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CERN COURIER

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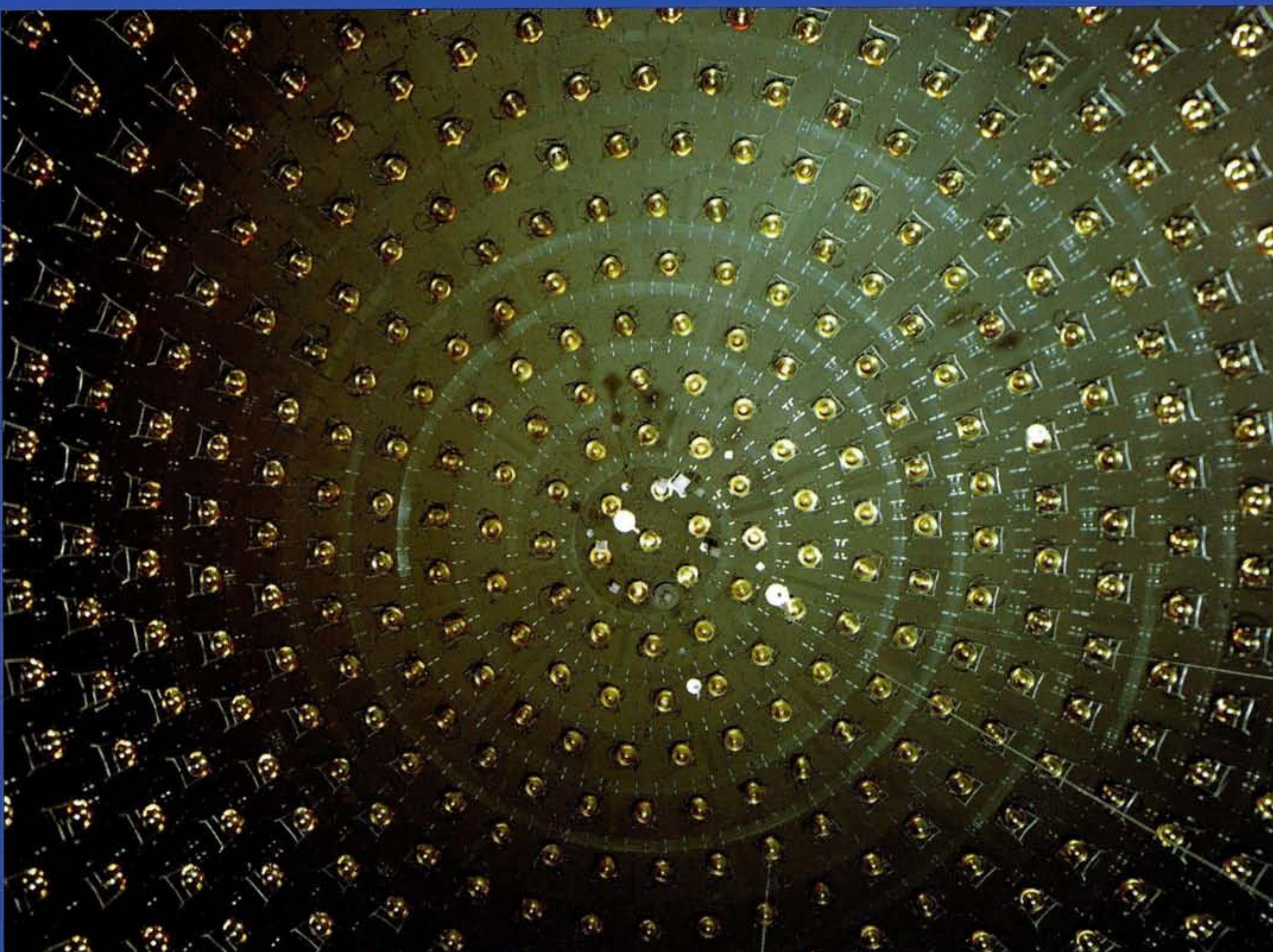

Accelerator neutrino physics enjoys a boon

MOONSHADOW
CERN experiment sees cosmic-ray shadow of the Moon p5

MICROWAVE BACKGROUND
Cosmic background imager supports spatially flat universe p11

B PHYSICS
Bottom quark physics reaches quarter century p13

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Pixel Size at Detector Surfaces:	51 x 51 microns	51 x 51 microns
Phospher (optimized):	1 X-ray Angstrom	1 X-ray Angstrom
Spatial Resolution FWHM:	90 microns; 1.76 pixels	90 microns; 1.76 pixels
Taper Ratio:	3.7 to 1	3.7 to 1
Optical Coupling (CCD to Taper):	Direct bond	Direct bond
CCD Type:	Thomson THX 7899 (2Kx2K)	Thomson THX 7899 (2Kx2K)
CCD Pixel Size:	14 x 14 microns	14 x 14 microns
Operating Temperature:	-50 degrees Celcius	-50 degrees Celcius
Cooling Type:	Thermoelectric	Thermoelectric
Dark Current:	0.015 e/pixel/sec	0.015 e/pixel/sec
Controller Electronics:	ADSC Custom	ADSC Custom
Readout Times (Full Resolution): (2x2 binned):	1 second 330 milliseconds	1 second 330 milliseconds
Read Noise (Pixel Rate):	(1 MHz): 18 electrons estimated	(1 MHz): 18 electrons typical
Full Well Depth (Full Resolution):	270,000 electrons typical	270,000 electrons typical

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Beam Height:
650 mm above base

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Angular accuracy: 0.005 degrees

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Maximum distance: 800 mm

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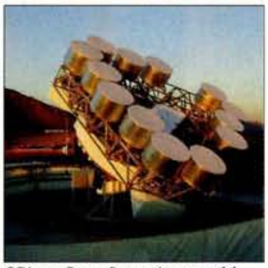
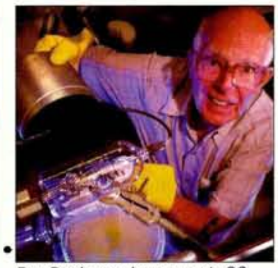
Astroparticle coordination p6


CBI confirms flat universe p11

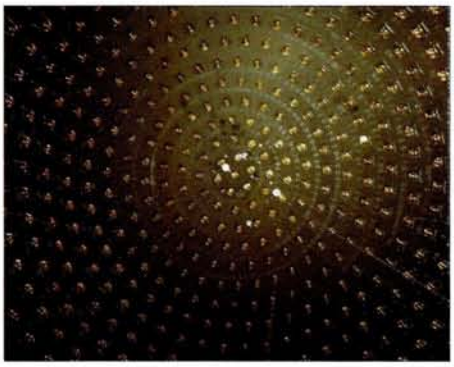

Ray Davis receives award p30

Cover: Fermilab's mini booster neutrino experiment (MiniBooNE) was filled with mineral oil in April. MiniBooNE will put the Los Alamos LSND experiment's result suggesting neutrino oscillations in a neutrino beam to the test. If the LSND oscillation signal is verified, a second detector (BooNE) is foreseen to allow a precision measurement of the oscillation parameters and a search for CP and CPT violation (p5).

NEUTRINOS

MiniBooNE detector is complete

The MiniBooNE experiment at the US Fermilab achieved two major milestones recently, as the tank was filled with the last drops of mineral oil and the first trickle of beam was delivered to the temporary absorber. The MiniBooNE experiment is designed to be a definitive investigation of the Los Alamos LSND experiment's evidence for anti-muon-neutrino to anti-electron-neutrino oscillations, which is the first accelerator-based evidence for oscillations. The detector consists of a 12 m diameter spherical tank covered on the inside by 1280 phototubes (each 20 cm in diameter) in the detector region and by 240 phototubes in the veto region. The tank is filled with 800 tonnes of pure mineral oil, giving a fiducial volume mass of 440 tonnes. The detector is located 500 m downstream of a new neutrino source that is fed by Fermilab's 8 GeV proton Booster. A 50 m decay pipe following the beryllium target and magnetic focusing horn allows secondary pions to decay into muon-neutrinos with an average energy of about 1 GeV. By switching the horn polarity, a predominately anti-muon-neutrino beam can be produced. An intermediate absorber can be moved into and out of the beam at a distance of 25 m, allowing a systematic check of the neutrino backgrounds.



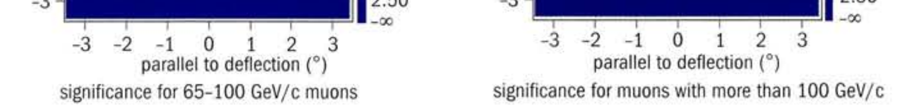
A view inside the MiniBooNE tank before it was sealed and filled with oil.

The MiniBooNE detector oil fill finished on 3 May, and the detector is now complete and taking data with cosmic rays and laser calibration flasks. The beamline commissioning is under way, with the first beam delivered to the temporary absorber; data-taking with neutrinos will begin this summer after the magnetic focusing horn is installed and the neutrino beamline is completed. With 5×10^{20} protons on target (about a year at design intensity), MiniBooNE will be able to cover the entire LSND allowed region with high sensitivity (>5 sigma). If the LSND oscillation signal is verified, then a second detector (BooNE) will be proposed to be built at the appropriate distance from the neutrino source, which will allow a precision measurement of the oscillation parameters and a search for CP and CPT violation.

COSMIC RAYS

Cosmic-ray apparatus images Moon's shadow

A dedicated cosmic-ray experiment making use of the muon identification system of CERN's L3 experiment collected around 12×10^9 cosmic ray muons between April 1999 until L3 finished taking data in 2000. The goal of the so-called L3 plus cosmics (L3+C) experiment is to study the cosmic muon spectrum precisely over the range 20–2000 GeV/c, allowing for normalization of the calculated muon-neutrino spectrum. Other topics under analysis by the experiment include the search for point-source burst signals, exotic events and studies of the composition of very-high-energy primary cosmic rays around 10^{15} eV, made possible by coupling the L3+C apparatus to a surface scintillator array.



The deficit of primary cosmic rays is clear in these pictures, covering two muon energy ranges. In each, a circle indicates the real position of the Moon. The axes correspond to the parallel and perpendicular directions of the deflection in degrees. The Moon's shadow is displaced more in the sample corresponding to the lower-energy cosmic rays (left).

Also interesting is the ability of the apparatus to image the shadow of the Moon. High-energy muons indicate the direction of the primary cosmic-ray particle. Since the Moon can absorb primaries – usually protons – on their way to Earth, the L3+C apparatus saw fewer muons originating from that direction and so observed a shadow. Moreover, since the Earth's magnetic field deviates the course of charged primaries, positive particles are shifted eastwards and the corresponding shadow is shifted to the west. The extent of the shift and the shape of the shadow depend on the momentum of the primary and the size and the direction of the field along its path.

Antiprotons, if any, would be deviated in the opposite direction, giving rise to an "anti-shadow". No such feature is seen. Work is continuing to set a limit to the antiproton to proton ratio in an energy range around 1 TeV, well above the present range of direct measurements, which extend up to 50 GeV.

ASTROPARTICLE PHYSICS

Europe coordinates astroparticle research

European astroparticle physics received a boost last year with the formation of the Astroparticle Physics European Coordination (APPEC), established in an agreement signed by funding agencies from France, Germany, Italy, the Netherlands and the UK. Astroparticle physics – which covers topics as diverse as cosmic rays, dark matter and gravitational radiation – falls between more traditional areas such as particle physics, nuclear physics and astronomy, and so can lose funding opportunities. Also, different countries have different ways of defining astroparticle physics. APPEC has been set up to promote co-operation within Europe's growing astroparticle physics community, and to develop long-term strategies at the European level, in particular for funding.

Italy's Gran Sasso laboratory – the site of a diverse range of experiments in astroparticle physics. (Oxford University PPU.)

APPEC's activities are organized through two main committees: a steering committee, currently led by Jean-Jacques Aubert of the French CNRS; and a peer-review committee, chaired by Ricardo Barbieri of the Scuola Normale Superior in Pisa. The steering committee, which meets twice a year and includes representatives from the initial partners, has already met in Berlin and London. One important action has been to begin work on a bid to the EU 6th Framework for up to €20 million for an Integrated Initiative Infrastructure (I3). The committee also seeks to widen APPEC's membership – Spain, for example, is joining, and other countries have been approached.

The peer-review committee, which also meets twice a year, aims to assess existing programmes in different areas of astroparticle physics, and to encourage future collaboration. The committee has already met twice, to review experiments in double beta decay and in dark matter. Its next meeting, in January 2003, will consider high-energy neutrino experiments.

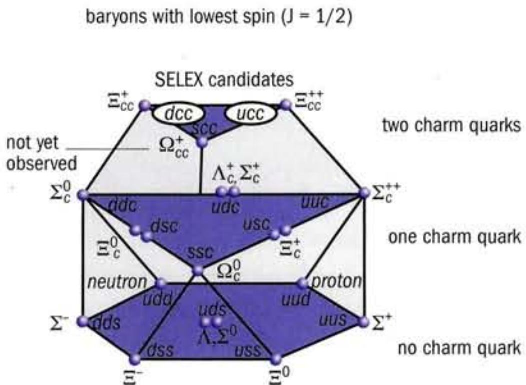
David Wark from Sussex and RAL, who is one of the members of the steering committee, said: "I believe this is a positive step for astroparticle physics, as it can help bring some of the rigour, co-operation and international clout to astroparticle physics that organizations like CERN and DESY bring to accelerator physics. It will also help to get astroparticle physics projects judged using similar criteria in all the countries from which they require support."

Aside from its committee meetings, APPEC will keep in touch with European astroparticle physicists throughout the year with an electronic newsletter and a website, to be launched later this year. In the meantime, to register interest in receiving the newsletter, please email sacquin@dapnia.cea.fr.

DOUBLE CHARM

Fermilab experiment hints at double charm

The SELEX experiment at Fermilab has announced three candidates for doubly charmed baryons. In a presentation at the US laboratory at the end of May, collaboration co-spokesman Jim Russ of Carnegie Mellon University described the painstaking analysis of data recorded in 600 GeV proton, pion and sigma hyperon collisions with a diamond target in 1996. The observation comes as a surprise to the collaboration, which did not expect to see doubly charmed baryons at all, and there remain uncertainties over the conclusion to be drawn. The SELEX candidates have the right characteristics to be up-charm-charm and down-charm-charm combinations, but the mass difference between the two states is larger than expected. Like the proton and neutron, the candidate particle pair is related by the replacement of an up by a down quark, so the mass difference was naively expected to be similar. SELEX, however, sees a mass difference 60 times larger.



Two of the SELEX candidates have spin 1/2 and fit the description of singly and doubly charged Ξ particles. Their mass difference, however, is larger than expected.

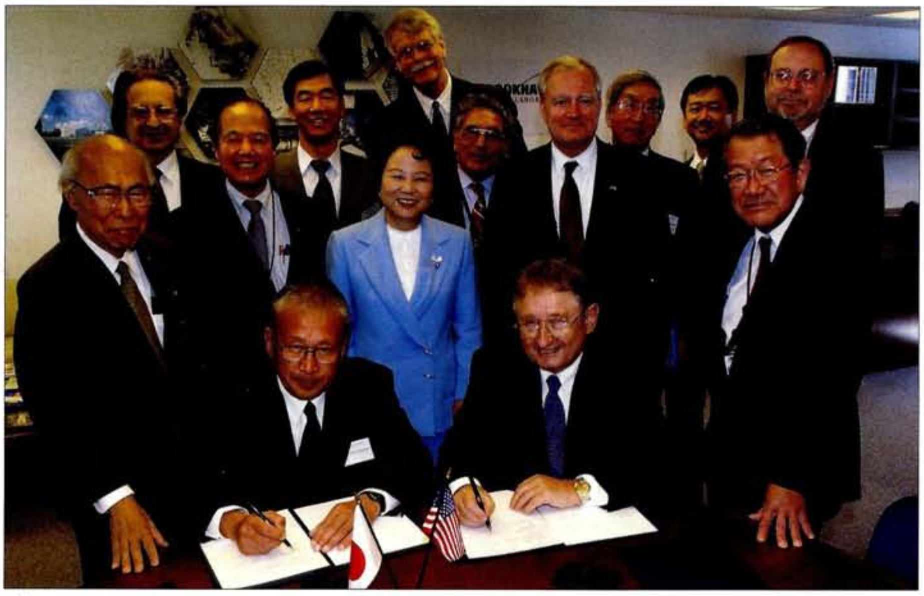
The collaboration chose to make its announcement in the hope that doing so would spur the broader community to take up the search. In particular, data from the BaBar and Belle collaborations at the SLAC and KEK B-factories in the US and Japan would be good places to look for doubly charmed baryons.

Multiply charmed baryons are a natural consequence of the quark model of hadrons, and it would be surprising if they did not exist. Whether or not the high-mass states that SELEX reports turn out to be the first observation of doubly charmed baryons, studying their properties is important for a full understanding of the strong interaction between quarks.

SPIN PHYSICS

RIKEN and Brookhaven renew their vows

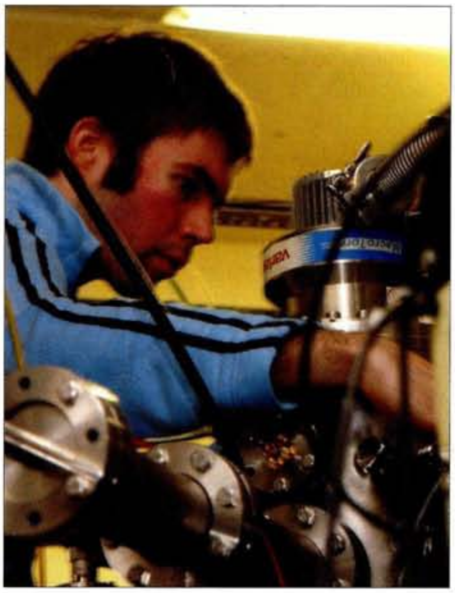
At a ceremony marking the beginning of spin physics at Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC; *CERN Courier* April p8), the US laboratory renewed its collaboration agreement with Japan's Institute of Physical and Chemical Research (RIKEN) for a further 5 years. Initially established in 1995, the RIKEN-BNL agreement has been instrumental in establishing the spin-physics programme at RHIC, and led to the establishment of the RIKEN-BNL Research Center (RBRC) in 1997.



