the superconducting TESLA project.

Meetings

- A Workshop on Polarized Protons at High Energies – Accelerator Challenges and Physics Opportunities – will be held at DESY, Hamburg, Germany from 17–20 May, covering both accelerator physics and spin physics in polarized scattering. The main topics include the machine physics aspects of attaining high-energy polarized proton beams, developments of high-intensity polarized sources and high-energy polarimetry, and physics studies for a polarized HERA and RHIC. Secretariat: H Haertel/heraspin, DESY; "heraspin@desy.de"; "http://www.desy.de/heraspin".
- The 6th Topical Seminar in a series devoted to experimental and theoretical results in high-energy particle physics and astrophysics will take place in San Miniato al Todesco, Italy, from 17–21 May. This year's topic is on "Neutrino and Astro-Particle Physics". Attendance is by invitation and will be limited to around 150 physicists. Information from: F-L Navarria, Dip. di Fisica, V.le Berti-Pichat 6/2, I-40127 Bologna. E-mail "kaos@bo.infn.it", "pelfer@fi.infn.it", "bruni@bo.infn.it". "http://www.bo.infn.it/sminiato/sminiato99.html".
- On 31 December, C N Yang retired as Einstein Professor and Director of the Institute for Theoretical Physics of the State University of New York at Stony Brook. To mark this occasion and to celebrate his many achievements, a symposium entitled "Symmetries and Reflections" will be held at Stony Brook on May 21–22. More details can be found at "http://insti.physics.sunysb.edu/itp/symmetries-99".
- The XVth Particles and Nuclei International Conference (PANIC) will be held in Uppsala, Sweden, from 10–16 June. The first conference in this series connecting nuclear and elementary-particle physics was held in Geneva in 1963 had the title High Energy Physics and Nuclear Structure. The previous conference in the series was held in Williamsburg, USA, in 1996. See "http://www.tsl.uu.se/panic99" or e-mail "panic99@tsl.uu.se".
- The second conference on New Developments on Photodetection will be held in Beaune (France) from June 21–25. Like the first one held three years ago, the conference will address: photodetection of visible, X and gamma radiation by: photomultipliers, solid-state devices, hybrid photodetectors and associated electronics in: high-energy physics, nuclear sciences, astrophysics, medecine and biology. Information from "http://WWW.in2p3.fr/Beaune99/".
- An International Workshop on the Lorentz Group, CPT, and Neutrinos will be held at the Universidad Autonoma de Zacatecas, Mexico, from 23–26 June. Participation will be by invitation only. Contact V V Dvoeglazov, Escuela de Fisica, UAZ, Apartado Postal C-580, Zacatecas, 98068, Zac., Mexico. Tel. (52 492) 4 13 14. Fax (52 492) 4 02 86. E-mail "valeri@cantera.reduaz.mx".
- The XXVII SLAC Summer Institute on Particle Physics will be held on 7–16 July, at Stanford, California. The theme of this year's Institute is CP Violation In and Beyond the Standard Model. Inquiries should be directed to the SLAC Summer Institute, Stanford Linear Accelerator Center, P.O. Box 4349, MS 62, Stanford, California, USA. Additional information from "http://www.slac.stanford.edu/gen/meeting/ssi/next/".

Recently formally retired from CERN is **Horst Wachsmuth** (left), seen here receiving a souvenir album from Dieter Schlatter of the Aleph experiment. A stalwart neutrino physicist, Horst Wachsmuth went on to play important roles in Aleph and in the public awareness of science. He now works for the Johannes Gutenberg University, Mainz, but remains at CERN.

Astrophysicist – CERN Theory Division Leader **Alvaro de Rujula** at the European Space Agency's Space Technology Centre (ESTEC) in Noordwijk, Holland, where he attended a board meeting of the European Physical Society/ European Astronomical Society's Joint Astrophysics Division.

Portuguese Minister of Science and Technology (and particle physicist) **José Mariano Gago** (right) with European Physical Society President **Deniș Weaire** of Dublin during a meeting in Portugal of the five-strong national physics review panel, headed by former CERN Director General Herwig Schopper and including three sometime EPS Presidents. Portugal is extending to all branches of science the grant for proposal system, with public presentation and peer review, which was launched to build a national infrastructure in particle physics, with guidance from the CERN–Portugal Committee.

Notable guest at the recent CERN retirement of expatriate Czech physicist **Ivan Lehraus** (left) was Czech ambassador **Miroslav Somol** (third from left), who underlined Lehraus' role in facilitating the Czech Republic's membership of CERN. With them are Mrs Lehraus and CERN Director for Technology Transfer and Scientific Computing Horst Wenninger.

John Bahcall wins US National Medal of Science

The US National Medal of Science, awarded annually for outstanding contributions in the sciences, went last year to John Bahcall of Princeton's Institute for Advanced Study for his pioneering efforts in neutrino astrophysics and his contributions to the development and planning of the Hubble Space Telescope.

