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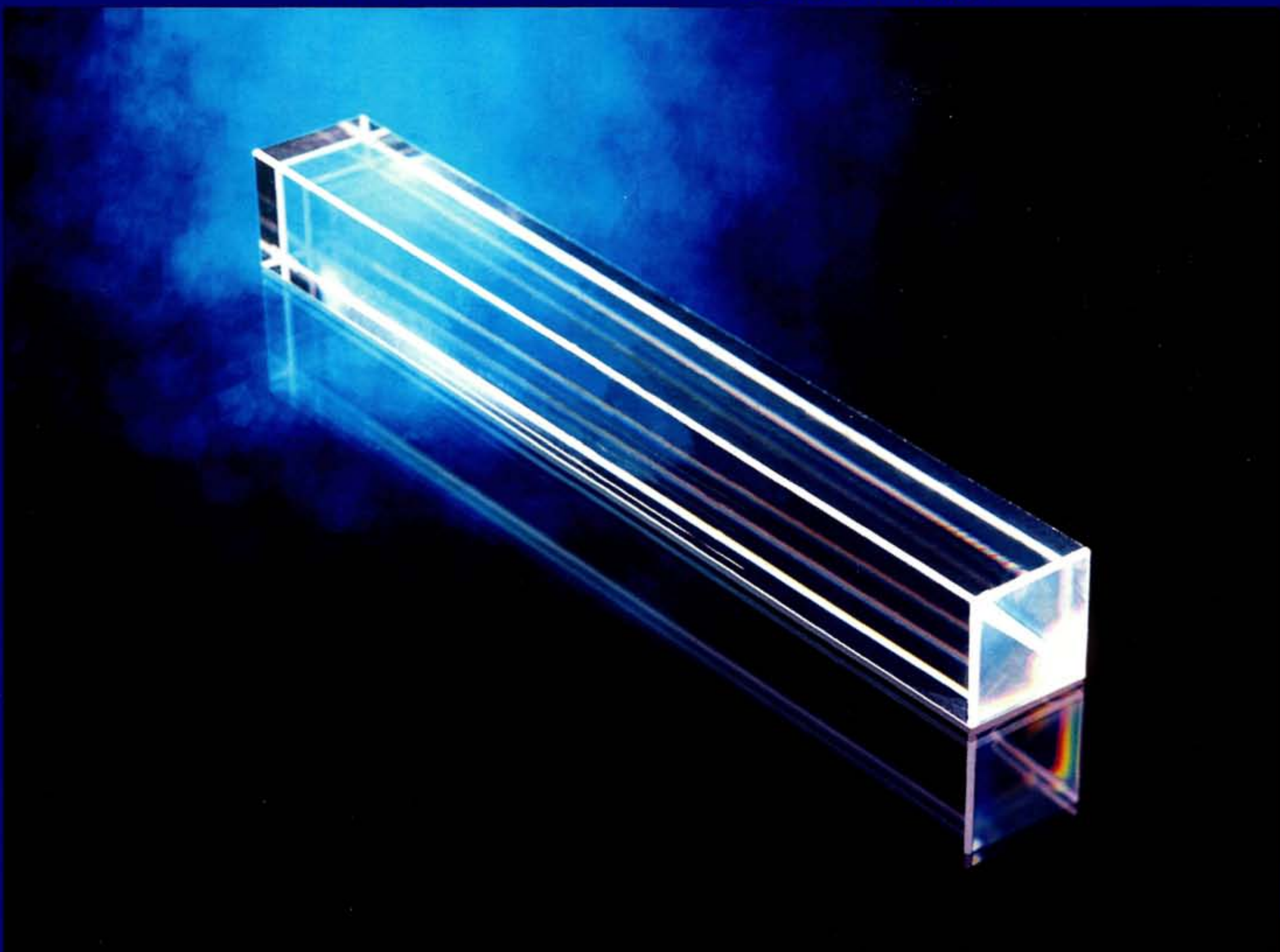

Denser than iron yet clear as crystal

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New experiment to take search into orbit p24

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

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Editor James Gillies
CERN, 1211 Geneva 23, Switzerland
Email cern.courier@cern.ch
Fax +41 (22) 782 1906
Web http://www.cerncourier.com

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Institute of Physics Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK
Tel. +44 117 929 7481
Email jo.nicholas@iop.org
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General distribution Jacques Dallemagne, CERN, 1211 Geneva 23, Switzerland. Email jacques.dallemagne@cern.ch
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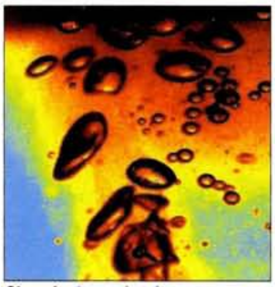

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Golden Hadron awards p32

Cover: A consignment of 500 lead tungstate crystals arrived at CERN from the northern Russian town of Apatity in May. Destined for the ALICE heavy-ion experiment in preparation for the Large Hadron Collider, each crystal is an 18 cm long rod with a 2.2 cm square section, and weighs some 750 g. A total of 17 000 crystals will make up the experiment's photon spectrometer (p6).

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INSTRUMENTATION

Turkey hosts regional instrumentation school

The first International Committee on Future Accelerators (ICFA) regional instrumentation school was held in June at the new instrumentation centre at Istanbul Technical University, Turkey, marking a new departure for this traditional series of schools. ICFA instrumentation schools are normally held every two years to provide education in the field of nuclear instrumentation for students of all nationalities, with the particular aim of giving students from developing countries first-hand access to information and equipment that may not be available in their home institutes. The last school was held in 2001 at South Africa's national accelerator centre near Cape Town, and 2002 would usually have been an off-year.

A new ICFA initiative, however, aims to establish regional schools that will have the same aims as the main schools, but will use local teachers and target a regional audience.

CERN's Alan Rudge explains noise in silicon detectors to students at the first ICFA regional instrumentation school in Istanbul.

The Istanbul school's 29 lecturers came from high-energy physics institutes around the world, selected by the ICFA instrumentation panel under the chairmanship of Albert-Heinrich Walenta of Siegen University, Germany. Laboratory demonstrators spent several months before the school preparing experiments on a range of subjects including medical imaging, high-precision spectroscopy and silicon detector applications, so that the 91 students could gain real hands-on experience. Many of the institutes that provided practical demonstrations have donated equipment so that the school can be repeated with local tutors for students from Turkey and surrounding countries.

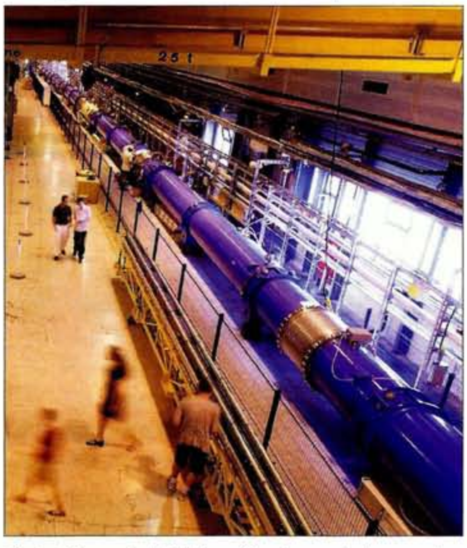
The Istanbul school was sponsored by the Scientific and Technical Research Council of Turkey, the US National Science Foundation and Department of Energy, the University of Siegen, Fermilab and ICFA. A second regional school organized along similar lines will be held in November at the University of Michoacan in Mexico.

LHC

LHC test-bed progresses to second phase

A complete cell of CERN's Large Hadron Collider (LHC) began tests at the laboratory in June. String 2, as the cell is known, has been built to validate LHC systems and operating procedures. It succeeds an original string made up of early prototypes, which was dismantled in December 1998. The present facility was first operated last year, although without its full complement of magnets. The full cell now consists of six dipole magnets, two straight sections (each comprising a quadrupole and corrector magnets), a prototype cryogenic distribution line and an electrical feedbox.

In its original configuration, String 2 had only three dipoles, all of which were prototypes. The three dipoles that have been added to make up the full cell are pre-production magnets that will form part of the future accelerator. The full cell is almost 120 m long and it is curved like the future accelerator to mimic the LHC as closely as possible. The amount of instrumentation and the complexity of the String 2 processes are also close to those of an LHC sector.



String 2 – a full LHC cell in the regular part of the collider's arc.

First tests went according to plan. Following mechanical checks to ensure there were no leaks and that the string could withstand the pressures that occur during a transition from the superconducting to the normal state (a quench), the assembly was cooled down to its nominal temperature of 1.9 K in just under 10 days. Powering up the circuits then followed without incident, with the dipole circuit reaching its nominal current of 11860 A, corresponding to a magnetic field of 8.335 T, on 17 June. An experimental programme that will run until the end of the year is now under way.

ALICE

ALICE crystals arrive at CERN

Members of the ALICE collaboration greet the arrival of the experiment's first 500 lead tungstate crystals. Their journey brought them to CERN, via Moscow, from the town of Apatity in the far north of Russia.

The first 500 crystals for the ALICE experiment's photon spectrometer (PHOS) arrived at CERN in May after a journey via Moscow from the town of Apatity in the Russian arctic region. The experiment is optimized to study heavy-ion collisions and is scheduled to start data-taking in 2007. These crystals are the first of 17 000 that will make up the experiment's PHOS – a sort of thermometer for the deconfined plasma of quarks and gluons that ALICE physicists hope to study. Denser than iron, the crystals' lead tungstate scintillates when struck by photons, allowing the photon spectrum to be measured.

ALICE is not the only Large Hadron Collider experiment that will employ lead tungstate crystals; CMS will use some 80 000 of them in its electromagnetic calorimetry (*CERN Courier* May 1999 p6). Such a large order tied up the existing production capacity for such crystals and meant that ALICE had to look elsewhere. The solution was to recommission facilities at a former military factory in Apatity in the Murmansk region of northern Russia. Crystals are grown in ovens at more than 1000 °C in a process that takes 60–70 h, during which the temperature must be constant and all vibration avoided. With 25 furnaces in operation at Apatity, around 100 people are employed in producing the ALICE crystals. Each furnace can produce 100 crystals per year. Meanwhile, a mechanical and optical testing device has been set up at the Kurchatov Institute in Moscow, where every crystal undergoes certification before being sent on to CERN.

ICHEP

Amsterdam hosts ICHEP conference

"Brilliant work by many people has resulted in an extraordinarily profound, precise description of the physical world," concluded Frank Wilczek of MIT, in summarizing the 31st International Conference on High-Energy Physics in Amsterdam. "Because of this we can ask, and formulate plans to answer, some truly awesome questions." Examples of new high-precision results presented at the conference included the measurements of the mass and width of the W boson at LEP and the Tevatron; the strong coupling constant at HERA and LEP; and CP violation in B mesons from the BaBar and Belle experiments, which Yossi Nir from the Weizmann Institute described in terms of the first successful precision test of the Kobayashi–Maskawa mechanism of CP violation. A full report of the conference will appear in next month's issue of *CERN Courier*.

New particle data

The 2002 edition of the *Review of Particle Physics* appears in the 1 July edition of Physical Review D (K Hagiwara *et al.* 2002 *Phys. Rev. D* **66** 010001). Full details and ordering information for the review and the accompanying particle physics booklet are available at http://pdg.lbl.gov/ and its mirror sites around the world.

ESO reaches 40

The European Southern Observatory (ESO) celebrates its 40th anniversary on 5 October. Next month, Astrowatch will report on the proceedings and focus on the important contributions of ESO astronomy.

ANTIFONT

Physicists create font for antimatter

Have you ever been frustrated by the difficulty of representing antiparticles in a Microsoft Word document, where you have to resort to writing "-bar" after the letter denoting the particle – for example as in K-bar? Now help is at hand, at least for Apple Macintosh users, in the form of a font that allows bars, or "overlines", to be added to English characters and the most commonly used Greek characters. Physicists from the University of Mississippi in the US have developed the font, LinguistA, which allows you to make a K-bar, for example, by simply typing shift-5 followed by K.

More information is available at http://www.arxiv.org/abs/hep-ex/0208028.

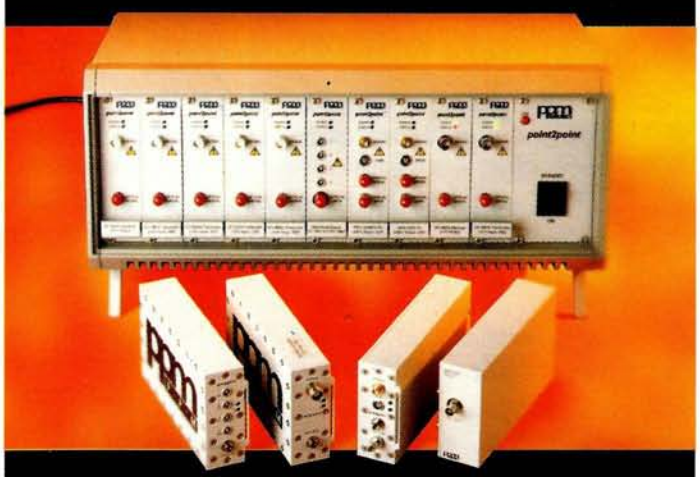
FORMER SOVIET UNION

CANDLE set to light up Armenian science

Originally in the running to host SESAME (*CERN Courier* June 2000 p6), Armenia launched its own synchrotron project when Jordan was chosen as the location for the Middle Eastern regional facility. Championed by the Armenian-American property magnate, Jirair Hovnanian, the Centre for the Advancement of Natural Discoveries using Light Emission (CANDLE) project aims to build a 3 GeV third-generation light source from scratch in the Armenian capital Yerevan. If successful, it will be the only facility of its kind within a 2000 km radius, serving users from countries of the former Soviet Union, parts of Europe, the Middle East and Asia. The Armenian government has provided an office building and 20 ha of land.

This building in the Armenian capital Yerevan could soon be home to the region's first third-generation light source.

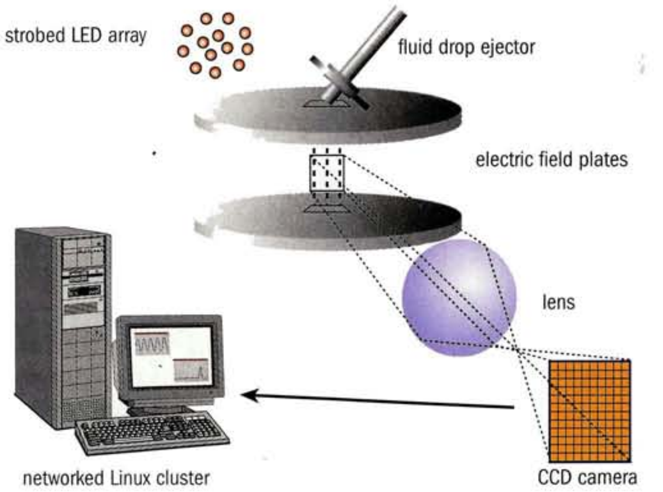
CANDLE received an important boost earlier this year when the US State Department allocated $500 000 (€510 000) for the preparation of a technical design report. This report was presented for review by the US National Science Foundation in Washington in August, along with details of scheduling, international participation and scientific programme. Riding on the outcome of the review could be a $15 million injection of US foreign aid towards CANDLE's projected $48 million price tag. If funding is secured, CANDLE's director, Alexander Abashian, is hopeful that construction could begin in 2004, allowing the first beamlines to be operational by 2007.



Edited by Archana Sharma

Modern Millikans search for exotic charge

"I have discarded one uncertain and unduplicated observation apparently on a singly charged drop, which gave a value of the charge on the drop some 30% lower than the final value of e," reported Robert Millikan in 1910. His words provided the inspiration for Martin Perl to take up the search for fractional charge as the 20th century entered its final decade. Perl's experiment, the microdrop particle search at the Stanford Linear Accelerator Center (SLAC), searches for isolated, fractionally charged particles in meteorite matter suspended in tiny droplets of oil just 25 μm in diameter. Researchers monitor the ziz-zag journey of these droplets as they fall from an aperture and enter an alternating electric field. Using the same basic physics as Millikan did – along with modern imaging, computing and microdrop-generation equipment – the group is able to calculate the charges on the tiny spheres, looking for hints of fractional charge.



Modern Millikan apparatus – SLAC researchers hope their microdrop particle search experiment will reveal hints of fractional charge.

The discovery of stable, fractionally charged particles would open a new field in elementary particle physics, improving theoretical models (which have often skirted issues of fractional charge), answering questions about the early universe, and perhaps leading to technological exploitation of the particles. Until now, no evidence of fractional charge has been seen, but with the introduction of carbonaceous chondrite meteorite matter the stakes have improved. The meteorite sample used by Perl's team is roughly 5000 million years old, and has never undergone any form of refining. This makes it a good candidate to have retained fractionally charged particles that may have been created during the Big Bang.

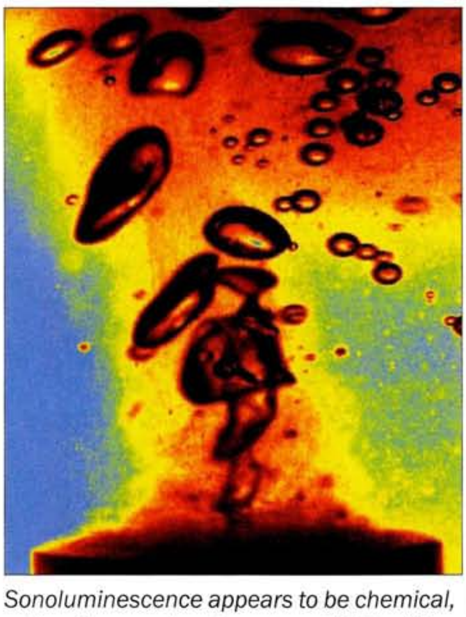
• Theorists who speculate about the existence of fractional charge expect that if such particles exist, they might, for example, show charges of multiples of 1/6 the electron charge. The particles would also need to be extremely massive to have so far escaped detection by detectors at the world's most powerful accelerator facilities.

Further reading

Robert A Millikan 1910 *Philos. Mag.* **110** 209.
http://www.slac.stanford.edu/exp/mps/FCS/FCS.htm.

Sonoluminescence could be chemical

Research at the University of Illinois points to a chemical nature for sonoluminescence, the phenomenon whereby ultrasound is converted into picosecond light pulses via the rapid oscillations of bubbles in a liquid. Earlier this year, scientists at the US Oak Ridge National Laboratory raised the possibility that sonoluminescence might be linked to nuclear fusion (*CERN Courier* May p11). However, the Illinois team has found that intense sound can compress bubbles in a liquid, increasing their temperature to 10–20 000 K. This is high enough for the gas molecules inside to become ionized, and results in a series of chemical reactions. Studies on a single bubble of air in water revealed reactant products of nitrite ions, hydroxyl radicals and light. The sonic energy largely goes into chemical reactions, with a small fraction resulting in light, leaving precious little to generate nuclear fusion. *AIP Physics News Update 599*


Sonoluminescence appears to be chemical, rather than nuclear, in nature. (K S Suslick and K J Kolbeck, University of Illinois.)

X-ray microscope has 3D vision

Atomic-scale snapshots in three dimensions may soon be possible, thanks to a new X-ray device developed by researchers at Stanford University, US. The microscope, developed by Jianwei Miao and colleagues, has so far been used to image structures down to 8 nm. Reaching the atomic scale of a few tenths of a nanometre should come from using brighter X-ray beams or longer exposures.

Miao's technique combines elements of diffraction and microscopy. A beam of coherent X-rays incident on a sample gives rise to a diffraction pattern in the reflected beam. Diffraction patterns allow 3D structures to be mapped. However, since the diffraction originates from a small region of the sample, the result is a microscope-like image showing local structure in three dimensions.

Nature Science Update, 14 August 2002

Edited by Emma Sanders

INTEGRAL prepares for lift-off

The launch of the International Gamma-Ray Astrophysics Laboratory (INTEGRAL) is scheduled for 17 October. Gamma-ray astronomy explores the most energetic phenomena in the universe and addresses some of the most fundamental problems in physics and astrophysics. INTEGRAL will study hard X-ray and gamma-ray sources in the energy range of 15 keV to 10 MeV.