RIKEN president Shun-ichi Kobayashi (seated left) and Brookhaven interim director Peter Paul sign the extension to the RIKEN–BNL agreement. Present at the ceremony were (left to right): Akito Arima of the Japanese House of Councillors; RBRC deputy director Nicolas Samios and director T D Lee; Isao Tanihata of RIKEN; Atsuko Toyama, Japanese minister of education, culture, sports, science and technology (MEXT); Thomas Kirk of Brookhaven; Peter Rosen of the US Department of Energy (DOE); presidential science adviser John Marburger; Tsutomu Imamura and Masaru Osanai of MEXT; Satoshi Ozaki of Brookhaven; and Denis Kovar of the DOE. (Brookhaven National Laboratory.)

ASYMMETRIES

New dipole moment centre inaugurated



Research fellow Jonathan Hudson is seen here at work at the University of Sussex's new Centre for the Measurement of Particle Electric Dipole moments.

A new laboratory inaugurated in May at the University of Sussex, UK, aims to shed light on matter–antimatter asymmetry by measuring the electric dipole moment of the neutron. The new Centre for the Measurement of Particle Electric Dipole Moments has been created thanks to a £1.7 million (€2.6 million) award from the UK's Joint Infrastructure Fund.

SYNCHROTRON LIGHT

Daresbury's proposed 4G light source moves forward

Following extensive peer review, the fourth-generation light source (4GLS) proposed for the Daresbury laboratory, UK, has been given the green light to proceed to the next stage of planning. In a further development, the US Jefferson Laboratory (JLab) has shown its support for the project by making available key equipment and technical advice on basic concepts and techniques pioneered at JLab.

The 4GLS team will now prepare a detailed business case and undertake initial design and feasibility studies aimed at full exploitation of the energy recovery linac and free-electron laser (FEL) technical capabilities central to the 4GLS project.

This wiggler array from JLab's demonstration FEL is to be sent to the Daresbury laboratory in the UK as part of a fourth-generation light source test facility.

These are both techniques in which JLab has considerable expertise, making an international collaboration a logical step forward. A wiggler magnet array from JLab will form the central part of a test facility that will be established at Daresbury during the initial phase of the project, and will be the first FEL facility to be established at a UK national laboratory. A formal agreement between the two laboratories lays the ground for future scientific and technical exchanges.

SUMMER STUDENTS

CERN's summer student programme turns 40

It was in 1962, when Victor Weisskopf was CERN director-general, that the laboratory's summer student programme began. CERN's administrative services division introduced the scheme as an offshoot of the fellows and visitors programme. The idea was to awaken the interest of undergraduates in CERN's activities by offering them the chance of hands-on experience during their long summer vacation. Member-state delegations were asked to sound out potentially interested institutions in their home countries, and work began at CERN to identify activities for the incoming students. The idea met with some scepticism at first about the usefulness of inexperienced youngsters joining experiments for just a few weeks, but enough places were found for the scheme to begin. Some 500 applications were received in the first year, and 70 students were selected.

Applicants were sorted according to their declared interests, and CERN team leaders made their selections on the basis of recommendations from the students' home institutes. Those selected came to CERN for 6–8 weeks, with travel and a daily stipend paid. Geneva University offered to house some of them in its student accommodation, while others were housed in the laboratory's temporary barracks, which finally closed for business in the mid-1990s.

Many of the newcomers worked hard during their stay, covering for holiday absences. Others, however, found themselves with time on their hands. Because of this, the summer students' lecture programme was started. This soon developed into a major activity, with physicists of Weisskopf's calibre regularly giving lectures. Today, it is not unusual to see more experienced physicists sitting next to their undergraduate counterparts in the laboratory's auditorium, brushing up on the basics.

CERN's 2001 summer students take in a lecture from Ronald Kleiss.

For many alumni of the summer student programme, their stay at CERN was the first step on the ladder of a successful career in physics. David Plane, for example, was a summer student in the first year of the programme, and went on to become spokesman of the OPAL collaboration that studied collisions in CERN's electron–positron collider, LEP. Distinguished Norwegian physicist Egil Lillestøl is another who can trace his career back to the programme.

Over the years, the summer student programme has flourished. In 2002, some 150 students are expected at the laboratory, and member-state students will be joined by colleagues from the US and Israel, funded by their home countries. In 1998, the programme was joined by a parallel initiative for high-school teachers, sharing the same lecture programme and bringing teachers together to work with physicists, exchanging ideas and developing new teaching materials.

Information about these programmes is available at http://humanresources.web.cern.ch/ for the summer students programme and http://teachers.web.cern.ch/ for the teachers programme. The students' view can be found at http://summerstudents.web.cern.ch/summerstudents/.

LATIN AMERICA

Latin American physics centre celebrates 40th anniversary

José Leite Lopes, one of the founders of CLAF, between former directors Roberto Bastos da Costa (left) and Carlos Aragão de Carvalho at the centre's 40th birthday celebrations.

The Rio de Janeiro-based Centro Latinoamericano de Física (CLAF) celebrated its 40th anniversary on 26 March. Founded under the auspices of UNESCO following the CERN model, CLAF was established to promote research in physics and provide postgraduate training to young physicists in the region. The physicists Juan José Giambiagi of Argentina, José Leite Lopes of Brazil and Marcos Moshinsky of Mexico were instrumental in its creation. Today, CLAF has 13 member states.

The celebrations took the form of a week-long international meeting in Rio that focused on CLAF's international collaborations and looked at the long-term future of the centre. Speakers included Faheem Hussain of the International Centre for Theoretical Physics in Trieste, Italy, which has been involved in a programme of joint PhD work with Latin American institutions since 1997. Vladimir Kadyshevsky, director of the Dubna-based Joint Institute for Nuclear Research, and Pavel Bogoliubov, who is responsible for the institute's international relations, spoke of a 4-year-old programme to train Latin American graduate students in Russia, and of the 25 MeV microtron built at Dubna to form the basis of a proposed regional laboratory in Havana, Cuba. CERN's Juan Antonio Rubio, who is responsible for the laboratory's education and technology transfer activity as well as links with Latin America, spoke of the agreement signed in 2001 between CERN and CLAF to organize a joint biennial school in Latin America. Staying with education, Ramón Pascual, former rector of the Universidad Autónoma in Barcelona, signed an agreement at the meeting allowing Latin American students to take part in the European Joint Universities Accelerator School.

Research was discussed by Ana María Cetto, coordinator of the Latin American Scientific Networks, who spoke of a project to foster greater Latin American use of observatories in Chile and the possibility of extending the facilities at Mount Chacaltaya in Bolivia.

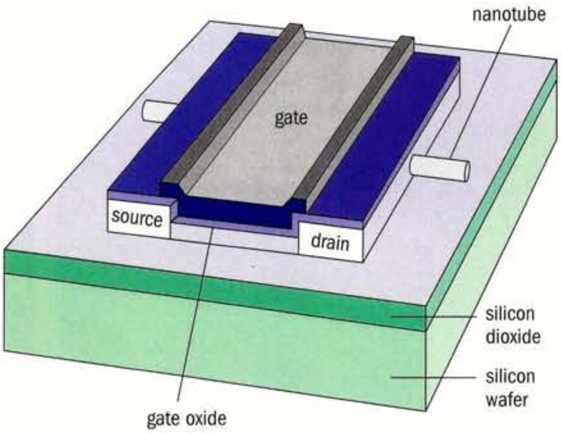
Looking to the future, CLAF support for the second CERN-CLAF school to be held in Mexico in 2003 was confirmed at the meeting, and CLAF announced the creation of a biennial school in medical physics and synchrotron radiation. The centre is also promoting improvements in postgraduate education through the ICTP programme and by coordinating a regional Masters degree programme. In research, CLAF will assume a stronger role in coordinating Latin American efforts in medical physics, condensed-matter physics and optics. It will also examine the possibility of building a proton accelerator for cancer treatment. The meeting concluded with a request to the governments of Latin America to increase their percentage of GDP spending on science and technology.

Edited by Archana Sharma

Nanotube transistors pave the way for future nanocomputer design

Nanotube transistors are valuable for future nanocomputer design. They exploit the fact that carbon nanotubes are ready-made wires that can conduct, semiconduct or insulate. In the latest development from IBM, nanotube transistor architecture has been reconfigured such that nanotubes acting as the conducting channel between the transistor source and drain are not exposed to air (top-gate configuration), and so that neighbouring transistors can be addressed individually.

By experimenting with different device structures, researchers have been able to achieve the highest transconductance (a measure of the current-carrying capability) of any carbon nanotube transistor to date. High transconductance means that transistors can run faster, leading to more powerful integrated circuits. Furthermore, the researchers discovered that the carbon nanotube transistors produced more than twice the transconductance per unit width of top-performing silicon transistor prototypes. *AIP*



IBM's carbon nanotube field effect transistor.

Further reading

S J Wind *et al.* 2002 *Appl. Phys. Lett.* **80** 3817.

Speed of light passes updated test with flying colours

Researchers in Germany have devised a state-of-the-art version of the classic 19th-century Michelson–Morley experiment, which first established that the speed of light is the same in every direction.

Certain versions of string theory suggest that special relativity may not hold exactly, and that violations might reveal themselves in high-precision measurements. But in this new version of the Michelson–Morley experiment, special relativity passes the high-precision test with flying colours – the speed of light does not depend on its direction of propagation to within 1.7 parts in 10^{15}, an accuracy about three times better than previously measured. In their experiment, the German team used two optical cavities each consisting of two mirrors held at a constant distance. The time taken for a light beam to make a round trip between the mirrors gives a direct measure of the speed of light perpendicular to the mirror surfaces. The cavities were oriented in different directions, and by rotating the set-up the team measured light speed in several directions. Potential sources of error due to variations in cavity length caused by temperature effects and material aging were avoided by using cavities made from an ultra-pure sapphire crystal, which is virtually impervious to aging, and operating it at liquid helium temperature. With the experiment still under way, the researchers hope to obtain another threefold improvement after collecting sufficient data. *AIP*

New laser improves medical imaging

Scientists from Italy and the UK have produced a low-power, compact solid-state terahertz laser that is set to advance medical imaging. Based on layers of the same semiconductors used in conventional visible and infrared lasers – gallium arsenide (GaAs) and aluminium gallium arsenide (AlGaAs) – the prototype gives better soft tissue resolution than ultrasound.

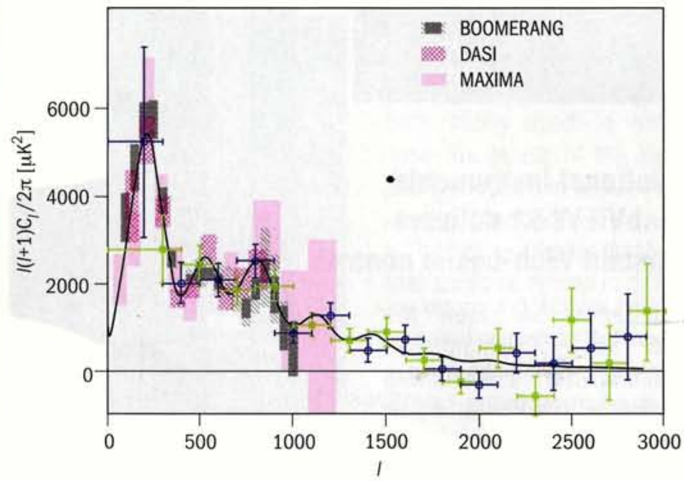
Semiconductor lasers produce light when electrons move between energy levels in the semiconductor. Usually, these levels are separated by the appropriate amount to produce visible or infrared light. The new laser produces terahertz radiation by using both GaAs and AlGaAs to produce closer energy levels.

Further reading

R Köhler *et al.* 2002 *Nature* **417** 156–159.

Edited by Emma Sanders

Cosmic Background Imager confirms flat universe observations



Left: CBI's 13 radio antennas. Right: the CBI power spectrum (with error bars in blue and green) compared with results from other experiments. (CBI/Caltech/NSF.)

The first results from the Cosmic Background Imager (CBI) were released in May. Observations of the microwave background are the closest astronomers can get to the Big Bang, and fluctuations in this radiation are evidence for the first clumping of matter particles. Measurements of the angular power spectrum give values for several fundamental cosmological parameters. The first signs are reassuring: CBI results agree with other recent observations suggesting a spatially flat universe.

CBI consists of 13 radio antennas operating at frequencies from 26 to 36 GHz. Located in the Atacama desert, CBI takes advantage of the low humidity at an altitude of 5080 m. The variations in temperature measured by the CBI are as small as 10 millionths of a degree.

CBI shares many design elements with DASI, an interferometer at the South Pole probing larger angular scales. Other complementary observations have been carried out by the balloon detectors BOOMERANG and MAXIMA (*CERN Courier* September 2000 p15).

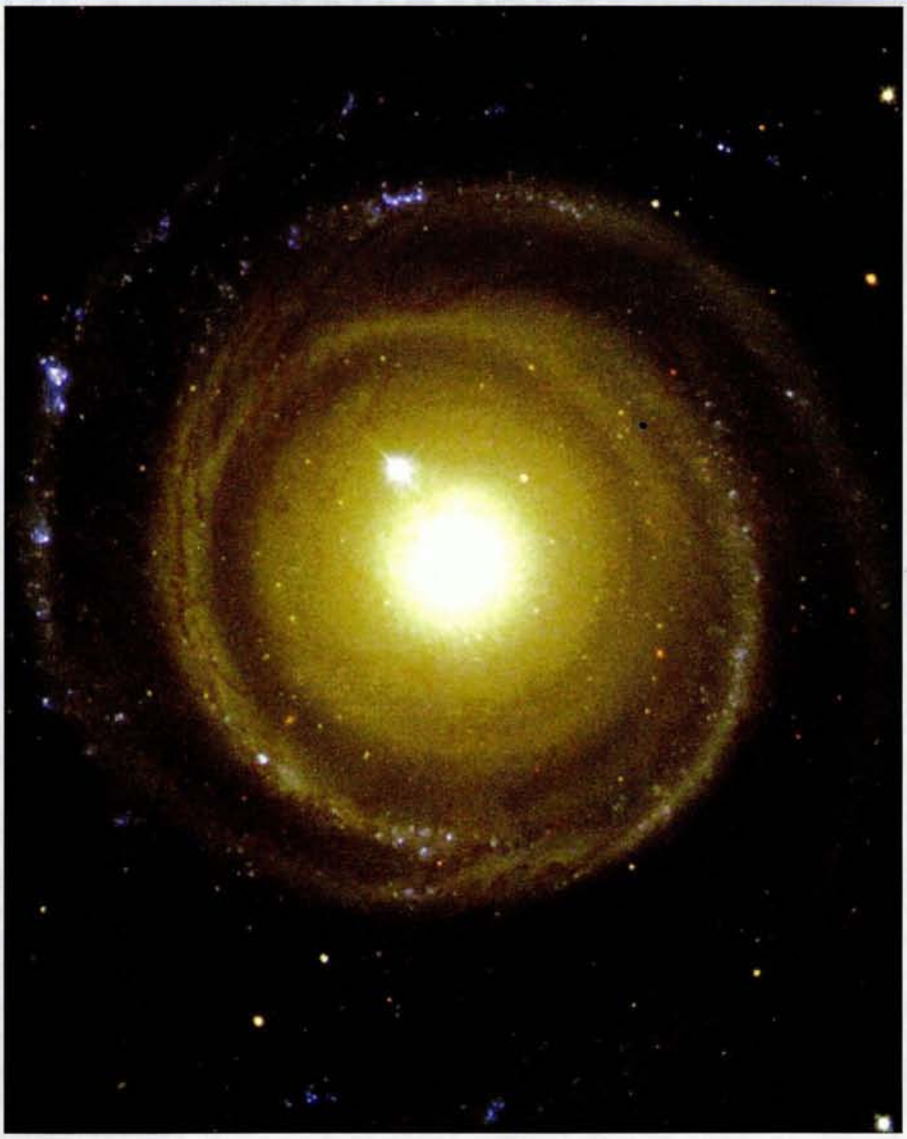
The power spectrum of the microwave radiation shows fluctuations in temperature due to sound waves in the early universe. The angular spectrum shows the intensity of these oscillations at different wavelengths. Other experiments have already revealed the first two or three peaks in the spectrum. CBI is now starting to reveal the higher "overtones" and the drop in the spectrum on small angular scales. Within errors, the results confirm the picture of a spatially flat universe with $\Omega = 0.99 \pm 0.12$, where Ω is the ratio of matter in the universe to the critical level needed to halt the universe's expansion.

CBI can also be used to observe the Sunyaev-Zel'dovich scattering of background radiation photons by the hot electrons in clusters of galaxies. Measurements of this effect can be used to study the properties of the hot cluster gas and the evolution of clusters, and to give a measure of the Hubble constant.

Reference

J L Sievers *et al.* (submitted May 2002) *Astrophys. J.*

Picture of the month



This spiral galaxy appears to be spinning backwards. Most spiral galaxies have arms of gas and stars that trail behind as they turn. In this case, the outer arms are "leading" – pointing in the direction of the clockwise rotation of the galaxy. This strange effect probably results from a past collision with another galaxy. (ESA/NASA Hubble Space Telescope.)

The B-ology of physics

The physics of B particles, containing the fifth (b) quark, is now a major research focus. The first such particle was discovered at Fermilab exactly 25 years ago.

A quarter of a century ago, particle physicists were accustomed to making a major discovery more or less every year. Some of the greatest drama was provided by the highly unexpected announcement of the J/psi particle in 1974 – the "November Revolution". After the initial amazement had died down, physicists learned that nature contained a fourth "charm" quark that augmented the traditional up-down-strange triplet.

However, even before this discovery, Makoto Kobayashi and Toshihide Maskawa had pointed out that more than four quarks were possible. To explain the mysterious violation of CP symmetry, they had suggested that six types of quark could be present. And so it came to be.

The muon pair spectrometer which discovered the upsilon resonances at Fermilab in 1977. (Fermilab Visual Media Services.)

