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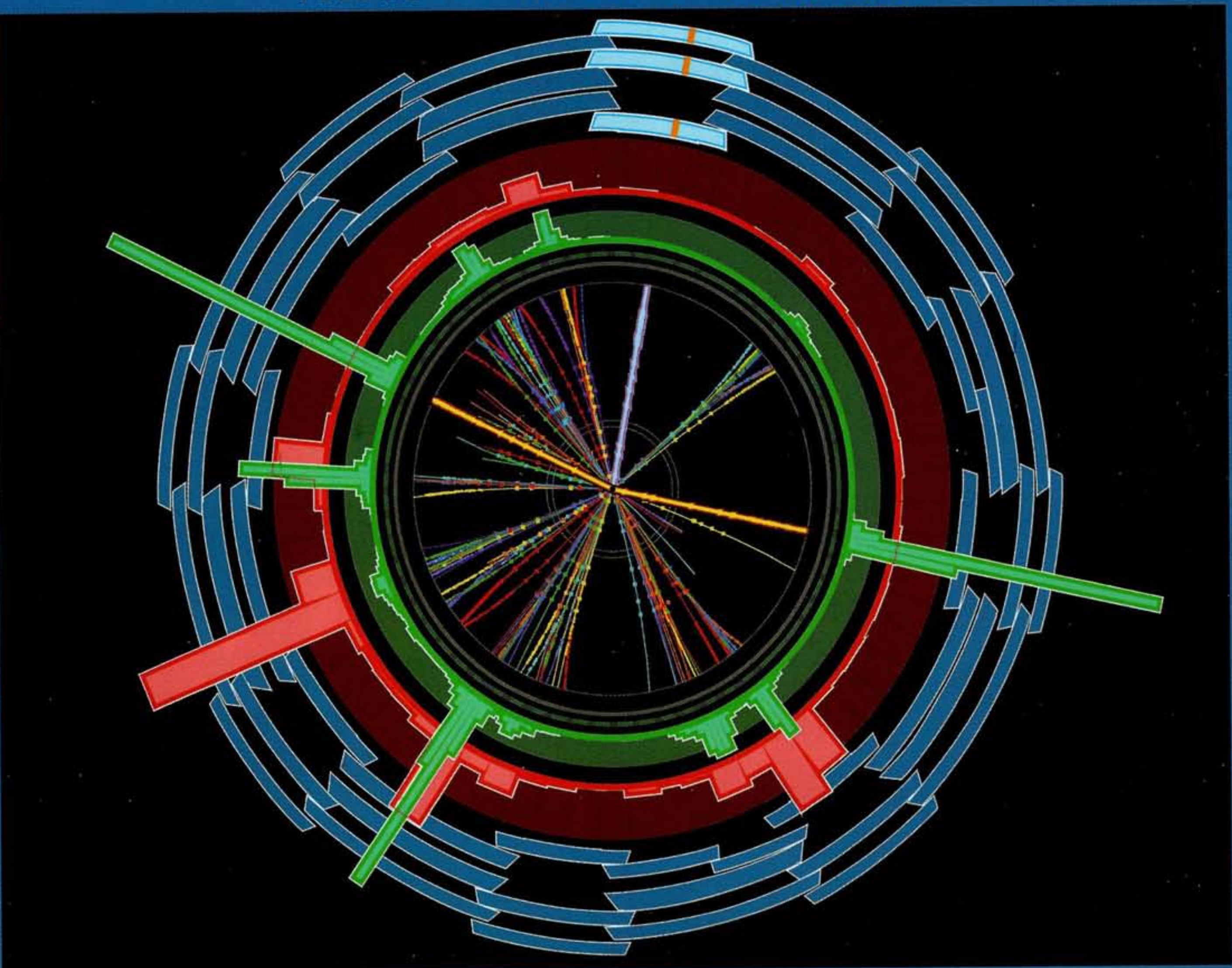

Bringing the heavens down to Earth

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Cover: A simulated collision event in the ATLAS detector, viewed along the beam pipe of the Large Hadron Collider (LHC). The event simulates the production and immediate decay of a mini black hole. This is just one example of the possibilities for exploring links between astrophysics and particle physics at colliders such as the LHC (see p17).