Bogolyubov Conference

The Russian Academy of Sciences, the National Academy of Sciences of the Ukraine and the Joint Institute for Nuclear Research (JINR, Dubna) together with the Lomonosov Moscow State University are organizing the International Conference on fundamental problems of theoretical and mathematical physics to commemorate the 90th anniversary of Nikolai Nikolaevich Bogolyubov (1909–92).

The Conference will be held in Moscow (27–29 September), the Bogolyubov Laboratory of Theoretical Physics, JINR, Dubna (30 September – 1 October) and the Bogolyubov Institute of Theoretical Physics and the Institute of Mathematics, Kiev (4–6 October). The Conference will cover the areas of mathematics, mechanics, theoretical and mathematical physics to which N N Bogolyubov made a fundamental contribution: mathematics and nonlinear mechanics; quantum field theory; elementary particle physics; statistical physics and kinetics; nuclear physics. 150–170 scientists will participate. The working languages will be Russian and English.

More information: "http://thsun1.jinr.ru/~bog1999/". All correspondence should be sent to: A N Sissakian, JINR, Joliot-Curie 6, 141980 Dubna, Moscow Region, Russia. Tel. (7 096 21) 62 268. Fax (7 096 21) 65 599. E-mail "bog1999@thsun1.jinr.ru".

At a Chinese reception at the Paris house of French aviation magnate Serge Dassault on the occasion of a major exhibition of Chinese art at the Grand Palais: right, 1976 Physics Nobel **Sam Ting** of MIT and CERN, with 1986 Chemistry Nobel and President of the Academia Sinica, Taipeh, **Yuan Tseh Lee** of Berkeley.

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RESEARCH ASSOCIATE POSITION IN PARTICLE PHYSICS ON BABAR/ FUTURE LINEAR COLLIDER

Rutherford Appleton Laboratory, Oxfordshire

The Particle Physics Department at the Council for the Central Laboratory of the Research Councils (CCLRC) invites applications for a Research Associate in particle physics. The appointment will be initially for three years, with a possible extension by up to two years.

The research will be divided between the BaBar experiment at SLAC, and a new R&D project for the future e^+e^- linear collider.

For BaBar, the RAL group are responsible for analysis of physics data, support for computing in the UK, and for components of the online and offline software. For the linear collider, the RAL group is involved in physics studies for heavy flavour identification in the TeV regime, and in a programme of R&D for a vertex detector at this machine.

Applicants should have a Ph.D. in particle physics, or equivalent experience.

Further information can be obtained from Chris Damerell e-mail C.Damerell@rl.ac.uk, or from Neil Geddes e-mail N.I.Geddes@rl.ac.uk. More information about the RAL Particle Physics Department can be obtained from: http://hepwww.rl.ac.uk

The salary range is between £14,140 and £26,600. Progression within the salary range is dependent upon performance. A non-contributory pension scheme, and a generous leave allowance are also offered.

Application forms can be obtained from: Recruitment Office, Personnel Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) quoting reference VN1771/99. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 31 March 1999.

The CCLRC is committed to Equal Opportunities and to achieving the Investors In People standard. A no smoking policy is in operation.

CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

FACULTY POSITION IN INTERMEDIATE ENERGY THEORETICAL PHYSICS DEPARTMENT OF PHYSICS AND ASTRONOMY

UNIVERSITY OF PITTSBURGH

The Department of Physics and Astronomy is searching for a faculty member in intermediate energy theory. This tenure-stream Assistant Professor appointment, which is subject to budgetary approval, would start on or after September 1, 1999. This appointment, is part of a proposed new partnership between the University of Pittsburgh and Jefferson Lab designed to promote our mutual interests in the quark structure of matter, especially nucleon resonances. The successful applicant will be based in Pittsburgh as a regular faculty member, but must also spend substantial periods at Jefferson Lab. Candidates should have an ability to teach effectively at both the graduate and undergraduate levels, and to carry out a significant research program in intermediate energy theory with emphasis on topics related to the University of Pittsburgh's experimental programs at Jefferson Lab. The candidate will be expected to attract their own research funding.

We expect the successful candidate to have broad scientific interests, to maintain an active research program, and to be capable of and interested in reaching out to other members of our Department and to the intermediate energy and particle physics community in Pittsburgh.

Please send a curriculum vitae, bibliography, statement of research interests, and a list of references to:

Professor Frank Tabakin, Chair, Department of Physics and Astronomy, 100 Allen Hall, University of Pittsburgh, Pittsburgh, PA 15260 Applications should be received before April 30,1999 to ensure full consideration.

The University of Pittsburgh is an Equal Opportunity, Affirmative Action Employer. Applications from minorities and women are particularly encouraged.