The launch is awaited with much anticipation. Many of the sources discovered by INTEGRAL's predecessor, the Compton Gamma-Ray Observatory, remain unidentified. Indeed, the new instruments on board INTEGRAL will provide a big leap forward in both fine spectroscopy and imaging, enabling sources to be positioned accurately.

In particular, INTEGRAL will be used to study the radiation from compact objects such as neutron stars and black holes, and to help pinpoint the origins of gamma-ray bursts. The mechanisms fuelling gamma-ray bursts are still unknown, and they are by far the most powerful events known to occur since the Big Bang itself.

The INTEGRAL spacecraft with some members of the science working team. (ESA)

Indeed, some of the universe's most energetic processes are the least understood, another example being the highly relativistic jets seen streaming from active galactic nuclei. Gamma-ray observations are essential for understanding the particle interactions and the acceleration processes taking place. INTEGRAL will also map the diffuse gamma-ray background and, on a smaller scale, galactic structure and the elements making up the interstellar medium. The spectrometer will be used to study the production of elements by stellar nucleosynthesis by observing, among other things, the radioactive elements ejected into space by supernovae.

Of course, astronomers also hope for many unexpected discoveries, mirroring the huge leap forward made since the launch of new X-ray satellites, Chandra and XMM Newton.

The countries participating in INTEGRAL are Switzerland, Germany, Denmark, France, Italy, Ireland, Poland and the US. The science data centre is located in Versoix, Switzerland (*CERN Courier* July/August p32).

Looking further into the future, the Gamma-ray Large Area Space Telescope (GLAST) is due for launch in 2006. Funded by the US, France, Germany, Italy, Japan and Sweden, its energy range will be from 10 keV to 300 GeV. Several ground-based gamma-ray facilities are also under construction (*CERN Courier* September 2001 p30).

Picture of the month

The cone nebula is a huge pillar of dust at the heart of a turbulent star-forming region.

Radiation from hot, young stars slowly erodes the nebula over millions of years. Ultraviolet light heats the edges of the dark cloud, releasing gas into the relatively empty region of surrounding space. There, additional ultraviolet radiation causes the hydrogen gas to glow, which produces the red halo of light seen around the pillar. Over time, only the densest regions of the nebula will be left, and it is inside these regions that stars and planets form.

This image was taken using the Hubble Space Telescope's new Advanced Camera for Surveys (ACS), which was installed during a successful servicing mission carried out in March of this year (*CERN Courier* May p13). (NASA/ESA.)

Quark matter conference highlights RHIC results

Following the 2000 announcement by the CERN heavy-ion community of evidence for a new state of unbound quark-gluon matter, heavy-ion physicists have been eagerly awaiting results from Brookhaven's RHIC. At the QM 2002 conference, they got their first major glimpse, as conference chair **Hans Gutbrod** and **Thomas Peitzmann** report.

At a seminar in February 2000, spokespersons from CERN's heavy-ion experiments presented compelling evidence for the existence of a new state of matter in which quarks, instead of being bound up into more complex particles such as protons and neutrons, are liberated to roam freely. The seminar marked a turning point in heavy-ion research, with the spotlight turning to the other side of the Atlantic, where the Brookhaven Laboratory's Relativistic Heavy-Ion Collider (RHIC) was about to switch on. Would the RHIC data corroborate or contradict CERN's findings at the lower-energy programme? Most of the hadronic signals measured at RHIC so far have confirmed the CERN data and their interpretation, but new findings on high transverse momentum (p_T) physics at RHIC have opened up a new avenue of enquiry. The impressively rich harvest of data from the first running periods of RHIC made QM 2002 a major milestone in the quark matter (QM) conference series.

CERN research director Claude Détraz (left) with QM 2002 conference organizer Hans Gutbrod, who put the host town Nantes firmly on the heavy-ion physics map.

The French town of Nantes was chosen to host QM 2002 last July in recognition of its importance as a focus for French heavy-ion research. As the home of the SUBATECH laboratory, founded in 1995, Nantes leads French participation in the ALICE heavy-ion experiment in preparation for the Large Hadron Collider (LHC) at CERN. The six-day conference programme saw 46 plenary talks and debates, 100 parallel session talks and more than 150 posters. Many of the speakers were appearing for the first time at a QM conference, the vanguard of a new generation to carry forward the physics of this field. The 700 participants came from all over the world.

Claude Détraz of CERN formally opened the conference, in the presence of the president of the Pays de la Loire regional council, with a look back at more than 20 years of heavy-ion history at CERN. It all began with the proposal of a US-German collaboration to bring a heavy-ion injector to CERN to do physics at the laboratory's proton synchrotron. This idea evolved into a physics programme at the super proton synchrotron (SPS), leading to a lead-ion beam being built by a consortium from France, Germany, Holland, India, Italy and Sweden, together with CERN. The result was a fully-fledged research activity at CERN that will continue with the LHC.

Results from CERN

The search for a new state of strongly interacting matter at CERN started with beams of oxygen in 1986, and has continued with lead beams since 1994. The SPS fixed-target programme still has several experiments taking data, and many of those that have completed data-taking are still delivering physics results. Measurements of hadronic observables (strange and non-strange particles, flow and interferometry) are now becoming complete thanks to the measurements of the NA49, CERES and NA57 experiments, which were discussed by Christoph Blume of the German GSI laboratory, Marco van Leeuwen of Holland's NIKHEF, Johannes Wessels of GSI, and ▷

Vito Manzari of the Italian INFN laboratory in Bari. Many of these studies have revealed interesting phenomena, which are also observed at RHIC.

New measurements at lower SPS energies allow excitation functions to be studied. These reveal interesting features, such as an indication of a maximum strangeness enhancement in an energy range between that achieved by Brookhaven's Alternating Gradient Synchrotron and the top SPS energies. Statistical effects dominate fluctuations to a large extent, but detailed studies have revealed small non-statistical fluctuations. This was discussed by Bedanga Mohanty of Calcutta. Stefan Bathe of Münster presented results on high p_T studies from the WA98 experiment. These do not exclude small jet-quenching effects (suppression of jets through medium-induced energy loss of hard-scattered partons) for very central lead–lead collisions compared with peripheral collisions. However, the clear suppression seen at RHIC is not observed at the SPS. Jet-quenching appears to be a signal that will be clearly accessible only at the colliders.

The most striking observation relevant to quark–gluon plasma formation is the suppression of J/ψ particles as measured by the NA38 and NA50 experiments at CERN. Luciano Ramello of the University of Piedmont Orientale presented improved data on J/ψ from NA50, with much better quality for peripheral reactions. Moreover, detailed momentum distributions of J/ψ are now available to constrain theoretical calculations. Philippe Crochet of Clermont Ferrand pointed out that data on J/ψ deserve a fresh look to understand all the details. Final results from the improved CERES experiment and the measurements of open charm, which will be performed by NA60, are eagerly awaited.

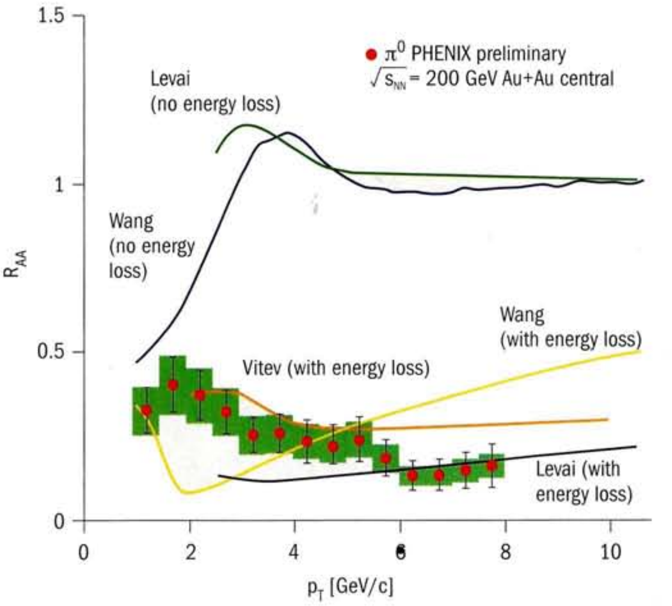


Fig. 1. Theoretical fits to the nuclear modification factor (R_{AA}) for neutral pions in central collisions of gold nuclei at RHIC describe the data better where energy loss in the medium is included.

Results from RHIC

While the SPS heavy-ion programme has reaped most of its harvest, results from the RHIC experiments only started to appear at last year's QM conference at Stony Brook, US, and became plentiful at this conference. Results on hadronic observables were presented by all four RHIC experiments in talks by Ian Bearden of the Niels Bohr Institute (NBI) for BRAHMS, Tatsuya Chujo of Tsukuba for PHENIX, Mark Baker of Brookhaven for PHOBOS, and by Lenny Ray of the University of Texas and Gene van Buren of Brookhaven for STAR. Their contributions took in global observables; spectra and yields of identified hadrons; interferometry; momentum, isospin and charge-fluctuations; and elliptic flow.

Full justice can only be done to all the new results from RHIC in the conference proceedings, but it is worthwhile drawing attention to some highlights. The ratios of produced particles can be described very accurately by statistical models of hadronization as discussed by van Buren, Chujo and Bearden for the experiments, and from the theory side by Andrzej Bialas of Krakow's Jagellonian University, Johann Rafelski of Arizona, and Volker Koch of Berkeley. This was already seen at the SPS, and can also be successfully applied to lower-energy heavy-ion reactions and to proton–proton and electron–positron reactions. Whether these statistical distributions are of thermal origin, or whether they are merely related to phase space dominance is not at all clear. Thermal concepts may be applicable to high-energy heavy-ion reactions, but this appears much more unlikely for electron–positron reactions. Interestingly, the associated "chemical temperature" for high-energy nuclear reactions is very close to the postulated phase-transition temperature.

Interferometry of charged pions leaves us with a few unresolved puzzles, as discussed by Ray and Chujo. The duration of emission of the most abundant particles appears to be very short. The apparent size of connected regions of the expanding fireball has similar dimensions in the radial and the tangential directions, unlike the predictions of most models for the expansion. The phase space density of pions is apparently very high, which can be interpreted in terms of very low entropy per pion.

The asymmetry of particle emission in the transverse plane (known as elliptic flow), which showed up in non-central heavy-ion reactions at lower energies, has not only survived at RHIC, but is even stronger as was demonstrated in the talks by Ray, Chujo and Baker. Since hydrodynamical models are so far the most successful in describing the features of this asymmetry, this is one of the strongest hints of an early local equilibration of the system. The strength of the asymmetry is still finite for very large transverse momenta, where one would expect production from hard scattering to dominate over any equilibrated contribution. This may be seen as a hint of asymmetric jet-quenching in the reaction zone; the quantitative interpretation is, however, not yet settled.

Fluctuations and multiparticle correlations may help in finding hints of new physics. Results on various different approaches were presented, with Ray giving one example from STAR. He proposed an interpretation in terms of very late hadronization in central collisions.

Jet-quenching

At QM 2002, it became even clearer than at last year's QM conference that RHIC has truly opened up the domain of hard scattering. This is particularly interesting, as it should allow the predicted jet-

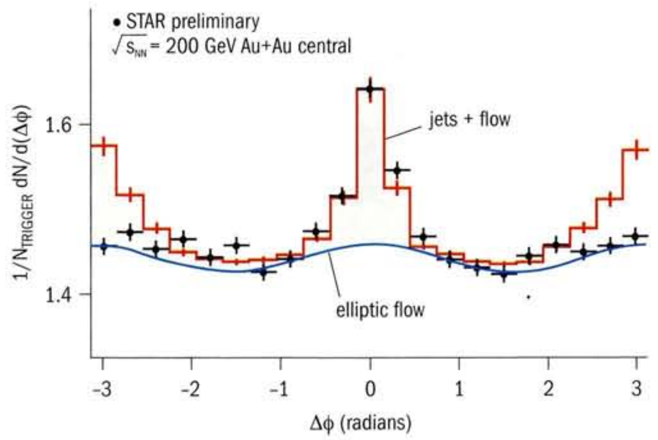


Fig. 2. The azimuthal correlation of charged particles relative to a high p_T trigger particle. The counter jet at $\Delta\phi = \pi$ in central collisions of gold nuclei at RHIC (black crosses) is suppressed compared to expectations from the proton–proton case (red histogram), while the trigger jet itself ($\Delta\phi = 0$) is unaffected.

quenching to be used as a signature of the hot, dense medium. Rudolf Baier of Bielefeld discussed jet-quenching in detail. Hadron spectra have been measured by all experiments and were presented in the talks by Saskia Mioduszewski of Brookhaven for PHENIX, Gerd Kunde of Yale for STAR, Christof Roland of MIT for PHOBOS, and Claus Jørgensen of NBI for BRAHMS. Only PHENIX and STAR have measured out to truly high momenta. Their spectra are compared to the expectation from proton–proton reactions. This is commonly done by calculating a so-called nuclear modification factor (R_{AA}), the ratio of spectra in nucleus–nucleus collisions to those in proton–proton collisions scaled by the number of possible binary nucleon–nucleon collisions within a heavy-ion reaction. Of particular importance was the measurement of neutral pions out to $p_T \approx 10$ GeV/c by PHENIX. This measurement is important, because the neutral pion can be well identified out to such high p_T and because PHENIX has also measured the spectra for proton–proton reactions within the same apparatus. The nuclear modification factor, which should be equal to 1 without any nuclear effects, is significantly below 1 up to the highest momenta analyzed (figure 1). Also shown in figure 1 are results of theoretical calculations with and without energy loss (jet-quenching). Calculations without energy loss miss the data completely. Calculations including energy loss provide the right order of magnitude for R_{AA}, but still fail to describe the data exactly.

While the suppression in inclusive spectra shown in figure 1 is quantitatively the best-established indication of jet-quenching, it is much more fascinating to see hints of jet structures themselves. Indications of such angular correlations relative to a high-momentum trigger particle, both at small angles and back to back, were discussed by David Hardtke of Berkeley for STAR and by Mioduszewski for PHENIX. STAR presented the most advanced analysis of these correlations, and was able to demonstrate modifications of the jet structures for central gold–gold collisions (figure 2). The trigger jet appears to be almost unaltered. The counter jet, however, is completely suppressed in central collisions. The quenching of jets relative to the expectation from the proton–proton case appears to be established. Nevertheless, the interpretation of this phenomenon is not completely clear. One of the major open questions remaining is that of the composition of the high p_T distributions of different particle species. Results from PHENIX seem to indicate that pions make up only around half of all charged hadrons even at very high p_T, in contradiction to expectations from perturbative quantum chromodynamics (QCD).

The study of rare probes at RHIC, such as J/ψ and direct photon production, is still under way. PHENIX collaboration members James Nagle of Columbia and Klaus Reygers of Münster presented the status of these analyses. Such results are likely to contribute to the experimental highlights of the next QM conference.

Looking ahead

The experiments have provided theorists with a huge amount of data to contemplate. Currently there is no comprehensive theory in sight that could describe all the data or even a larger fraction of them, as Brookhaven's Robert Pisarski pointed out. Theories or models can describe limited sets of data, but for some observables even such attempts fail. For example, the precise shape of the nuclear modification factor observed at RHIC cannot be described. A lot of effort is needed in the coming years to close the gap between theory and experiment. Progress has so far been made in areas of limited scope. Pasi Huovinen of Minnesota pointed out how hydrodynamical models are successful in describing certain bulk properties of the reactions. Direct photon calculations have been stimulated by the available measurement of WA98, which apparently requires a hot initial state to be explained. François Gélis of Orsay discussed new ideas, including the precise treatment of the Landau–Pomeranchuk–Migdal effect, which predicts a suppression of low-energy photon production in a dense medium. Frithjof Karsch of Bielefeld said that the possible use of the maximum entropy method to calculate production rates is very promising. The idea of saturation has been developed to very fruitful theoretical recipes, as presented by Edmond Iancu of Saclay. Lattice calculations approach realistic parameter settings, but as Tsukuba's Kazuyuki Kanaya pointed out, the question of the nature of the phase transition remains open. Zoltan Fodor of Eötvös University discussed the possibility of calculating properties of QCD at finite baryochemical potential on the lattice.

Future directions were the subject of the final sessions. The major avenue of quark matter research leads to the LHC heavy-ion programme, which was presented by Helsinki's Keijo Kajantie and Paolo Giubellino of INFN Turin, where still higher-energy density and temperature at negligible net baryon density are expected. An important follow-up on the lower-energy front was presented by Jochen Wambach of Illinois, who discussed a new facility at GSI that aims to study the highest net baryon densities.

Further reading:

http://alice-france.in2p3.fr/qm2002/.

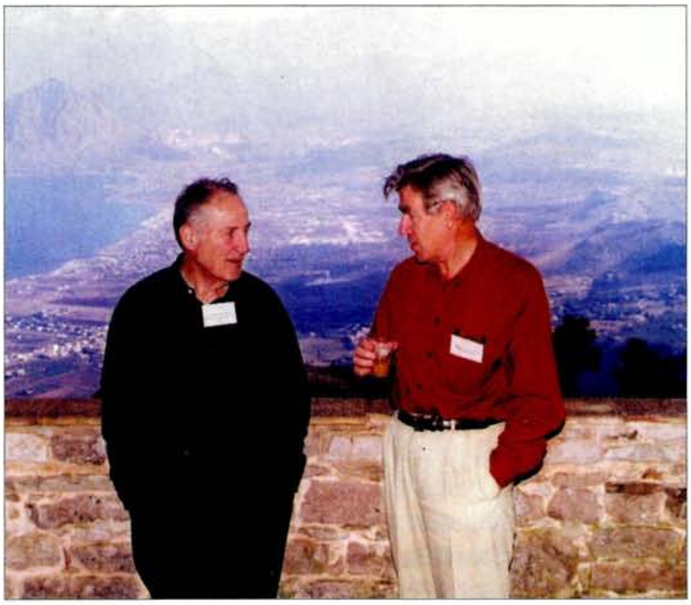
Proceedings to be published by North-Holland Elsevier.

Hans Gutbrod *and* **Thomas Peitzmann**, *GSI.*

Workshops focus on photon–hadron collisions

As well as taking proton–proton and heavy-ion physics into a new energy regime, CERN's LHC will produce the world's highest-energy photon–hadron interactions, providing a powerful fundamental physics laboratory. **Kai Hencken** and **Sebastian White** explain.

In 1924 Enrico Fermi travelled to Leiden, the Netherlands, to visit Paul Ehrenfest on a three-month fellowship from the International Education Board, which had been founded the year before by John D Rockefeller Jr for the "promotion and advancement of education throughout the world". Fermi was just 23 years old. During his stay in Leiden, he developed a method to calculate the interactions of charged particles with matter, which he called "äquivalente strahlung". This was extended to the relativistic case in the 1930s by Carl Friedrich von Weizsäcker and E J Williams, who realized that charged particles in cosmic rays could deliver the highest-energy (virtual) photon beams to study pair production of the positron. Today, the technique is known as the equivalent photon approximation, and it provides a powerful tool for fundamental physics.



Adrian Melissinos (left) and Ingvar Lindgren discuss strong fields during a break at the Erice workshop.

In an echo of the insight of von Weizsäcker and Williams, a growing community of physicists is looking to CERN's forthcoming Large Hadron Collider (LHC) as a new source of very-high-energy photon–hadron interactions. When the LHC stores colliding lead beams at a centre of mass energy of 5.4 TeV per nucleon, for example, lead ions in grazing collisions will be bombarded with photons of energy extending to hundreds of tera-electron-volts in their rest frame. Similarly, photon–photon invariant masses in the range of 100 GeV will be created in this way.