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

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HYPERNUCLEI

FINUDA's first results open up new window on exotic nuclei

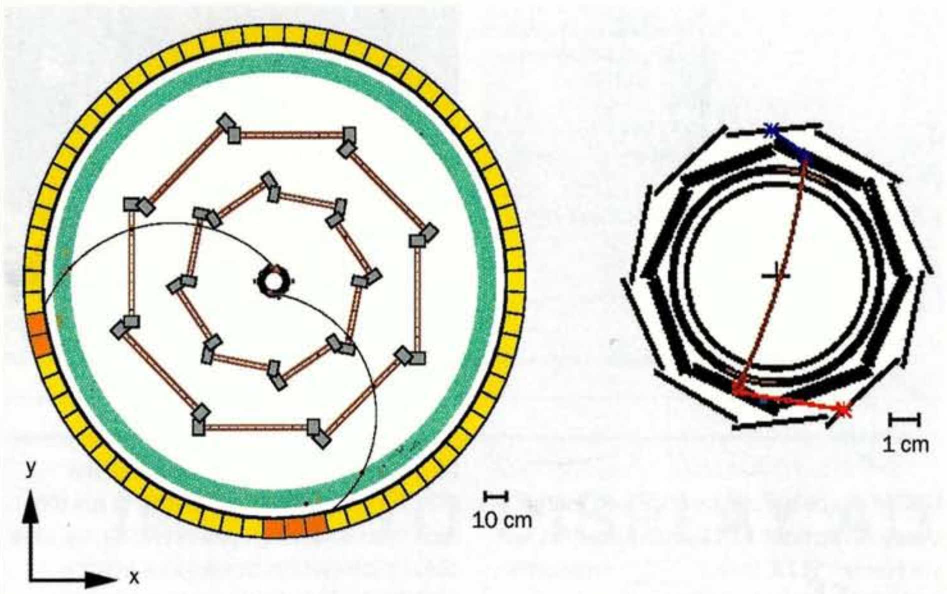


Fig. 1. A candidate for a hypernuclear-formation event (left) in FINUDA, with a μ^+ from the decay of the K^+ and a π^- from the interaction of the K^- in a ^6Li target. The enlarged view of the vertex region (right) shows the trajectories of the initial K^+ and K^- formed from the ϕ decay.

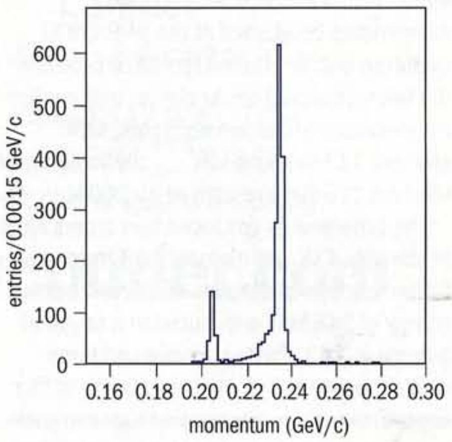


Fig. 2. The momentum distribution of positive tracks coming from the stopping points of K^+. The peak at 236 MeV/c corresponds to the decay $K^+ \rightarrow \mu^+\nu_\mu$, while that at 205 MeV/c corresponds to $K^+ \rightarrow \pi^+\pi^0$. The width of the μ^+ peak implies a momentum resolution of 1% FWHM.

The first results from the FINUDA experiment at INFN's Frascati National Laboratory show that the detector is performing well and is in good shape for its future studies of hypernuclear physics. At the XLII International Winter Meeting on Nuclear Physics in Bormio, Italy, at the end of January, the FINUDA team presented data on the performance of the detector, as well as preliminary observations of the formation of hypernuclei and their decay spectra.