NEW MEXICO CENTER FOR PARTICLE PHYSICS

Post Doctoral Research Associate Positions

UNIVERSITY OF NEW MEXICO

The New Mexico Center for Particle Physics seeks applicants for two Post Doctoral Research positions to start as early as Spring, 1999. Our research program includes the CDF experiment at Fermilab, the ATLAS experiment at the LHC, and the High Resolution Fly's Eye (Hi Res) and Pierre Auger (Auger) extreme high energy cosmic ray experiments. The current openings are in the silicon pixel program in ATLAS and in the air fluorescence programs in HiRes/Auger. As minimal qualifications, applicants should possess a PhD. in Experimental High Energy Physics or Particle Astrophysics and have demonstrated a potential for excellence in research. Interested individuals should submit a letter of application including curriculum vitae, and the names of three references to: **Professor John Matthews, Department of Physics and Astronomy, University of New Mexico, 800 Yale Blvd. NE, Albuquerque, NM 87131.** *The University of New Mexico is an Equal Opportunity/Affirmative Action Employer and strongly encourages applications from members of traditionally underrepresented groups.*

University of Houston

Postdoctoral Position in Experimental Particle Physics

The Experimental Intermediate Energy Physics group at the University of Houston is seeking postdoctoral candidates to work with the group in its experimental research programs. We are particularly interested in persons who would commit to work on our upcoming research involving strangeness in nuclei at the Jefferson Laboratory (http://www.jlab.org), but overlap with other areas of interest is also possible. An outline of the research programs of the group can be obtained at http://bart.phys.uh.edu.

Interested candidates are asked to contact

Ed Hungerford (Department of Physics, University of Houston, Houston, TX 77204 hunger@uh.edu)

and supply a current vita, a letter expressing interest in the position and the names and addresses of at least three references. The position is available immediately. Applications from minorities or other under-represented groups are encouraged to apply.

Imperial College of Science, Technology and Medicine London

Lectureship in High Energy Physics

Applications are invited for the post of Lecturer in High Energy Physics at the Blackett Laboratory, Imperial College, London.

The group's active experimental programme embraces the ALEPH experiment at LEP, the ZEUS experiment at HERA, the BABAR experiment at SLAC, the CMS and LHC-B experiments at LHC and the UK Dark Matter Experiment. It has also recently joined the D0 experiment at the Tevatron. Within the group there is a strong tradition of detector development and construction which has led to key activities in the above experiments. Further details of the group's programme may be found on:

http://www.hep.ph.ic.ac.uk/

It is anticipated that the starting date for this position will be October 1st, 1999 and that the appointee will initially take responsibility for the new D0 activity.

Following a successful 3 year probationary period this will become a tenured teaching position.

Salary will be in the range £16,655 - £29,048 plus £2,134 London allowance.

Further information may be obtained from
Professor P J Dornan,
Blackett Laboratory, Imperial College, London SW7 2AZ, UK.
Email: P.Dornan@ic.ac.uk
to whom applications, comprising a curriculum vitae, a list of publications and the names and addresses of three referees should be sent, by **10 May 1999.**

The College is striving towards Equal Opportunities
At the leading edge of research, innovation and learning

Jefferson Lab

STAFF SCIENTIST
(Position #PR2140)

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

Jefferson Lab invites applications for a staff scientist position with the Hall C group. This is intended to be a senior level position, but more junior candidates with exceptional qualifications may be considered.

The core Hall C equipment consists of two focussing magnetic spectrometers, high power $^{1,2}H$ and $^{3,4}H$ cryogenic targets, and dynamically polarized H and D targets. Flexibility is the key to the Hall C program and special purpose detector systems are developed as required. In the next few years, we will be conducting experiments on deuteron photodisintegration, the pion charge form factor, inclusive and exclusive measurements in the nucleon resonance region, electroproduction of lambda hypernuclei, G_{Ea} form factor measurements, studies of short range correlations, and the G_0 parity violation experiment.

A Ph.D. in experimental nuclear, particle, or high-energy physics is required plus a minimum of 5 years of relevant experience beyond the Ph.D. The successful candidate should have a track record of relevant publications in experimental nuclear, particle, or high-energy physics. Experience with spectrometers, detectors and data analysis from intermediate/high energy experiments is essential, and experience with electromagnetic probes is preferred. The successful candidate will be expected to support and expand the physics research program for Hall C.

Applicants should send a curriculum vitae, copies of any recent (un)published work, and arrange to have letters from at least three references sent to: **JEFFERSON LAB, Attn: Employment Manager, Mail Stop 28D, 12000 Jefferson Ave., Newport News, VA 23606, USA**

Please specify position number PR2140 and job title when applying.

Jefferson Lab is an Affirmative Action/Equal Opportunity Employer.

RESEARCH ASSOCIATE POSITIONS IN THE BABAR EXPERIMENT

The High Energy Physics Group at Lawrence Livermore National Laboratory (LLNL) has immediate openings for post-doctoral research associate positions in the BaBar experiment at **Stanford Linear Accelerator Center (SLAC)**.

LLNL plays a major role in BaBar detector development, simulations and data analysis. Our main contributions have been in the neutral hadron/muon detector (IFR) subsystem, partially designed and constructed by LLNL, and in the global simulation of the BaBar detector, to which we apply our large-scale computational resources. Our group is also conducting a dark-matter axion search and is involved in the MINOS neutrino oscillation experiment at Fermilab and fixed-target experiments at Fermilab, Brookhaven and Los Alamos and the development of Next Linear Collider detectors.