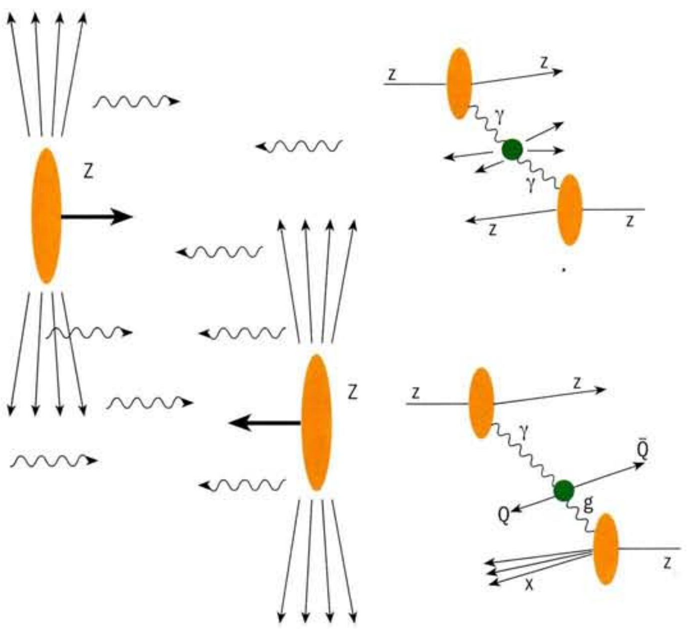
Ultraperipheral collisions

Such collisions are known as ultraperipheral, and have the general feature of an absence of particles produced along at least one beam direction (Bjorken's "rapidity gap"), because the photon is neutral. In many cases the produced system can be measured in a rather clean way in any of the LHC's detectors. The strong field of these "quasi-real photons" has found many interesting applications in atomic, nuclear and particle physics.

In October of Fermi's centenary year, 2001, a workshop in Erice, Sicily, focused on ultraperipheral collisions. It was followed by a second meeting at CERN last March. The Erice workshop – Electromagnetic Probes of Fundamental Physics – was organized by Bill Marciano and Sebastian White from the US Brookhaven National Laboratory, and featured sessions on the muon g-2, ultraperipheral collisions at Brookhaven's Relativistic Heavy-Ion Collider (RHIC) and the LHC, as well as topics in strong field research.

Francis Farley of Yale University, US, gave a review of 44 years of g-2, while David Hertzog of Illinois, US, presented the latest results from Brookhaven. Andreas Höcker of Orsay, France, Simon Eidelman of Novosibirsk, Russia, and Marciano discussed the theoretical side, with an emphasis on hadronic corrections. Since the meeting, higher-precision results on g-2 have been announced (*CERN Courier* September p8). Teams from Brookhaven, Novosibirsk and the ALEPH experiment at CERN's large electron–position collider presented results on the related analyses of electron–positron annihilation to hadrons and semi-leptonic tau lepton decays. An intriguing discrepancy between the electron–positron and tau analyses is now the focus of the interpretation of g-2 as a potential indicator of physics beyond the Standard Model. New data from the Belle, BaBar and Kloe experiments at Japan's KEK laboratory, SLAC in the US and Frascati in Italy are eagerly awaited.

Ilya Ginzburg and Valery Serbo of Novosibirsk presented the related topic of future photon–photon colliders. The spontaneous ▷



The strong Coulomb field of the fast-moving heavy ions is an abundant source of quasi-real photons. At the LHC, a range of photon–photon and photon–hadron collisions will occur at high photon energies.

breakdown of the vacuum by intense lasers was discussed by Adrian Melissinos of Rochester University, US, while Andreas Ringwald of Germany's DESY laboratory talked about the science that will be accessible with the X-ray free-electron lasers being developed by the DESY-led TESLA project. The sources and interactions of ultra-high-energy cosmic rays were the subject of talks from Alex Kusenko of UCLA and Steve Reucroft of Boston's Northeastern University, US.

Carlos Bertulani of Michigan State University, US, and Spencer Klein of Berkeley, US, along with Kai Hencken of Basel University, Switzerland, and Gerhard Baur of Jülich, Germany, reviewed the theoretical background of ultraperipheral collisions, while also pointing out the opportunities in both photon–photon and photon–hadron physics.

After presentations on recent experimental results from RHIC by Jim Thomas and White of Brookhaven, and Pablo Yepes of Rice University, US, the discussion turned to a prioritized list of the opportunities at RHIC and the LHC. These are summarized in an Erice white paper on hot topics in ultraperipheral collisions, which is included in the workshop proceedings (see Further reading).

The white paper was adopted as the point of departure for an exploratory meeting on ultraperipheral relativistic heavy-ion collisions that was held at CERN in March. This meeting, organized by Hencken and Yepes, was well attended not only by theoreticians, but also by experimentalists from the LHC collaborations interested in ultraperipheral collisions.

SLAC's Stan Brodsky gave the introductory talk, followed by Baur. Both presented a range of interesting applications from a theoretical point of view for photon–photon and photon–hadron collisions at RHIC and the LHC. Leonid Frankfurt of Tel Aviv University, Israel, discussed photoproduction of vector mesons on protons and ions. The first results from the STAR experiment at RHIC for coherent rho-meson production were presented by Falk Meissner of Berkeley. Joakim Nystrand of Lund University, Sweden, showed that interesting interference phenomena, due to the fact that each ion can either be the source of the photon or the target, can be studied in these collisions. Highlights from the rich photon–hadron programme at DESY's HERA electron–proton collider were presented by Giuseppe Iacobucci of the INFN in Bologna, Italy.

The strong electromagnetic excitation of heavy ions in ultraperipheral collisions is largely due to the strong source of low-energy photons. As they subsequently decay, heavy-ion fragments can be used for luminosity monitoring by detecting the neutrons in a zero-degree calorimeter, as discussed by White, Igor Pshenichnov of Moscow's Institute for Nuclear Research and Vladimir Korotkikh from Moscow State University, Russia.

Physics opportunities

A range of physics opportunities was discussed at the CERN workshop. Berkeley's Ramona Vogt pointed out the possibility of deducing the gluon structure function within the nuclear medium using heavy-quark production in photon–gluon fusion. Krzysztof Piotrzkowski from Louvaine-la-Neuve, Belgium, described how the possibility of tagging protons in a forward detector after photon emission permits the study of photon–photon collisions at invariant masses beyond the Z mass. This would allow researchers to look at the electromagnetic coupling of W bosons and also to search for new physics. Brookhaven's Anthony Baltz and Hencken, and Frank Krauss of Cambridge University, UK, discussed aspects of lepton pair production. These include bound-free pair production and the production of muonium.

Studies on detecting ultraperipheral collisions within the LHC detectors were presented by Serguei Sadovsky of Protvino, Russia, for ALICE and Yepes for CMS, both of whom emphasized the importance of having a trigger for these events. Daniel Brandt of CERN discussed the possibilities of different ion beams at the LHC, where electromagnetic processes can limit the maximum beam luminosity.

One tangible outcome of the workshop is the formation of a working group on ultraperipheral collisions, paying particular attention to the potential for this physics at the LHC. Another meeting is scheduled to take place at CERN on 11–12 October. Its goal will be to start work on a report giving full details of the physics of ultraperipheral heavy-ion collisions accessible within the LHC detectors as currently conceived. With such an intense source of photons, the conclusion of the workshops was that the future is bright for ultraperipheral collisions at the LHC.

Further reading

Fermi's original work on the equivalent photon approximation: See e-print hep-th/0205086 at http://www.arxiv.org/.

Hot topics in ultraperipheral collisions is available as e-print hep-ex/0201034 at http://www.arxiv.org/.

For CERN workshop details see http://quasar.unibas.ch/upc/.

Kai Hencken, *Basel University, and* **Sebastian White**, *Brookhaven.*

Physicists and statisticians get technical in Durham

Particle physicists and statisticians got together in Durham, UK, last March to discuss statistical techniques of relevance to particle and astroparticle physics analysis. Conference initiator **Louis Lyons** reports.

Durham University's Institute for Particle Physics Phenomenology (IPPP) hosted a conference on advanced statistical techniques in particle physics on 18–22 March this year. Building on the success of workshops held at CERN and Fermilab in early 2000 covering the extraction of limits from the non-observation of sought-for signals, the meeting covered a wider range of statistical issues relevant to analysing data and extracting results in particle physics. Astroparticle physics was also included, since many of the analysis problems encountered in this emerging field are similar to those in traditional accelerator experiments.

Almost 100 physicists and two professional statisticians gathered at Durham's IPPP in March to discuss statistical techniques in particle physics.

The IPPP provided an excellent venue for both formal sessions and animated informal discussions, and the only complaint seemed to be that no time was set aside for the participants to visit Durham's impressive cathedral. Almost 100 physicists attended the conference, joined by two professional statisticians whose presence was invaluable, both in terms of the talks that they gave, and for their incisive comments and advice.

The meeting began with a morning of introductory lectures by Fred James of CERN. Although these lectures were aimed primarily at those who felt the need to be reminded of some statistical principles before the conference proper began, they were attended and enjoyed by most of the participants. James emphasized the five separate statistical activities employed by physicists analysing data: estimating the best value of a parameter; interval estimation; hypothesis testing; goodness of fit; and decision-making. He stressed the importance of knowing which of these activities one is engaged in at any given time.

James also discussed the two different philosophies of statistics – Bayesianism and frequentism. Bayesians are prepared to ascribe a probability distribution to the different possible values of a physical parameter, such as the mass of the muon neutrino. To a frequentist this is anathema, since the mass presumably has a particular value, even if not much is currently known about it. The frequentist would therefore argue that it is meaningless to talk about the probability that it lies in a specified range. Instead, a frequentist would be prepared to use probabilities only for obtaining different experimental results, for any particular value of the parameter of interest. The frequentist restricts himself to the probability of data, given the value of the parameter, while the Bayesian also discusses the probability of parameter values, given the data. Arguments about the relative merits of the two approaches tend to be vigorous.

Michael Goldstein, a statistician from Durham, delivered the first talk of the main conference. On the last day, he also gave his impressions of the meeting. He is a Bayesian, and described particle physics as the last bastion of out-and-out frequentism.

Durham is one of the world's major centres for the study of parton distributions (describing the way that the momentum of a fast-moving nucleon is shared among its various constituents). Because of this, special attention was given to the statistical problems involved in analysing data to extract these distributions, and to the errors to be assigned to the results. There were talks by Robert Thorne, a phenomenologist from Cambridge, and Mandy Cooper-Sarkar, an Oxford experimentalist working on DESY's ZEUS experiment. This was followed by a full-day parallel session in which the parton experts continued their detailed discussions. Finally there ▷

was an evening gathering over wine and cheese, at which Thorne summarized the various approaches adopted, including the different methods the analyses used for incorporating systematic errors.

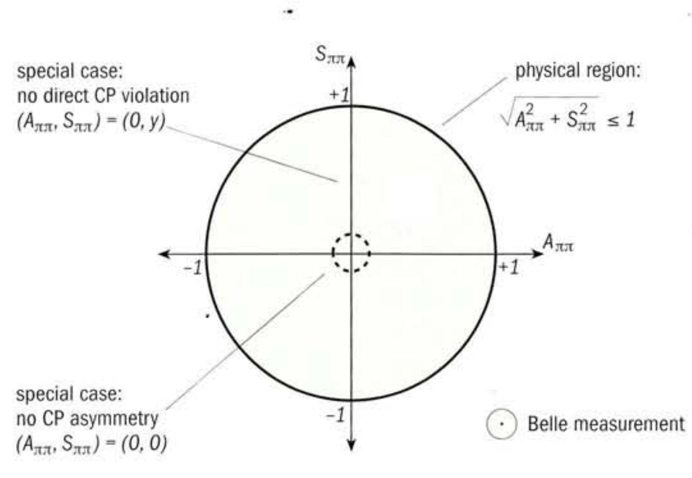


Fig. 1. In a plot of CP-violation parameters, $A_{\pi\pi}$ and $S_{\pi\pi}$, physical reality is bounded by the unit circle. The Belle experiment's measurement of these parameters lies outside the circle, thereby complicating the interpretation of the result.

Confidence limits

Confidence limits – the subject of the earlier meetings in the series – of course came up again. Alex Read of Oslo University had some beautiful comparisons of the CL_s method and the Feldman–Cousins unified technique. CL_s is the method used by the LEP experiments at CERN to set exclusion limits on the mass of the postulated Higgs particle that might have been produced at LEP if it had been light enough. The special feature of CL_s is that it provides protection against the possibility, arising from a statistical fluctuation of the background, of excluding Higgs masses that are so large that the experiments would be insensitive to them. The main features of the Feldman–Cousins technique are that it reduces the possibility in the standard frequentist approach of ending up with an interval of zero length for the parameter of interest, and it provides a smooth transition between an upper limit on a production rate when the supposed signal is absent or weak, to a two-sided range when it is stronger. Read's conclusion was that CL_s is preferable for exclusion regions, and Feldman–Cousins is better for estimating two-sided intervals.

Staying with limits, Rajendran Raja of Fermilab thought it was important not only to set the magnitude of a limit from a given experiment, but also to give an idea of what the uncertainty in the limit was. Dean Karlen of Ottawa's Carleton University suggested that as well as specifying the frequentist confidence level at which an interval or limit was calculated, one should also inform the reader of its Bayesian credibility level. This again was an attempt to downplay the emphasis on very small frequentist intervals, which can occur when expected background rates are larger than the observed rate. Another contribution by Carlo Giunti of Turin emphasized that it may be worth using a biased method for obtaining limits, as this could give better power against excluding alternative parameter values.

Discovery significance

Hopefully, not all experiments searching for new effects will obtain null results, and simply set limits. When an effect appears, it is important to assess its significance. This was the subject of a talk by Pekka Sinervo of Toronto, which included several examples from the recent past, such as the discoveries of the top quark and of oscillations in neutral mesons containing bottom quarks.

Several talks dealt with the subject of systematic effects. Roger Barlow of Manchester gave a general review. One particularly tricky subject is how to incorporate systematic effects in the calculation of limits. For example, in an experiment with no expected background and with detection efficiency ε, the 95% confidence level upper on the signal rate is $3.0/\varepsilon$, from both frequentist and Bayesian approaches. However, what happens when the efficiency has an uncertainty? From an ideological point of view, it is desirable to use the same type of method (Bayesian or frequentist) both for the incorporation of the systematic and for the evaluation of the limit. Some interesting problems with the Bayesian approach were discussed by Luc Demortier of Rockefeller University, while Giovanni Punzi and Giovanni Signorelli, both of Pisa, spoke about features of the frequentist method, with illustrations from a neutrino oscillations experiment.

The question of how to separate signal from background was another popular topic. It was reviewed by Harrison Prosper of Florida State University, who is active in Fermilab's Run 2 advanced analysis group, where the topic is actively studied. His talk was complemented by that of Rudy Bock of CERN, who compared the performance of various techniques used for separating cosmic-ray air showers initiated by photons or by hadrons. The relatively new method of support vector machines was described by Tony Vaiciulis of Rochester, while Sherry Towers of Stony Brook made the point that including useless variables could well have the effect of degrading the performance of the signal-to-background separation technique. She also spoke about using kernel methods for turning multidimensional Monte Carlo distributions into probability density estimates. Monte Carlo methods were the subject of two talks by CERN's Niels Kjaer. With the need for large Monte Carlo samples, it is important to understand how to use the generators efficiently.

In searching for new or rare effects, it is important not to use the data to tune the analysis procedure so as to maximize (or minimize) the sought-for effect. One way of avoiding this is to perform a blind analysis. Paul Harrison of Queen Mary, University of London, described the psychological, sociological and physics issues in using this increasingly popular procedure.

Whatever the method used to extract a parameter from the data, it is important to check whether the data is consistent with the assumed model. When there is enough data, the well known χ^2 method can be employed, but this is less useful with sparse data, especially in many dimensions. James of CERN and Berkan Aslan of Siegen both spoke about this topic, with the latter showing interesting comparisons of the performance of a variety of methods.

A mundane but very important topic is the understanding of the alignment of the different components of one's detector. Hamburg's Volker Blobel explained how this can be done using real tracks in the detector, without the need to invert enormous matrices. In a separate

Problems do arise from different experiments making different assumptions, for example about systematic effects

talk, also involving the clever use of matrices, he described his method for unfolding the smearing effects of a detector. This enables one to reconstruct a good approximation to the true distribution from the observed smeared one, without encountering numerical instabilities. Glen Cowan of Royal Holloway, University of London, gave a more general review of deconvolution techniques.

Although textbook statistics can give neat solutions to data analysis problems, real-life situations often involve many complications and require semi-arbitrary decisions. There were several contributions on work at the pit-face. Chris Parkes of Glasgow described how the LEP experiments combined information on W bosons. Their mass is fairly precisely determined, and the well known best linear unbiased estimate (BLUE) method has been used for combining the different results. Nevertheless, problems do arise from different experiments making different assumptions, for example about systematic effects. These difficulties multiply for determining such quantities as triple gauge couplings where the errors are large, where likelihood functions are non-Gaussian and can have more than one maximum, and where the experiments use different analysis procedures. Here again, sociology plays an important role.

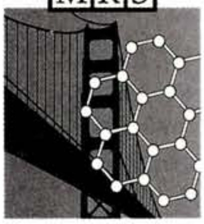
Nigel Smith of the UK Rutherford Appleton Laboratory and Daniel Tovey of Sheffield University presented interesting contributions on dark matter searches. Fabrizio Parodi of Genoa talked about B_s oscillations, and a whole variety of results from the Belle experiment at Japan's KEK laboratory were also discussed. An interesting point from the last talk, by Bruce Yabsley of Virginia Tech, related to the determination of two parameters ($A_{\pi\pi}$ and $S_{\pi\pi}$) in an analysis of B decays to $\pi^+\pi^-$, to look for CP violation. Physically the parameters are forced to lie within the unit circle. In the absence of CP violation, they are both zero, while if there is no direct CP violation, $A_{\pi\pi}$ is zero. The Belle estimate (figure 1) lies outside the unit circle. This sounds like a case for taking the physical region into account from first principles (as in Feldman–Cousins), but there are complicated details that make this difficult to implement.

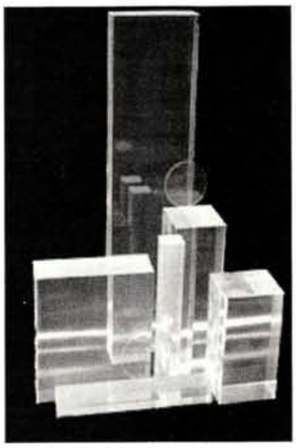
Many discussions started at the conference have continued, and some issues will undoubtedly resurface at the next meeting, scheduled to be held at SLAC in California, US, on 8–12 September 2003.

Further reading

The conference website is at http://www.ippp.dur.ac.uk/statistics/.

Louis Lyons, *Oxford University.*





University hosts premier rare-isotope facility

Since it was founded in the 1980s, Michigan State University's National Superconducting Cyclotron Laboratory has evolved to become the US's premier rare-isotope facility. **Georg Bollen** reports on its varied activities.

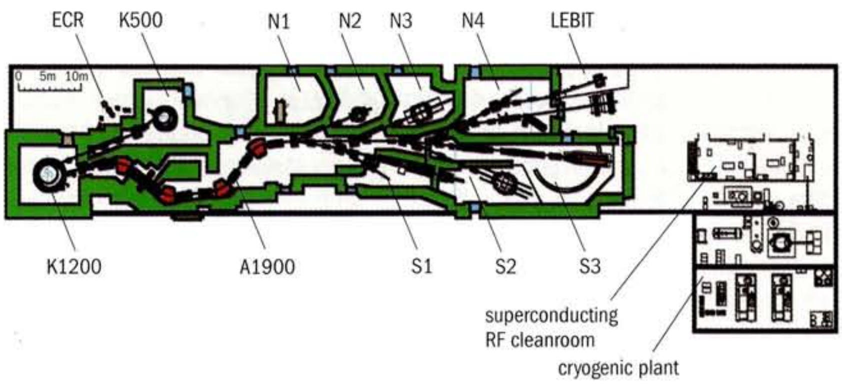
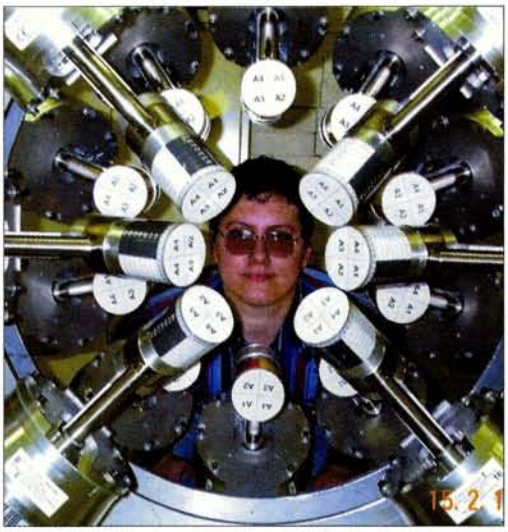


Fig. 1. The NSCL experimental area showing the ECR sources, the two superconducting cyclotrons (K500 and K1200), the superconducting beam analysis system (A1900) and subsequent beamlines, the various experimental vaults and areas (N1-4, S1-3 and LEBIT), the SRF R&D area and the cryoplant.