The FINUDA detector was installed at the DAFNE "ϕ factory" in Frascati in the spring of 2003 (see *CERN Courier* April 2003 p13). The experiment makes use of the low-energy negative kaons emitted in the decays of the ϕ particles created in DAFNE. The decays produce an almost monochromatic beam of K^- with an energy of about 16 MeV. These low-energy K^- can come to a stop in thin targets and interact with nuclei via a strangeness-exchange reaction, where the strangeness of the kaon is transferred to a nucleus in which a neutron (containing udd quarks) becomes a lambda particle (uds).

The use of thin targets means that the FINUDA experiment can make the most of its intrinsic momentum resolution in order to provide high-resolution measurements of hypernuclear energy levels. In addition, the apparatus is designed to detect charged and neutral particles with large angular coverage and high statistics. The experiment can also measure spectra from different targets at the same time, so reducing the number of possible systematic errors.

Once the commissioning of FINUDA was complete in October 2003, data taking could begin with a set of targets of different nuclei – ^{6}Li, ^{7}Li, ^{12}C, ^{27}Al and ^{51}V – that were chosen to allow a variety of simultaneous studies of the formation and decay of hypernuclei. The targets form an octagon surrounding the interaction region, where the K^- are produced in the decay of ϕ particles to K^+K^- pairs. Within the target array, thin slabs of scintillator detect the highly ionizing low-energy kaons. Hypernuclear-formation events are selected by a trigger that picks out K^+K^- pairs accompanied by a fast particle (a pion) coming from the interaction of the K^- in a target (see figure 1).

The data collected so far indicate a momentum resolution, $\Delta p/p$ of 1.1% full width at half maximum (FWHM), corresponding to a resolution of approximately 2.5 MeV on hypernuclear energy levels (see figure 2). This value should improve after final calibration and detector alignment. The indications are that during its first phase of data taking FINUDA should collect about 10^5 useful events per target – which is enough for some high-resolution spectroscopy on the various nuclei.

Further reading

M Agnello *et al.* 2003 Frascati preprint LNF-03/23(P); to appear in *Nucl. Phys. B (Proc. Suppl.)*.

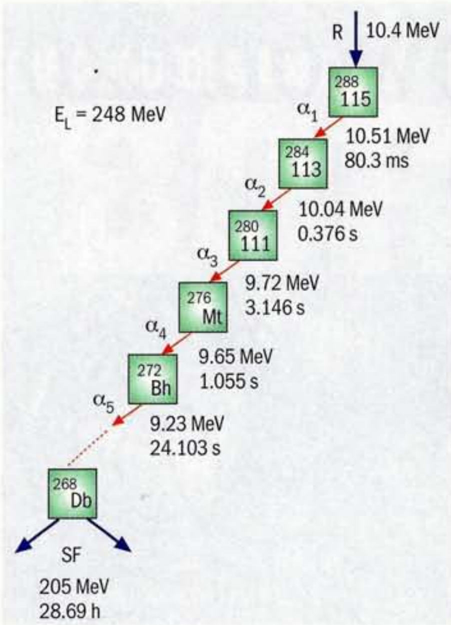
NUCLEAR PHYSICS

Superheavies extend periodic table to 115

A team from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, and the Lawrence Livermore National Laboratory (LLNL) in the US, has published results on the synthesis of two new superheavy elements, element 113 and element 115. In experiments conducted at the JINR U400 cyclotron with the Dubna gas-filled separator, the team observed decay chains that confirm the existence of the two elements, with element 113 produced via the alpha decay of element 115 (Oganessian *et al.* 2004).