Successful applicants will work on the BaBar experiment and are expected to take a leading role in the commissioning of the IFR detector, in software development for data reconstruction and in data analysis for CP violation physics. Experience in C++ programming, large UNIX computer systems, and detector hardware is desired.

Candidates should send a curriculum vitae, and three letters of recommendation to: University of California, Lawrence Livermore National Laboratory, Dr. Douglas Wright, L-50, Dept. AJCY319PH, P.O. Box 808, Livermore, CA 94551. Or e-mail directly to: wright20@llnl.gov. Lawrence Livermore National Laboratory is an equal opportunity employer, with a commitment to workforce diversity.

Applications will be considered until the positions are filled.

University of California
Lawrence Livermore National Laboratory

UNIVERSITY OF FLORIDA

Senior Electrical Engineer

The Department of Physics at the University of Florida has an immediate opening for a senior engineer to participate in the development of digital and analog electronics for several large international projects in high-energy physics and astrophysics. This work includes the design of high-speed digital processor boards, data acquisition systems, control systems, and test facilities. Preparation of bids, reports, papers, and presentations is required. Minimum requirements are a Bachelor's degree in an appropriate area of specialization and two years of appropriate experience, or a high school diploma and six years of appropriate experience. Experience in the development of electronics for physics experiments is desired. Experience with VMEbus and field-programmable gate-arrays also is preferred. Salary $40,000-56,000 commensurate with experience.

Applicants should send a resume to:

Prof. Darin Acosta, Department of Physics, University of Florida, P.O. Box 118440, Gainesville, Florida 32611, USA. Enquiries may be sent by e-mail to: acosta@phys.ufl.edu.

Applications will be considered until the position is filled.
If accommodation is needed to apply for this position, please call **(+1) 352-392-4621** or TDD **(+1) 352-392-7734**, and refer to job positions, **#607880** and **#804790**.

AA/EA/EEO.

UNIVERSITY OF OXFORD

in association with Magdalen College or St Hilda's College

UNIVERSITY LECTURERSHIP IN EXPERIMENTAL PARTICLE PHYSICS

Applications are invited for the above post, tenable from 1 October 1999. Oxford University has a wide ranging research programme in particle physics and particle astrophysics. We are involved in preparations for the MINOS, LHCb, and ATLAS experiments, while continuing participation in ZEUS, DELPHI, and CDF. The particle astrophysics activities include the ANTARES neutrino telescope, the SNO solar neutrino experiment, the CRESST dark matter search and further development of cryogenic detectors for dark matter searches and other applications such as x-ray astronomy. The appointee would be expected to participate in the future development of this programme.

The University salary will be according to age on the scale £16,655 to £31,010 per annum. The successful candidate may be offered a tutorial fellowship by either Magdalen College or St Hilda's College under arrangements described in the further particulars, in which case the combined university and college salary would be according to age on a scale up to £37,113 per annum. Additional college allowances may be available.

Further particulars of the duties and emoluments of both the university and college posts may be obtained from Mrs. Sue Geddes, Nuclear and Astrophysics Laboratory, Keble Road, Oxford OX1 3RH, UK, (email s.geddes@physics.ox.ac.uk). Applications including a statement of research interests and teaching experience, curriculum vitae, a list of up to ten major publications, and the names of three referees (not more than two from the same institution) should be mailed to the above address to arrive no later than 15 April 1999. The referees should be asked to send letters of reference directly to the same address to arrive by the closing date. It is expected that short-listed candidates will be interviewed in Oxford 1-2 months after the closing date. Applicants are asked to provide an e-mail address, fax, or telephone number where they can be contacted.

The University of Oxford is an equal opportunity employer.

ISAAC NEWTON GROUP OF TELESCOPES ASTRONOMY RESEARCH FELLOW LA PALMA, CANARY ISLANDS

The UK Particle Physics and Astronomy Research Council (PPARC) is funding a Postdoctoral Research Fellowship at the Isaac Newton Group of Telescopes, La Palma, tenable for up to three years. The position will be available from 1 June 1999.

The successful candidate will be expected to spend up to half of their time on operational activities of the Observatory, such as supporting visiting astronomers or taking responsibility for an instrument. For the balance of his/her time, they will be free to conduct their own research programme. No specific area of astronomy is excluded from consideration, although an interest in wide field astronomy (either imaging or spectroscopy) or adaptive optics is essential. It is expected that applicants will be able to demonstrate the ability to compete successfully for time on major astronomical facilities.

The Fellowship will be at Band 4 (ex-HSO) with a salary range of £17, 530 to £26,732, or Band 3 (ex-SSO) with a pay range of £21,913 to £33,840, depending on age and experience. Appointment would normally be to the lower end of the range, with pay progression linked to performance. In addition, the successful candidate will be paid overseas allowances and be provided with free, furnished accommodation for him/her and their dependants. There is also a relocation package available.