NSCL's segmented germanium detector array as used in nuclear gamma spectroscopy.

The National Superconducting Cyclotron Laboratory (NSCL) is a rare-isotope facility at Michigan State University (MSU) in the US. Since it started operating as a user facility in the late 1980s, the NSCL has established a successful history of research in nuclear physics. The facility has been extended and upgraded several times including a major upgrade from 1999 to 2001. This has dramatically improved the number and intensity of rare-isotope beams that the facility can provide, and has made the NSCL the premier rare-isotope user facility in the US.

The upgraded NSCL facility is based on two coupled superconducting cyclotrons and can produce intense energetic beams of primary heavy ions from hydrogen to uranium. A high-acceptance fragment separator allows efficient production and the in-flight separation of a broad range of secondary rare-isotope beams produced by projectile fragmentation or fission reactions. These beams are sent to various experimental devices that serve a community of researchers from the US and abroad.

Research at the NSCL is devoted to experimental and theoretical nuclear physics, nuclear astrophysics, accelerator physics and the development of related instrumentation. A key activity is investigating the properties of rare isotopes that are far away from stability. This includes measuring the structural and decay properties of nuclei near the drip lines; determining astrophysically important data on neutron- and proton-rich nuclei that participate in the r and rp (rapid neutron and proton capture) nucleosynthesis processes; and measuring mass precisely. Furthermore, beams at the NSCL allow the creation of nuclei at temperatures and densities commensurate with the liquid–gas phase transition in the phase diagram of nuclear matter. Here, the NSCL's research addresses questions concerning the thermodynamics of strongly interacting quantum many-body systems, and especially the determination of the equation of state of asymmetric nuclear matter.

Technical innovation

The NSCL has a history of technical innovation. It has been a pioneer in applying superconducting magnet technology to the design and construction of cyclotrons, spectrographs and beam-transport systems. The NSCL designed, built and commissioned the first superconducting cyclotron for cancer therapy by neutron irradiation at Harper Hospital in Detroit. Today, the NSCL's conceptual design ▷

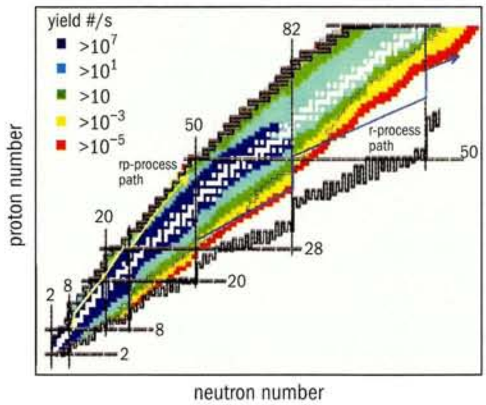


Fig. 2. The scientific reach of the NSCL Coupled Cyclotron Facility is illustrated in terms of the projected intensities of fast beams of rare isotopes.

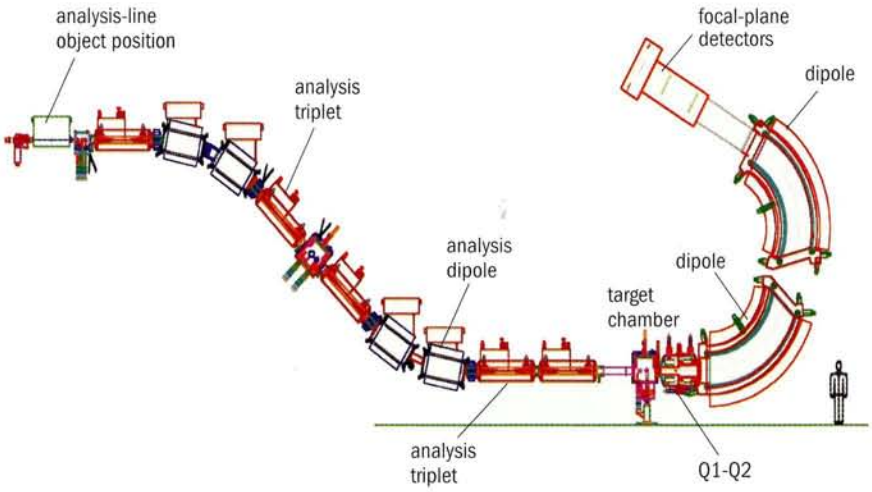


Fig. 3. The S800 magnetic spectrograph and the S800 beamline. All the dipoles bend the beam in the vertical plane, so the target position is below ground level.

for a superconducting 250 MeV proton cyclotron is the basis of the proton-therapy facility at the Paul Scherrer Institut which is being built by ACCEL with technical assistance from the NSCL. Perhaps the most important new initiative is the development of superconducting radiofrequency structures for use in linear accelerators. These structures may be used in the next-generation rare-isotope beam facility Rare Isotope Accelerator (RIA; *CERN Courier* March p15). RIA is now the highest new-construction priority of the US nuclear-physics community. NSCL played a key role in developing the RIA concept and MSU is naturally one of the prime candidate sites.

Rare-isotope production at the NSCL starts with a set of electron cyclotron resonance (ECR) ion sources (figure 1) that can ionize essentially any chemical element. Multiply-charged ions are injected into the first of NSCL's two cyclotrons, the K500. Here the ions are accelerated to an energy of about 10 MeV per nucleon and sent to the K1200 cyclotron. Inside the K1200 the ions pass a stripper foil that removes most – and, in the case of light elements, all – electrons. In this way maximum beam energies of 200 MeV per nucleon for lighter elements and 90 MeV per nucleon for uranium are achieved after final acceleration. These energetic primary beams can be used directly in experiments, or they can be converted into a broad range of radioactive ions by impinging them onto a thin target, where the choice of material and thickness optimizes the production of the desired isotopes.

To become useful for experiments the rare isotopes produced by projectile fragmentation or fission reactions have to be mass separated. This happens in the A1900 fragment separator/beam analysis system. The techniques used in the A1900 are so sensitive that one nucleus out of 10^{18} can be selected and studied. The A1900 can also be used as a monochromator to define the energy and emittance of the primary beam. Downstream from the A1900 is a beam switchyard that allows all the radioactive ion beams to be transported to any experimental station at the NSCL.

The facility's scientific reach is determined by the predicted intensities after separation in flight with the A1900 (figure 2). Far away from the valley of stability such predictions can be very uncertain. Nevertheless, the figure gives an idea about what will be in reach. For orientation, the approximate paths of nucleosynthesis via the astrophysical rapid proton (rp) and rapid neutron (r) processes are indicated. With beams from the CCF it may be possible to extend our knowledge of the neutron drip line (nucleons with a large number of neutrons) from oxygen to silicon or even sulphur. It will be possible to study a large number of rp-process nuclei and r-process nuclei up to $A \approx 140$, and at the same time to explore how nuclear structure evolves as one recedes to the borderlines of nuclear stability.

Experimental devices

The largest experimental device connected to the NSCL beam-line system is the S800 (figure 3). This is a superconducting magnetic spectrograph well matched to reaction studies with rare isotopes. It offers high-energy resolution ($E/\Delta E = 10^4$), large momentum acceptance ($\Delta p/p = 5\%$) and a large solid angle ($\Delta\theta = 20$ msr). The S800 enables various types of reaction studies to be performed with high resolution and high sensitivity. It is a key instrument for a large part of the experimental programme carried out at the NSCL.

The 4π array is a low-threshold "logarithmic" 4π detector that has been successfully used and will be used for intermediate-energy heavy-ion collision experiments. It consists of 32 position-sensitive, parallel-plate, multiwire detectors, backed by segmented Bragg ionization chambers, backed in turn by an array of 170 so-called phoswich detectors, each consisting of a fast-slow plastic scintillator combination. Upgraded with higher-granularity forward arrays it will allow studies of collisions of very heavy systems at the higher energies now available (for example, Au + Au at $E/A \geq 40$ MeV).

In addition to this fixed major equipment, a number of special-purpose detector arrays exist for the coincident detection of γ-rays, neutrons and charged particles. An important new instrument is a set of 18 segmented germanium detectors. This system has been designed for the efficient high-resolution detection of γ-rays emitted in flight from fast rare isotopes, but can also be used for online decay studies. For example, it will be used in intermediate-energy Coulomb-excitation studies, which investigate the collective properties of very-neutron-rich isotopes.

The lab has a pair of large area neutron detectors, or "neutron walls", and a third, MONA, is being constructed by a collaboration

At work on a neutron wall being prepared for use in neutron time-of-flight spectroscopy.

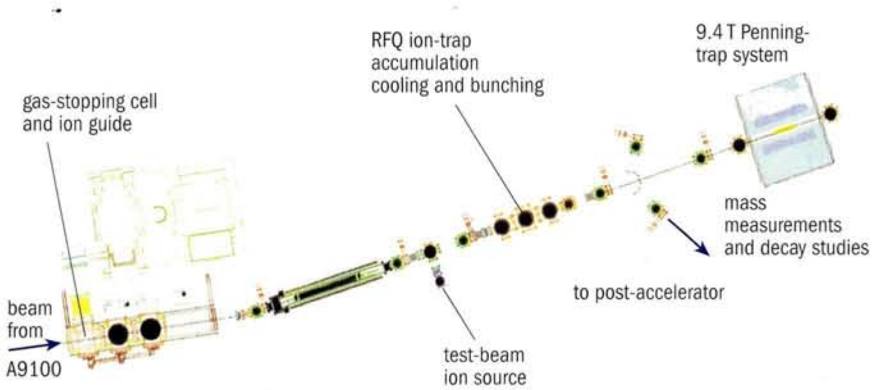


Fig. 4. Layout of the NSCL Low Energy Beam and Ion Trap (LEBIT) facility.

between several universities and undergraduate colleges. MONA is a modular system with a total area of 4 m^2 and an efficiency of about 70% for neutron energies above 50 MeV. It will be used with a large-gap superconducting "sweeper" magnet (4 Tm) that is being constructed at Florida State University's High Magnetic Field Laboratory. The magnet will serve as a high-acceptance magnetic spectrometer and, combined with neutron detectors, will be used for neutron time-of-flight spectroscopy.

A number of experiments require high-quality low-energy beams, such as those available at CERN's ISOLDE facility. This type of beam is not usually available at projectile-fragmentation facilities, which on the other hand do provide beams of all elements and have advantages in the production of the most short-lived isotopes. Providing such low-energy beams and making them available for experiments is the task of the Low Energy Beam and Ion Trap (LEBIT) facility (figure 4).

The key element of the LEBIT facility is a high-pressure (up to 1 bar) helium gas cell for slowing down and collecting energetic rare isotopes from the A1900 fragment separator. Ions slowed down in the gas cell remain singly charged and can be extracted with high efficiency. Electric fields guide the ions from the stopping volume through an exit nozzle into a radiofrequency quadrupole (RFQ) system that directs the ions through a differential pumping system. The continuous ion beam is then transported into a linear RFQ ion trap, which acts as a beam accumulator, cooler and buncher. The energy of the extracted ion bunches can be varied between 5 and 60 keV by means of a pulsed drift tube to satisfy the requirements of a variety of experiments. The system is in an advanced stage of construction and gas-stopping tests are under way. Experience gained in gas stopping and beam manipulation in LEBIT will provide valuable insight for the design and construction of a similar facility at RIA.

The first experiment to be set up is a Penning-trap system. A superconducting solenoid magnet with a field of 9.4 T will allow the extension of high-precision Penning-trap mass measurements to isotopes with half-lives as short as 10 ms. Later there are plans to add laser spectroscopy for isotopic-shift and nuclear-moment measurements, and atom-trap experiments for fundamental tests of weak interactions. Finally, beams from the LEBIT facility are well suited to post-acceleration to medium energies, as featured at CERN's REX-ISOLDE (*CERN Courier* January/February p4). A design study for such a scenario has already been carried out.

Further reading

NSCL website at http://www.nscl.msu.edu.
RIA March 2000 *Scientific Opportunities with Fast Fragmentation Beams* (http://www.nscl.msu.edu/future/ria/process/whitepapers/opportunitiesffbeam.pdf).
RIA Physics White Paper summary of the town meeting held at the RIA 2000 Workshop in Durham, North Carolina, 24–26 July 2000. A copy can be downloaded from http://www.nscl.msu.edu/future/ria/process/whitepapers/durham2000meeting.pdf.

Georg Bollen, *Michigan State University.*

PAMELA set to take pa

The PAMELA experiment, scheduled to be launch
provide a better understanding of the antimatte

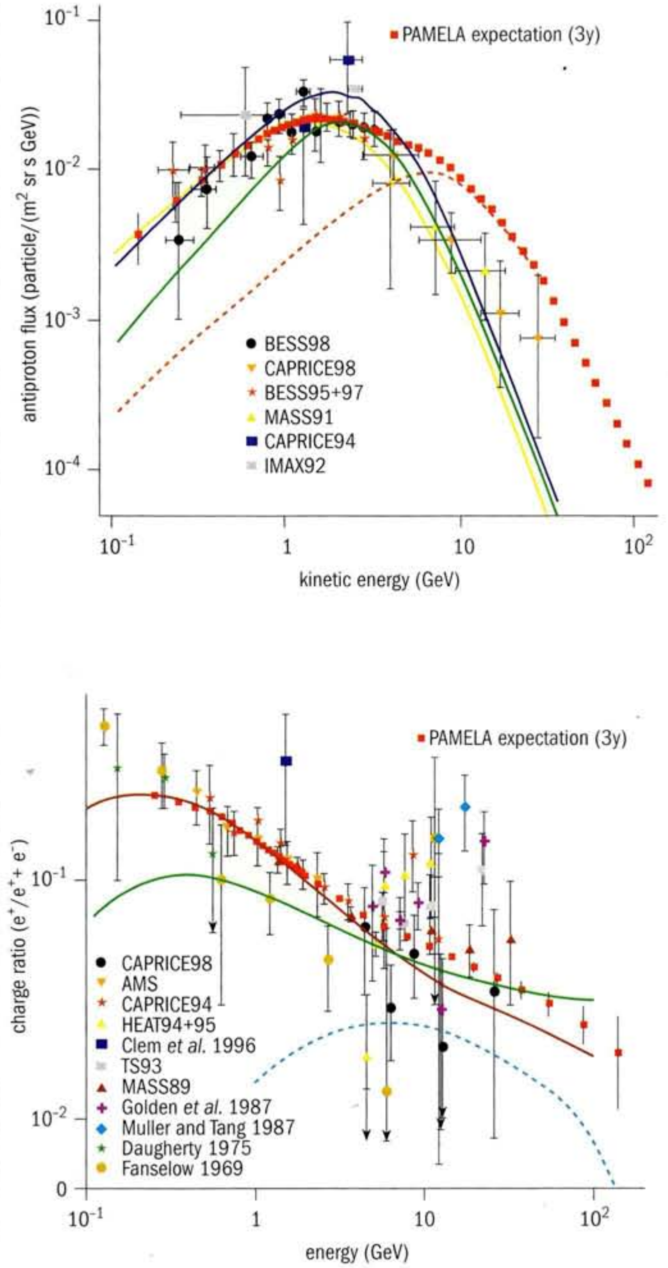


Fig. 1. The current status of measurements of the antiproton (top) and positron (bottom) energy spectra. The solid lines indicate the expected spectra from different models of secondary production. The dotted lines indicate the distortion to the spectrum expected from "exotic" sources, in this case the annihilation of supersymmetric neutralinos. Current data can be explained only using secondary production models. The red squares indicate the quality of data expected from PAMELA after three years of data taking.

The PAMELA experiment (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) will lift off aboard a Soyuz TM2 rocket in 2003, hitching a ride on the Russian Resurs-DK1 earth-observation satellite. While one end of the satellite will look down towards the earth, PAMELA will enjoy a clear view into space from the other. Data taking is expected to last for three years, and will result in better understanding of the antimatter component of the cosmic radiation.

The primary objective of PAMELA is to measure the energy spectrum of antiprotons and positrons in the cosmic radiation. At least 10^5 positrons and 10^4 antiprotons are expected per year. All existing antiproton measurements originate from balloon-borne experiments operating at altitudes around 40 km for approximately 24 h (figure 1; this also shows the situation for positrons). There is still a residual amount of the earth's atmosphere above the detecting apparatus at this altitude, with which cosmic rays can interact. A satellite-borne experiment benefits from a lack of atmospheric interactions and a much longer data-taking time. In figure 1, the PAMELA expectation after three years of data taking is shown. These data sets exceed what is available today by several orders of magnitude, and will allow significant comparisons between competing models of antimatter production in our galaxy. Distortions to the energy spectra could originate from exotic sources, such as the annihilation of supersymmetric neutralino particles – candidates for the dark matter in the universe. Sensitivity to the low-energy part of the spectrum is a unique capability of PAMELA, and arises because the semi-polar Resurs-DK1 orbit overcomes the earth's geomagnetic cut-off. Another PAMELA goal is to measure the antihelium to helium ratio with a sensitivity of the order of 10^{-8} – a 50-fold improvement on the current limits. An observation of antihelium would be a significant discovery, as it would be the first sign of primordial antimatter left over from the Big Bang.

WiZard collaboration

PAMELA is being constructed by the WiZard collaboration, which was originally formed around Robert Golden, who first observed antiprotons in space. There are now 14 institutions involved. Italian INFN groups in Bari, Florence, Frascati, Naples, Rome and Trieste, and groups from CNR, Florence and the Moscow Engineering and Physics Institute form the core. They are joined by groups from The Royal Institute of Technology (KTH) in Sweden, Siegen University in Germany, Russian groups from the Lebedev Institute, Moscow, and the Ioffe Institute, St Petersburg, and American groups from New Mexico State University and NASA's Goddard Spaceflight Centre.

The WiZard collaboration has a long history of performing cosmic-ray experiments. It ran six balloon flights between 1989 and 1998 using instrumentation novel for space, such as multisense drift cham-

rticle physics into orbit

ıed from the Baikonur cosmodrome next year, is set to ər component of cosmic rays. **Mark Pearce** reports.

bers in the strong magnetic field of a superconducting magnet; imaging streamer tubes and silicon-tungsten calorimeters; a transition radiation detector (TRD); and solid and gas ring-imaging Cerenkov detectors. Many important results were obtained during studies of antiprotons, positrons and light nuclei. In particular, the last balloon flight experiment of the WiZard collaboration, CAPRICE98, was the first to mass-resolve high-energy (above 20 GeV) antiprotons in cosmic rays. A subset of the collaboration has also built several small space experiments: the NINA-1 and NINA-2 satellite experiments (silicon detector systems used to investigate cosmic-ray nuclei); and SILEYE-1, -2 and -3 (silicon sensor telescopes used to study the radiation environment inside the MIR and the ISS space stations). These experiments were also used to study the nature of particles producing the light flashes seen by astronauts.

PAMELA is built around a 0.48 T permanent magnet spectrometer tracker equipped with double-sided silicon detectors, which will be used to measure the sign, absolute value of charge and momentum of particles. The tracker is surrounded by a scintillator veto shield (anticounters) that will reject particles that do not pass cleanly through the acceptance of the tracker. Above the tracker is a TRD based around proportional straw tubes and carbon fibre radiators. This will allow electron-hadron separation through threshold velocity measurements. Mounted below the tracker is a very compact and deep silicon-tungsten calorimeter, to measure the energies of incident electrons and allow topological discrimination between electromagnetic and hadronic showers (or non-interacting particles). A scintillator telescope system will provide the primary experimental trigger and time-of-flight particle identification. A scintillator mounted beneath the calorimeter will provide an additional trigger for high-energy electrons. This is followed by a neutron detection system (^{3}He-filled tubes within a polyethylene moderator) for the selection of very high-energy electrons and positrons (up to 3 TeV), which will shower in the calorimeter but will not necessarily pass through the spectrometer.