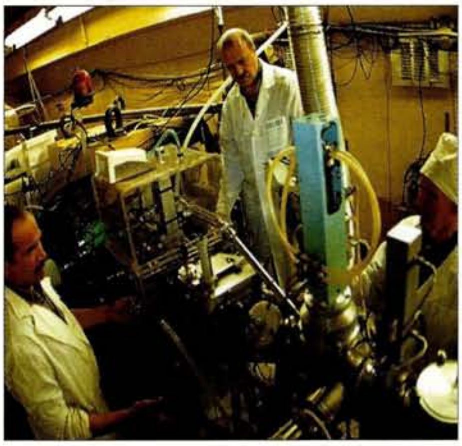
The experiments produced four atoms each of element 115 and element 113 through the fusion reaction of calcium-48 nuclei at an energy of 248 MeV with nuclei in a target of amercium-243. The team observed three similar decay chains, each consisting of five consecutive alpha decays that together took less than 30 seconds and terminated in the spontaneous fission of dubnium-268, an isotope of element 105 (which was named after Dubna) with a half-life of 16 hours. An interesting fourth decay chain ending in dubnium-267 was also observed when the energy of the incident calcium ions was slightly increased.

The discovery was made possible through the use of the intense calcium-48 beam from



One of the decay chains observed for the decay of element 115 to dubnium-268, via element 113, indicating the measured energies and the time intervals.

JINR's U400 cyclotron. "Twenty years ago no one would have ever thought that this was possible because the technology to produce such an element just wasn't there," explained



The gas-filled recoil separator that is used in the heavy element experiments at JINR. (Photo: Yu A Tumanov, JINR.)

Joshua Patin, LLNL's primary data analyst on the team. "But with the efficiency of the Russian cyclotron and the ability to run the experiments for long periods of time, we were able to achieve this tremendous accomplishment." The americium target material was supplied by the LLNL.

Further reading

Yu Ts Oganessian *et al.* 2004 *Phys. Rev. C* **69** 021601–1.

POLICY

OECD committee endorses future linear collider

Ministers meeting at the end of January for the Committee for Scientific and Technological Policy of the OECD (Organisation for Economic Cooperation and Development) have acknowledged the importance of ensuring access to large-scale research infrastructures in high-energy physics and of the long-term vitality of the field. The ministers also noted the worldwide consensus of the scientific community in choosing an electron–positron linear collider as the next accelerator-based facility to complement and expand on discoveries that are likely to emerge from the Large Hadron Collider (LHC) at CERN. They agreed that the planning and implementation of such a large, multi-year project should be carried out on a global basis, and should involve consultations among not only scientists but also representatives of science funding agencies from interested countries.

At their previous meeting in 1999, the ministers had endorsed the creation of the OECD Global Science Forum, which provided a useful venue for consultations among senior science policy officials and programme managers, and was a valuable mechanism for bringing together government officials with representatives of scientific communities. Now, at the January 2004 meeting, the ministers were in a position to devote their attention to the forum's work concerning high-energy physics. In particular the ministers endorsed the statement prepared by the forum's Consultative Group on High-Energy Physics and noted several important points that were articulated in the group's report. These included the need to have large, next-generation facilities funded, designed, built and operated as global-scale collaborations; the need to educate, attract and train young people in the fields of high-energy physics, astrophysics and cosmology; and the need for a strong international R&D collaboration and studies of the various issues required to realize the next major accelerator facility on the consultative group's roadmap – a next-generation electron–positron collider with a significant period of concurrent running with the LHC.

● The complete document of the committee's final conclusions is available at: www.oecd.org/document/15/0,2340,en_2649_34487_25998799_1_1_1_1,00.html.

PARTICLES IN SPACE

ASACUSA probes the astrophysical 'ice age'

Given the apparent absence of antimatter at the cosmic scale, it might seem strange that a recent paper from the ASACUSA collaboration on quantum tunneling effects in collisions between antiprotonic helium atoms and H_2 and D_2 molecules may be relevant to astrophysics. This is because antiprotonic helium consists of a one-electron "cloud" surrounding a composite, singly charged "nucleus" made up of an alpha particle (two positive charges) and an antiproton (one negative charge), so that it looks rather like a hydrogen atom.