QUALIFICATIONS

Applicants must have submitted their PhD thesis before taking up this post. Additionally, for consideration for appointment at Band 3, applicants must have had postdoctoral work experience in an appropriate research or development environment. Candidates must also be able to demonstrate the ability to compete successfully for observing time on international facilities and have effective communication skills both orally and in writing.

Applicants should include a curriculum vitae, list of publications, a statement of proposed research programmes, and the names and addresses of three referees familiar with the applicants work.

Further information about this post can be obtained from the ING's Head of Astronomy, Dr Danny Lennon on 00 34 922 425441 or djl@ing.iac.es or from the personnel contact, Les Edwins on 00 34 922 425418 or lie@ing.iac.es

Closing date for applications is 1 April 1999.

SCIENTIST/ENGINEER

Brookhaven National Laboratory, under contract with the U.S. Department of Energy, is a multi-disciplinary laboratory engaged in a diverse program of basic and applied research.

Our National Synchrotron Light Source Department presently has an opportunity available as X-ray Ring Manager. Responsibilities include implementing improvements and upgrades in the operation and performance of the ring and playing a leading role in the daily operational aspects of the facility. Experience in the development and utilization of accelerator hardware and diagnostic systems, as well as demonstrated accomplishment in accelerator technology are required. The ability to communicate effectively with Department staff and users, and to manage scientific and technical activities is essential. Under the direction of Dr. Richard Heese.

For consideration, please forward your CV and three letters of reference, indicating position #MK7836, to: M. Kipperman, Brookhaven National Laboratory, Bldg. 185, PO Box 5000, Upton, NY 11973-5000. Visit our website for more information about BNL. We are an equal opportunity employer committed to workforce diversity.

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
www.bnl.gov

VACANCIES FOR RESEARCH SCIENTISTS

The Institut Laue-Langevin (ILL) is an international research institute funded by France, Germany and the United Kingdom. Agreements on scientific collaboration have also been signed with Austria, Italy, Spain, Switzerland, the Czech Republic and Russia. The Institute operates the most powerful source of neutrons in the world, a 58 MW reactor, which was completely refurbished in 1995. The reactor forms the basis for a programme of research covering a wide variety of fields, supplying neutrons to a broad range of instruments which are available to scientists from the member countries.

The posts, which are offered on a fixed-term basis, represent an excellent opportunity for young postdoctoral scientists to develop their expertise, broaden their experience and interact with leading scientists from many countries. More experienced scientists on detachment may also be considered.

Successful candidates will be expected to carry out their own research programme, assist ILL users in conducting their experiments and participate in the operation and development of relevant instruments.

Two posts are available in the **Diffraction Group**, for each of which applicants should have 1-2 years post-doctoral experience.

1) Polarised neutron diffraction (99/02)
This post is for the second instrument responsible on the polarised neutron diffractometer D3 (http://www.ill.fr/yellowBook/D3.) The successful candidate will join a dynamic team who are in the forefront of the development of new polarised neutron techniques which are opening up new scientific areas. While some experience with polarised neutrons would be an advantage, candidates must be excellent physicists with strong scientific motivation.

2) Single crystal, power or liquids diffraction (99/03)
Opportunities are available for a scientist in any of these areas. Candidates should have a strong motivation to promote and develop the use of neutron diffraction in structure determination, especially in areas complementary to current ILL expertise. An interest in instrumentation and a sound practical knowledge of computing are also important.

Further information can be obtained by contacting Dr. A.W. Hewat, tel. (33) 476 20 72 13 (e-mail:hewat@ill.fr) or via the World WideWeb http://www.fr/dif/.

Successful candidates will be offered a fixed-term contract, the duration of which will under no circumstances exceed five (5) years and will be set according to their experience and qualifications. In addition to a competitive salary, certain benefits (reimbursement of removal expenses, adaptation allowance, etc) may be offered.

Applications quoting the appropriate reference, with curriculum vitae, list of publications and the names of two academic referees, should be sent no later than 31.03.1999 to:

The Associate Director (Science) INSTITUT LAUE-LANGEVIN B.P.156 38042 Grenoble Cedex 9 FRANCE
http://www.ill.fr

UNIVERSITY *of* GLASGOW

Department of Physics and Astronomy

RESEARCH ASSOCIATES IN PARTICLE PHYSICS

£15,735 - £23,651

Two openings are available from summer/autumn 1999, initially for up to two years, on the ZEUS and ATLAS experiments. In ZEUS the Glasgow group has made major contributions to the analysis of deep inelastic scattering and hard photoproduction. For ATLAS we are constructing part of the semiconductor tracker system, using our in-house facilities and expertise. We are looking for outstanding applicants with experience in experimental particle physics analysis or in related technology and who hold, or soon will have, a PhD. Both positions will involve working overseas.

Applications for either post, including CV, publications list, and the names and addresses of two referees, should be sent by 16 April 1999 to Professor D H Saxon, Kelvin Building, University of Glasgow, Glasgow G12 8QQ, Scotland from whom further particulars are available. Telephone 0141 330 4673, E-mail d.saxon@physics.gla.ac.uk

The University is committed to equality of opportunity in employment.