But in 1974, many physicists had trouble digesting a fourth quark, and initially paid little attention to a call for any more. In the newly-extended four-quark picture, the charm quark was paired with the strange quark to form a second doublet, a heavier counterpart of the up-down pair which make up the protons and neutrons of stable nuclear matter. These two quark doublets could also be associated with two then-known electrically charged weakly interacting particles (leptons), the muon and the electron. The muon, being heavy, went with the heavier charm-strange quark pair, while the electron was associated with the lighter doublet.

Then, in the mid-1970s, a group led by Martin Perl working at the SPEAR electron-positron collider at the Stanford Linear Accelerator Center (SLAC) discovered a third electrically charged lepton, the tau, which was much heavier than the muon. It took time for the idea to be accepted, but a third charged lepton called for a third doublet of quarks, making the sextet suggested by Kobayashi and Maskawa.

Talk of heavier quarks became commonplace, and the shadowy third doublet was called either "top" and "bottom" (reflecting the "up" and "down" of everyday quarks) or "truth" and "beauty" by the more romantic. (The "top" label has now eclipsed "truth", but "beauty" and "bottom" are both widely used. In either case the labels of the third quark doublet can be abbreviated to "t" and "b".)

The first awareness that leptons could be served in different ways had come with Lederman, Schwartz and Steinberger's 1962 neutrino beam experiment at Brookhaven, which showed that neutrinos (electrically neutral leptons) come in two kinds – one associated with electrons, the other with muons. (Describing this discovery in the March 1963 issue of *Scientific American*, Lederman wrote: "These days, the discovery of a new elementary particle is scarcely news...")

Neutrino beams became a new physics tool, and one idea was to use them to uncover the W and Z carrier particles of the weak force, which are analogous to the photon carrier of electromagnetism. The signature of a W, the charged carrier of the weak force, would then be a pair of oppositely charged leptons (electrons or muons). This search soon bypassed the need for a neutrino beam altogether, and focused instead on the production of charged lepton pairs at high energy.

The upsilon

The W was not found via this route, but in the late 1960s Lederman's team at Brookhaven uncovered a bump in the spectrum of muon pairs. The reason for this mysterious effect was not immediately clear, but Lederman's curiosity was aroused. Physicists had learned that charged lepton pairs (either muons or electrons) could be a pointer to other photon-like particles, created in the annihilation of quarks and antiquarks deep inside subnuclear processes.

In this way, Sam Ting codiscovered the J/psi particle at Brookhaven in 1974. This, with a parallel experiment by Burt ▷

Left: in the 1990s, Cornell's CESR electron–positron collider became a focus for the physics of particles containing the b quark. Right: Leon Lederman's insistent study of muon pairs led to the discovery of a fifth kind of quark. (Fermilab Visual Media Services.)

Richter at SLAC's SPEAR ring, catalysed the November revolution. The J/psi is a tightly bound charmed quark-antiquark pair.

Having missed out on the J/psi discovery, which earned a Nobel prize for Richter and Ting, Lederman diligently continued his study of muon pairs, this time in a new energy domain using the Fermilab synchrotron. An initial sighting near 6 GeV triggered a discovery action plan, with the Greek letter upsilon being reserved for a possible new particle. This signal went away, but in 1977, muon pairs began to accumulate at 9.5 GeV. This time it was a new particle.

The upsilons (on close examination, there were several of them) are b quark-antiquark pairs, in the same way that the J/psi is made up of a charmed quark and antiquark. Unlike the J/psi, the upsilon was not discovered via the electron-positron annihilation route, as in 1977 no electron-positron collider had enough energy. Nearest in energy was the DORIS machine at DESY, Hamburg, and following the upsilon news the DORIS beam energy was turbocharged in a crash programme. By the following summer, the PLUTO and DASP detectors at DORIS had seen their first upsilons.

The lightest upsilons are tightly bound and therefore cannot decay into their component b quarks. The next collider to arrive on the B physics scene was Cornell's CESR electron-positron collider, which came into operation in 1979, and with its higher energy could reveal a full array of upsilon resonances. By the following year, the CLEO and CUSB detectors at CESR were seeing the first B particles (containing the b quark) produced via the decay of the heaviest (4S) upsilon.

For the next few years, these detectors, together with the ARGUS detector at DORIS, were major players in B physics, which went on to become mainstream science at major machines all over the world. In a major effort, the spectroscopy of B particles took shape, and the parameters of the b quark were documented.

In the 1970s, the economical SPEAR electron-positron collider at SLAC showed how effective these machines could be. Bigger colliders - PETRA and PEP - were proposed at DESY and SLAC, respectively. Even bigger was the TRISTAN machine at the Japanese KEK laboratory. Unfortunately, the energy ranges covered by these machines were not as rich in discovery potential as SPEAR's had been.

B-factories

The next chapter in the B physics saga is being written by a pair of new high-intensity machines which mass-produce B particles - PEP-II at SLAC and KEKB at KEK. Proposed in the mid-1990s, these machines are now making their first precision measurements (*CERN Courier* May p6), and provide the right conditions to explore CP violation in a new setting - B physics. The wheel has turned full circle - after providing the first indication that a third generation of quarks exists, CP violation is now being measured using those quarks.

Eclipsed by the new B-factories after making a decade of milestone contributions, notably with a line of CLEO detectors, the CESR machine at Cornell stopped for B physics in 2001. The physics of b quarks is far from being fully understood, and major mysteries remain. For the future, B physics will continue to be a major focus, notably at Fermilab's Tevatron collider and with the LHCb detector at CERN's LHC collider. (The "top" or t quark, the companion of the b quark in the third quark doublet, and the heaviest quark of all, was discovered at Fermilab in 1995, giving that laboratory a proprietary interest in the heaviest quark pair.)

Gordon Fraser, *CERN.*

Twenty years

The 20th anniversary of B physics in 1997 was marked by a symposium at the Illinois Institute of Technology in Chicago, US. The proceedings of this meeting, edited by Ray Burnstein, Daniel Kaplan and Howard Rubin, and published in the *American Institute of Physics Conference Proceedings Series* (Volume 424), provide a valuable pointer to early developments in B physics. Its title – "Twenty Beautiful Years of Bottom Physics" – underlines the continuing confusion about what to call the fifth (b) quark.

CERN workshop studies electron clouds

Clouds of electrons triggered by synchrotron radiation or by seed electrons created by ionization of residual gas are likely to set performance limits on high-intensity particle storage rings like the forthcoming Large Hadron Collider. A recent workshop hosted by CERN examined the phenomenon.

Some 60 participants from 17 institutes took part in the electron-cloud workshop at CERN in April.

By replacing its Large Electron Positron collider with a proton–proton collider, CERN will be able to generate much higher energy collisions for physicists to examine. The amount of energy lost to synchrotron radiation by particles on curved paths decreases with the mass of the particles, and is therefore much less for protons than for electrons. Synchrotron radiation nevertheless poses a problem for designers of high-intensity proton accelerators, since although the energy loss is less, the number of photons emitted can actually be higher and their energy increases with the cube of the beam energy. These photons can lead to a number of undesirable phenomena, including heating and gas desorption from the vacuum chamber walls. Perhaps the most difficult to deal with, however, is photoemission of electrons from the vacuum chamber, which at 7 TeV in the Large Hadron Collider (LHC) is the dominant mechanism of electron generation and can lead to the establishment of an electron cloud that can cause beam deterioration.

Electron-cloud phenomena have been observed at many accelerators around the world, including CERN where LHC-type beams in the proton synchrotron and super proton synchrotron (SPS) have generated clouds. In the LHC bending arcs at full energy, the process begins with synchrotron radiation photons emitted in a narrow band striking the outside wall of the accelerator's vacuum chamber. The majority liberate electrons, which are turned back by the dipole magnetic field and reabsorbed. Some photons, however, are reflected and go on to liberate electrons from the top or bottom of the vacuum chamber. These electrons are accelerated by the charge of a passing bunch of positively charged particles and can go on to free further low-energy electrons from the opposite wall of the chamber. If a sufficiently large fraction of low-energy electrons survives long enough, successive passing bunches lead to a runaway effect known as multipacting, which generates the electron cloud.

A copper-coated beam screen will be installed within the ▷

vacuum chamber of the LHC (*CERN Courier* July/August 1999 p29). This serves to carry away heat, and also controls the electron cloud in the dipole magnets by limiting the number of reflected electrons. The pressure increase caused by the electron cloud, its impact on beam diagnostics and, for the LHC, the heat load on the beam screen and cold bore are further primary concerns. Surface conditioning by electron bombardment will rapidly lower gas desorption and secondary electron yield of the beam screen surface. When electron multiplication is sufficiently reduced, it will no longer compensate for electrons lost between two successive bunches, and there will be little or no build-up of the electron cloud. This principle has recently been demonstrated at the SPS.

Future machines

The CERN workshop brought together some 60 participants from 17 institutes to discuss electron-cloud simulations for proton and positron beams. Simulations for future linear colliders and intense proton drivers suggest that in these machines, electrons in the vacuum chamber may reach densities some 10–100 times higher than in existing machines. Workshop participants reviewed a number of simulation codes that have been developed using different approximations and including different physics. Key aims of the meeting were to review current analytical, simulation and modelling approaches to the electron-cloud problem, determine the important outstanding questions, and develop a strategy for future studies. Reports on the current status of experimental observations worldwide served as a motivation and benchmark for the simulation studies.

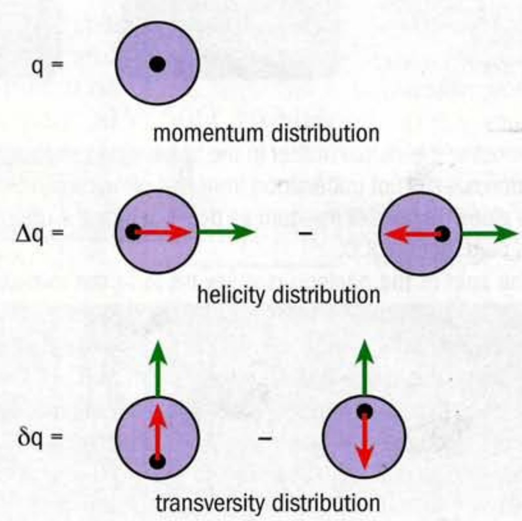
Experimental work carried out at many different laboratories in Europe, Japan and the US was reported in the two opening sessions of the workshop. Results from laboratory measurements of secondary electron emission and electron energy spectra – an invaluable input for the electron-cloud modelling – were also discussed. Presentations on simulations of electron-cloud build-up and associated beam instabilities included the physics models that form the basis of existing simulation codes, simulation results and comparisons of simulations and observations. Two sessions concentrated on future studies, including plasma physics approaches, and on possible remedies to electron-cloud problems.

Summarizing the workshop, Weiren Chou of Fermilab highlighted the need to strengthen international collaboration on electron-cloud effects. A tangible result of the workshop was the establishment of a few key contact people who have agreed to coordinate future worldwide activities related to laboratory measurements, theoretical approaches and simulation-code comparisons. Details are available at http://slap.cern.ch/collective/ecloud02/.

Francesco Ruggiero, **Giovanni Rumolo** *and* **Frank Zimmermann**, *CERN*.

Nucleon insights: echoes from QCD-N'02

A recent workshop on the nucleon has pinpointed near to mid-term goals for QCD hadron structure physics. **Nicola Bianchi** and **Rainer Jakob** report.



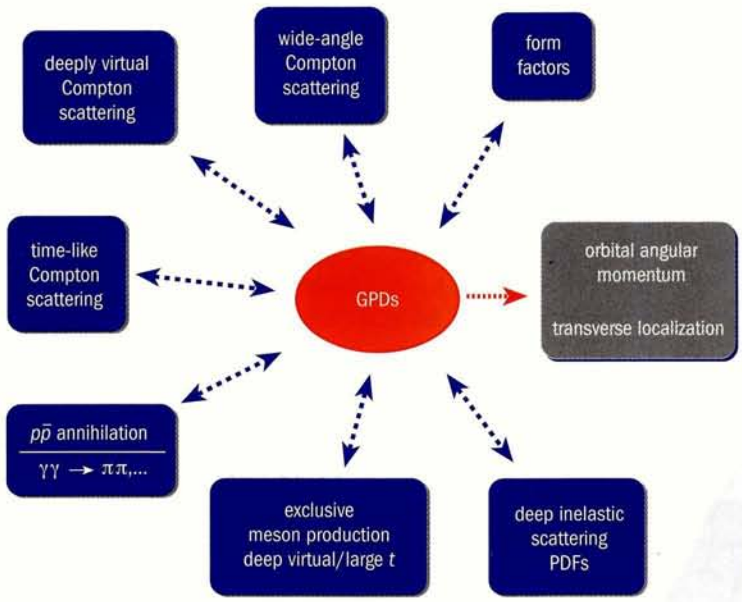
Left: Enzo De Sanctis and Wolf-Dieter Nowak, co-chairs of the Ferrara workshop's international organizing committee. Right: the three leading distributions of quarks within a nucleon. The momentum and helicity distributions are well measured, but for a full description of nucleon structure, the still unknown transversity is also required. The green and red arrows indicate nucleon and quark spin orientation.

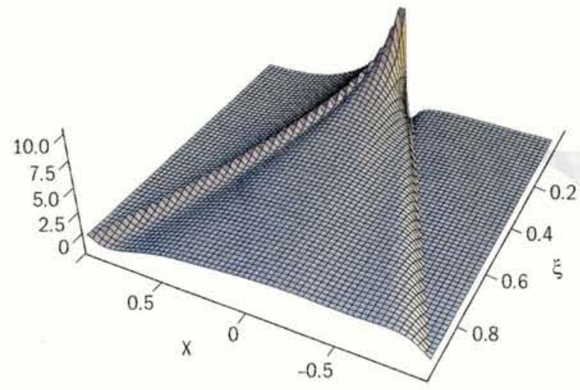
Exploration of the internal structure of the nucleon has reached a new stage. The international community of physicists studying hadron structure with electromagnetic probes has identified the main aims and goals for the near and mid-term future. This was the conclusion of the European Workshop on the QCD Structure of the Nucleon (QCD-N'02), which was held at the splendid Castello Estense in Ferrara, Italy, in April. Some 120 theorists and experimentalists reached a remarkable level of agreement on the hot new topics in the field, and on the avenues and strategies that need to be followed to unravel the inner structure of hadrons. This consensus has been translated into the "Declaration of Ferrara", which has already been signed by many scientists interested in the future of hadronic physics.

Paola Ferretti Dalpiaz of Ferrara, Enzo De Sanctis of Frascati and Wolf-Dieter Nowak of DESY chaired the workshop, at which some 60 presentations focused on the issues of new distributions and fragmentation functions, generalized parton distributions and exclusive reactions, diffraction, nuclear effects and lattice quantum chromodynamics (QCD). A special session and a panel discussion, led by Peter Kroll of Wuppertal and Dirk Ryckbosch, spokesman of DESY's HERMES experiment, was devoted to future facilities and measurements.

Hadronic origins

Several speakers emphasized the fact that the fundamental question of the origin of hadronic matter calls for a better understanding of the phenomenon of confinement in strong interactions. After all, only about 2% of the mass of the nucleon can be assigned to current quark masses, which are expected to be explained by the Higgs mechanism. The major part of the mass of hadrons is likely to originate from massless gluons – in other words from binding effects of strong interactions. The inner structure of nucleons, which make ▷





Left: generalized parton distributions (GPDs) provide a unique framework for describing many different hard processes and accessing new fundamental observables such as quark orbital angular momentum. Above: a typical GPD model of quark and antiquark distributions. (Marc Vanderhaeghen, Mainz.)

up most of the visible matter in the universe, as well as that of other hadrons, is still not understood from first principles in terms of quark and gluon degrees of freedom as described by the underlying quantum field theory, QCD.

The spin of the nucleon is a key issue in the investigation of its structure. It has been confirmed that the nucleon's quark and antiquark constituents carry only 20–30% of its longitudinal spin. The rest is provided by the polarization of gluons and by the orbital angular momenta of quarks and gluons. First indications on the sign and size of the gluon polarization have been seen by the HERMES experiment, and precision measurements are on the way from COMPASS at CERN, and in the US from RHIC-spin at Brookhaven and E-161 at SLAC. However, another fundamental piece of the puzzle is still missing for the full picture – to complete our knowledge of nucleon spin we have to consider a situation where the nucleon spin is oriented perpendicularly to the direction of its motion. The associated distribution function is dubbed "transversity", and has recently been the subject of major theoretical and experimental efforts. The difficulty with measuring transversity is related to its unusual spin property (it is a chirally odd function), which requires the occurrence of a second object with a similarly unusual spin property in an observable. It can be measured by looking at final-state hadrons in semi-inclusive experiments (where particles in the final state are studied), which involves additional fragmentation functions that help to describe certain spin-related aspects of hadronization. These new fragmentation functions are not only indispensable tools for the extraction of transversity, but are also of interest in themselves, since they bear witness to how confinement comes about. The use of the nuclear medium as a "fermiometer" to understand the scales and the dynamics of the hadronization processes of quarks was pointed out at the workshop. Information from the clean process of lepton–nucleus scattering is also needed for a better understanding of the hadron yield and spectra produced in heavy-ion reactions.

The complexity of the task of mapping transversity requires the interplay of different and highly complementary measurements. A strong combined effort in this direction was presented as a major part of the programme of HERMES, COMPASS, RHIC-spin and BELLE at Japan's KEK laboratory.

Transverse localization

Physicists have realized in the last few years that there is more to learn about nucleon structure from exclusive reactions. The advent of new fundamental and conceptual ideas, the so-called generalized parton distributions (GPDs), has triggered enormous theoretical and experimental activity. GPDs provide a unified description of exclusive (where all produced particles are studied in conjunction with the incident particle) and inclusive (averaged over all final states) hard reactions. Moreover, the formalism of GPDs has a sound basis in QCD and relies on formal factorization theorems.

Discussion on GPDs was initiated by the exciting possibility of accessing the orbital angular momentum contribution of the nucleon's spin, which is so far completely unknown. A qualitative new feature of GPDs is that they allow insight into the transverse structure of the nucleon. Inclusive deep inelastic scattering processes probe the ordinary momentum distribution of the nucleon. Exclusive reactions, on the other hand, allow the distribution to be probed as a function of the distance of a quark or gluon from the centre of mass of the nucleon. In other words, this effectively enables nucleon tomography, since by combining information from different measurements the nucleon can be scanned in transverse slices.