No data exist on the reactions between H and D atoms and their molecules H_2 and D_2 at the low temperatures, around 30 K, that are characteristic of cold interstellar clouds and cold pre-stellar cores. These are exactly the astrophysical environments where more complex molecules may eventually be formed. For example, in certain regions the abundances of molecules such as H_2O, H_2S, CH_3OH and C_2H_5OH are so enhanced that surface ice chemistry must be occurring, while the reactants remain in close proximity to one another for 10^5 years or more!

This image of the Eagle nebula, M16, which was constructed from data from ESA's Infrared Space Observatory (ISO) satellite, reveals clouds of interstellar material at temperatures below −100 °C. A stellar nursery, the nebula's cold temperature is a key requirement for star birth to occur. (Credit: ESA/ISO/ISOGAL team.)

However, such reactions may not take place at all at these temperatures without tunnelling effects, so anything that provides a greater understanding of quantum tunnelling at low temperatures is of importance in answering the outstanding questions about ice chemistry. This is where the data from the ASACUSA experiment, reported in the paper "Quantum tunnelling effects revealed in collisions of antiprotonic helium with hydrogenic molecules at low temperatures" (Juhasz *et al.* 2003), may play an important role. The ASACUSA results provide a promising benchmark for theoretical models of such collisions, which could be generalized to more complex systems and may lead to a better understanding of astrophysical ice chemistry.

Further reading

B Juhasz *et al.* 2003 *Chem. Phys. Lett.* **379** 91.

CERN strengthens links with AMS experiment

CERN and the collaboration behind the Alpha Magnetic Spectrometer (AMS) experiment have signed a new memorandum of understanding (MOU) for the execution of the experiment, which will take place not at CERN, or elsewhere on Earth, but in space. The new MOU foresees the establishment at CERN of the experiment's Payload Operations and Control Centre, and the Science Operations Centre. CERN will also provide areas for the assembly and testing of the AMS detector, as well as offices for users and secretarial support.

AMS is a major international collaboration that is led by Sam Ting of MIT (*CERN Courier* April 2002 p5). The principal goal of the AMS experiment, which will be located on board the International Space Station, is to look for antiparticles in the primary cosmic radiation of outer space. Other objectives of the experiment include searching for dark matter and carefully analysing details of the cosmic-ray spectrum. The detector will be equipped with a powerful superconducting magnet and sophisticated detectors for precision tracking, particle identification and photon detection.

The 12 "racetrack" coils and two dipoles for the AMS superconducting magnet, built by Space Cryomagnets, UK, laid out in their approximate positions in the detector.

The signature of the MOU on 15 December 2003, with Claude Détraz, left, representing CERN and Manuel Aguilar-Benítez of CIEMAT, Spain, representing the AMS collaboration.

AMS has been a "recognized experiment" at CERN since 1997. The new MOU, which is a significant upgrade of the previous agreement, has a duration of five years and can be renewed.

ACCELERATORS

PPARC approves new funding for UK accelerator R&D

The UK Particle Physics and Astronomy Research Council (PPARC) has approved a £21 million (~€31 million) programme of accelerator R&D for future facilities in particle physics, including a linear collider and a possible neutrino factory. This will develop the UK's academic base in these important areas. PPARC's investment, in partnership with the Council for the Central Laboratory of the Research Councils (CCLRC), will fund a research programme and create two new university research centres. The aim is to build on existing academic expertise and develop a strong research base in accelerator R&D, in order to enhance the UK's position in experimental particle physics.