The University of Glasgow is an exempt charity dedicated to teaching and research.

Postdoctoral Research Position in Relativistic Heavy Ion Physics at the University of Heidelberg

The relativistic heavy ion group is searching for applicants with a strong interest in high speed/high bandwidth data acquisition systems. A new data acquisition system is part of a major upgrade of the CERES/NA45 experiment at the CERN SPS. In the future, the group will be increasingly involved in setting up two major detector components for the heavy ion experiment ALICE at CERN.

The applicant should have some experience with data acquisition systems, both on the hardware and software side, and should have a strong interest in working in an object-oriented environment (C++, and modern HEP computing packages). In addition to the contributions to the data acquisition system, the successful applicant is expected to play an active role in the physics program of CERES.

The position (BAT2a) is initially for 3 years, renewable up to 5 years. Applications, including vitae, list of publications and names for references should be addressed to:

Prof. Johanna Stachel, Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, D-69120 Heidelberg, Germany Tel: +49-6221-549224, e-mail: stachel@ceres1.uni-heidelberg.de

University of California, San Diego

Department of Chemistry & Biochemistry (0359)

POSITION IN X-RAY PROTEIN CRYSTALLOGRAPHY USING PIXLE DETECTORS

Position open for a Postdoctoral Fellow or Assistant Project Scientist (salary range $30K - $65K) to participate in the design and commissioning of a Digital Pixel Array Detector for X-ray Protein Crystallography. This project is in the forefront of Protein Crystallography which plays an important role in Biotechnology (especially in Rational Drugs Design). Demonstrated ability in the design and integration of particle detector hardware required. Must know how to design and test complex solid state electronic circuitry. Should be familiar with data acquisition architecture including CME/VXI/CAMAC. Familiarity with CHDL/HDL, PAL design and ASIC testing preferred. Send CV and the addresses of 3 reference to **Prof. Nguyen-huu Xuong, Dept of Chemistry & Biochemistry (0359), U.C.S.D., 9500 Gilman Drive, La Jolla, CA 92093-0359. Tel: (619) 534-2501; Fax: (619) 534-7042; Email: nxuong@ucsd.edu .**

The deadline for application is May 5, 1999, but until the position is filled all applications receive will be assured full consideration.

The University of California is an equal opportunity/affirmative action employer.

Weill Medical College, Cornell University

Research fellow positions in magnetic resonance imaging are open at Cornell MR research group. Basic knowledge of physics, digital electronics or signal processing, and computer language C is required. The positions are expected to develop new imaging methods on GE MR scanners and collaborate with clinicians to evaluate your methods on volunteers and patients.

Our work is focused on developing innovative techniques for imaging blood flow in the heart and brain, and applying these techniques in diagnosing cardiovascular diseases, the No. 1 killer in US. The major challenge for imaging the heart is motion, and we are developing a navigator-based "auto focusing" approach to minimize motion effects. The major challenge to imaging function of the brain and other organs is the underlying biophysics mechanism, and we are developing quantitative models and corresponding acquisition strategies to map out pathophysiology.

Candidates should submit CV and references to the following contact

Yi Wang, PhD.
Assistant Professor of Physics, Director of MR Research, Department of Radiology, Weill Medical College, Cornell University, 1300 York Avenue, New York, NY 10021
212.746.3853 (tel), 212.746.8046(fax)
yiwang@mail.med.cornell.edu http://mri.med.cornell.edu/~wang

DISPLAY AD INDEX

POST DOCTORAL POSITION IN EXPERIMENTAL PARTICLE PHYSICS

Rutherford Appleton Laboratory,
University College London

UCL

Applications are invited for a post doctoral position in experimental particle physics to be jointly supported by CLRC and University College London. The successful applicant will be based at RAL for the initial portion of the 4 year tenure of this post. It is expected that the person appointed will work on the MINOS experiment, the long baseline neutrino oscillation search experiment recently approved at Fermi National Accelerator Laboratory. The successful applicant will be expected to contribute to the construction of the detector and to the physics analysis, first data being expected in the year 2002.

Applicants should have a Ph.D. in particle physics, or have equivalent experience.

Further information can be obtained from Peter Litchfield (e-mail P.J.Litchfield@rl.ac.uk.) More information about the RAL Particle Physics Department can be obtained from: http://hepwww.rl.ac.uk.

The salary range is between £14,140 and £26,600 and the starting salary is dependent on experience. Progression within the salary band is dependent on performance. A non-contributory pension scheme and a generous leave allowance are also offered.

Application forms can be obtained from: Recruitment Office, Personnel Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, UK. Telephone (44) 1235 445435 (answerphone) quoting reference VN1770/99. More information about CLRC is available from CCLRC's World Wide Web pages at http://www.cclrc.ac.uk

All applications must be returned by 31 March 1999.

The CLRC is committed to Equal Opportunities and to achieving the Investors in People standard. A no smoking policy is in operation.