Encouraging first results along these lines from the H1, ZEUS and HERMES experiments at DESY, and from CLAS at Jefferson Lab in the US were presented at the workshop. These are in general agreement with more recent GPD expectations, and so have demonstrated the feasibility of proposed future measurements. Moreover, the emerging interest to link the classical diffractive description of exclusive processes at high energy with the GPD description of exclusive processes will require precise measurements over a broad kinematic range.

Moments of the transversity distribution and of the generalized parton distributions are among the quantities amenable to lattice gauge calculations. For example, results on the lowest moment of transversity, the so-called tensor charge, were reported. The strongly QCD-inspired instanton model calculations also provide verifiable predictions. These are very promising ways to link phenomenological observations to first principle theoretical considerations.

The Declaration of Ferrara

After presentations of current exploratory studies and discussions of new ideas, workshop participants concluded that future dedicated facilities are needed. This led to the view of a large community of European hadron structure researchers being expressed in the Declaration of Ferrara.

It has become clear that in-depth studies of the energy, momentum and spin-dependence of exclusive cross-sections cannot be performed with the current generation of accelerators and spectrometers, but require substantial advances in experimental facilities and techniques. This is mostly due to luminosity, duty-cycle and kinematic resolution limits, since the most interesting reactions are rare and have large backgrounds. High experimental precision can only be accomplished with luminosities of at least $10^{35}\ cm^{-2}s^{-1}$, requiring an accelerator with a duty cycle of 10% or more. Beam energies of 25–50 GeV are needed to cover a kinematic range suitable for extracting cross-sections and their scale-dependence in exclusive measurements. For non-exclusive studies of hadron structure, the optimal beam-energy range is 50–100 GeV. The highest possible polarization of beam and targets is required in both cases. Large-acceptance detector systems with high-rate capabilities and with a mass resolution of the order of a third of the pion mass, essential for the measurement of exclusive channels, will also lead to a new quality of meson and baryon spectroscopy in lepton-nucleon scattering.

Several scenarios for a new generation of precision experiments to study QCD with electromagnetic probes are being studied in Europe and the US. Collider and fixed-target options are fully complementary, since the former cover a wider kinematic range and the latter provide considerably higher luminosities. The fixed-target option, favoured by European scientists, can be technically realized in a cost-effective way based upon the technology being developed for future linear colliders, especially if existing or projected infrastructure can be used.

The conclusion of the workshop was that in order to keep Europe's leading role in studying hadron structure and QCD at all scales with energetic electromagnetic probes, a new fixed-target facility with a high duty cycle providing polarized beams in the energy range 25–100 GeV is needed.

Further reading

The full text of the Declaration of Ferrara and a call for support can be found at http://www.fe.infn.it/qcd-n02/.

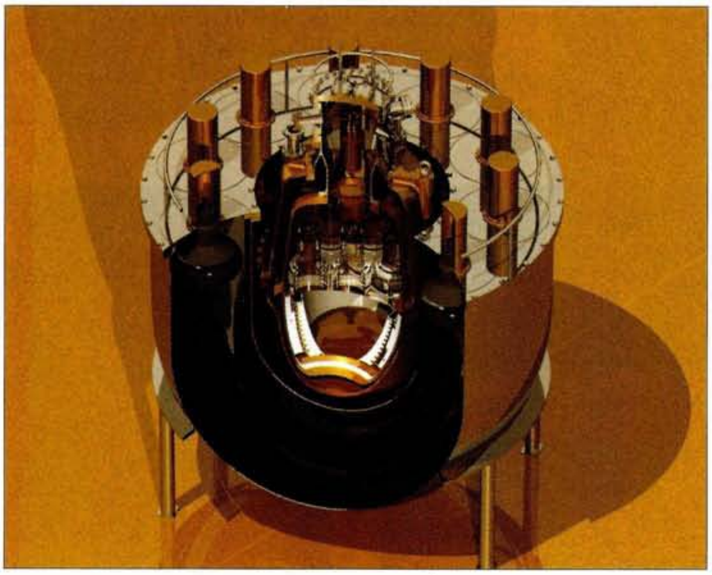
Nicola Bianchi, *INFN Frascati, and* **Rainer Jakob**, *University of Wuppertal.*

Symposium aims to uncover dark secrets

The 5th Symposium of Sources and Detection of Dark Matter and Dark Energy in the Universe, held in February at Marina del Rey, California, focused on the current state of detection and theoretical studies of dark matter particles. Meeting organizer David B Cline reports.

The universe around us is nothing like it looks. The stars make up less than 1% of the matter in the universe; while all the gas and other forms of baryonic matter account for less than 5%. We know little about the other 95% except that it is probably divided into 35% cold dark matter and about 60% dark energy.

Dark energy is detected by the recent acceleration of the universe and is observed by the study of type 1a supernova sources. A series of symposia have been organized in Southern California for the past 8 years to hear the latest in the developments in this field of particle cosmology. It was at the 1998 meeting that the two teams that have observed the accelerating universe first made a joint announcement of these important results.



An artist's impression of the ZEPLIN II detector being prepared by UCLA and the UK dark matter collaboration for installation in the Boulby potash mine. (Roy M Preece/RAL.)

The particle physics of dark matter is perhaps the most advanced in our understanding of these phenomena. Perhaps the best motivated and best understood form of particle dark matter comes from supersymmetry (SUSY).

This theory gives a "semi-natural" explanation of the amount of dark matter in the universe, which would take the form of weakly interacting massive particles (WIMPs) – the parameters are constrained by data from CERN's LEP experiments and elsewhere. The strong interplay between proposed dark matter detectors and the direct observation of SUSY particles at CERN's forthcoming Large Hadron Collider (LHC) reveals a strong connection between collider particle physics and astroparticle physics.

There was a complete discussion of the current search for SUSY dark matter and future detectors at the meeting. The DAMA experiment at Italy's Gran Sasso underground laboratory continues to claim a signal for SUSY due to an observed annual variation. However, there are now three experiments – Edelweiss at Modane in France, ZEPLIN I at Boulby in the UK, and CDMS I at the Stanford Linear Accelerator Center in the US – that cut deeply into the region allowed by DAMA. These experiments all use some form of background discrimination.

A joint analysis of the CDMS I data at DAMA was claimed to exclude the DAMA signal from a WIMP source to 98% confidence level, even assuming all of the CDMS I events are not neutron-induced. The DAMA group disputes this claim, however. The DAMA experiment is being upgraded and hopefully this dispute will be resolved soon. The current predictions for the rate of SUSY WIMP detectors are nearly all well below the DAMA sensitivity, as was discussed extensively at the meeting.

Bigger machines

It was generally agreed that a new generation of much larger detectors will be needed to provide a clean detection of the SUSY WIMP signal. There are several discriminating detectors in the 10–30 kg mass range being constructed or upgraded such as CDMS II, ▷

Edelweiss and ZEPLIN II. To provide a clear study of the WIMP signal, detectors of the target mass of 1 tonne will be needed, and there are preliminary studies of possible detectors for this mass range. It is truly remarkable that detectors of this great sensitivity are being developed.

Dark energy

The issue of the origin of dark energy is more complex and possibly much more obscure. After the pioneering work of the two teams working on type 1a supernovae, there are projects for two impressive detectors that will to try to identify the equation of state of the dark energy.

The SNAP satellite would observe type 1a supernovae out to a redshift of around $z = 1.5$. The other possibility is to study type 1a supernovae from the ground using a large "dark matter" telescope in Chile called the Large Synoptic Survey Telescope (LSST). It may be that both of these methods will be needed to unravel the equation of state and demonstrate that the effect is either due to a cosmological constant or some other elementary particle-like source.

During the course of the Southern California meetings, a much clearer picture of the bulk of components of the universe has emerged, but we have yet to find any evidence of what this stuff really is

In one of the most interesting talks at the meeting, Paul Stenhardt of Princeton discussed the impact of an accelerating universe on the old question of whether the universe may be cyclic in time. It is possible that an accelerating universe could wipe out the entropy of the universe over a long time and then if the equation of state of the dark energy complies, the universe might contract to a "big crunch". According to this viewpoint, the accelerating state of the universe is actually required rather than being a bizarre add-on to a Friedmann universe as currently held belief would prefer.

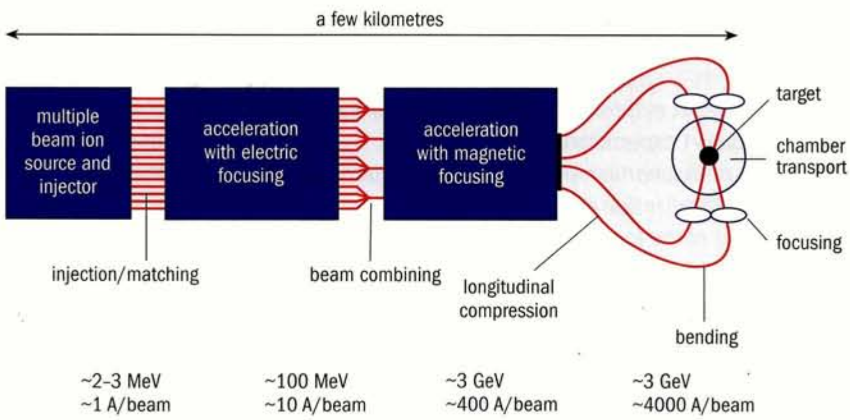
There was considerable discussion of the possibility of self-interacting, warm and hot dark matter (in light of recent claims for the observation of double-beta decay; *CERN Courier* March p5). None of these issues was clarified at the meeting.

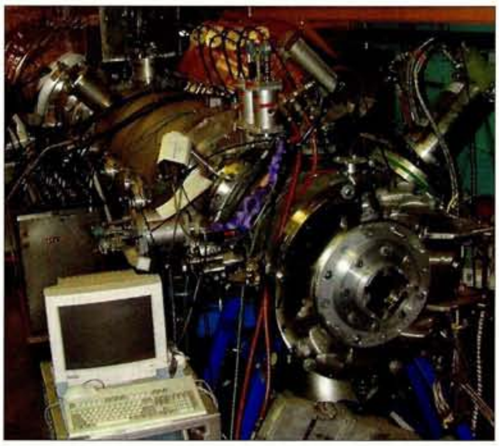
During the course of the Southern California meetings, a much clearer picture of the bulk of components of the universe has emerged, but we have yet to find any evidence of what this stuff really is. Hopefully this will change as the new WIMP detectors underground and new detectors in space start taking data and the LHC is turned on. The next symposium will be held in February 2004 in Marina del Rey.

David B Cline, *University of California, Los Angeles.*

Heavy ions offer a new approach to fusion

Three US laboratories have teamed up to form the Heavy-Ion Fusion Virtual National Laboratory to investigate a novel approach to fusion energy. **Christine Celata** profiles the highly tangible programme of the fledgling virtual lab.





Left: research being carried out at the US HIF-VNL laboratory could result in power stations of the future looking like this. Right: this apparatus at the LBNL saw its first beam in January. It is being used to investigate the physics of high-current beam transport.

In the mid-1970s Al Maschke of the US Brookhaven National Laboratory suggested that heavy-ion beams, rather than laser beams, could be used as a driver to implode inertial-fusion targets for the commercial generation of electrical power. The beams would deliver the kinetic energy that would heat the surface of a capsule containing deuterium and tritium, with the resulting ablation driving a compression that causes nuclear fusion. Heavy ions have the advantage that energy deposition is simpler with them than with photons, while much of the accelerator technology necessary has already been demonstrated to have long life, a sufficiently high pulse repetition rate and high electrical efficiency.

In the US, researchers from three laboratories – Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL) and Princeton Plasma Physics Laboratory (PPPL) – have formed the US Heavy-Ion Fusion Virtual National Laboratory (HIF-VNL) to coordinate their work on heavy-ion fusion.

Heavy-ion fusion research is carried out in several laboratories around the world. As well as the HIF-VNL in the US, a high-space-charge electron ring at the University of Maryland will study intense beam physics. Researchers from the Naval Research Laboratory, the Mission Research Corporation, the University of Michigan, the Massachusetts Institute of Technology, the Sandia National Laboratory and the Stanford Linear Accelerator Center are also involved in the US heavy-ion fusion programme. Other efforts aimed at both accelerator physics and studying the interaction of heavy ions with hot matter exist at GSI in Germany; the Tokyo Institute of Technology, RIKEN, Utsunomiya University and Osaka's Institute of Laser Engineering in Japan; Orsay in France; and the Russian Institute for Theoretical and Experimental Physics. This article describes the progress and plans of the HIF-VNL programme.

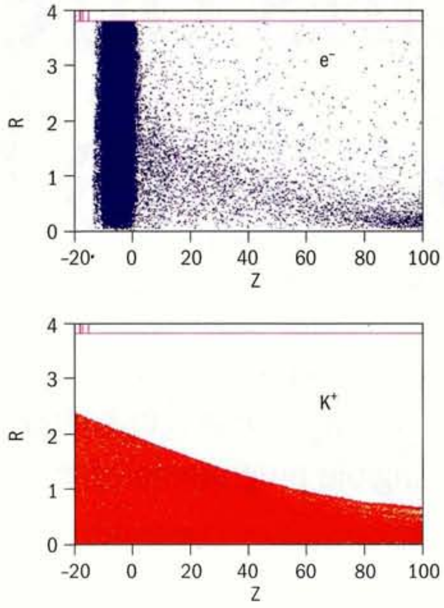
Induction linac drivers

For its driver accelerator the US programme has chosen an induction linac – a linear accelerator that accelerates ions by changing the strength of a magnetic field in magnetic material encircling the beams. The induction cores of such linacs have high efficiency at the high beam currents that fusion demands, and their cost is relatively low. Moreover, electrical losses in induction cores remain effectively constant as the beam current increases, while more and more energy goes into the beam, since essentially the same electric accelerating field is produced. And because linacs are one-pass machines, they are able to stably transport the extremely intense beams that are ▷

necessary to implode the target; around 1–7 MJ must be deposited in approximately 10 ns, corresponding to around 10^{16} ions of mass 200 amu at 3 GeV.

Quadrupole focusing field limits make it very uneconomical to transport such a large amount of charge in a single beam. The approach being followed is therefore to transport multiple (100–200) beams in parallel through a common set of induction cores that would encircle the beam array. Beams from a multiple-beam injector would enter the linac at an energy of about 2 MeV. They would then be accelerated over a few kilometres to a few GeV. Electrostatic quadrupoles would be used for focusing up to about 100 MeV in some designs (see diagram on p23); thereafter focusing would be done by arrays of superconducting quadrupoles.

At the end of the accelerator a coherent "velocity tilt" would be applied, accelerating the tail of the beam more than the head to produce longitudinal compression of a factor of 10–20, shortening the pulse to around 10 ns. The beams would then go through a final focusing system, and transport through the target chamber to the target. The pulse repetition rate would be about 5 Hz, with clearing of the chamber of target debris, molten salt, and gas being the limiting factor. The challenge is to maintain very low emittance, both transverse and longitudinal, in the presence of the beams' high space charge, so that the beams will focus to a spot a few millimetres across at the end of the driver.



Simulations show that electrons in the neutralized transport experiment will follow a positive potassium ion beam, providing 94% neutralization (top). The resultant focusing of the ion beam is shown below.

Beam dynamics in this accelerator are determined largely by space charge – the space-charge depression of the betatron phase advance per lattice period is approximately a factor of 10, so that space charge nearly cancels out external focusing forces. The beams act like non-neutral plasmas, exhibiting normal modes and instabilities not found in single-particle dynamics. Therefore self-consistent particle-in-cell (PIC) time-domain simulations are the main tools used to calculate beam behaviour. In the target chamber the problem is complicated by the need to shield the chamber walls from neutrons, radiation and target debris. Designs include sheets and crossed jets of the neutron-thick molten salt FLiBe (a salt of fluorine, lithium and beryllium) in the target chamber, shielding the walls from these target products. Beams pass through spaces between the jets. FLiBe vapour can then neutralize the beam, helping focusing, but will also strip beam ions, and under some conditions can lead to plasma instabilities. Photoionization of the salt also provides a copious source of electrons near the target after ignition. Modelling in the target chamber therefore requires multi-species, 3D, time-dependent electromagnetic simulation with fully self-consistent space charge.

Experiments at LBNL in the 1980s and 1990s showed that space-charge-dominated beams are stable, and can be accelerated and compressed in an induction accelerator, combined and focused to a spot. A quarter-turn experiment at LLNL demonstrated the bending of an intense beam. These were scaled experiments at up to 1 MeV, with currents of a few tens of milliamps or less. Dimensionless physics parameters were designed to be in the same range as in a driver, so that physics tests were valid. The HIF-VNL programme is now moving to experiments with currents similar to those of a driver beam at low energy (0.1–1 A), so that effects dependent on the beam's electrostatic potential can be studied. The programme currently focuses on three experimental thrusts: the High Current Experiment (HCX); a Neutralized Transport Experiment (NTX); and experiments exploring a new "minibeamlet" injector concept.

New experiments

The HCX at LBNL saw its first beam in January and is in the process of commissioning. Its main mission is to investigate the optimum aperture for transporting an intense high-current beam. Since induction cores must encircle the whole array of beams in a driver, the selection of the transverse aperture allotted to each beam can significantly affect driver cost, and therefore design optimization. The HCX programme will investigate the influence on beam propagation and brightness of a range of physics – image forces, mismatch of the beam envelope to the focusing system (which through a resonance can pump ions into a halo), and gas and electrons produced by scraping halo. The HCX is a single-beam experiment, using a drifting 0.2–0.5 A, 1.0–1.8 MeV beam of K^+ ions. Since the beam potential is about 2 kV, beam space charge has a strong effect on electron orbits.

The experiment currently consists of an injector followed by 10 electrostatic quadrupoles. At least four magnetic quadrupoles will be added to study the production and orbits of electrons produced intentionally by beam scraping. Next year up to 30 more quadrupoles will be added to continue the dynamic aperture studies. Finally a small induction core will be used to explore the longitudinal confinement of the beam by tailoring the induction pulse.