The two centres that are being created are the Cockcroft Institute: National Centre for Accelerator Science and the Oxford/ Royal Holloway Centre. The Cockcroft Institute is being established with £7.03 million (~€10.50 million) from PPARC, in partnership with the Northwest Development Agency, and the universities of Liverpool, Lancaster and Manchester. The second centre, which will receive £2 million (~€3 million) from PPARC, is a partnership with the University of Oxford and Royal Holloway, University of London. The centres will work closely with CCLRC's Accelerator Science and Technology Centre to create a leading capability in accelerator science in the UK.

An electron–positron linear collider has been accepted by the international particle-physics community as the next large facility that is needed, and construction could start as early as 2009. UK scientists are focusing on developing the beam delivery system, which will take the accelerated particles to the collision point.

The neutrino factory is a proposed international experiment to study neutrinos, and will rely on a beam of muons to create the neutrinos. To achieve this, a new mechanism has been proposed for cooling the muons, and the Muon Ionisation Cooling Experiment (MICE) is designed to test this principle. A collaboration of more than 150 physicists and engineers from Europe, the US and Japan would like to build and test a section of a realistic cooling channel on a beamline, which could be constructed on the ISIS accelerator at CCLRC's Rutherford Appleton Laboratory. The funding for MICE is at present only provisional, and depends on the project passing through some further review procedures.

CERN COURIER ARCHIVE: 1962

To celebrate the 50th anniversary of CERN, we look back at some of the items in the early issues of *CERN Courier*

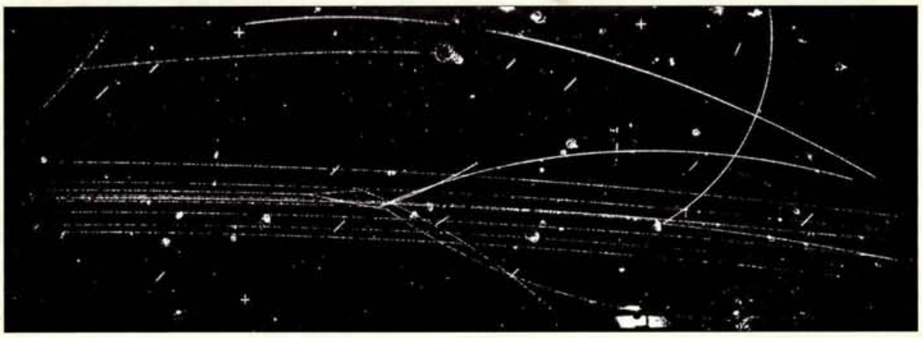
CERN AND BROOKHAVEN

New fundamental particle discovered: the anti-xi-minus

The discovery of the xi-minus antiparticle, a positively charged xi and one of the few hitherto undiscovered "strange particles", was reported simultaneously in the *Physical Review Letters* of 15 March by physicists working at CERN and at the Brookhaven National Laboratory.

Thus one of the two remaining question marks on the list of so-called "elementary" particles can now be replaced by factual evidence. As professor Weisskopf [then director-general of CERN] has commented: "This is an important discovery. In filling a gap in the theoretical knowledge of fundamental physics, it allows physicists the world over to base more firmly their investigations on one of the great riddles of our time: what is matter made of and why is it so?"

The elementary particles now number 30. At the end of the list the heaviest are the xi particles, which are also called cascade particles. They have either a negative or zero electric charge and a mass of about 2580 times that of the electron, one of the fundamental blocks of nature, which is taken as the unit of particle mass. The xis are thus listed by physicists as heavy particles, or baryons, in one of four classes of particles. They decay in 10^{-10} s (one tenth of a thousandth of a millionth of a second), each into a lambda particle and a pion. It is the antiparticle of the negative xi (a positively charged xi) that has now been discovered.