CLRC

COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

UNIVERSITY OF FLORIDA

Postdoctoral Position

The Department of Physics at the University of Florida has an immediate opening for a postdoctoral research position. The position is affiliated with the Hadron Collider Group strongly engaged in two experiments: CMS (endcap muon chambers, level-1 muon trigger) and CDF (CDF II luminosity monitor, physics analysis). More detailed information on the research of the group is available at http://www.phys.ufl.edu/hee/hee.html.

The University of Florida is a site for final assembly and testing of CMS muon chambers and the successful candidate will be in charge of this task.

The CMS endcap muon system is based on 360 large cathode strip chambers with state-of-the-art analog and digital electronic readout.
In addition, the opportunity of being involved in CDF data analysis is always open. To match these tasks, applicants should have adequate hardware experience (design, construction, or commissioning of detectors, good knowledge of front-end and/or DAQ electronics) and data analysis skills.

Candidates should send a curriculum vitae and three letters of recommendation to: Prof. Andrey Korytov, Department of Physics, University of Florida, P.O. Box 118440, Gainesville, FL 32611, USA. Enquiries may be sent by e-mail to: korytov@phys.ufl.edu. Applications will be considered immediately and until the position is filled.

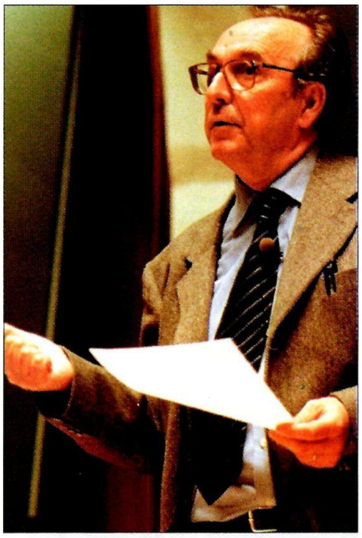
Managing a world laboratory from a European pedestal

Set up as a European laboratory which became a role model for other scientific organizations, CERN has now evolved into a truly world laboratory. Managing a world laboratory from a European pedestal is a challenge, but I am sure the result will again go on to become a role model for subsequent ventures.

The LHC collider is the focus of the world particle-physics community and naturally dominates the CERN programme. I am often asked if I am disturbed by having such a major commitment to a single predetermined objective.

The answer is emphatically "no". The LHC was approved as a result of a concerted international effort (which I strongly supported), spurred by the deep-seated conviction that it was the right machine at the right time. This conviction still holds.

Regarding LHC progress, I am also frequently asked if we are on track for commissioning of the machine and its experimental programme in 2005. Today, after careful consideration, I have no reason to doubt that we are, but with no money in reserve the only contingency available is time. If any major unforeseen problem occurs, then LHC commissioning will have to be pushed back. I trust this will not happen.



CERN's new Director-General Luciano Maiani looks in the crystal ball.

Although many worthwhile and even valuable research lines had to be sacrificed to liberate resources for the LHC, CERN's ongoing research programme is still a remarkable one. The LEP2 collider, aiming for 100 GeV per electron and positron beam and sitting right on top of the energy region where the Higgs and supersymmetric particles could be seen at any time, is a worthy flagship project to sail from one millennium to the next.

The NA48 experiment with its precision study of CP violation, and the studies at the new Antiproton Decelerator, together could provide vital new information about any differences between the behaviour of matter and antimatter. This would deepen our understanding of the fundamental processes which produced our universe from the Big Bang. The major COMPASS experiment using muon beams has a broad range of objectives.

The ISOLDE on-line isotope separator, itself a world leader in its field, continues to provide valuable results across a research field which extends even wider than physics, while Carlo Rubbia's spallation studies could lead to a new project to provide new progress in neutron beams. The study of heavy-ion collisions shall continue for some time, paving the way to the new generation RHIC and LHC experiments.

The chief casualty in the runup to the LHC would seem to be neutrino physics, traditionally a major player on the CERN research scene. This is especially ironic now, when convincing new results point to the possibility of neutrino oscillations.

We will do our best to keep front-rank neutrino physics alive in Europe. The possibility of a long-baseline experiment, sending neutrinos from CERN to detectors at the Italian Gran Sasso laboratory 730 kilometres distant (November 1998, page 13) is the most attractive option. As far as CERN is concerned, the main criterion to be borne in mind is to avoid any interference with LHC preparations. However, with CERN already fully committed, this additional project would require extra support from Europe.

Turning away from scientific research as such, I see communication as being of vital importance. Particle physics is the bedrock of our understanding of the world in which we live, but particle physics is in real danger of becoming isolated. Particle physicists therefore have to look outwards rather than inwards. The dissemination of scientific culture, what is now termed "outreach", has to be nurtured and encouraged. This is true for particle physicists everywhere, but CERN has a special duty to pull together European efforts. In addition, CERN needs to become more transparent to the local population in Geneva and neighbouring France. Special programmes are being implemented.