Princeton is making a plasma source for the NTX, which is currently at the design stage and will also be at LBNL. Starting in 2003, it will investigate beam physics in the final focus system along with intentional neutralization of the beam after the final lenses. The NTX will consist of a 400 keV injector followed by a four-quadrupole focusing system. A plasma source downstream will study various neutralization methods that could counteract the space charge of the beam, producing a smaller spot at the target. The effects of both a small plasma source upstream of the target chamber and bulk plasma in the target chamber – as would be produced by photoionization of FLiBe – will be investigated. Another important area of interest for the NTX is the correction of aberrations in the final lens system. This is a well known problem for beams with negligible space charge, but the effects of space charge in the HIF case are significant and the prescription for aberration correction is not well understood.

A new concept for an intense beam injector is in the design stage, with an experimental test planned for 2004. The Child–Langmuir law shows that, because voltage limits increase only as (approximately) the square root of the voltage for a large diode, the current density of the beam increases as the current and radius of the beam decrease. Therefore it is theoretically possible to make the injector more compact – a very important feature for a multibeam accelerator – by making each of the accelerated beams with small, very bright beamlets, which merge later in the injector to form a single beam. Arranging the beamlets to match parameters for the downstream lattice can also eliminate the transverse blow-up of the beam in the matching section. The experiment will merge around 100 high-current-density beamlets of 1–2 mm radius near the end of the injector to make a single 0.5 A, 1.6 MeV heavy-ion beam. 3D PIC simulations project the emittance to be similar to that of beams from a standard large diode. The beamlet-merging idea has already been used in neutral-beam-heating accelerators for tokamaks, but in that case protons were used and emittance was not important.

Once the experiments are completed, the programme will be ready for a source-to-target experiment that integrates all the beam manipulations needed in a driver. A workshop held in October 2001 chose the overall design parameters for an Integrated Beam Experiment (IBX). The IBX is envisioned as a single-beam experiment, possibly upgradable to more beams, with final energy in the 10–20 MeV range. It will incorporate almost all of the physics of the driver (and much engineering at full scale), the exceptions being in the areas of beam-target physics, multiple-beam interactions and high-energy effects such as self-magnetic and inductive effects. In particular, the experiment will be able to study longitudinal beam dynamics, including wave motion on the beam, halo formation and beam heating over intermediate transport lengths, the bending of space-charge-dominated beams, and self-consistent final drift compression, final focus and neutralization.

Looking ahead, the HIF-VNL envisions an Integrated Research Experiment of a few hundred MeV that carries arrays of multiple beams all the way to the target and is capable of beam-target studies. All this is taking the accelerator aspects of heavy-ion fusion research in the US from exploration of the concept through to proof of principle.

Further reading

News from the HIF-VNL is at http://hifnews.lbl.gov/.

Christine Celata, *Lawrence Berkeley National Laboratory.*

Cosmic-ray observatior

Some 50 people attended the NEEDS workshop in Karlsruhe in April to discuss how accelerator experiments can help in understanding cosmic-ray data. The meeting brought together experimentalists and theorists from the accelerator and non-accelerator areas. **Lawrence Jones** reports.

Some 50 particle and cosmic-ray physicists got together in Karlsruhe to

The Karlsruhe Forschungszentrum is the home of several of the most active theorists and Monte Carlo modellers in cosmic-ray physics. It is also the site of the densely instrumented KASCADE cosmic-ray air-shower array, which has produced some of the most definitive data for energies below 100 PeV (1 PeV = 10^{15} eV). Karlsruhe was therefore an obvious venue for the Needs from Accelerator Experiments for the Understanding of High-Energy Extensive Air Showers (NEEDS) workshop, organized by Hans Bluemer, Andreas Haungs and Heinigerd Rebel of Karlsruhe, and Lawrence Jones of the University of Michigan.

Physicists generally understand that cosmic rays with energies up to about 1 PeV are produced by shock acceleration in supernovae. At energies up to around 10^{14} eV, their composition is similar to that of stars, with minor and well understood differences – for example additional lithium, beryllium and boron from spallation of carbon nuclei on interstellar nuclei. The differential spectrum falls steeply with energy as about $E^{-2.7}$. At higher energies, however, it is unclear what the acceleration mechanism is – it is difficult to provide the required energy from supernovae shocks. Furthermore, there are indications that the composition changes, with heavier primaries becoming relatively more abundant. There is also a change in the slope of the spectrum, steepening to about E^{-3} at about 3 PeV. This corresponds to the momentum range where particles may escape confinement in the microgauss-level galactic magnetic fields.

Astrophysicists are interested in learning about the sources, composition and energy spectrum of the cosmic rays extending to energies above 10^{20} eV. Below about 10^{14} eV, the spectrum and composition are well known from direct observation with sophisticated detectors flown on balloons and earth satellites. However, at energies above 1 PeV, the flux is only about 100 particles per square metre per steradian per year – too low for useful direct observation. Consequently, everything we know at such energies is based on ground-level observations of air showers of electrons and photons with coincident hadrons and muons. Properties such as their densities, radial distributions, energy distributions and dependence on depth in the atmosphere can be interpreted in terms of the primary cosmic-ray energies and nuclear mass numbers.

Such interpretations of ground-level observations are heavily dependent on Monte Carlo simulations of the primary interaction in the upper atmosphere and the evolution of the resulting particle cascade. The cascade is dominated by lower-energy phenomena that are reasonably well understood. However, the primary and early subsequent interactions involve energies up through the PeV range, and existing Monte Carlos are almost entirely based upon data from fixed-target accelerator experiments below 1 TeV. A sense of the confusion that currently exists is clear on a plot showing the average of the logarithm of the nuclear mass number of the primary cosmic rays versus energy (figure 1).

Small angle measurements

Fermilab's Tevatron Collider provides proton–antiproton collisions at a centre of mass energy approaching 2 TeV, equivalent to a cosmic ray of about 2 PeV incident on a stationary proton. Brookhaven's Relativistic Heavy Ion Collider (RHIC) provides energies of more than 100 GeV per nucleon in beam–beam collisions of nuclei. For exam-

ns need accelerator data

discuss the accelerator-based needs of cosmic-ray research.

NEEDS'02 conference participants visit the KASCADE array.

ple, a nitrogen–nitrogen collision at RHIC is equivalent to a 5×10^{14} eV cosmic-ray nitrogen nucleus incident on an air nucleus. CERN's Large Hadron Collider (LHC), with collisions of 14 TeV in the centre of mass, will provide energies equivalent to a proton of about 10^{17} eV incident on a stationary proton. The LHC will also produce nucleus–nucleus collisions.

The current generation of colliders plus the LHC will, in principle, be able to provide the data for the refinement of Monte Carlo models to provide a less ambiguous interpretation of cosmic-ray air-shower data. However, most accelerator studies are made with detectors that do not cover angles within one or two degrees of the beamline. Since it is within such small angles that most of the final-state energy flow occurs, this is the region that dominates air-shower observables. About 80% of the final-state energy flow in the Tevatron, for example, is estimated to be within a 28 mrad cone centred on the beam. For the LHC, this figure is 95%.

If a 2 PeV primary proton collides with an air nucleus and continues with half its initial energy, acquiring 200 MeV/c transverse momentum in the collision, it makes an angle of only 0.2 μrad with its initial direction. The equivalent Tevatron process is a TeV proton colliding with an antiproton and scattering at an angle of 0.4 mrad, well within the cone that is unobserved by detectors. This is a typical final state of interest in the calculation of air-shower development, and it is here that measurements are needed. The average value and distribution of inelasticity (1 minus the fraction of the incident energy carried by the most energetic final state hadron) in a nucleon–nucleon collision and its distribution are also quite uncertain, and vary among current Monte Carlo models. A highly inelastic interaction of a high-energy cosmic-ray proton could produce ground-level observables indistinguishable from those from a low-inelasticity first interaction of a heavier primary nucleus of the same energy.

The Karlsruhe group has developed CORSIKA, an elegant Monte Carlo code for simulating air showers. One input to this code is the physics of the first interaction of the primary cosmic ray with an air nucleus, and several codes have been developed for that simulation. It is here that the problems arise.

Markus Risse, Gerd Schatz and Andreas Haungs from Karlsruhe, and Johannes Knapp and Markus Roth from Leeds, among others, discussed results from KASCADE, from air-shower and emulsion experiments at mountain elevations, and from other observations, citing their comparisons with various Monte Carlo models. In general, none of the models fit the data as well as could be hoped for. It was encouraging, however, to learn that the models have been tuned recently to improve their agreement with data. Eugene Loh of Utah discussed events of over 10^{20} eV, the highest energy observed, with the Fly's Eye technique, and Oscar Saavedra of Turin discussed unusual cosmic-ray events observed at 5200 m on Bolivia's Mount Chacaltaya.

The status of Monte Carlo models and their varying degrees of success in simulating observations was discussed by Dieter Heck ▷

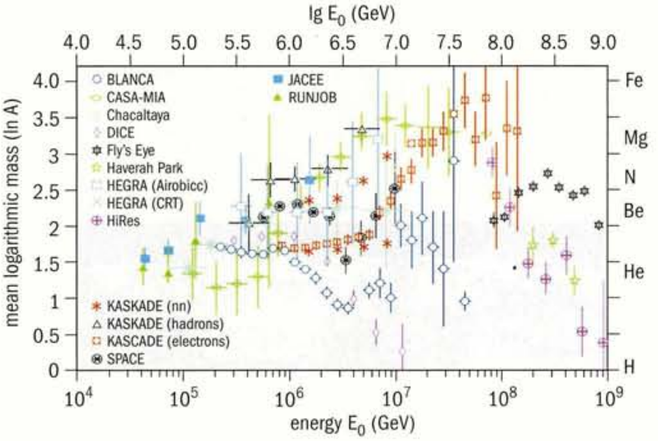


Fig. 1. The scatter of points on a plot of the average logarithm of the nuclear mass number of the primary cosmic rays versus energy clearly shows the need for more input from accelerators.

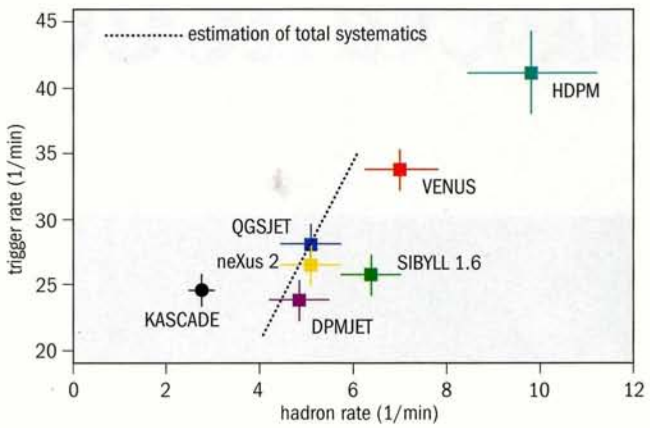


Fig. 2. Trigger rates are just one area where current Monte Carlo models fail to agree. This plot compares data and Monte Carlo for hadron event rates versus trigger rates in the 320 m^2 KASCADE hadron calorimeter.

and Sergej Ostapchenko of Karlsruhe, Ralph Engel and Todor Stanev of the University of Delaware, Hannes Jung of Lund, Jean-Noel Capdevielle of the College de France, and Giuseppe Battistoni of Milan. Following these discussions, the accelerator experiments relevant to these questions were described. Speakers included Andrei Rostovtsev and Martin Erdmann of DESY, Damian Bucher and Johannes Ranft who discussed Brookhaven's RHIC, Valeria Tano of Fermilab, and Stefan Tapprogge and Aris Angelis who discussed projects in preparation for the LHC. Lower-energy fixed-target experiments at the three laboratories, with beams of 5–120 GeV, were also discussed. Kai Zuber and Giles Barr presented the CERN's HARP experiment. Brett Fadem of Iowa State University discussed Brookhaven's E941, and Carl Rosenfeld of the University of South Carolina presented Fermilab's main injector particle production (MIPP) experiment, all of which measure particle production cross-sections that are valuable for high-energy cosmic-ray work.

Priority list

A primary objective of the workshop was to develop a priority list of desired accelerator measurements that could be used to reconstruct cosmic-ray interactions in Monte Carlo models much more accurately than is currently possible. These would significantly improve the interpretation of cosmic-ray observations. The highest priority is to obtain inclusive final state spectra for protons, neutrons, charged pions, neutral pions and charged kaons from proton-proton (or proton-antiproton) interactions over the range $0.1 < x < 1.0$, where x is the ratio of the longitudinal momentum of the final-state hadron to its kinematic maximum. These data would be desirable over the energy ranges spanned by RHIC, the Tevatron and the LHC. Similar data from RHIC and the LHC would be desirable from proton-nitrogen collisions, representing proton collisions with air nuclei. Inclusive final-state data from nucleus-nucleus collisions would also be useful. The primary cosmic rays of interest range up to iron, so data from iron-nitrogen collisions would be very interesting. Total cross-sections and total inelastic cross-sections for proton-proton, proton-nucleus and nucleus-nucleus collisions are highly desired, particularly for nitrogen. Pion-proton and pion-nucleus inclusive final state data would be useful, although such measurements are limited to fixed-target sub-TeV energies for the foreseeable future. The lower-energy data from the HARP, MIPP and E491 experiments will also be valuable for tuning CORSIKA and other Monte Carlos that model the atmospheric cascade.

Loh's contribution to the priority list concerns the use of the Earth's atmosphere as a calorimeter. The air scintillation technique used in the Fly's Eye detectors is quite well understood, but the fraction of the total energy of the incident cosmic ray that does not appear as ionization is based on educated guesswork. It would be very useful to know better what fraction of the total incident energy is invisible to the air scintillation observations, taking the form of neutrinos, high-energy muons that lose most of their energy in the earth and nuclear binding energy, for example.

The final item on the list came from the Karlsruhe group, who would like to see spectra dependent on centrality (how close to head-on the collisions are). Such data would make microscopic knowledge of interaction mechanisms possible, rather than the currently available data averaged over all impact parameters.

Although not on this accelerator priority list, Saavedra, Jones and others noted the desirability of locating an air-shower detector array with the complexity and sophistication of KASCADE at high mountain elevations.

The workshop concluded that two elements are of primary importance; stronger links between the accelerator and cosmic-ray high-energy communities, and commitment on the part of cosmic-ray physicists to contribute actively to accelerator experiments.

Those who took part in the NEEDS workshop believe that they have taken a step towards realizing these goals.

Further reading

All presentations from the workshop are available at http://www-ik.fzk.de/~needs/.

Lawrence W Jones, *University of Michigan.*

AWARDS

Particle physicists recognized by APS awards

The American Physical Society made a number of awards at its April meeting, held jointly with the high-energy astrophysics division of the American Astronomical Society in Albuquerque, New Mexico.

The W H K Panofsky Prize went to **Masatoshi Koshiba**, **Yoji Totsuka** and **Takaaki Kajita**, all from the University of Tokyo, for "compelling experimental evidence for neutrino oscillations using atmospheric neutrinos".

Gordon Baym of the University of Illinois at Urbana-Champaign received the Hans A Bethe prize for his "superb synthesis of fundamental concepts, which have provided an understanding of matter at extreme conditions, ranging from crusts and interiors of neutron stars to matter at ultrahigh temperatures".

The "pioneering work in the development of superstring theory" of Cambridge University's **Michael Green** and Caltech's **John Schwarz** was recognized by the award of the Dannie Heinemann Prize, given jointly by the APS and the American Institute of Physics.

Alexander Skrinsky, director of the Budker Institute of Nuclear Physics in Novosibirsk, received the Robert R Wilson Prize for his "major contribution to the invention and development of electron cooling and for his contributions to the physics of the electron-positron colliders at the Budker Institute".

Alexander Skrinsky (left), seen here with APS President William Brinkman, was among the recipients of APS awards in Albuquerque in April.

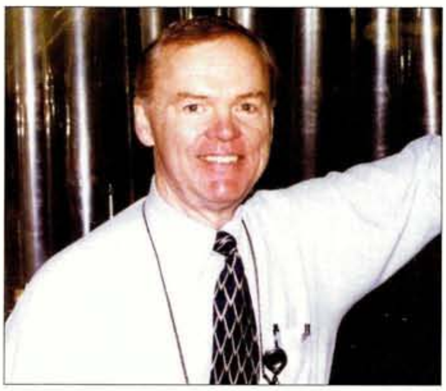
J David Bowman of the Los Alamos National Laboratory received the Tom W Bonner prize for his "leadership in performing precision measurements involving tests of fundamental symmetries, including his studies of parity non-conservation in compound nuclei".

Hampton University's **Oliver Keith Baker** received the Edward A Bouchet prize for his "contribution to nuclear and particle physics; for building the infrastructure to do these measurements; and for being active in outreach activities, both locally and nationally".

Alberto Sirlin of New York University and **William J Marciano** of Brookhaven were awarded the J J Sakurai prize for their "pioneering work on radiative corrections, which made precision electroweak studies a powerful method of probing the Standard Model and searching for new physics".

The Joseph A Burton Forum Prize went to **Adrian Mellott** of the University of Kansas for "his outstanding efforts in helping to restore evolution and cosmology to their proper place in the K-12 scientific curriculum. As a distinguished cosmologist and respected member of the clergy, he played a key role in helping the people of Kansas reverse their State Board of Education's anti-science action".