Final versions of the anticounters, calorimeter and tracker and a final prototype of the TRD were successfully tested with proton and electron beams at CERN in June. Integration and final tests of the other subdetectors continue in Rome and will be completed by the end of the year. PAMELA will then be shipped to Samara in Russia for integration with the Resurs-DK1 satellite. After this, the satellite will move to the Baikonur cosmodrome in Kazakhstan for launch preparations.

Further reading

http://wizard.roma2.infn.it/pamela.

Mark Pearce, *KTH Stockholm (for the PAMELA collaboration).*

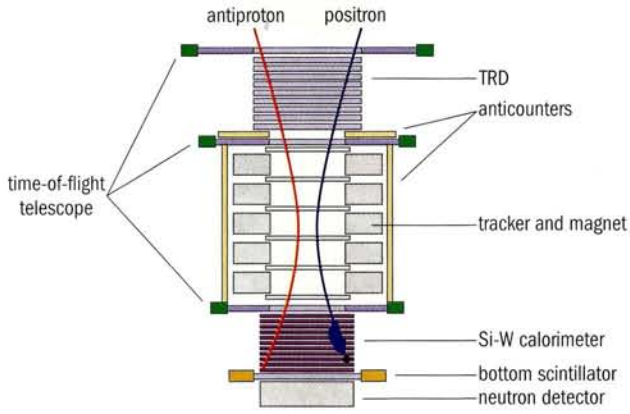
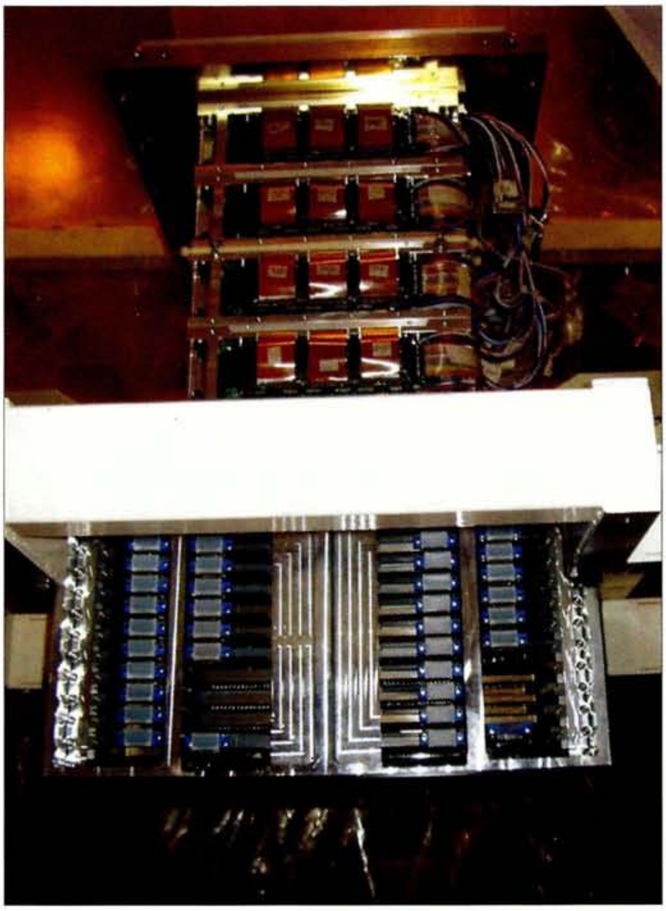


Fig. 2. Detection of antiprotons and positrons in PAMELA. The detector is approximately 1.2 m tall and weighs 470 kg. Its power consumption is only 360 W.



PAMELA's flight model tracker (upper) and calorimeter (lower) mounted together in preparation for beam tests at CERN. Four of the five magnet segments are visible, along with the tracker's front-end electronics. The silicon–tungsten layered structure of the calorimeter can also be seen.

PASI studies new states of matter

For nearly two decades nuclear and particle physicists have been searching for experimental evidence of a new state of deconfined hot quark-gluon matter. A recent study institute in Brazil took stock of their progress so far.

The Leão da Montanha (Mountain Lion) hotel in Campos do Jordão played host to the PASI on new states of matter in hadronic interactions. (Takeshi Kodama.)

The search for a phase transformation between hadronic matter and a state of deconfined colour charge, generically known as quark-gluon plasma (QGP), began in the mid-1980s with experiments at CERN's Super Proton Synchrotron (SPS) in Europe, and Brookhaven's Alternating Gradient Synchrotron in the US. In 2000, the search moved onto the Relativistic Heavy Ion Collider (RHIC) at Brookhaven (*CERN Courier* March 2001 p6). A deconfined quark phase is predicted by numerical solutions of quantum chromodynamics (QCD) at finite temperature, and so its identification would be a dramatic manifestation of the theory that governs strong interactions.

The idea of organizing a Pan American advanced study institute (PASI) under the auspices of the US National Science Foundation's Americas programme was first advanced in early 2000. A number of heavy-ion researchers recognized that such an institute could help emerging research groups in Latin America, and would serve as a focus for potential new participants from widely scattered and distant locations in the region. Planned as an advanced school rather than a conference or workshop, the objective of the institute was primarily pedagogical, although the presentation of the most recent results in both theory and experiment was also on the agenda. Of equal importance, however, was PASI's role as a meeting place where participants could forge new working relationships, and the selection of the small Brazilian mountain resort of Campos do Jordão as the venue was made with this in mind.

Regional balance

The participation reflected a good regional balance, with 20 US and European physicists, and 28 Latin Americans. There were 5 US/European and 16 Latin American postdocs, and 23 US/European and 36 Latin American students. The primary lecturers delivered hot-off-the-press scientific material on all aspects relevant to heavy-ion research, including the theory of strong interactions and experimental heavy-ion collision results. Lectures ranged from elementary tutorial-style introductions to technical seminars at the forefront of the subject. The study of the properties of QGP and the confining vacuum structure was at the heart of the meeting. Daily discussion sessions allowed the principal lecturers and the participants to interact. One afternoon was devoted to a survey of research activities in Latin America. The school was supported by the US National Science Foundation and Department of Energy, Brazilian federal and state agencies (CNPq, FAPERJ, FAPESP, the Federal University of Rio de Janeiro and the University of Sao Paulo), and by Germany's GSI laboratory.

Broad programme

Wit Busza of MIT presented a general introduction course to the physics of heavy-ion collisions. His lectures were complemented by several brilliant tutorials on the foundations of this interdisciplinary field. These were given by Guido Altarelli of CERN on QCD, Takeshi Kodama of Rio de Janeiro on relativistic gases, Berndt Muller of Duke University on the properties of quark matter, Johann Rafelski of Arizona on hadrochemistry, and Columbia's Bill Zajc on the correlation observables such as Hanbury-Brown and Twiss (HBT) intensity interferometry.

The experimental programmes were thoroughly covered in several courses. John Harris of Yale and Bill Zajc gave a survey of the RHIC physics programme and surveyed the latest results from the Brookhaven collider's STAR and PHENIX experiments. Christof Roland of MIT presented the latest work of another RHIC experiment, PHOBOS. CERN's SPS experimental programme was reported by Federico Antinori of Padova, while Karel Safarik of CERN took the students into the instrumental realm of particle tracking in a detailed and ▷

fascinating lecture. In his presentation, Seattle's Tom Trainor clearly showed the complexity of some experimental results.

The study of vacuum structure, confinement, lattice gauge theories and quantum transport was addressed by Dima Kharzeev of Brookhaven, Adriano Di Giacomo of Pisa, Frithjof Karsch of Bielefeld, and Hans-Thomas Elze of Rio de Janeiro. Bira van Kolck of Arizona and Brookhaven introduced the power of effective theories in the study of strong interactions, while Jörg Aichelin of Nantes showed how this method can be used in the study of phase transition dynamics.

Poster sessions gave room for lively discussion. Left to right: Guido Altarelli, Robert Thews and Thomas Trainor. (Takeshi Kodama.)

These hard-core theoretical topics were accompanied by more gentle phenomenological courses by Bob Thews of Arizona on charm, Klaus Werner of Nantes on event generators, and Laszlo Csernai of Bergen on hydrodynamics and flow. Frankfurt's Horst Stöckers' survey of QGP signals relied on exotica such as stable black hole formation in heavy-ion collisions, quite in contrast to the more traditional discussion of strangeness and entropy evidence for the formation of deconfined states, offered by Arizona's Johann Rafelski.

Among more than 15 seminars and lectures reporting the latest progress were many notable theoretical and experimental contributions. Frederique Grassi of Sao Paulo introduced open issues in particle emission, US PASI student Paul Sorensen from UCLA surveyed azimuthal anisotropy in strange particle production, and Latin American PASI student Javier Castillo discussed multistrange particle production at RHIC.

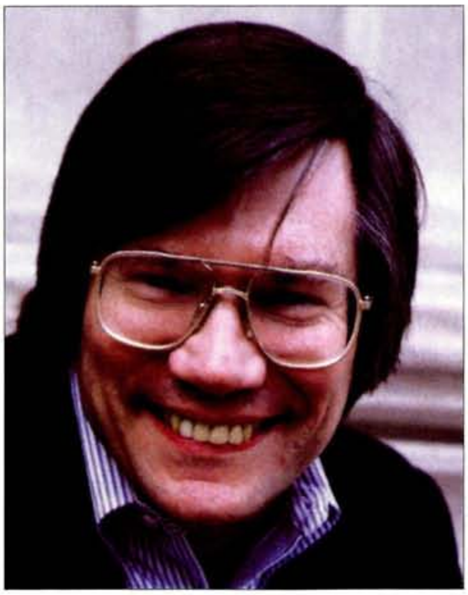
Constantino Tsallis of Rio de Janeiro gave the institute's final lecture on non-extensive statistics and its applications, leading to a discussion which carried on well into dinner. Rainy weather hampered the programme of excursions to the local countryside, but ensured that the lecture rooms were always full of enthusiastic students, which was both stimulating for the lecturers and very promising for the future of the field.

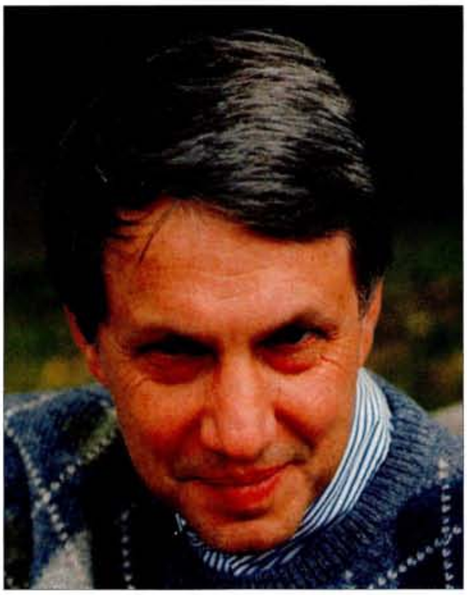
Further reading

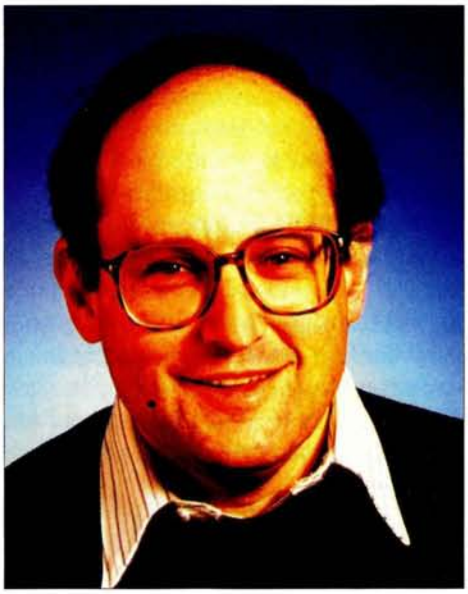
http://www.physics.arizona.edu/~pasi/.
http://omnis.if.ufrj.br/~pasi/.
H T Elze, E Ferreira, T Kodama, J Rafelski and R L Thews (eds) (in press) *New States of Matter in Hadronic Interactions* (AIP New York, October 2002). http://proceedings.aip.org/proceedings/confproceed/631.jsp.

Johann Rafelski, *University of Arizona for the directors of the PASI on new states of matter in hadronic interactions.*

Dirac prize is awarded to inflation pioneers

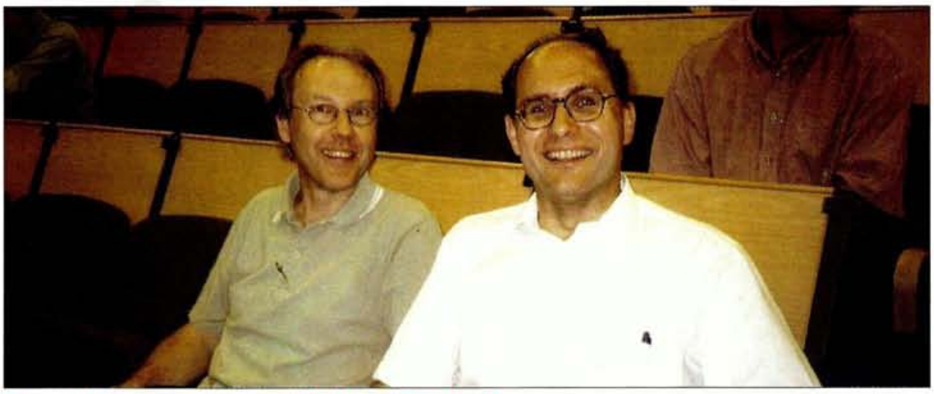

Alan Guth of MIT. (Donna Coveney, MIT.)


Andrei Linde of Stanford.


Paul Steinhardt of Princeton.

The Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, has awarded this year's Dirac Medal and Prize to **Alan Guth** of MIT, **Andrei Linde** of Stanford and **Paul Steinhardt** of Princeton for the development of cosmological inflation. While the possibility of an exponential expansion of the early universe had been noted before, it was Guth who first realized that inflation would solve some of the major problems confronting Big Bang cosmology. Difficulties with the original inflationary model were recognized from the start, and were overcome with the introduction of "new" inflation by Linde, Steinhardt and Andreas Albrecht, a student of Steinhardt's. Linde went on to propose other promising versions of inflationary theory, such as chaotic inflation. Guth and Steinhardt, among others, showed that inflation leads to a spectrum of density perturbations that can seed galaxy formation and explain the fluctuations in the cosmic microwave background.

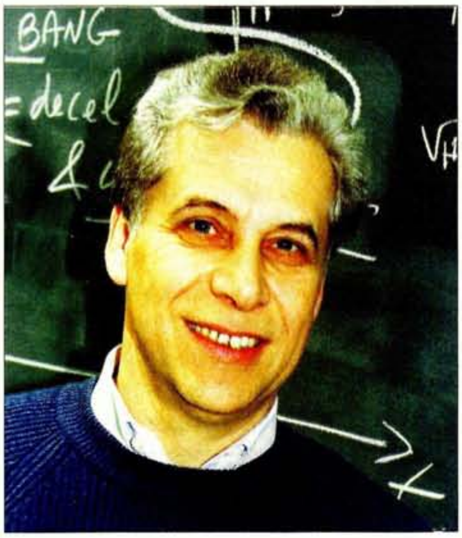
Although not yet firmly established, the idea of inflation has had notable observational successes, and has become the paradigm for fundamental studies in cosmology. Its greatest success has been in accounting for the existence of inhomogeneities in the universe and predicting their spectrum.


Gunnar Ingelman (left) and **Torbjörn Sjöstrand** attended a symposium at Lund University, Sweden, in June to celebrate the 25th anniversary of the Lund model and to honour one of its pioneers, Bo Andersson, who died earlier this year (*CERN Courier* May p40). Both Ingelman and Sjöstrand were students of Andersson and his long-time collaborator Gösta Gustafson. The Lund model that they developed together has proved an indispensable tool for high-energy physics, and has given rise to a range of Monte Carlo event generators whose names – Ariadne, Jetset and Pythia, for example – are common currency to physicists. The original 1983 paper of Andersson, Gustafson, Ingelman and Sjöstrand has been cited some 1400 times.


Takashi Kohiriki (right) presented elements of the ATLAS superconducting tracker to CERN research director **Roger Cashmore** (centre) and ATLAS collaboration spokesman **Peter Jenni** during a visit to the Japanese KEK laboratory in June.

Veneziano joins French Academy

CERN's Gabriele Veneziano (below) was among 24 new foreign associates received into France's Academy of Science at a ceremony under the Institut de France's famous Coupole in June. Head of CERN's theoretical physics division from 1994 to 1997, Veneziano is already a member of the Italian Accademia dei Lincei. He is best known for starting the string theory ball rolling with his 1968 description of the strong force in which fundamental particles behave as strings rather than points. In the physics section of the Academy, Veneziano shared the honour with MIT's Daniel Kleppner.



US physicist **Richard L Garwin** (left) has been awarded the French Academy of Science's Grand Medal for 2002. A student of Enrico Fermi in Chicago, Garwin has led a distinguished career touching many aspects of science and its impact on society. In 1960, he led the landmark muon magnetism (g-2) experiment at CERN, one of the young laboratory's first major achievements. He also studied liquid and solid helium using nuclear magnetic resonance, and was granted a key patent in the application of this technique to medical use.

His contributions to areas as diverse as high-speed laser printing, superconducting computing, satellites and arms control have been described by Nobel prize-winner Georges Charpak as "examples of the work of a highly talented scientist who also applies his talents to the resolution of society's problems with a remarkable independence of spirit". Garwin is a member of the US Academy of Science, the Academy of Engineering and the National Institute of Medicine. He is the recipient of numerous prizes both for his scientific work and his contributions to peace.

At the same session, the academy awarded its Jaffé prize to **Ioanis Giomataris** (right), a physicist working at the French Atomic Energy Commission's Saclay research centre. This prize recognizes Giomataris's work on detectors, in particular the micromegas device which he invented with Charpak. A novel gas-filled tracking device, micromegas is competitive with silicon and has been used in a number of experiments including COMPASS at CERN. The award ceremony will take place under the Coupole of the Institut de France in Paris in November.

Thomas Brzustowski (centre), president of the Natural Sciences and Engineering Research Council of Canada, visited CERN in August to see at first hand the fruits of Canadian efforts towards the Large Hadron Collider project. During the visit, ATLAS collaboration spokesman **Peter Jenni** (left) and ATLAS Canada spokesman **Robert Orr** showed Professor Brzustowski around the assembly stand for the experiment's hadronic end-cap calorimeter.

Professor Che-Ho Wei, chairman of the National Science Council in Taipei, Taiwan, signs the guest book during a visit to CERN in August. Taiwanese physicists are involved in the ATLAS and CMS experiments.

AWARDS

2002 Pomeranchuk winners announced

The Pomeranchuk Prize for 2002 is awarded to **Ludvig Dmitrievich Faddeev** of the Steklov Mathematical Institute in St Petersburg, Russia, and to **Bruce DeWitt** of the University of Texas, Austin, US, for the discovery and development of quantization methods in gauge theories, which laid the foundation for understanding the quantum dynamics of gauge fields.

Professor Faddeev is director of the Euler International Mathematical Institute. He is a full member of the Russian Academy of Sciences (RAS) and the head of the Division of Mathematical Sciences of the RAS. Among his most famous theoretical research achievements is the development (in collaboration with Victor N Popov and independently DeWitt) of the method for quantization of non-Abelian gauge theories. Faddeev also found the complete solution of the quantum three-body problem and since that time "Faddeev's equations" have become nuclear physics folklore. Together with Vladimir E Zakharov he developed an extremely useful Hamiltonian approach to the theory of solitons and put forward the soliton quantization. With Evgueni K Sklyanin and Leon A Takhtajan, Faddeev developed the quantum inverse scattering method, which constitutes one of the approaches to modern quantum group theory. He is the author of several books and monographs, and was awarded the Heineman Prize for mathematical physics by the American Physical Society in 1974, and the ICTP Dirac medal in 1991.