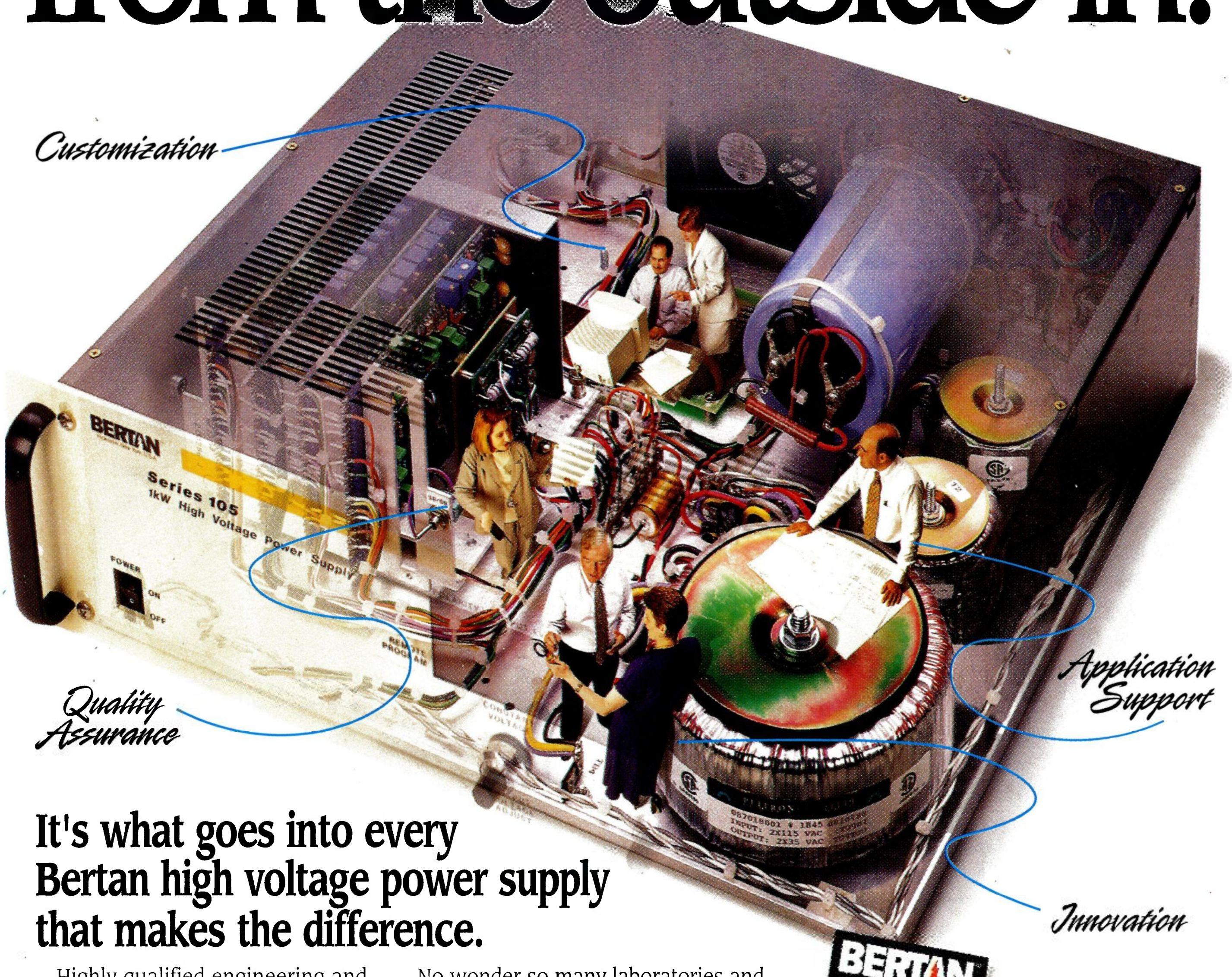
Frontier science goes hand in hand with new technology. New experimental frontiers bring demanding new requirements in precision engineering, data handling, electronics, ultra-high vacuum, cryogenics etc. These challenges catalyse technology transfer, opening profitable new domains for industry and for mankind as a whole. CERN already has an impressive technology transfer portfolio and new measures are being taken to ensure this continues and grows.

But the LHC will not be particle physics' and CERN's last major machine, only the next step in a distinguished series of projects. Looking further ahead, we need to begin now investing in research and development work to bear fruit many years hence.

Whatever physics the LHC will produce, the parallel electron-positron collider route has also to be explored, and CERN's CLIC scheme (September 1998, page 18) has been acknowledged as the most promising contender in this field, for the next big step in energy.

Ongoing accelerator R&D work has to involve national laboratories to an increasing degree, both inside Europe and further afield, and CERN will seek to reinforce its already strong ties with these research centres. In this way CERN will be able to consolidate its position as one of the main world foci of scientific research.

Engineered from the outside in.



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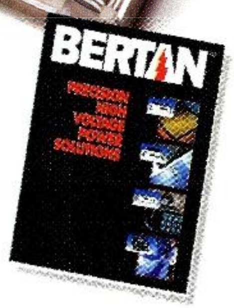

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