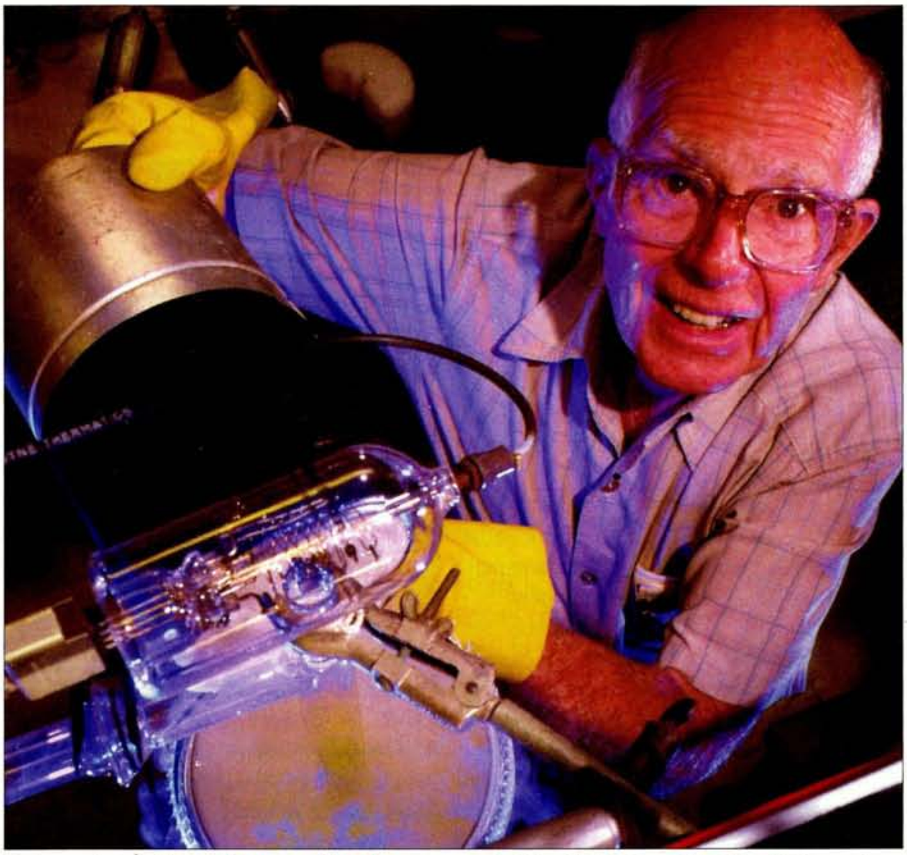
Bruce Knuteson of the University of Chicago won the Tanaka Dissertation award for work on Fermilab's D0 experiment, and **Jiunn-Wei Chen** of the University of Maryland won the dissertation in nuclear physics award. **James Cederberg** of St Olaf College in Minnesota won the prize for a faculty member in an undergraduate institution, and the Leo Szilard Lectureship award went to the president of the federation of American Scientists, **Henry C Kelly**.



The US Jefferson Lab appointed two new directors in April. Lia Merminga (left) assumes the reins of the Center for Advanced Studies of Accelerators, which was founded in 2001 to pursue a broad programme of theoretical and experimental research in accelerator and beam physics. Warren Funk becomes director of a new Institute for Superconducting Radio-Frequency Science and Technology.

Participants in the 30th ITEP and 5th Moscow Winter School of Physics, held outside Moscow in February, wrapped up warm for the traditional group photograph. More than 120 people from 15 countries took part. Lectures from the school are available at http://face.itep.ru/ws2002/.

The Hungarian physics community celebrated the 75th birthday of **George Marx**, a leading figure in Hungarian astroparticle physics, in May. Beyond his personal contribution to the discovery of lepton number conservation in 1953 and the derivation of an astrophysical upper bound to neutrino mass in 1972, Marx played a key role in starting the series of Neutrino Conferences (the first was held 30 years ago at lake Balaton). He was also a key player in establishing the regional cooperation in theoretical particle physics called the Bratislava–Budapest–Vienna Triangle Collaboration at the end of the 1960s. His ceaseless activity in the modernization of the high-school science curriculum is also widely acknowledged in Hungary. The celebrations took the form of a series of lectures on the history and future prospects of cosmology, astrophysics and particle physics. Marx (left) is seen here in discussion with **Rocky Kolb** of Fermilab and **John Ellis** of CERN.



Solar neutrino pioneer **Raymond Davis** was awarded the US National Medal of Science in May. Using detectors deep underground in the Homestake gold mine in South Dakota starting in 1967, Davis was the first to detect solar neutrinos. His measurements revealed only one-third of the neutrinos that standard theories predicted, giving rise to the solar neutrino puzzle, whose solution has only just been confirmed in the form of neutrino oscillation (*CERN Courier* June p5). Davis first read about neutrinos in 1948, and has devoted his life's work to these elusive particles. "Back then," he explained, "neutrino physics was a brand new field, but it has captivated me now for more than half a century. It hasn't been work; it's been fun."

MEETINGS

A Workshop on High-Power Couplers for Superconducting Accelerators will be hosted by Jefferson Laboratory on 30 October – 1 November. It will be an informal meeting where members of diverse scientific, technological and industrial communities can explore possibilities for advancing the science, engineering and art of cost-effective RF power coupler design, manufacture and use. Details are available at http://www.jlab.org/hpc2002/; email hpc2002@jlab.org.

The XVI International Conference on Particles and Nuclei (PANIC02) will be held on 30 September – 4 October in Osaka, Japan. Details are available at http://www.rcnp.osaka-u.ac.jp/~panic02. It will be preceded by the **2nd International Workshop on Nuclear and Particle Physics at the KEK/JAERI 50 GeV proton synchrotron**, which will be held at Kyoto University on 27–29 September. See http://www-jhf.kek.jp/NP02/.

A workshop on Neutrino News from the Lab and the Cosmos will be held at Fermilab on 17–19 October. It will focus on cosmological and terrestrial probes of neutrino masses and mixing, highlighting the implications of recent results, and aiming to bring together members of the particle and astrophysics communities. Emphasis will be placed on the interplay and complementarity of cosmological and laboratory-based methods. Details are at: http://www-astro-theory.fnal.gov/Conferences/NuCosmo/.

An exhibition on the life and work of Werner Heisenberg will be on display at CERN on 1–23 July. The exhibition was produced in 2001 by the University Archive of Leipzig University and the Max-Planck Institute in Munich to mark the centenary of Heisenberg's birth (*CERN Courier* December 2001 p18). A related celebration will take place on 18 July, and will include reminiscences on Heisenberg's life and work from his daughter, Barbara Blum; his last postgraduate student, Helmut Rechenberg; and CERN's Valentine Telegdi.

POS2

ESA hosts second Physics on Stage event

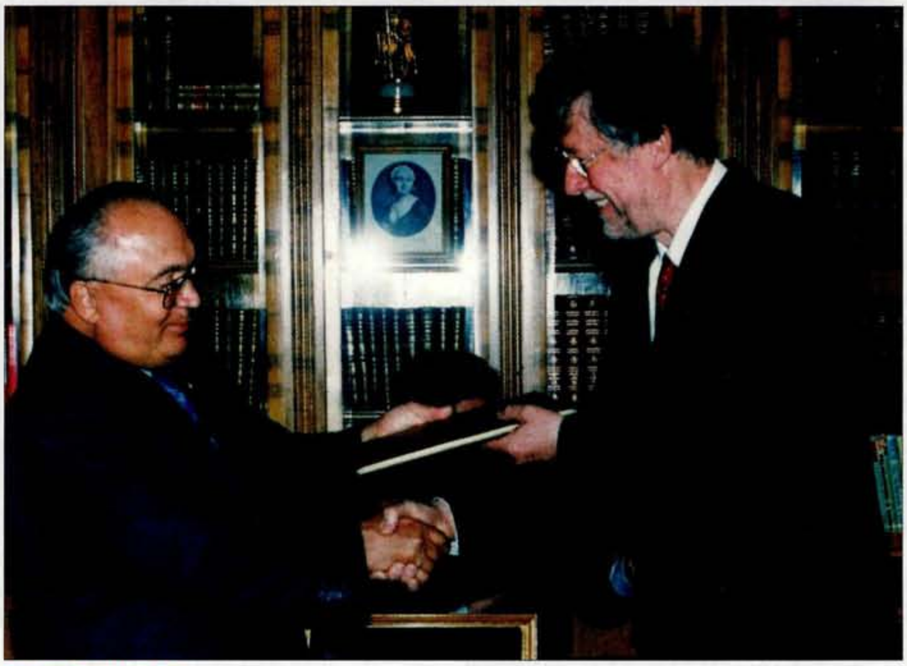
Father and son Miguel and Isaac Cabrerizo of Spain won the top prize at POS2 for their demonstrations on general physics.

CERN's David Williams (right) learns about "the linear elastic medium", presented by Elias Kalogirou on the Greek stand.

Michael Kobel of Bonn University (standing) and CERN's Horst Wenninger discuss particle physics with teachers.

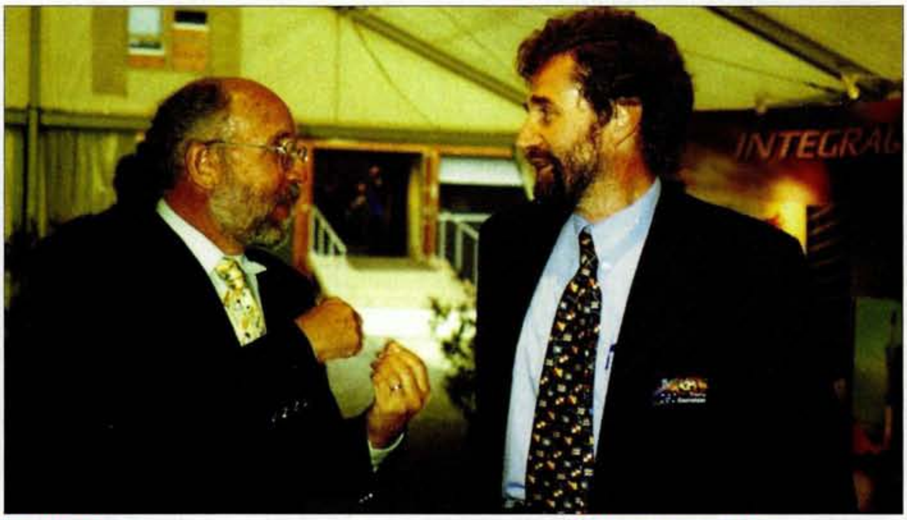
Physics returned to centre stage in April at the Physics on Stage 2 (POS2) event held at the European Space Agency (ESA) Space Research and Technical Centre in the Netherlands. POS2 follows up the huge success of the first Physics on Stage, which was held at CERN in November 2000, and organized by CERN, ESA and the European Southern Observatory. This year, three further European research organizations, the European Fusion Development Agreement, the European Molecular Biology Laboratory and the European Synchrotron Radiation Facility, also took part. The goal of Physics on Stage is to give teachers from 22 European countries the opportunity to network and exchange ideas and materials. This year, prizes were awarded for the best projects.

Arriving passengers collecting their luggage at Geneva's Cointrin airport now come face-to-face with a panel bearing the message that CERN, the world's largest particle-physics research laboratory and birthplace of the World Wide Web, is just 5 min away. That probably comes as news to most of the 7 million people who pass through airport every year. The initiative to highlight CERN at the airport came from the chairman of its board of directors, Geneva state councillor Carlo Lamprecht, who spent 15 years working at the laboratory before moving into politics. Lamprecht (left) inagurated the panel on 24 May with CERN director-general Luciano Maiani and airport director Jean-Pierre Jobin.



Victor Sadovnichy (left), rector of the Lomonosov Moscow State University, presented Albrecht Wagner, chair of the DESY board of directors, with an honorary doctorate in May. The university's scientific council made the award in recognition of Wagner's "prominent contribution to the field of particle physics and to fruitful collaboration between the Moscow State University and the Deutsches Elektronen-Synchrotron". The university is a member of DESY's ZEUS collaboration, and is active in DESY's synchrotron radiation programme.

Spanish scientific delegate to CERN Council, **Manuel Aguilar-Benítez**, read his entrance dissertation entitled "Particles and Interactions" at the Spanish Royal Academy of Sciences on 3 April. A senior scientist at Spain's Research Centre for Energy, Environment and Technology, CIEMAT, Aguilar-Benítez is the first experimental high-energy physicist to enter the Academy.



Michel Mayor, director of Geneva Observatory (left), with **Thierry Courvoisier** at the inauguration of the INTEGRAL Science Data Centre (ISDC) in April. Courvoisier is the ISDC's principal investigator. Acting as the interface between the European Space Agency's International Gamma-Ray Astrophysics Laboratory (INTEGRAL) satellite and the research community, the ISDC will play an important role in the development of high-energy astrophysics in the next decade. It will receive data continuously from the satellite and perform a quick first-look analysis before distributing the data around the world. Located near Geneva, the ISDC is attached to Geneva Observatory, which is part of Geneva University.

CERN received a visit from members of the Iranian parliament in May. Left to right: **Ali Mojtahed-Shabestari**, deputy ambassador of the Islamic Republic of Iran in Geneva; CERN's **Diether Blechschmidt**; **Abdol-Rahim Baharvand** and **Hossain Amiri** from the Iranian Parliament; **Norbert Siegel** of CERN; **Hossain Afarideh**, **Rasool Seddighi** and **Ahmad Shirzad** from the Iranian Parliament. Iranian physicists are involved in the CMS experiment at CERN through a collaboration with the Institute for Studies in Theoretical Physics and Mathematics in Tehran.

Erich Lohrmann (right), chairman of the association of the friends and sponsors of Germany's DESY laboratory, awarded the association's prize for an excellent PhD thesis in June. This year's recipients are **Florian Goebel** (left) from the University of Hamburg for his studies of diffractive processes with the ZEUS detector, and **Burkard Reisert** from the Max-Planck Institute for Physics in Munich for his measurements on structure functions at the H1 detector.

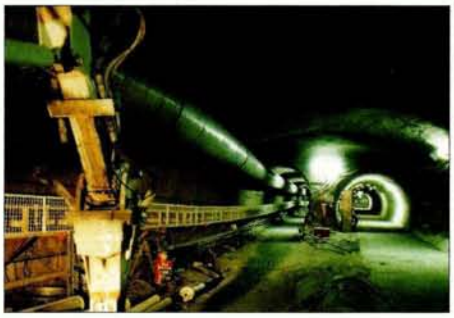
Robert Eisenstein, former assistant director for mathematical and physical sciences (MPS) at the US National Science Foundation (NSF), has stepped down from the job to spend a year at CERN as a member of the ATLAS collaboration. Eisenstein joined the NSF in 1992 and has served as head of MPS since 1997. A staunch supporter of US participation in CERN's Large Hadron Collider project, he has been a member of the US delegation to CERN Council since 1997. Eisenstein's successor has yet to be named, but John B Hunt of the NSF will fill the position in an acting capacity while a search is conducted.

After more than 30 years of service, **Helen Tuck**, seen here with theoretical physicist **Steve Frautschi**, retired from Caltech's theoretical physics group on her 75th birthday in May. As secretary to physicists such as Richard Feynman and Murray Gell-Mann, Tuck has enjoyed a privileged position witnessing the evolution of modern physics. So much so that some of her memories found their way into the recent play, *QED*, and Alan Alda, who played Feynman, visited Tuck in her office to prepare for the part. She saw the play twice and thought Alda "did a wonderful job".

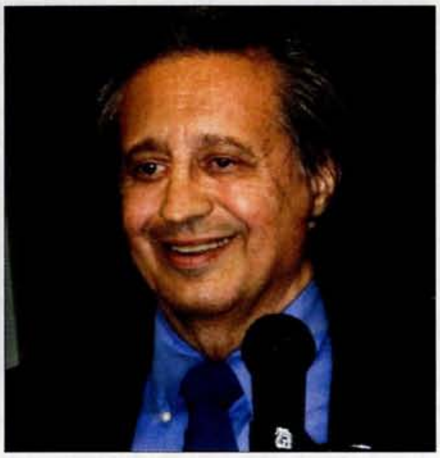
Latin American, Portuguese and Spanish ambassadors and representatives to the international organizations in Geneva visited LHC magnet test facilities at CERN in June. Left to right: CERN's **Juan Antonio Rubio**; **Gustavo Albin** of Mexico; **Joaquín Pérez-Villanueva y Tovar** of Spain; **Alvaro de Mendonça e Moura** of Portugal, CERN's **Norbert Siegel**; **Juan Enrique Vega** and **Rodrigo Espinosa** of Chile; **Horacio Emilio Solari** of Argentina; CERN's **John Ellis**; and **Enrique Ochoa** of Mexico.

CERN doctor retires with photo record

CERN resident doctor, Etienne Maquet (above with the CERN medical service team, second from left), retires this year. A keen amateur photographer, Dr Maquet takes with him a photographic record of the laboratory stretching back to 1971, the year he joined CERN. These pictures (right), taken in April with Jean-Luc Baldy, head of civil engineering at CERN, give an underground snapshot of the status of civil engineering for the LHC project.

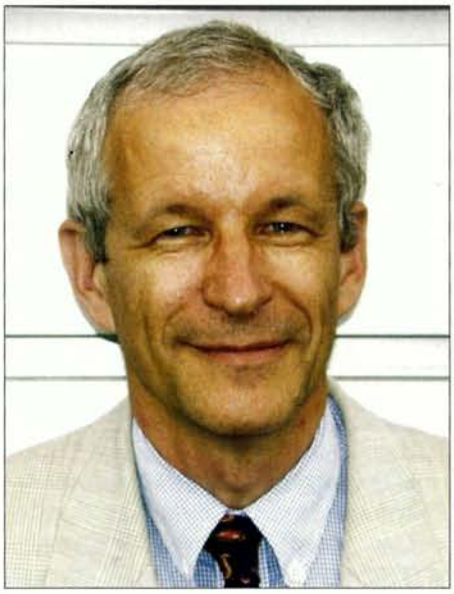


Top right: the LHC tunnel, inherited from the Large Electron Positron collider, is on the right. The tunnel on the left will house one of the LHC's beam dumps. Middle: emerging from the lift in the cavern that will house the CMS experiment. On the left is a concrete wall, ingeniously built before excavation began, that will separate the experimental hall from the one that will house services supplying the CMS detector. Bottom: light at the end of the tunnel. The LHC tunnel breaks into the ATLAS experiment's cavern.