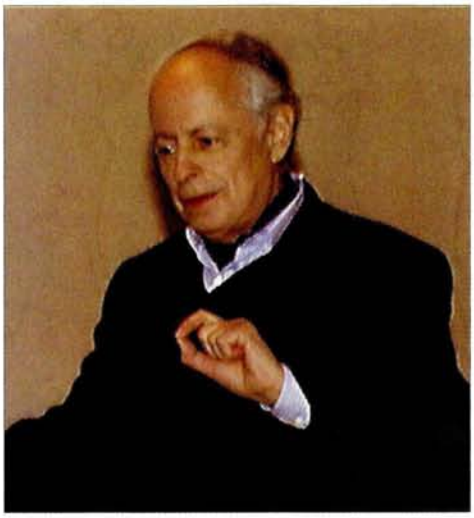
Professor Emeritus Bruce S DeWitt's outstanding achievement is the extension of the methods of quantum theory to non-Abelian gauge fields including quantum gravity. He created an approach to quantum field theory, which consistently combined this theory with geometry and thus became a basis of the modern development. He is also credited with a covariant renormalization theory, which in a more general setting is known as the Schwinger-DeWitt technique. The so-called Wheeler-DeWitt equation constitutes the basis of quantum cosmology. DeWitt is a pioneer of numerical methods in general relativity. His work on the radiation of gravitationally accelerated charge had a prominent impact on the many-worlds interpretation of quantum mechanics. He is the author of several books and important review articles. His latest monograph *The Global Approach to Quantum Field Theory* sums up a whole epoch in this area of theoretical physics. DeWitt received the ICTP Dirac medal in 1987.

Nominations for the Pomeranchuk Prize 2003 should be sent to pomeron@heron.itep.ru no later than 1 February 2003. Further information is available at http://face.itep.ru/pomeranchuk.html.

EPS rewards communicators of physics

The European Physical Society (EPS) has awarded its annual prize for the public understanding of physics to **Rafel Carreras**. With his unique gift for communicating science, Carreras enthralled public audiences at CERN for decades until his retirement in 1998. His lectures – presented under the banners of "Science for All" and "The Sciences of Today" – touched on all aspects of science, and were delivered with clarity, understanding and an infectious enthusiasm.

Carreras is also the author of the popular CERN publication, *When Energy Becomes Matter*. He combines his gift for communication with a genuine and unassuming modesty. In accepting the prize, he traced his enthusiasm for science popularization back to his childhood. "As a schoolboy, I often found it difficult to understand what my classmates understood easily," he explained, "so when I understood something I was so happy that I wanted to share my recently acquired knowledge with everybody I met!"



Rafel Carreras – a unique gift for communicating science.

Michael Kobel – bringing physics into the classroom.

At the same time, the society's high-energy physics board awarded its annual outreach prize to **Michael Kobel** of Bonn University, Germany, for his efforts in bringing high-energy physics into the classroom. Kobel has worked directly with educators in Germany to introduce high-energy physics into the school curriculum, both through the creation of new materials and the imaginative use of concepts developed in other European countries. He is a member of the ECFA European particle physics outreach group, and coordinator for German involvement in the "Physics on Stage" teachers' programme.

ATLAS

French town hosts ATLAS overview meeting

Left: ATLAS spokesperson Peter Jenni (left) receives the medal of Clermont-Ferrand from the town's mayor Serge Godard. Robert Pickering, vice-president of Blaise Pascal University, is in the background. Right: Clermont-Ferrand's Polydome conference centre was host to the ATLAS collaboration for the Journées ATLAS 2002. (Daniel Massacrier.)

The ATLAS collaboration, which is building a detector for CERN's Large Hadron Collider, held an overview week away from CERN in June. Following similar gatherings at Dubna in Russia two years ago and at Brookhaven in the US last year, the French town of Clermont-Ferrand welcomed collaboration members to the Journées ATLAS 2002. During the welcome ceremony at the Clermont-Ferrand town hall, Mayor Serge Godard awarded medals of the city to members of the ATLAS management, while the Blaise Pascal University presented ATLAS members with a text written by Blaise Pascal, who was born at Clermont in 1623, printed on hand-crafted paper.

CERN recognizes LHC suppliers with Golden Hadron awards

CERN's partnership with industry took centre stage on 12 August when the project leader for the laboratory's Large Hadron Collider (LHC), Lyn Evans, presented awards to some of the project's major suppliers. Golden Hadron awards have been established to recognize outstanding performance of LHC suppliers. The first three went to Russia's Budker Institute of Nuclear Research (BINP), Belgian steel firm Cockerill-Sambre, and US company Wah-Chang.

The BINP received the award in recognition of high standards of fabrication of the 360 dipole and 185 quadrupole magnets that will equip the two transfer lines carrying proton beams into the LHC. BINP director Alexander Skrinsky was unable to attend the ceremony and will collect the award in September.

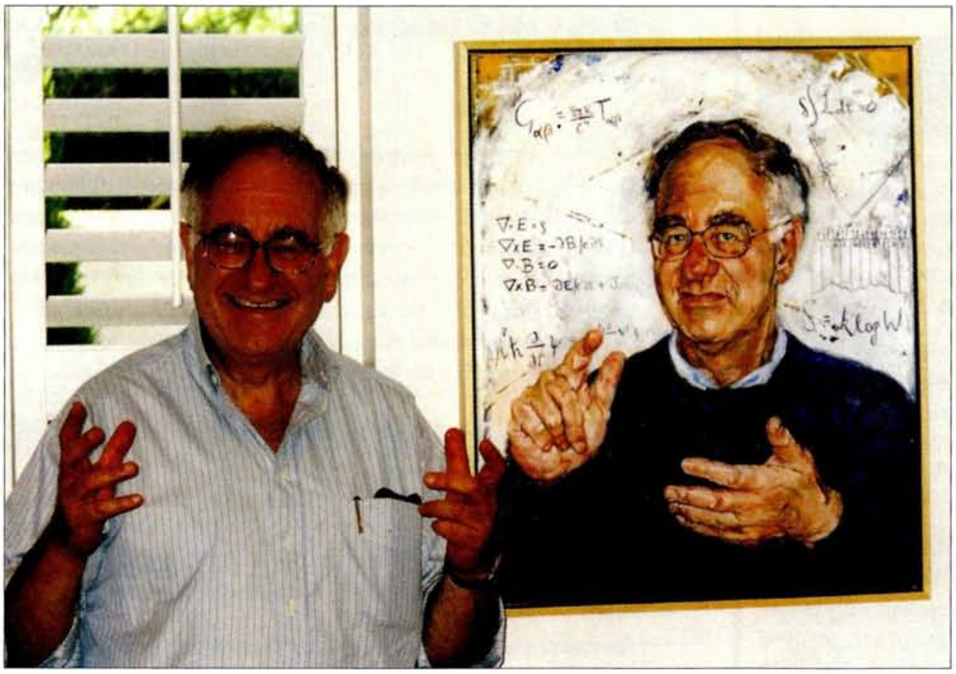
LHC project leader Lyn Evans (centre) with recipients of the first Golden Hadron Awards, Santo Comel of Cockerill-Sambre (left) and Lynn Davis of Wah-Chang.

Cockerill-Sambre has been supplying CERN with steel since the early 1970s, and in presenting the award, Evans drew attention to the company's long-term dedication to achieving the best results. Accepting the award, company representative Santo Comel said: "CERN is not just a client, but above all a partner," going on to explain how innovations developed with CERN over the years have helped the business as a whole.

The final recipient of the first round of awards, US firm Wah-Chang, was recognized for similar dedication to excellence in the production of high-quality niobium-titanium for superconducting cable. The company's president, Lynn Davis, received the award.

OBITUARY

Geoffrey Opat 1935 – 2002



Geoffrey Opat with a portrait commissioned to mark his retirement at the end of 2000.

Geoffrey Opat, one of Australia's most noted and versatile physicists, died suddenly on 7 March. Born in Melbourne on 16 November 1935, he was educated at the University of Melbourne, where he obtained his PhD in theoretical photonuclear physics in 1961. He won a Fulbright Fellowship and spent the next three years working at the University of Pennsylvania, with the late Henry Primakoff. Their work on radiative muon capture has stood the test of time and in recent years was the subject of experimental verification at TRIUMF. He returned to Melbourne in 1964, where he was the founder of Australia's first Experimental High-Energy Physics group, which worked initially with the Brookhaven 30 inch bubble chamber (filled with deuterium), studying antiproton–neutron interactions.

That experiment alone yielded 20 publications, including some measurements that are still the best available. Some notable results were on topological cross-sections, later to be verified (and improved upon) at the LEAR ring at CERN, on G-parity and on beam-target reversal symmetry, a concept that he first postulated. Later the group carried out experiments at the US Argonne National Laboratory and at the UK's Rutherford Laboratory.

Opat was appointed to the Chair of Experimental Physics in 1973. After that, much of his research was concerned with wave-optical experiments using beams of low-energy neutrons, and more recently, neutral atoms and molecules. He also studied the effects of gravity and inertia on the electromagnetic properties of metals. He enjoyed sabbatical years at the Rutherford Laboratory, the University of British Columbia in Vancouver, Canada, and the University of Washington in the US. He was best known internationally for his work on neutron optics, in particular experimental verifications of the Aharonov–Casher and Scalar Aharonov–Bohm effects, carried out with colleagues from the University of Melbourne, and collaborators at the University of Missouri. This led to the joint award in 1990 with his lifelong friend and collaborator, Tony Klein, of the prestigious Walter Boas Medal of the Australian Institute of Physics, and to his election as a fellow of the Australian Academy of Science.

Opat had an enormous influence on the teaching of physics at all levels, in Melbourne, in Australia, and in several neighbouring countries that sought out his advice. As a profound scholar, great teacher and wonderful friend, he is sorely missed by colleagues, former students and friends on all continents.

RECRUITMENT

For advertising enquiries, contact CERN Courier recruitment/classified, Institute of Physics Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Rates per single column centimetre: mono £36, single colour £38, full colour £40. Please contact us for more information about publication dates and deadlines.

UNIVERSITY OF FLORIDA

Three Scientists Needed for Global Grid Laboratory

The Physics Department of the University of Florida invites applications for three new positions at the Assistant or Associate Scientist level (non-tenure accruing), to begin Oct. 15, 2002 and continuing for the lifetime of the project, contingent on Federal funding. We are looking for an outstanding individual to act as a technology scientist for the International Virtual Data Grid Laboratory, **(http://www.ivdgl.org/)**, an exciting five-year technology deployment initiative funded by the National Science Foundation. The iVDGL will deploy a global Grid laboratory, together with US and international partners, that will be utilized by advanced scientific experiments, including those in high energy physics, nuclear physics, gravitational wave searches (LIGO), virtual astronomical observatories (NVO) and other disciplines. The Laboratory will be based on the Globus and Condor Toolkits and draw on Grid technologies from GriPhyN, Particle Physics Data Grid (PPDG) and the European Union DataGrid projects. It is expected that the iVDGL will encompass dozens of sites in the U.S., Europe, Asia and South America.

Candidates should have a strong background in computational science and technical skills in areas such as modern OO programming, scripting languages such as Python, distributed (grid) computing, and have experience with production quality software development for large scientific experiments.

- Two positions will be onsite at the University of Florida. Successful candidates will participate in a wide variety of iVDGL testbed activities, including developing and deploying cluster hardware and software infrastructure, conducting testbed experiments and production exercises, integrating Grid toolkits and coordinating with US and international partners.
- One position will be offsite in the Chicago area, where close interaction with grid and ATLAS database software developers is anticipated. The candidates's responsibilities will include integrating the GriPhyN Virtual Data Toolkit with the ATLAS software framework and providing software configuration support for the U.S. ATLAS prototype Tier 2 centers.

Applicants should submit a letter outlining their qualifications and interests and a curriculum vitae, including a list of publications and brief summaries of research interests and accomplishments. Send applications to, and arrange to have at least three letters of reference sent directly to,

Prof. Paul Avery P.O. Box 118440 Dept. of Physics
University of Florida Gainesville, FL 32611-8440 USA

For e-mail applications, only PDF and text file enclosures will be accepted.

Questions can be addressed by e-mail to **avery@phys.ufl.edu** or by phone to 352-392-9264. To ensure full consideration, applications must be received before October 1, 2002.

The University of Florida is an Equal Opportunity, Affirmative Action Institution.

Deutsches Elektronen-Synchrotron DESY

Kryogenik

DESY ist eines der weltweit führenden Beschleunigerzentren. Das Forschungsspektrum reicht von der Elementarteilchenphysik über Festkörperphysik bis hin zur Molekularbiologie.

Unsere Gruppe –MKS– ist verantwortlich für den Betrieb der Helium-Kälteanlagen zur Versorgung des supraleitenden Protonenrings von HERA und der supraleitenden TESLA-Testfacility, für den Bau kryogenischer Komponenten und supraleitender Magnete sowie für den Einbau supraleitender Hochfrequenzresonatoren in Kryostate.

Für die Leitung der Gruppe suchen wir zum nächstmöglichen Zeitpunkt eine/-n

Physiker/-in
BAT Ia

Sie werden eine Gruppe von ca. 55 Mitarbeitern und Gästen leiten, die entsprechend ihrer Fachaufgaben in die 3 Fachgruppen Kryogenik, Kryokontrollen und Magnetmessungen eingeteilt sind. Außer dem Abschluss eines Hochschulstudiums der Physik oder gleichwertiger Qualifikation erwarten wir von Ihnen gute Kenntnisse der Tieftemperaturphysik, Kryotechnik, Magnettechnik und Messtechnik. Darüber hinaus sollten Sie idealerweise über langjährige Erfahrungen mit dem Betrieb von Helium-Kälteanlagen und mit dem Bau und Betrieb supraleitender Magnete und/oder supraleitender Hochfrequenzresonatoren verfügen. Voraussetzung sind insbesondere gute organisatorische und planerische Fähigkeiten und die Fähigkeit zur Kommunikation und Mitarbeiterführung. Sollten diese Aufgaben Ihr Interesse geweckt haben, senden Sie bitte Ihre Bewerbungsunterlagen an unsere Personalabteilung.

Die Vergütung und sozialen Leistungen entsprechen denen des öffentlichen Dienstes. DESY ist offen für moderne Arbeitszeitmodelle.

Schwerbehinderte Menschen werden bei gleicher Eignung bevorzugt berücksichtigt.

DESY fördert die berufliche Entwicklung von Frauen und bittet Frauen deshalb nachdrücklich, sich um die zu besetzende Stelle zu bewerben.

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Kennziffer: 128/2002 • Notkestraße 85 • 22603 Hamburg
Telefon 040/8998-3409 • www.desy.de
E-Mail: personal.abteilung@desy.de

Bewerbungsschluss: 15.12.2002

CORNELL

TWO PROFESSORIAL POSITIONS
EXPERIMENTAL ELEMENTARY PARTICLE PHYSICS

Cornell University is seeking outstanding individuals for two professorial positions in experimental elementary particle physics. One position is at the level of tenure-track Assistant Professor and the other is at the level of tenure/tenure-track Assistant, Associate or Full Professor. In addition to teaching undergraduate and graduate courses, responsibilities will include supervision of graduate students and participation in the research program of the Laboratory for Elementary Particle Physics, which is based on the CESR e^+e^- storage ring and the CLEO experiment, with future involvement in the international linear collider. CLEO provides a unique opportunity for high precision measurements in the Upsilon family, at the J/ψ, and near the DD and $D_s D_s$ production thresholds. The Laboratory envisions a substantial role in both the particle physics and accelerator development of the linear collider. A PhD in Physics and experience in experimental elementary particle physics is required. Both positions will be available on or before August 1, 2003. Please send an application and at least three professional letters of recommendation to

Prof. Ritchie Patterson, Search Committee Chair
Newman Laboratory, Cornell University Ithaca, NY 14853

Applications should include a curriculum vitae, a publication list, and a short summary of teaching and research experience. Applications received before January 15, 2003 will be given full consideration. Electronic submissions and mail inquiries may be addressed to **search@lns.cornell.edu**.

Cornell is an equal opportunity/affirmative action employer.

http://www.lns.cornell.edu/public/eppprof.html

Scientific Staff Position

The Physics Department of Brookhaven National Laboratory presently has an opportunity, under the direction of Dr. H. Gordon, for a scientist to work with the ATLAS experiment.

Position requires a Ph.D. and a minimum of five years experience past Ph.D. (more senior candidates will be considered), demonstrated leadership and innovation in collider physics analysis. Experience with hadron collider analysis is desirable. Responsibilities will include focusing on the software development leading toward physics analysis of the ATLAS experiment. BNL has a leading role in ATLAS liquid argon calorimetry, the muon spectrometer, software and is the location of the U.S. Tier 1 computing facility. Will work with present staff to develop the capability for physics analysis.

Interested candidates should submit a cover letter indicating research interests, a CV and arrange to have three letters of recommendation sent to Dr. Howard Gordon, Physics Department, Brookhaven National Laboratory, Bldg. 510 A, P.O. Box 5000, Upton, New York 11973-5000. BNL is an equal opportunity employer committed to workforce diversity.

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Zukunft beginnt bei uns

RWTH RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

Die RWTH ist mit ca. 30.000 Studierenden und ca. 10.000 Beschäftigten eine der größten Technischen Hochschulen Europas und die größte Arbeitgeberin und Ausbilderin in der Region. Lehre und Forschung sind international, innovativ, industrienah und fachübergreifend ausgerichtet.

C3-Universitätsprofessur

Experimentalphysik (Hochenergiephysik)
(Nachfolge Prof. Böhm)

Fakultät für Mathematik, Informatik und Naturwissenschaften

Zum 01.08.04 wird eine Persönlichkeit gesucht, die dieses Fach in Forschung und Lehre vertritt. Besonders erwünscht sind Erfahrungen auf dem Gebiet der experimentellen Elementarteilchenphysik. Zu den Lehraufgaben gehört in erster Linie die Ausbildung in den Physik-Diplom- und Lehramtsstudiengängen (Vorlesungen, Übungen, Seminare, Fortgeschrittenenpraktikum). Dazu kommt eine Beteiligung an der Ausbildung von Studierenden anderer Fächer. Der Schwerpunkt der Forschungen soll im Bereich der experimentellen Elementarteilchenphysik liegen. Eine Zusammenarbeit mit den anderen in diesem Bereich forschenden Arbeitsgruppen an der RWTH ist erwünscht, insbesondere am CMS-Projekt.

Voraussetzung ist ein abgeschlossenes Universitätsstudium, Promotion, Habilitation oder gleichwertige wissenschaftliche Leistungen sowie didaktische Fähigkeiten.

Ihre schriftliche Bewerbung richten Sie bitte bis zum 30.11.02 an den Dekan der Fakultät für Mathematik, Informatik und Naturwissenschaften , Herrn Prof. Dr. A. Krieg, RWTH Aachen, Templergraben 55, D-52062 Aachen.

Die RWTH strebt eine Erhöhung des Frauenanteils an wissenschaftlichem Personal an. Auf § 8 Abs.6 Landesgleichstellungsgesetz NW (LGG) wird verwiesen.

Bewerbungen Schwerbehinderter sind erwünscht.

UNIVERSITY OF BERGEN

EUROPEAN RESEARCH INFRASTRUCTURE

Bergen Computational Physics Laboratory

CALL FOR PROPOSALS

Bergen Computational Physics Laboratory (BCPL) is a Research Infrastructure at the University of Bergen, Norway, with a scientific staff working on modeling of subatomic, atomic and molecular reactions, using supercomputing facilities, including a 499.2 GigaFlop IBM e-Server p690 as its present top facility.

BCPL offers access to researchers or research teams from the EU and its Associated States in order to solve computational physics problems in the above mentioned fields. Short stays (approx. 2-4 weeks) for established researchers are supported by the EC in the framework of the Access to Research Infrastructure activity of the Improving Human Potential program.

Contact:
Prof. L.P. Csernai, BCPL, University of Bergen, Allegt. 55, 5007 Bergen, Norway
e-mail: **bcpl@fi.uib.no**,
URL: **http://www.fi.uib.no/~bcpl/**

Deutsches Elektronen-Synchrotron

DESY is one of the leading accelerator centers worldwide. The research spectrum ranges from elementary particle physics and solid state physics to molecular biology.