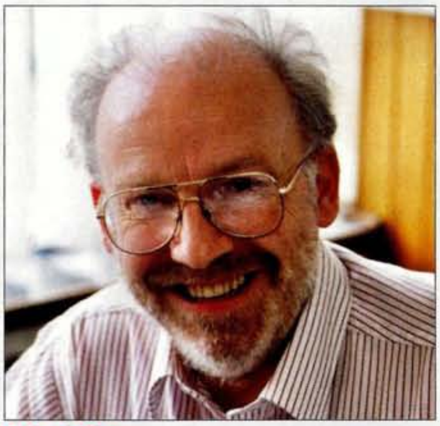


Nicholas Samios, former Brookhaven director, celebrated his 70th birthday at the laboratory on 16 May. Samios joined Brookhaven in 1959. He became chairman of the laboratory's physics department in 1975, and was named deputy director for high-energy and nuclear physics in 1981. The following year he was appointed director, a position he held for 15 years. Samios is currently deputy director of the RIKEN–Brookhaven research centre. His career in high-energy physics has seen many important contributions to the field. Early on, he was involved in experiments that demonstrated parity violation in hyperon decays. He went on to become a leading player in many particle discoveries, notably those of the Omega minus and the first charmed baryons. These discoveries provided important input to the formulation of Quantum Chromodynamics and the Standard Model.

New director for PSI



Ralph Eichler, current deputy director and head of the particles and matter division of Switzerland's Paul Scherrer Institute, has been elected by the Swiss Federal Council to take over the directorship from Meinrad K Eberle, who retires at the end of June 2002 after 10 years in the post. Eichler, currently professor of experimental physics at ETH-Zurich, is pursuing his long-standing interest in high-energy physics with his participation in the H1 experiment at Germany's DESY laboratory, where he was former spokesperson of the H1 Collaboration. He also serves as a Swiss delegate to CERN Council and has just retired as chairman of the Scientific Council of DESY.



John Dainton, Professor of Physics at the University of Liverpool, has been elected as a Fellow of the Royal Society, London. He was distinguished "for his leading contribution to the understanding of the fine structure of matter, through the high-energy scattering of leptons and photons by protons. One of his seminal contributions has been in developing, through experiment, a deeper understanding of hadronic interactions in terms of a calculable gauge theory." In the early 1980s, Dainton worked with the PLUTO collaboration at the PETRA electron–positron collider at DESY in Hamburg. He then led the UK group in the design and construction of the H1 detector at DESY's HERA electron–proton collider. From 1997 until 1999, a period during which an upgrade was defined, approved and begun, he was H1 collaboration spokesman. He has since continued to play a major role in the experiment.

Christian Scherf (left), former managing director of the Helmholtz association's GKSS Research Center, joined the DESY directorate with responsibility for administration in June. His predecessor **Helmut Krech** has moved to the European Synchrotron Radiation Facility in Grenoble.

New faces in the IN2P3 management

France's national institute of nuclear and particle physics (IN2P3) saw two members of its management replaced during the last year. The full team now consists of (left to right): Marcel Lieuvin, technical deputy director, who replaces François Dupont; Guy Wormser, scientific deputy director responsible for quarks and leptons, computing, and accelerator physics; director Jean-Jacques Aubert; Natalie Gregoire, administrative deputy director; Daniel Guerreau, scientific deputy director responsible for nuclear physics, hadronic physics, nuclear fuel management and applications, and the physics-biology interface;

and Stavros Katsanevas, scientific deputy director responsible for neutrino and astroparticle physics, replacing Michel Spiro.

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please email cern.courier@cern.ch.

CERN pioneers

I read with great interest the article devoted to the role played by American physicists in the creation, launching and development of CERN (*CERN Courier* April p13).

You will, perhaps, allow me to point out that the first American initiative in this area was the work of Robert Oppenheimer.

I first met Oppenheimer and Isidor Rabi in the course of my duties as representative of France to the United Nations Commission for international control of atomic energy (1946–1948).

I quickly became friendly with Oppenheimer and his wife, and my wife and I spent many weekends at their Princeton house. Here in substance is what he told me in the course of these get-togethers: "What we know we have learnt in Europe, but henceforth fundamental research in particle physics will demand large resources which are beyond the scope of European countries taken individually. It would be basically unhealthy for the Europeans to have to go to the US or the USSR to be able to continue contributing to fundamental research. It is therefore necessary for the Europeans to pool their human and financial resources to give themselves the tools needed to pursue research".

I organized meetings between Oppenheimer, Pierre Auger, Francis Perrin and Lew Kowarski, who came to New York as scientific advisers in my delegation to the UN Commission. Naturally, Rabi was in complete agreement with Oppenheimer on this matter.

On my return to Paris, I undertook a tour of European capitals with Francis Perrin to see what sort of reception would be given to Oppenheimer's idea.

I must say that these approaches, made in 1949 and 1950, aroused little enthusiasm except on the part of Amaldi in Italy, Scherrer in Switzerland and Niels Bohr in Denmark.

This lack of interest was largely due to a twofold reticence, on the one hand that shown by governments who, having not the slightest idea of what was involved, thought in terms of a European atomic bomb project; and on the other hand that shown by the many researchers for whom the plan would have the effect of drying up the already meagre resources allocated to their own laboratories. It was, as you quite rightly say, the intervention by Rabi at the 1950 UNESCO conference in Florence that set things in motion.

If, then, Oppenheimer was the spiritual father of CERN, it was Rabi at Florence and Pierre Auger afterwards who were the midwives.

Gordon Fraser's articles showing the intensity of co-operation that has been established between European and American researchers in the framework of CERN, and the fact that many American teams work there, would have deeply delighted Oppenheimer as well as Rabi. Their wish was that Europeans would not be constrained to cross the ocean to carry out advanced research: it seems to me that the co-operation as Fraser describes it is established on a footing of perfect coherence and complementarity between researchers on the two sides of the ocean.

François de Rose, president of CERN Council 1959–1962.

Intellectual atmosphere

Maury Tigner's article (*CERN Courier* May p50) rings true. In a time of belt-tightening in particle physics, it is interesting to look back to the late 1970s when CERN actually had slightly more money than it needed to carry out its approved programme. This allowed the laboratory to foster the intellectual atmosphere in accelerator physics that Tigner speaks of, and to act on one particularly imaginative idea – Carlo Rubbia's proposal for converting the newly commissioned Super Proton Synchrotron into a proton–antiproton collider. This was a daring suggestion. Antiprotons are hard to make and you need a lot to get any useful luminosity, so the first thing you need is an antiproton factory. Moreover, experience from CERN's intersecting storage rings showed that it could be difficult to extract interesting physics at a hadron collider. The first problem was solved by Simon van der Meer's beautiful idea of stochastic cooling – a prime example of the sort of intellectual creativity Tigner calls for – which allowed antiprotons to be stacked and the beam phase space to be reduced so that "dense" bunches of antiprotons could be produced.

Stochastic cooling worked superbly, and even more surprisingly, the signals from both Zs and Ws turned out to be very clean. The W events were so clean because of the novel technique of missing transverse energy used to identify and measure the Ws. This was a revolutionary discovery because it killed off the old prejudices about hadron colliders being "dirty" and pointed the way to the future. The quickest and cheapest way to achieve the highest-energy collisions was with hadron colliders. Fermilab's Tevatron took over from the CERN collider and went on to discover the top quark – it may well make many more discoveries. The next big exciting steps in particle physics will come when CERN's 14 TeV proton–proton collider, the LHC, starts operating in 2007.

We can only speculate where our field would be today had CERN not been in a position to foster and exploit intellectual activity in accelerator physics back in the 1970s. I will leave that question to historians of alternative histories.

Tony Weidberg, Oxford University.

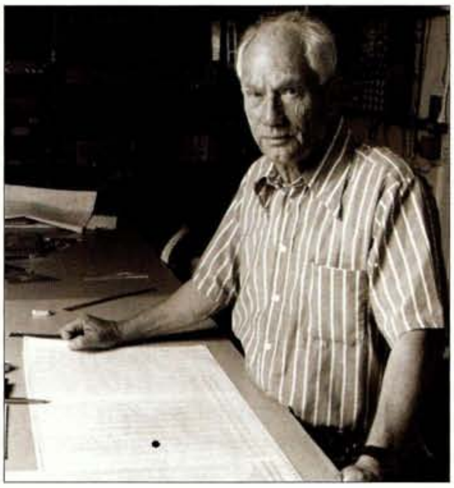
OBITUARIES

Oreste Piccioni 1915–2002

"Pinocchio, Niels Bohr called our experiment Pinocchio, the false puppet," explained Oreste Piccioni in a recent presentation to the students of the Liceo Virgilio in Rome, about the experiment he performed with Marcello Conversi and Ettore Pancini in the same liceo during the Second World War. "And nobody believed us at first. But our results were crystal clear and the paper of Fermi, Teller and Weisskopf put them in the proper perspective: the mesotron wasn't the particle of Yukawa, but a new kind of electron-like particle."

Born in 1915 in Siena, Italy, Piccioni graduated from the University of Rome in 1938 under Enrico Fermi. In 1942 he and Conversi started a direct precision measurement of the mesotron lifetime and tests of the behaviour of positive and negative mesotrons. According to contemporary theories, mesotrons, the penetrating component of cosmic rays, were the mediators of the strong force foreseen by Yukawa; therefore the negative mesotrons had to be more likely captured by nuclei, while the positive ones (repelled by positively charged nuclei) undergo spontaneous decay with higher probability.

After the bombing of the Rome University campus in July 1943, the researchers moved to the Liceo Virgilio, near the Vatican, which they hoped would be better protected. "We hid ourselves from the Nazis until the liberation of Rome in June 1944. Working in those days required guts." Then they were joined by Ettore Pancini, who graduated in Padua with Bruno Rossi and was a resistance leader in northern Italy. The team used magnetic lenses to distinguish between positive and negative mesotrons and fast electronic anti-coincidence detection. "Electronic tubes were not available and we had to build them by ourselves." Their striking result, published in 1947, demonstrated that negative mesotrons in light absorbers, like carbon, almost always decayed instead of being captured by the positive nucleus. The mesotron was not the Yukawa particle. Many authors, including Bethe and Alvarez, have frequently quoted their experiment as the one marking the origin of modern



Oreste Piccioni 1915–2002.

Boyce D McDaniel 1917–2002

On 8 May 2002 Boyce D McDaniel, emeritus professor and former director of the Cornell University Laboratory of Nuclear Studies, died of a heart attack at the age of 84 at his home in Ithaca, New York.

Mac, as he was known to everyone, came to Cornell as a graduate student in 1940 after a BA degree at Ohio Wesleyan University and an MA at Case School of Applied Science. As a graduate student of Robert Bacher, he built one of the first multichannel neutron time-of-flight spectrometers and used it to make precision measurements of the energy levels of indium. After his Cornell PhD in 1943 he spent a few months at MIT as a post-doc and the rest of the war years at Los Alamos working on the Manhattan Project. He returned to Cornell in 1946 as a faculty member in the Department of Physics.

Mac was a versatile experimenter in nuclear, particle and accelerator physics. He worked on each of the Cornell machines, the 2 MeV cyclotron (the first outside of Berkeley), the 0.3, 1, 2 and 10 GeV electron synchrotrons, and the Cornell Electron–Positron Storage Ring (CESR). The pair spectrometer, which he invented for the study of gamma-ray

Boyce McDaniel as a young man, working at the Cornell 2 MeV cyclotron.

particle physics.

In 1946, Piccioni emigrated to the US, first at MIT with Bruno Rossi and then at Brookhaven National Laboratory, where he developed fast electronic circuitry – reaching a resolving time of 3 ns in 1954 – and devised a magnetic scheme to eject, steer and focus fast proton beams at the Cosmotron.

Based on his expertise in magnetic optics, Piccioni suggested a detecting scheme based on quadrupole focusing lenses and time-of-flight measurements to the Berkeley group lead by Emilio Segrè hunting for antiprotons at the newly built Bevatron. The experiment successfully detected antiprotons in 1955, and the achievement won Segrè and Chamberlain the 1959 Nobel prize.

In September 1955 Piccioni joined Berkeley where, with a beautiful experiment, he demonstrated the existence of antineutrons produced by antiprotons, and detected (by a spectrograph containing five quadrupole lenses) two timed-flight paths to eliminate pions simulating antiprotons. He remained proud of this discovery: "Everybody was convinced of the existence of antiprotons since the discovery of positrons in 1932, for reasons of symmetry, and it was only a question of an accelerator with the necessary energy. On the other side, there were much less compelling reasons for an antiparticle of the neutron, being electrically neutral".

Afterwards, Piccioni turned his attention to the puzzling properties of neutral kaons. With Abraham Pais, he developed the theory of "regeneration" of kaons: since the long-lived K_L is a superposition of K^0 and $\bar{K}^0$, the crossing of matter will upset the fine balance between the two amplitudes and therefore what will emerge will not be a pure K_L but a superposition of K_L and of the short-lived K_S. With the help of a powerful Berkeley team, Piccioni experimentally confirmed the regeneration prediction.

At CERN at the end of 1960, Piccioni collaborated in the construction of the first secondary beam of antiprotons; his was the analogue computer used for studying the optics of the beam, based on magnetic deflectors and quadrupoles. Also in 1960, he became a professor at the University of California at San Diego (UCSD), where he founded the experimental particle physics group, which is involved in major experiments worldwide. He retired from UCSD in 1986, becoming a professor emeritus, and devoted himself to working on the foundations of quantum mechanics.

Piccioni felt he had been deprived of recognition for contributions to the discovery of the antiproton, and in 1972 he sued the two prizewinners. The courts dismissed the lawsuit, saying it had been filed too late. His challenge to the establishment triggered discussions in the scientific community on the social aspects of research and on professional ethics.

Oreste Piccioni died on 13 April at his home in Rancho Santa Fe, California. Our community has lost a combative pioneer in particle physics, a highly skilled experimentalist and a brilliant and creative genius.

Alessandro Pascolini, INFN Padua.

transitions in nuclear reactions, was the standard instrument for precision gamma spectroscopy for many years. He was a pioneer in sophisticated time-of-flight measurements and led the first experiments on strange particle photoproduction in the 1950s and 1960s.

Mac's prowess as a technical problem solver and accelerator expert was legendary. Besides having a vital role in the design, construction and successful operation of each of the Cornell machines, he spent several years leading the commissioning of the Fermilab accelerator. He was not only a master at making complex technical systems work, but also a skilled scientific leader. Mac served under Bob Wilson as associate director of the Cornell laboratory from 1960, becoming director in 1967 when Wilson left for Fermilab. He continued and enhanced Wilson's aggressive do-it-yourself effort to keep Cornell at the forefront of particle physics and accelerator development. In the late 1970s he spearheaded the effort to extend the reach of the 10 GeV synchrotron by adding an electron–positron storage ring in the same tunnel. The very successful CESR run of the past 23 years and the simultaneous exploitation of the by-product X-ray radiation by the CHESS laboratory could not have happened without Mac's crucial leadership in the early years. He would always be pitching in where the need was greatest – in the accelerator tunnel, the control room, the machine shop, or in Washington. Nothing was left to chance.

After his nominal retirement in 1985, Mac continued to serve the laboratory and the high-energy physics community. At CESR he took an active role in upgrade projects, designing and installing magnets and instrumentation, participating in control room accelerator dynamics experiments, building things and making them work. Other laboratories and agencies relied on Mac for his wisdom and experience. He served as trustee of Associated Universities Inc. (Brookhaven) and of Universities Research Association (Fermilab). He served on ICFA and HEPAP and was chairman of the board of overseers of the SSC. He helped guide many other projects for the NSF and DOE.

Mac's colleagues at Cornell and high-energy physicists everywhere will greatly miss his technical skills, leadership, wisdom, kindness, and his unselfish efforts for the general good.

Mac is survived by his wife Jane, daughter Gail and son Jim. A memorial get-together is being planned for the autumn.

RECRUITMENT

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All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.
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The closing date for applications is 1 September 2002. Applicants should send a curriculum vitae, a research plan, and a description of teaching experience and interests. The applicants must arrange to have at least three confidential letters of reference sent to the address below, on or before September 1, 2002:

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Dr. Joseph Natowitz or Dr. Donald May, Texas A&M University, Cyclotron Institute, College Station, TX USA 77843-3366.

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For an informal discussion about any of these posts please contact **Dr. R. P. Walker, Diamond Technical Director, tel.: +44-(0)1235-446212, e-mail: r.p.walker@rl.ac.uk**
Further information about these and future posts, and how to apply, is available from our web site at: **http://www.diamond.ac.uk** or can be obtained from: **HR Operations, Human Resources Division, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX. Telephone (01235) 445435 (answerphone) or email recruit@rl.ac.uk** quoting the appropriate VN number.

Applications should be returned by Friday 12th July 2002

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The RNC group has a key role in the STAR experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The group currently has a strong physics program in nucleus-nucleus collisions at RHIC and intends to become a major player in spin physics. Candidates having an interest in spin physics at RHIC are encouraged to apply.

Applicants are requested to email a curriculum vitae, list of publications, statement of research interests, and the names of at least five references, no later than October 1, 2002, to afnsemployment@lbl.gov. Please reference job number AF/014946/JCERN in your cover letter. LBNL is an EEO/AA employer.

BERKELEY LAB

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Prof. François Corriveau
Physics Department, McGill University
Montréal, QC, H3A 2T8, Canada

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hsiung@hep1.phys.ntu.edu.tw
fax: +886-2-23693472, tel: +886-2-33665135

Prof. George W.S. Hou, Department of Physics, National Taiwan University, Taipei, Taiwan 10764, R.O.C.
wshou@phys.ntu.edu.tw
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Prof. Lawrence Gibbons,
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BOOKSHELF

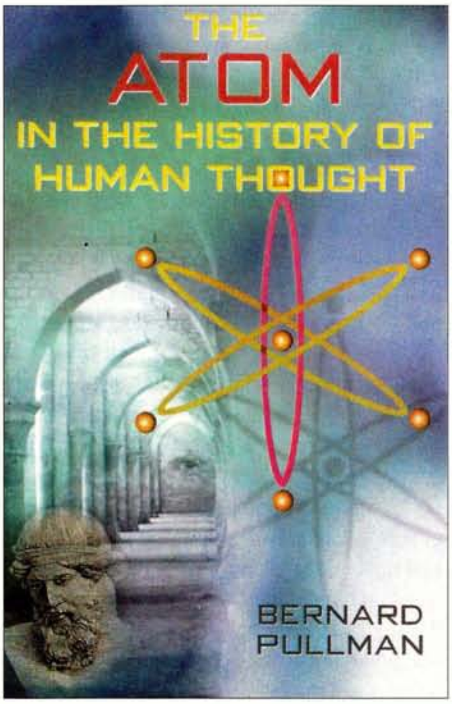
The Atom in the History of Human Thought by Bernard Pullman (late professor of Quantum Chemistry at the Sorbonne, and director, Institut de Biologie Physico-Chimique, France), Oxford University Press, ISBN 0195114477, £14.95 (€23). Translated from the original French, Editions Fayard, ISBN 2213594635, €29.3.