The group is involved in operation and upgrade of the H1 detector at the ep collider HERA as well as in physics analysis of the collected data. We have an opening for an

Experimental Particle Physicist

You have a Ph.D. in physics and several years of experience in experimental particle physics in the framework of a large experiment and you are active in research in this field. You have an established record in analysis and interpretation of particle physics data.

You will take a leading role in the research program of the group with the current focus on ep physics at HERA. You should be willing to take considerable responsibility in the physics analysis and also participate in the operation and upgrade of the detector. Please send your application incl. list of publications and the names of three referees to our personnel division.

Salary and benefits are commensurate with public service organisations (BAT Ib). DESY operates flexible work schemes, such as flexi-time or part-time work.

DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Deutsches Elektronen-Synchrotron DESY
member of the Helmholtz Association
code: 111/2002 • Notkestraße 85 • D-22603 Hamburg • Germany
Phone +49 40/8998-4594 • www.desy.de
email: personal.abteilung@desy.de

Deadline for applicants: 01.11.2002

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY & MEDICINE

High Energy Physics Group
Department of Physics

Research Fellow/Research Lecturer

Applications are invited for the post of Research Fellow/Research Lecturer in High Energy Physics at the Blackett Laboratory, Imperial College, London. The appointment is a two-year, fixed-term contract.

The group has an active experimental programme embracing the CMS and LHC-B experiments at LHC, the D0 experiment at the Tevatron, the BABAR experiment at SLAC and the ZEUS experiment at HERA. The group is one of the leaders in the UK R & D programme, which will lead to a future neutrino factory and is planning participation in one of the neutrino 'superbeam' experiments. Within the group, there is a strong tradition of detector development and construction, which has led to key activities in the above experiments. These now extend to prototypes for the electromagnetic calorimeter appropriate for a future linear collider detector. Further details of the group's programme may be found on: http://www.hep.ph.ic.ac.uk/

It is anticipated that the starting date for this position will be 1 January 2003. The postholder will be expected to take on a full teaching load.

The salary will be in the range £24,435 - £32,537 plus £2,134 London Allowance per annum, depending on qualifications and experience.

Application forms are available either electronically or by post from Ms Paula Brown, Tel: (020) 7594 7823, email: paula.brown@ic.ac.uk

Completed application forms should be sent to Ms Paula Brown, Imperial College of Science, Technology & Medicine, Physics Department, Blackett Laboratory, Prince Consort Road, London SW7 2BW, email: paula.brown@ic.ac.uk

Closing date: Friday, 11 October 2002.

The College is committed to equality of opportunity.

RESEARCH ASSOCIATE
Detector Physicist
Competition #885

TRIUMF is Canada's national research facility for particle and nuclear physics and we are located in Vancouver, British Columbia. A laboratory for advanced detector development, being set up at TRIUMF in cooperation with the University of British Columbia, will support R&D on new detectors for high energy and nuclear physics, medical imaging, and other fields. In support of this development, we are currently seeking a Research Associate who will participate in the expansion and research of the detector development laboratories and facilities.

A PhD in Physics, or a related field, is required, and preference will be given to those applicants within 5 years of their degree. Knowledge of electronics, and experience and familiarity with the design, construction and usage of gas tracking chambers, liquid xenon or liquid argon ionization detectors, calorimeters, scintillation detectors, and semiconductor detectors will all be considered assets when reviewing applications. The initial appointment will be for a one-year term and may be renewable for a second and third year.

TRIUMF is an equal opportunity employer. We invite qualified applicants to submit resumes, and arrange for 3 reference letters to be sent to: **TRIUMF Human Resources, (Comp. #885). Fax (604) 222-1074.** Closing date for applications is **December 31st, 2002**. For more information contact Doug Bryman: doug@triumf.ca. *Please note that in the event where 2 final applicants are equally qualified, preference will be given, if applicable, to the Canadian Citizen or Landed Immigrant.*

SENIOR THEORIST
TRIUMF/UBC
Competition #886

TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, and the Physics and Astronomy Department of the **University of British Columbia (UBC)**, are seeking to appoint a prominent international theorist to lead TRIUMF's theory group. The group leader will be expected to have sufficient breadth to provide theoretical leadership across all areas of the TRIUMF research portfolio, including in particular ISAC, TRIUMF's new radioactive isotope facility. As a full faculty member of the Physics and Astronomy Department of UBC, the appointee will also have an opportunity to teach both at the graduate and undergraduate levels.

The level of this appointment will be one of the most senior in the laboratory, and given that the successful candidate will be an established theoretician of international stature with exceptional qualifications, the appointment to UBC will be at the level of Associate or Full Professor.

TRIUMF and UBC hire on the basis of merit and are committed to employment equity. All qualified applicants are invited and encouraged to apply; however, if any two candidates equally meet the stringent requirements for this position, then preference will be given to the Canadian citizen or permanent resident. Applications containing curriculum vitae, a statement of research achievements and plans, and up to four reference letters should be sent by **December 30th, 2002** to: **TRIUMF Human Resources (Competition # 886), 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3 Fax: (604) 222-3791.** Applications will not be accepted by E-mail. Inquiries may be directed to Eileen Conning, Administrative Assistant to the Director, TRIUMF, at: econning@triumf.ca.

Information on the Department of Physics and Astronomy at the University of British Columbia may be found on the Web at: http://www.physics.ubc.ca; TRIUMF's Web site is: http://www.triumf.ca.

Postdoctoral Research Associate

The Physics Department of Brookhaven National Laboratory presently has an opportunity for an experimental high energy research associate. This position requires a Ph.D. Will work with one of the ongoing experiments including the ATLAS experiment at the LHC, the DO experiment at Fermilab, the g-2 experiment at BNL or the rare K decay program.

Interested candidates should submit a cover letter indicating research interests, a CV and arrange to have three letters of recommendation to be sent to: Dr. Howard Gordon, Physics Department, Brookhaven National Laboratory, Bldg. 510 A, P.O. Box 5000, Upton, New York 11973-5000. BNL is an equal opportunity employer committed to workforce diversity.

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POSTDOCTORAL FELLOW
CENTER FOR COSMOLOGICAL PHYSICS

The NSF established the Center for Cosmological Physics (CfCP) at the University of Chicago in August 2001. Research at the Center focuses on interdisciplinary topics in cosmological physics: characterizing the Dark Energy, studying the inflationary era, and understanding the highest energy cosmic rays. Studies of the CMB (polarization anisotropies and the Sunyaev-Zeldovich effect) and Cosmic Infrared Background; analysis of Sloan Digital Sky Survey and other large-scale structure data; high energy astrophysics with photons and cosmic rays, direct detection of DM particles and numerous topics in theoretical cosmology constitute the current slate of activities. The CfCP has active visitors, symposia, and education/outreach programs.

Up to three Fellow positions are now open. Center Fellows have the freedom to work on any of the efforts in our Center.

We seek candidates with a recent Ph.D. in physics, astrophysics, or related fields, with an interest in pursuing experimental or theoretical interdisciplinary research in cosmology. Prior experience in Cosmological Physics is not a requirement. Positions are for two years, with possible renewal for a third.

A CV, statement of research interests, and at least three letters of recommendation should be sent to **centerfellow@cfcp.uchicago.edu** or to **Bruce Winstein, Director, Center for Cosmological Physics, Enrico Fermi Institute, 5640 S. Ellis Avenue, Chicago, IL 60637.**

Information about the CfCP can be found at **http://cfcp.uchicago.edu/.**

Women and minorities are encouraged to apply.

The deadline is December 1, 2002 for positions that will begin in the Summer or Fall of 2003.

THE UNIVERSITY OF
CHICAGO

MIT

The Department of Physics of the Massachusetts Institute of Technology invites applications for junior faculty positions. Faculty members at MIT teach undergraduate and graduate physics courses, serve as mentors and advisors, and oversee students' research projects. Candidates must show promise in teaching as well as in research. Preference will be given to applicants at the Assistant Professor level. **Applicants should submit by regular mail a curriculum vitae (include email address), a publications list, a brief description of research interests and goals, and should have at least three letters of reference sent directly to the appropriate committee chair listed below.**

EXPERIMENTAL PARTICLE AND NUCLEAR PHYSICS

Currently, the research groups in the division and LNS have strong interests in QCD (PHOBOS, BLAST, Jefferson Lab., Mainz and HERMES), flavor physics and Electroweak Symmetry breaking (BaBar, CDF, ATLAS, and CMS), dark matter searches (AMS and axions) and neutrino physics (SuperKamiokande and Borexino). Strong candidates in new areas of experimental nuclear and particle physics are particularly welcome. (See http://pierre.mit.edu/ for a description of current research activities). Application materials, specified above, should be sent directly to: **Professor Peter Fisher, Chair, Experimental Particle and Nuclear Physics Search Committee, Massachusetts Institute of Technology, 77 Massachusetts Avenue, 44-118, Cambridge, MA 02139-4307. Send inquiries to Fisherp@mit.edu.**

PARTICLE THEORY

This search is focused on high-energy theory covering the energy scales from just beyond the standard model to the Planck scale. Current faculty in the Center for Theoretical Physics span a broad range of interests, including QCD, electroweak physics, unification, cosmology, and string theory. Candidates will be evaluated on the basis of potential contributions to the research programs carried out in the Center for Theoretical Physics. Application materials, specified above, should be sent directly to: **Professor Washington Taylor, Chair, Particle and Nuclear Theory Search Committee, Center for Theoretical Physics, 77 Massachusetts Avenue, 6-308, Cambridge, MA 02139-4307. The deadline for applications is December 1, 2002. Send inquiries to ctp-search@mit.edu.**

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SLAC

Tenured Professorial Position
Experimental Elementary Particle Physics

The Stanford Linear Accelerator Center (SLAC) is seeking an outstanding individual for a tenured faculty position in experimental elementary particle physics at the rank of Associate or Full Professor. We are looking for candidates with significant accomplishments and promise for important future achievements. We are particularly interested in candidates with near term research interests involving the BaBar experiment.

The successful candidate is expected to take a leadership role in the ongoing BaBar activities, in developing new initiatives at the lab and in creative scholarship. As a member of the Academic Council of Stanford University, there will be opportunities to teach and supervise undergraduate and graduate students.

Candidates should submit a curriculum vitae, publication list, a statement of research interests, and the names of four references to

Prof. Persis Drell, SLAC-MS 75, 2575
Sand Hill Rd, Menlo Park, CA 94025.

The deadline for receipt of applications is November 1, 2002.

SLAC is committed to equal opportunity through affirmative action in employment. We strongly encourage qualified minority and women candidates to apply.

THE UNIVERSITY OF BRITISH COLUMBIA

DEPARTMENT OF PHYSICS AND ASTRONOMY
CANADA RESEARCH CHAIR IN ORIGINS

The Department of Physics and Astronomy at the University of British Columbia is looking for outstanding researchers for appointment as a Canada Research Chair at the Tier II level in the general theme of "Origins", which is an integral component of the department's future hiring plans. For more information on the Canada Research Chair program see: www.chairs.gc.ca. The Department expects to make a number of tenure track appointments at the Assistant Professor level over the next few years in this broad area. In the next year the department will be making one or more hirings in the areas of

- subatomic physics
- observational or theoretical cosmology

The Department has strong groups in theoretical and experimental subatomic physics (including string theory), gravity, and astronomy and astrophysics, with whom the successful candidates would interact, and has close ties to TRIUMF with its outstanding experimental and developmental facilities in nuclear and particle physics. For more information see: www.physics.ubc.ca. Candidates whose research could bridge the two disciplines or who would strengthen the growing group in computational physics are encouraged to apply. Although primarily directed to junior candidates at the Assistant Professor level, outstanding senior candidates whose research falls in the broad theme of Origins may also be considered for appointment at a higher rank.

The University of British Columbia hires on the basis of merit and is committed to employment equity. We encourage all qualified persons to apply. There is no restriction with regard to nationality or residence, and the position is open to all candidates. Offers will be made in keeping with immigration requirements associated with the Canada Research Chairs program. Applicants should submit their curriculum vitae, a statement of current research interests and future plans, and have three referees send letters of reference by November 15, 2002 to:

Prof. T. Tiedje, Head
Origins Competition
Department of Physics and Astronomy,
The University of British Columbia,
6224 Agricultural Road,
Vancouver, B.C., Canada V6T 1Z1.

Applications will not be accepted electronically.

UNIVERSITY OF WISCONSIN MADISON

MATHEMATICAL PHYSICS/STRING THEORY CLUSTER HIRING

The Department of Mathematics and Physics anticipate an opening for one or two positions to begin August 25, 2003, at either the tenure track (assistant professor) or tenured (associate/full professor) level. This cluster hiring is a part of the Madison Initiative and is intended to establish a prominent research group connecting the existing groups in particle physics phenomenology in the Physics Department and topology/geometry in the Mathematics Department. Applications are especially encouraged from theorists pursuing innovative research in string theory quantum gravity, physics with extra dimensions, quantum field theory, supersymmetry, and unification theories; as well as from mathematicians working on aspects of string theory or related topics. Successful candidates will be encouraged to participate in interdisciplinary research which will strengthen ties between the two departments. Joint appointments in the Mathematics and Physics Departments are contemplated.

Candidates should exhibit evidence of outstanding research records, normally including achievements significantly beyond the doctoral dissertation. A strong commitment to excellence in instruction at both undergraduate and graduate levels is also expected. Applicants should send a curriculum vitae with includes a publication list, and brief descriptions of research and teaching accomplishments and goals to:

Math/Physics Cluster Hiring Committee Dept. of Mathematics,
Van Vleck Hall University of Wisconsin Madison
480 Lincoln Drive Madison, WI 53706-1388

Applicants should also arrange to send to the above address, three letters of recommendation, which should address the applicant's research potential and teaching experiences. Review of applications will begin on November 1, 2002. Applications will be accepted until the positions are filled. Additional letters will be solicited by the hiring committee for senior appointments.

The Departments of Mathematics and Physics are committed to increasing the number of women and minority faculty. The University of Wisconsin is an Affirmative Action, Equal Opportunity Employer and encourages applications from women and minorities. Unless confidentiality is requested in writing, information regarding the applicants must be released upon request. Finalists cannot be guaranteed confidentiality.

Additional departmental information is available on the websites
http://www.math.wisc.edu; http://www.physics.wisc.edu
Information about the cluster hiring initiative is available at
http://wiscinfo.doit.wisc.edu/cluster/

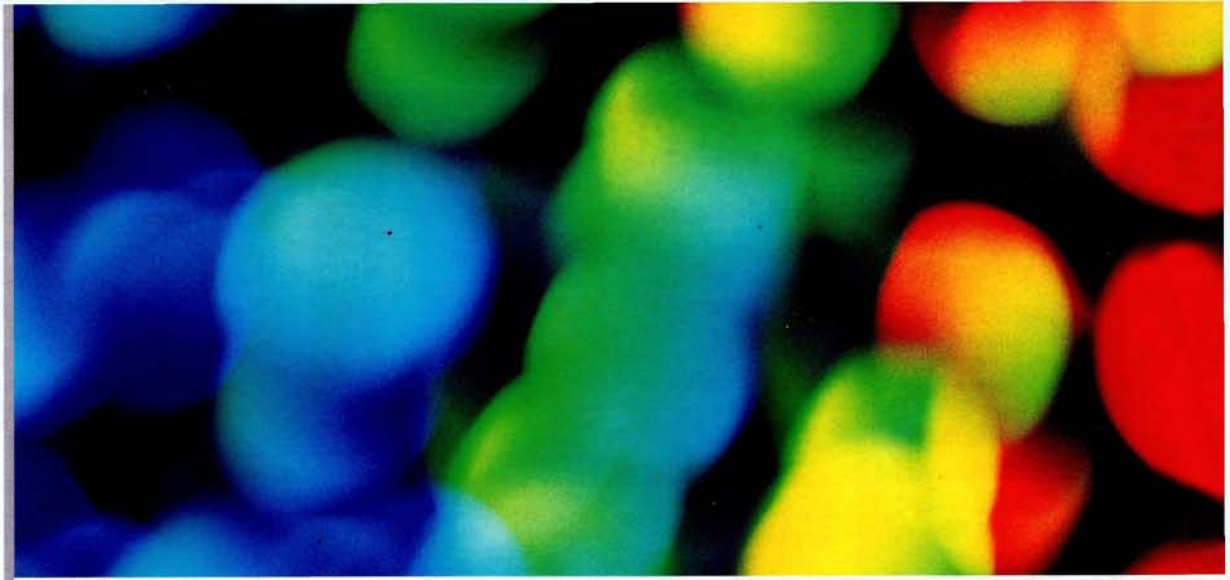
LIP

Laboratory for Instrumentation and Experimental Particle Physics
Av. Elias Garcia 14 – 1º, 1000-149, Portugal

The Lisbon branch of LIP anticipates the opening of a three year research position for experimental high energy physicists. Only applicants with a solid CV and, at least, two years experience after PhD will be considered. This position can be converted in a staff position at the end of the three year contract.

The present activities of LIP Lisbon group cover both the participation in experiments at CERN (NA50, DELPHI, ATLAS and CMS) and the preparation of experiments to be installed in the International Space Station (AMS and EUSO).

Further det ails can be found in http://www.lip.pt.
Questions and declaration of interest should be addressed to Natalia@lip.pt



Exhibitors at CS-MAX 2002 will include:

Accent Optical Technologies
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AIXTRON
APT/Telemark
ASML Special Applications
Axic Inc
Bede Scientific Inc
BOC Edwards
Compound Semiconductor
Corning Tropel
CVD Equipment Corp
Epichem
Evans Analytical Group
Gavish
Hologenix
IPAG - Innovative Processing AG
IQE
JIPELEC
JMAR/SAL Nanolithography
Kopin Corporation
Lehighton Electronics
Loomis Industries
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Mattson Technology
Maxwell Technologies
MicroChem
MKS Instruments
Modular Process Technology Corp
Nippon Sanso Corporation
OSEMI
Oxford Instruments
Philips Analytical
Praxair Semiconductor Materials
Riber
SAMCO International
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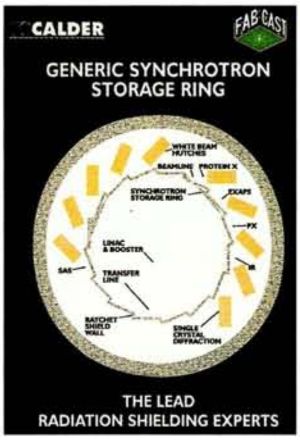

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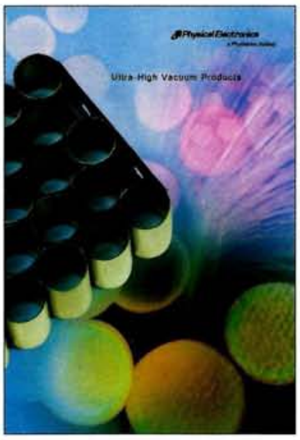

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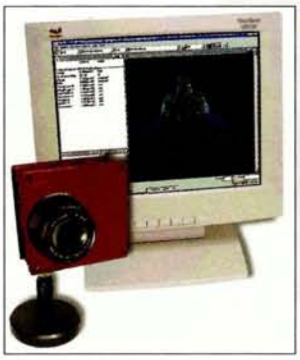

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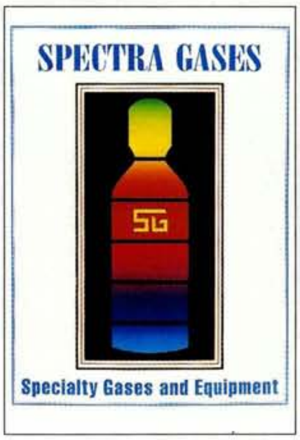

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BOOKSHELF

Space Radio Science by Oleg I Yakovlev, Taylor & Francis 2002, ISBN 0415273501, £60 (€94).

The twinkling of radio sources due to propagation effects is a nuisance most of the time, and radio astronomers try hard to remove these effects and sharpen up their radio maps. However, the scintillation can also be used in a positive way to probe conditions in the Earth's atmosphere and ionosphere, the interplanetary medium, the solar wind and the interstellar medium. For example, regular monitoring of the scintillations of extragalactic radio sources is now used to map out the interplanetary weather and the solar wind on a daily basis.

Artificial Earth satellites and deep-space probes have opened up even more elegant possibilities for remote sensing of planetary atmospheres and ionospheres and the solar wind. Satellites have many advantages compared with natural radio sources, as they are truly point-like and can transmit coherent monochromatic signals at several frequencies. Professor Yakovlev has devoted most of his scientific life to devising and interpreting such experiments. This extended monograph gathers together many of the insights he has gained, and provides a graduate-level introduction to this fascinating field of radio science. The book includes an extensive bibliography covering the period 1960–1999.

Chapter 1 starts with the basic physics of radio propagation through the Earth's atmosphere and ionosphere between ground stations and spacecraft, and ends with the topical subject of ionospheric tomography, in which satellite systems (such as GLONASS and GPS) transmitting coherently at several frequencies are observed simultaneously from different locations on the ground. This is a powerful tool for studying the ionosphere.

Professor Yakovlev's speciality, radio occultation studies, comes next. Reading between the lines I could glimpse the excitement of some of the early experiments. For example, the atmosphere of Venus is so thick that radio waves passing within 40 km of the surface are refracted by 6°, while waves that try to pass within 34 km of the surface of the planet suffer critical refraction and are captured. The radio occultation studies of the giant planets Jupiter, Saturn, Uranus and Neptune by the Pioneer and Voyager probes are outstanding achievements of space science in the 20th century. The same techniques have also been used to study the very rarefied plasmas around

smaller bodies, including Halley's Comet. Nearer to home, experiments between Mir and a geostationary satellite have demonstrated exciting possibilities for global monitoring of the Earth's atmosphere using satellite-to-satellite paths at several frequencies.

The core of the book covers radio sounding of the solar wind and the interplanetary plasma. By ingenious application of the techniques already expounded, Yakovlev explains how to measure the scale sizes and velocities of irregularities in the solar wind, the magnetic field, how to study magnetosonic and Alfven waves, and much more. The book then changes direction slightly to deal with radar observations of planets, asteroids and comets, including detailed treatments of scattering from a rough surface, back scattering, effects of planetary rotation, bistatic radar experiments and sideways-looking synthetic-aperture radar. Finally there is a short, and to me disappointing, chapter covering basic principles for interstellar radio communications. This is fairly standard material, presented without the unique insights that make the rest of the book so much more interesting. Russian space probes have been monitored at Jodrell Bank since the early 1960s. Many of us wondered exactly what was going on up in Lab 5, and what became of the large number of data tapes forwarded to Russia. With the arrival of this book on my desk things have become clearer to me. I have enjoyed learning from an expert guide the joys of watching the signals twinkle and fade as spacecraft pass behind a planet.

Jim Cohen, Jodrell Bank Observatory, University of Manchester.

High-Energy Particle Diffraction by Vincenzo Barone and Enrico Predazzi, Springer Verlag 2002, ISBN 3540421076, €74.95 plus local VAT.

Diffraction has played a fundamental role in physics for centuries, beginning with the realization of the wave nature of light. Given the wave-particle duality of quantum mechanics (QM), diffraction continued to be an important concept in non-relativistic QM scattering, and later in the study of elementary particle scattering using relativistic S-matrix theory.

For some decades after 1950, a vast experimental and theoretical effort went into the study of high-energy elastic and diffractive scattering of elementary particles, culminating in the largely unexpected discovery that cross-sections grow with energy. Being essentially non-perturbative processes, theory could not provide a really detailed description of elastic and diffractive scattering, but it did introduce a new idea that is truly fundamental. This new idea was the concept of complex angular momentum in non-relativistic QM (now a vital component in any serious book on QM) and its connection with the behaviour of relativistic scattering amplitudes at high energy. This led to the theory of Regge poles, which enjoyed enormous success in correlating the data on many reactions, though it also experienced some failures. Terms like Regge pole, pomeron and reggeon became household words. (A non-physicist spouse, upon being introduced to Tulio Regge at a party in the 1960s, is reported to have said: "Ah, Mr Pole, I have heard so much about you.")

The discovery of the partonic structure of hadrons and the advent of quantum chromodynamics (QCD) led to a dramatic change in the thrust of experimental high-energy physics, away from the study of elastic and diffractive scattering. Because of its property of asymptotic freedom, QCD was able to predict interesting correlations between experimental data in certain kinematical regions characterized by a hard scale. Consequently, a huge effort has gone into the study of such deep inelastic reactions.

But history, according to the Italian philosopher Vico, is supposed to be cyclical. So we should not be surprised to learn that there is a connection between certain aspects of ▷

deep inelastic reactions and Regge concepts, and that the relatively new field of hard diffraction opens up the possibility of a bridge between Regge theory and QCD (leading, one hopes, to an understanding of Regge theory in the language of QCD).

Unfortunately, the concepts and language of Regge theory have largely fallen into disuse, so that several generations of young physicists, whose education had a lacuna in this field, now find themselves working on experiments in which such concepts are of importance. It is for these lost generations, and, of course, for the present generation of elementary particle physicists that this volume will be of great value. It manages to succinctly introduce all the important ideas in the Regge theory of diffraction (now referred to as soft diffraction) and attempts to connect these to the recent developments in hard diffraction and its interpretation in the framework of QCD.

There are three main sections to this book. The first offers a rapid but clear survey of scattering theory in both classical wave optics and non-relativistic QM. It also includes a discussion of the eikonal approximation, which plays a major role in later chapters, when attempting to understand the high-energy behaviour of very complex QCD Feynman diagrams. A chapter on relativistic kinematics introduces the concepts of rapidity and rapidity gaps, the latter being the current focus of intense experimental study in lepton-hadron deep inelastic scattering (DIS).

The second part of the book surveys concisely the old soft diffraction from the "golden age" of Regge theory. Here the emphasis is on those aspects of theory and experiment that are directly relevant to the present-day resurgence of interest in diffraction – i.e. to the diffractive aspects of hard interactions. The essential ideas of dispersion relations, Muller's generalization of the optical theorem to inclusive reactions and the key, rigorous theorems on permissible growth with energy of cross-sections are presented. Also discussed is the Pomeranchuk theorem relating particle-particle to particle-antiparticle asymptotic cross-section growth, but, surprisingly, no attention is drawn to the optics-diffraction motivation for the key assumption in the proof of this "theorem".

The reasons for introducing complex angular momentum, crucial in the development of Regge theory, are simply and convincingly explained, and there follows an intelligible treatment of diffractive dissociation, the triple Regge limit (relevant to contemporary experiments), and how Regge theory can emerge from a field theoretic point of view. The latter is one of the most challenging issues in the study of perturbative QCD.

This section ends with a chapter devoted to the phenomenology of soft diffraction, summarizing cross-section growth, diffraction peaks and diffractive dissociation. The successful description of the energy behaviour of cross-sections in terms of Regge poles and the soft pomeron (that has an intercept of approximately 1.08) is emphasized. Included is a brief mention of the odderon, the intriguing object that seems to emerge from QCD and would be responsible for the breaking of the Pomeranchuk theorem, giving rise to a difference asymptotically between particle-particle and particle-antiparticle reactions.

The third section, about half of the book, is addressed to the relatively new subject of hard diffraction, which is currently under intense experimental study at DESY's HERA collider and Fermilab's Tevatron, and will be pursued at Brookhaven's RHIC and the LHC at CERN. This is a difficult subject. The theoretical approaches involve very complex and subtle calculations requiring the summation of an infinite series of Feynman graphs. The phenomenology is difficult to describe. The kinematic specification and experimental isolation of the class of events one wants to study is highly non-trivial and technically complex.

This final section begins with the theory of the BKFL equation, a perturbative treatment of generalized two-gluon exchange – summed to all orders in leading logarithmic approximation (LLA) – in parton-parton scattering. This leads to the conclusion that the gluon itself "reggeises", i.e. it behaves as a Regge pole and, perhaps more dramatically, that a pomeron-like object – the hard pomeron – emerges to control the high-energy behaviour of parton-parton scattering with an intercept of about 1.5. Perturbation theory breaks down in the range of small momentum transfer where the soft pomeron is operative, so it is not clear whether there is any incompatibility with the hard QCD pomeron. Unfortunately, studies going beyond the LLA appear to change the intercept appreciably and the full story remains untold.

After this challenging chapter we are offered a gentle introduction to lepton-hadron DIS and then led to the intriguing question of the behaviour of the structure functions at very small Bjorken-x. Here the soft pomeron, the QCD hard pomeron and the small-x behaviour of the DGLAP evolution equations confront each other. The theoretical aspects seem, unavoidably, to be complicated.

The last two chapters are devoted to the new field of hard diffraction, first the phenomenological aspects, mainly in DIS, where the topology of rapidity gaps, the concept of diffractive structure functions and parton densities, and the partonic structure of the pomeron are explained. There is also a brief description of single and double diffraction in hadron-hadron collisions. In the final chapter the BFKL version of the hard pomeron and the colour dipole picture of a highly virtual photon are used to derive theoretical predictions for various hard diffractive reactions. Many processes of current interest are covered: jets in diffractive DIS, diffractive production of open charm and vector mesons, nuclear shadowing, colour transparency and the cross-section for $\gamma^* \gamma^*$ scattering.

High-Energy Particle Diffraction offers a comprehensive survey of the theoretical and experimental sides of one of the major areas of study in current elementary particle physics. It provides essential background information for younger physicists who were not taught about soft physics and Regge theory, and for those who were it is a helpful bridge to the newer area of hard diffraction. This book is not easy going. Some of the theoretical approaches are inherently very complex and, despite the efforts of the authors, remain an intellectual challenge. This is somewhat exacerbated by a large number of typographical errors, which will hopefully be rectified in the second edition.
Elliot Leader, Imperial College, University of London.

Modern Cosmology edited by S Bonometto, V Gorino and U Moschella, IOP Publishing Ltd 2002, ISBN 0750308109, £75 (€118).

Cosmology has become a phenomenological science where large amounts of data from a host of precise experiments are being contrasted every day with concrete theoretical ideas about the early universe, based on general relativity and high-energy particle physics. Until recently, this happy situation was only envisioned as a dream in the minds of a few.

This book is a heterogeneous compilation of articles based on lectures, mostly from theorists, describing both the foundations and the present status of cosmology. The lectures were given in the spring of 2000, at a doctoral school in Como, Italy. Unfortunately, as with any science in rapid progress, the book has become quickly outdated. Some of the authors, like Piero Rosati, still write the standard formulae of luminosity and angular diameter distances as a function of redshift assuming zero cosmological constant, two years after the discovery of the acceleration of the universe by the Supernova teams. Others, like Rita Bernabei (for dark-matter searches with the DAMA experiment) or GianLuigi Fogli (for neutrino masses and mixings) describe experimental results that are obsolete or outdated, given the great advances that these fields have made in the past two years (thanks to Edelweiss and the Sudbury Neutrino Observatory, respectively). The same applies to the chapter on galaxy clusters and large-scale structure (LSS), or the one on the anisotropies of the cosmic microwave background (CMB), where the Sloan Digital Sky Survey and the Two Degree Field Galaxy Redshift Survey for LSS, and BOOMERANG, MAXIMA, CBI and VSA for CMB, have revolutionized their respective fields since the spring of 2000.

However, the reviews by John Peacock on the physics of cosmology, Arthur Kosowsky on the microwave background, Antonio Masiero on dark matter and particle physics, Philippe Jetzer on gravitational lensing and Andrei Linde on inflation, are very up to date and enlightening. They are a pleasure to read and may be extremely useful to PhD students and even researchers in other fields. The reviews of George Ellis on cosmological models, and Renata Kallosh on supergravity are somewhat technical and are probably beyond the level of doctorate students. On the other hand, I miss some discussion on gravitational waves, the Sunyaev–Zeldovich effect and perhaps even ultra-high-energy cosmic rays.

In summary, I think the book is a nice compilation of the status of cosmology in the year 2000. It gives the right perspective of what is to come in the next few years, or even decades, with inflationary cosmology as the early universe paradigm at the heart of a standard cosmological model, connecting astrophysics with high-energy particle physics.
Juan Garcia-Bellido, CERN.

Books received

The Theory of Open Quantum Systems by H P Breuer and F Petruccione, Oxford University Press, ISBN 0198520638, £55.00 (€86).

Finite Element and Boundary Element Applications in Quantum Mechanics by L Ramadas Ram-Mohan, Oxford University Press, ISBN 0198525222, £24.95 (€39).

LETTERS

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

Summer students

As an old CERN friend and alumnus I have much enjoyed the recent articles in *CERN Courier*, by Gordon Fraser and others, looking back on CERN's early years. In the July/August issue (p8) you very appropriately reminded readers of the beginnings of the Summer Student Programme, which was conceived with great foresight by the administration of the early 1960s.

However, I don't think it is quite correct to credit the origin of the programme to Victor Weisskopf's directorship. If I am not mistaken, the programme started in a modest fashion as early as 1960, when information was spread in member state institutions that advanced students could apply for a 6–8 week stay at CERN, with travel and a modest subsistence paid by the laboratory. I myself was lucky enough to be accepted as a summer student the following year, after having been encouraged by my professor, Alexis C Pappas, in Oslo to apply. One of the events I remember most vividly from that summer of 1961 was the gathering of staff and visitors outside the steps of CERN's main building in early August when Viki, on crutches, took over as CERN director-general from a young John Adams.

As I recall there was no organized lecture programme for summer students in 1961, but we had ample opportunity to attend seminars and conferences taking place at CERN. I was attached to the nuclear chemistry group, where my task was to adapt a novel technique for preparing thin samples for absolute beta-counting. It is quite remarkable and pleasing for an old member that this group, some years later renamed ISOLDE and still residing in the same old offices, has maintained its world leadership in the study of short-lived radioactive nuclei to this day.

Although I cannot claim comparison with the distinguished physicists mentioned in your article, it is certainly true for me that the short stay as a summer student in 1961 staked out the path of a future career where CERN has always played an important role. After pursuing work in nuclear chemistry and physics in Norway, Denmark and Sweden, I returned to CERN as a staff member in 1969 in the ISOLDE group until 1976, followed by a period as corresponding fellow for another three years. A few years later, after having moved on to a new career in research administration at home, I became heavily involved with CERN again as a member of the Norwegian delegation to the finance committee and Council.

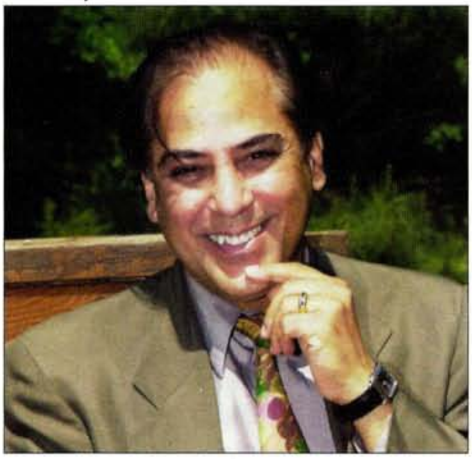
I congratulate the CERN Summer Student Programme on its first 42 years and convey my best wishes for an equally successful future.
Leif Westgaard, Norwegian delegate to CERN Council.

Accelerators for nano- and biosciences

Practical, affordable yet unique and exciting new accelerator facilities could advance vital research capabilities for nano- and bioscience, says **Swapan Chattopadhyay**.

From a historical perspective, large particle-accelerator facilities entered the scientific arena as grand instruments that enabled us to understand the fundamental workings at the heart of matter. Ever since Ernest Orlando Lawrence's invention of the cyclotron in 1930, we have witnessed the scientists' obsession with increasingly higher-energy particle beams to probe deeper into the nucleus, the nucleons and the elementary particles to understand the fundamental forces and processes at work. The result has been a scientific culture and sociology that defined the so-called "big science", with numerous spin-off benefits to society at large (such as large international collaborations and information networking via the creation of the World Wide Web). On the flip side, however, the economics, sociology and politics relevant to the envisioned next big accelerator facility addressing the frontier of particle physics are daunting to the point of paralyzing the field and driving its artisans – especially accelerator scientists – to extinction.

The value of accelerator science and technology is not limited to high-energy physics; witness the flourishing of accelerator-based synchrotron radiation sources worldwide that serve a much broader scientific community. While the energy of speed-of-light particles is an important parameter that determines the resolution with which we can see things in the microscopic world (whether using the particles directly or using the synchrotron radiation they generate when bent in a magnetic field), the intrinsic value of a particle beam goes far beyond its mere energy. It provides bursts of energy in suitably packaged pulses in space and time that have critical applications in today's emerging sciences of the nano- and bioworld. Such critical characteristics as the brightness, time structure, spatial dimensions, polarization, coherence, simultaneous and concurrent use of synchronized multiple light and particle beams are all important factors that can be tailored to address many relevant fundamental scientific issues of our times. And a careful examination shows that indeed it is possible to conceive affordable mezzo-



scale unique accelerator facilities that can produce creative space-time patterns of particle and/or wave energy to address specific issues that cannot be done otherwise.

Different worlds

What are some of the critical issues in nano- and biosciences today? The nanoworld is concerned with designing microscopic structures on a nanometre scale atom-by-atom and understanding the properties of these intermediate structures – made naturally or in the laboratory – which exhibit classical and quantum behaviour in a special and peculiar way. The relevant space dimensions are micrometres to nanometres, and the timescales for fundamental processes in the nanoworld range from picoseconds for vibrational electronic phenomena to femtoseconds for collective surface atomic nucleus motion and attoseconds for truly quantum single atomic phenomena. The bioworld is concerned with larger biomolecules where the energy transfer and topological deformations within the longer, functional biomolecules, such as proteins, demand suitable bursts of energy to initiate the energy-transfer mechanisms and ultrashort pulses to probe and image the molecules while still in a functional state, before being destroyed by the pulsed energy of the beam. An electron beam of up to a few giga-electron-volts in particle energy can be manipulated to produce pulses of electromagnetic waves from a picosecond to an attosecond in duration, and focused from a few micrometres to a few nanometres with wavelengths that can probe atomic motion. Such modest practical accelerator facilities are clearly possible for accelerator science and technology today. As an example I can only point to the exciting possibilities now opening up with various energy-recovered linear-accelerator concepts, short wavelength, high-power and high-brightness free-electron lasers, and various ultrashort/ultrafast pulse-production and slicing techniques actively pursued at major laboratories (such as DESY, PSI, Daresbury, Spring-8, Jefferson Lab, Cornell, Berkeley, SLAC, BNL and ANL).

Today's scientists working with light and speed-of-light particles grapple with classical power electromagnetics; microwave superconductivity; surface physics of metals and dielectrics; laser physics and technology; atomic physics of semiconductors; atomic and surface phenomena under extreme high fields (1–100 GV/m); precise detection of near-field and far-field radiation; nonlinear phenomena; studies of controlled high-density plasma waves; and the whole spectrum of space-time phenomena ranging from milliseconds to attoseconds and centimetres to nanometres. The transition from electronics (GHz) to optronics (THz) to photonics (PHz) is visible on the horizon – it is no longer only the domain of traditional physics and/or electrical engineering. We need to recognize this situation and seek to engage experts from all these disciplines to make a difference in the world. Let's extend our vision outwards from the world at femtometres to embrace the nano- and bioworld, where we have much to contribute. The accelerator community should take an active role in understanding the needs of the nano- and biosciences, and in educating the scientific community, government agencies and society via proper articulation of the tremendous hidden potential for bringing these capabilities to fruition.

Swapan Chattopadhyay, associate director at Jefferson Lab.

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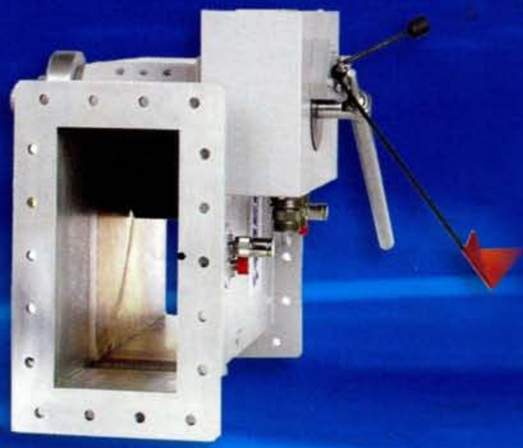

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