"This book endeavours to describe the turbulent relationship between atomic theory and philosophy and religion over a period of 25 centuries," states the preface – a daunting task by any standards. Pullman admits that he is neither a philosopher nor a man of religion, but a chemist "having long lived side-by-side with atoms". As such, he achieves a great deal.

The book begins with the birth of the atomic theory – the "Greek miracle" of the 7th-5th centuries BC in Pullman's words, when a few Hellenic thinkers shed the Greek pantheon in favour of a natural philosophy. This began with theories advocating various primordial substances – water (Thales), air (Anaximenes), fire (Heraclitus) and earth (Xenophanes) – from which all things come to be. The two fundamental concepts of atomism – impenetrable, indivisible (atomos) corpuscles and void through which they travel – were formulated around 450 BC by Leucippus and Democritus, and refined a century later by Epicurus and Lucretius to a logical structure that remained essentially unchanged for the next 2000 years. The book also touches on Hindu and Buddhist atomism, which evolved independently at about the same time, but had no impact on the atomic theory of the Western world.

The book then moves on to "a few scattered revivals" during the 1st-15th centuries AD. After describing the antiatomistic position of the Church as put forward by Basil of Caesarea, St Augustine and Thomas Aquinas (among others), some mediaeval Christian atomists make an appearance. These are divided into chroniclers (such as Isidore de Seville), sympathizers and proponents. The sympathizers include Adelard of Bath (a translator of scientific Arab texts) and Thierry of Chartres (a reviver of the works of antiquity). Among the proponents are Constantine the African, a physician from Carthage who explicitly defined atoms as the fundamental constituents of substances; William of Conches; and William of Ockham.

Jewish philosophy from the 9th to the 13th centuries is discussed. This was largely opposed to atomism, although Moses Maimonides (1135–1204) described the



teaching of the Arab atomists. The schismatic Jewish sect of the Karaites (founded in the 8th century) adopted the atomic theory borrowed directly from teachings of Muslim philosophers and theologians.

While Greek atomism was to free mankind from invisible powers, Arab atomism is decidedly religious in nature. The Arab atomic doctrine is expressed in the Kalam, a set of 12 propositions, one of which introduces the notion of "accidents". These reside within atoms, and include characteristics such as life and intelligence, along with inanimate properties such as colour and odour.

Moving into the Renaissance and the age of enlightenment, Pullman describes the resurgence of atomic theory starting with Pierre Gassendi, who is counted among the Christian atomists along with the likes of Galileo, Bruno, Newton and Boyle. Gassendi criticized Aristotle and defended ancient atomists, especially Epicurus, whose teachings he tried to make acceptable to the Church. The doctrine of John Locke, who doubted any future experimental proof of the existence of these atoms, is labelled "agnostic atomism". Pullman also discusses Maupertuis and Diderot, with their sensitive and intelligent atoms; Holbach, with his materialistic atoms; and Maxwell, who believed that atoms exist due to the action of a creator.

Christian antiatomists – philosophers or scientists who use religious arguments to reject the theory – include Descartes, who rejected the concept of void; and Leibniz with his metaphysical atoms (monads). Others mentioned are Roger Boscovitch, who tried to blend Leibniz's monads with Newton's laws of attraction and repulsion; George Berkeley, who rejected matter, material corpuscles and void; and Immanuel Kant, who is labelled an "atomist turned antiatomist".

The final part of the book moves into the modern era with the advent of scientific atomism through the 19th and 20th centuries. Pullman begins with the demise of the 2000-year-old theory of four elements by the demonstration of Lavoisier that water, and of Cavendish and Priestley that air, have a compound structure. Elements came to be defined as substances that could not be decomposed. Confusion over nomenclature followed until Canizzaro formulated a distinction between atoms and molecules in 1860. Soon afterwards, Mendeleev arranged the first 63 elements in the periodic table.

Controversy, however, continued. Philosophers such as Hegel and Schopenhauer were both opposed to atomism. So were die-hard antiatomists like Berthelot, Mach and Ostwald, and a few that Pullman calls "nostalgic philosophers", such as Nietzsche, Marx and Bergson.

Nevertheless, atomic theory was almost universally accepted by the time J J Thomson discovered the electron in 1897, bringing the hypothesis of indivisible atoms to an end.

Pullman then brings us into the quantum age in 1900 with Planck's famous constant. He guides us through Rutherford's 1911 conclusion that atoms are mainly vacuum with a tiny nucleus surrounded by electrons, to Bohr's 1913 observation that Planck's constant leads to stable orbits in the atom and to discrete spectral lines. The rest of the modern atomic picture is carefully covered, with Chadwick's 1932 discovery of the neutron; de Broglie's postulation of the wave-like character of matter particles, and its subsequent confirmation by Davisson and Germer; and Schrödinger's wave mechanics leading to serious conceptual difficulties among scientists.

Chemical bonding naturally plays a large part in the book, given that its author was a chemist. Covalent bonding, where electrons are shared between atoms, leads Pullman to an interesting analogy developed in the chapter "Society of atoms: marriage", where he concludes that ▷

"as always in life, this implies the ability and even obligation both to give and to receive".

In a closing chapter, Pullman delves into the nanoworld. Here he describes how the scanning-tunnel microscope and the atomic-force microscope led to visualization and manipulation of single atoms interacting with bulk surfaces, and how complete isolation of single (charged) atoms surrounded by vacuum was accomplished using ion traps.

No-one can contest that the atoms conceived 2500 years ago as invisible and indivisible impenetrable philosophical constructs have today become divisible and visible objects of reality. But are they really in human thought? They are certainly in the thoughts of scientists and philosophers, but I doubt they are uppermost in the minds of most people, as Pullman suggests when he claims that "quantum physics has stoked an interest in the 'problem of God' among a general public". The book is let down by its index, which is difficult to use and occasionally inaccurate. That said, however, to read this book is a fruitful learning exercise, and it has a host of informative notes.

Horst Wachsmuth, CERN.

Handbook of Radiation Effects by Andrew Holmes-Siedle and Len Adams, 2nd edn (2002), Oxford University Press, ISBN 019850733X, £65 (€102).

This book is aimed at specialists – engineers and applied physicists – employing electronic systems and materials in radiation environments. Its prime role is to explain how to introduce tolerance to radiation into large electronic systems. The reader is expected to be familiar with the theory and operating principles of the various devices. The book mainly addresses components used in space, but also discusses issues specific to other fields, such as military and high-energy physics applications.

The book starts with a quick overview of radiation concepts, units and radiation detection principles, followed by a brief review of the various radiation environments likely to have a degrading effect on electronic devices and systems as encountered in space, energy production (fission and fusion), high-energy physics and in military applications (nuclear weapons). This is followed by a chapter dedicated to a general description of the fundamental effects of radiation in materials and devices: atomic displacement and ionization; as well as colourability of transparent material, single-event phenomena and other transient effects.

Seven central chapters form the core of the handbook, addressing in detail the mechanisms responsible for the degradation of performance of various devices. Each chapter is dedicated to a class of devices: MOS; bipolar transistors and integrated circuits; diodes and optoelectronics such as phototransistors and CCDs; power semiconductors; various types of sensors; and miscellaneous electronic components. The physical problems of total-dose effects and how to predict the electrical changes caused in MOS devices are discussed, along with some of the best solutions to the radiation problem. Long-lived effects, which can be separated into surface and bulk mechanisms, of various radiation types on bipolar transistors are described. How these effects influence the radiation response of bipolar integrated circuits is discussed. The response of the many different types of diodes to radiation is thoroughly discussed in a dedicated chapter. Optoelectronic devices in a hostile environment are subject to multiple effects, and radiation can cause mulfunctioning in a highly tuned, high-technology system. Silicon power devices used as regulators in power subsystems of large space equipment, radiation-generating equipment and nuclear-power sources also suffer from radiation damage. One chapter is devoted to discussing the physics, chemistry and practical problems associated with windows, lenses, optical coatings and optical fibres. Another chapter concentrates on the effects of radiation on polymers and other organics, classifying the main forms of organic degradation under irradiation and summarizing some of the most important examples and problems met with polymers in engineering and science.

Two chapters are dedicated to aspects of radiation shielding of electronic devices and various computer methods for particle transport, essentially with reference to space applications (very thin shields). The three final chapters discuss radiation testing, equipment hardening and hardness assurance. Radiation testing is made unavoidable by the variability in the sensitivity of semiconductors and electronic devices to radiation, which makes it impossible to rely on theory alone to predict the effect on a device of a certain exposure to a given type of radiation. The authors provide guidelines on radiation sources that may be used in irradiation tests, in test procedures and in engineering standards. Finally, they discuss the technologies and methodologies employed in fabricating radiation-hard devices, as well as providing rules of hardening against various types of radiation and for various applications, including remote handling equipment and robots.

Each chapter ends with a summary of its most important points. Besides the usual subject index, a useful author index helps greatly in searching through the large number of references provided at the end of each chapter. With respect to the first edition (1993), the book has been enriched with many references to useful websites, including databases. Surprisingly, the old units rad, rem and curies are used throughout the book, although SI units are provided in brackets. The authors admit they thought hard about what to use, and finally opted for the old system.

It is unfortunate that this otherwise excellent volume contains, here and there, a number of typographical and punctuation errors, and mistakes in some formulae. In a few cases there are contradictory statements a few paragraphs apart. The impression is that the text was not proofread carefully enough before going to print. There are also a few statements that are clearly wrong, such as that X-rays and gamma rays leave no activity in the material irradiated (what about photonuclear reactions above a given threshold?); and others that are confusing, such as in discussing the whole-body dose limit for members of the public. In general, activation phenomena and related problems are also somewhat generally underestimated throughout the book.

Nevertheless, this volume contains a lot of valuable material and is not only a handbook, but also an excellent textbook.

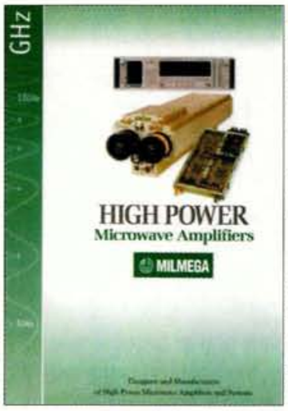
Marco Silari, CERN.

Books received

Quarks, Leptons and the Big Bang (2nd edition) by Jonathan Allday, Institute of Physics Publishing, ISBN 0750308060, £16.99 (€27).

This edition is a revised and updated version of the King's School, Canterbury teacher's popular high-school introduction to particle physics and cosmology.

Deparameterization and Path Integral Quantization of Cosmological Models by Claudio Simone, World Scientific, ISBN 9810247419, £19 (€30).



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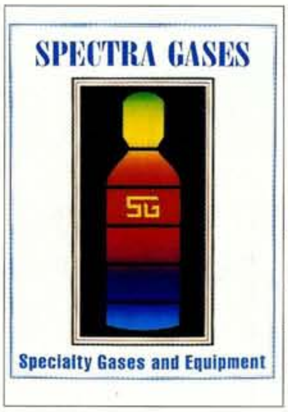

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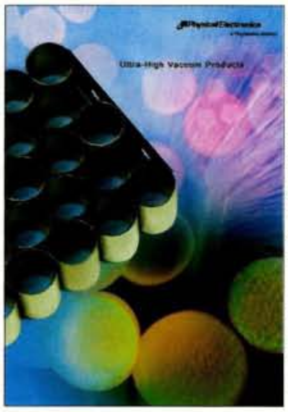

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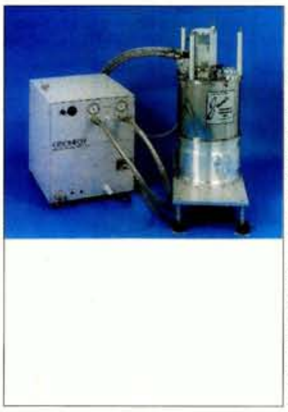

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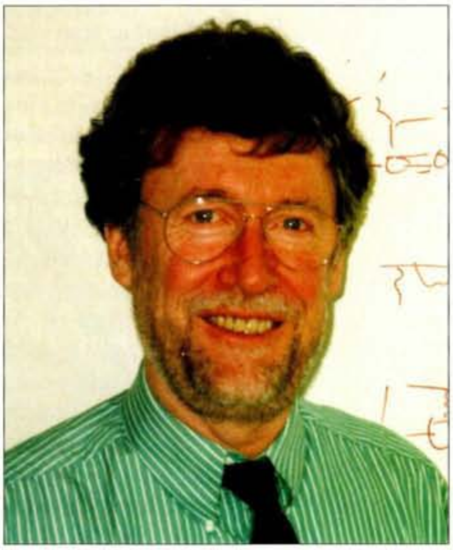
Globalization, collaboration and trust

Big science needs its own brand of globalization, argues chairman of the DESY directorate, **Albrecht Wagner**.

Industry pushes economic globalization to strengthen its market position. The process is driven by the need and desire to increase efficiency and reduce costs, but also by the wish to make the best use of different competencies in different countries. Take the European aircraft industry: parts of planes, such as the wings, tail unit, body and engines are built in different regions of Europe, and finally assembled at one plant. This has enabled distributed regional industries to jointly play a major role on the international market. Yet people are afraid to be at the mercy of some anonymous pressure, and thus increasingly oppose globalization.

Large-scale facilities in science are also increasingly tackled on a global scale. Radio-astronomers around the world have united behind the idea of jointly building their next project, ALMA, a merger of the major millimetre-array projects into one global project. Particle physics has for quite some time moved in the same direction: the large experiments have always been a role model for the shared construction of large equipment. The LHC is built with components from around the world, like HERA before it.



Global challenge

To meet the challenges of the future, accelerator-based particle physics needs to become even more global than in the past. One possible concept, the Global Accelerator Network (GAN), was originally developed as a way to build a linear collider as an international collaboration, to make the best use of worldwide competence, ideas and resources, to maintain and foster the centres of excellence in accelerator physics around the world, and to root the linear collider as an international project firmly inside the national programmes (*CERN Courier* June 2000 p19).

Global projects rely on collaboration. In the past, particle physicists have developed a culture of collaboration that has worked very successfully. Indeed, they had to do so to meet the scientific challenges. Collaborations function well if their leadership acknowledges the individuality and freedom of all the partners. They do not have a strong hierarchical structure, but are driven instead by a common scientific goal. They probably would not function with an industry-style management.

Therefore the question arises as to whether a model that works for experiments can be extended to accelerators. Or to put it differently: what is needed to make this model work for accelerators as well? These questions were studied by an ICFA working group in 2001, and are now being addressed within the framework of a series of workshops, the first of which, "Enabling the Global Accelerator Network", took place in March at Cornell. This workshop dealt with technical aspects of the remote operation of facilities, which is a key ingredient of the shared operation of accelerators. No basic problems are expected here. In fact, the TESLA test facility has already been operated remotely from Italy and France.

On the other hand, it became clear at the workshop that the sociological aspects of such a joint endeavour are probably the true challenge. As the GAN concept is built on the principle of shared responsibility, the sharing of know-how and controls is also part of the concept. The laboratory at which the facility is located would therefore relinquish the project control it traditionally had to become one of the equal partners. Mutual trust is the critical element required in order for such a collaboration to be successful.

It is well known that distributed organizations need to build up and maintain trust. Sharing working time from the very beginning is a powerful agent in establishing this trust. This requires a mixture of face-to-face interactions and the use of appropriate communication and collaboration technologies. These interactions should start as early as possible, even during the planning and R&D phase. Mutual trust and interest will continue to grow during the build-up time of the project, and will have to be sustained through the transition from early commissioning to operation and scientific exploitation. Industry is developing many tools to support the full spectrum of situations, ranging from planned, structured activities (such as scheduled meetings) to unplanned interactions.

Trust and involvement of both institutions and individuals have to be maintained over a long time – the duration of the project being typically more than 20 years. Producing exciting science and meeting technological challenges will be the key ingredients for ensuring a long-term interest of all the partners. Working on the frontiers of technology creates the need for a continuous upgrade culture. This culture needs to be distributed around the world.

However, even if the necessary trust is established, we need to solve many questions of key relevance in order to guarantee the success of the project and the major investment it requires. These questions include the management structure and organizational forms. They again are closely related to trust – we cannot afford for scientists and engineers to become disenchanted and to walk away. We need to approach global collaboration on large scientific infrastructure projects with a lot of imagination and determination.

The future of particle physics is no longer determined by scientific challenges only.

Albrecht Wagner, DESY.

AS&E High Energy Systems Division

X-Band SYSTEMS

Typical Electron Beam Energy (MeV)	1 to 12
Typical Electron Beam Power (kW)	0.3 to 1
Typical Electron Beam Head Mass (kg)	160
Typical Overall System Mass (kg)	700
Typical Characteristic Dimensions (mm³)	700 x 500 x 400

EXTREMELY LIGHTWEIGHT, COMPACT, EASY TO OPERATE, AND INEXPENSIVE

S-Band and L-Band SYSTEMS

Typical Electron Beam Energy (MeV)	1 to 20
Typical Electron Beam Power (kW)	1 to 30
Typical Electron Beam Head Mass (kg)	500
Typical Characteristic Dimensions (mm³)	1500 x 1200 x 1200
Scan Horn	As required

MEDIUM AND HIGH POWER, EASY TO OPERATE, SMALL FOOTPRINT

OPTIONS:

- Electron beam energy regulation while maintaining wall-plug efficiency (up to 40%)
- Compact robot-mounted systems (up to 15 kW)
- Turn-key installation with local biological shield (small footprint)
- Custom design
- Systems with electron beam energy up to 800 MeV

PORTABLE AND COMPACT HIGH POWER ELECTRON BEAM SOURCE BASED ON LINEAR ACCELERATORS

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