Antiprotons arrive [from the left] with momenta of 3 GeV/c and pass at high speed through the liquid hydrogen of the 81 cm bubble chamber. One of these antiprotons is seen to travel about 20 cm in the chamber, and then collide with a hydrogen nucleus (a proton), resulting in mutual annihilation. The mass of the proton and the mass and kinetic energy of the anti-proton give birth to two heavy particles: a negative xi and its antiparticle, which is a positively charged anti-xi. [The xi and anti-xi are visible as the first faint fork to be seen in the tracks, left of centre; the decay of the anti-xi then gives rise to the more visible spray of tracks.]

In the CERN experiment that led to the discovery, 85 000 pictures were taken just before last Christmas in the 81 cm hydrogen bubble chamber. This apparatus was built by a group of engineers from the Department "Saturne" of the Centre d'Études Nucléaires de Saclay, France, and physicists from the Laboratoire de Physique, École Polytechnique, Paris. It was installed at CERN near the largest European accelerator, the 28 000 million electronvolt proton synchrotron. The accelerated protons hitting a target produced secondary particles, from which antiprotons with an energy slightly above 3 GeV were selected and transported in a 100 m long channel to the bubble chamber, by means of an electrostatic separator, magnetic lenses and magnets.

About 15 European physicists can be considered as responsible for the discovery made at CERN. They decided to credit not their own personal contribution but the co-operative effort of the CERN European enterprise, coupled with the work of the Paris École Polytechnique and Department Saturne of Saclay.

• *Taken from* CERN Courier *March 1962 p4.*

NEWS FROM ABROAD

US government approves Project M

For the record, we would like to report that "Project M" (for Monster!) has received US government approval, and the first moves are being made in the construction of what will be the largest and most expensive research instrument of its kind in the world.

This is the 20 GeV electron linear accelerator, to be built at Stanford University, California, financed by the US Atomic Energy Commission. It will accelerate electrons inside a straight vacuum tube 2 miles (3 km) long, in a concrete tunnel buried under 11 m of earth. Every 12 m, radio waves will be fed into the tube from a total of 240 large klystron oscillators to provide the energy to speed up the electrons to 99.999999% the speed of light. Proposed experiments include studies of the processes induced by high-energy electrons, studies of nuclear-particle structure, experiments with secondary particle beams produced by the high-intensity electron beam, a test of the basic theory of electromagnetism, maybe even the study of new particles and other phenomena as yet unknown. It is planned eventually to raise the maximum energy to 40–45 GeV by feeding power from 1 klystron every 3 m.

• *Taken from* CERN Courier *March 1962 p9.*

EDITOR'S NOTE

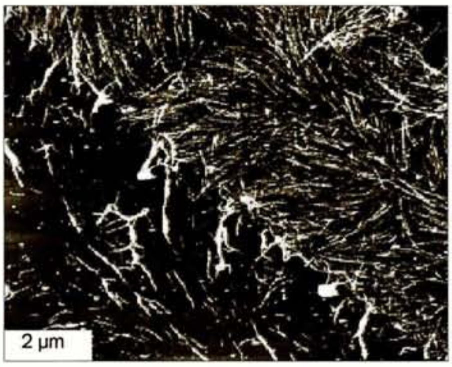
In 1962 *CERN Courier* reported on the discovery of the anti-xi-minus, while just over 40 years later experiments are beginning to discover what seem to be exotic relatives of the xi, the so-called pentaquarks (see p29). The discovery of new particles is a continuing theme in particle physics, with the discovery of the W and Z particles being one of CERN's major achievements (see p13).

• Apology: the wrong reference was given on the archive page in the previous issue (March 2004 p9); the excerpts were in fact taken from September 1962, not August.

Compiled by Steve Reucroft and John Swain

Carbon nanotubes found to be wiggly when wet

Take a pinch of carbon nanotubes, add a dash of water, and what do you get? The answer, rather surprisingly, is almost anything you want. While most work to date would lead one to think of carbon nanotubes as stiff rods just a few nanometres across, Vladimir Tsukruk and his colleagues at Iowa State University in Ames have found that all this changes when the nanotubes are wet. They become very flexible and will spontaneously bend into interesting forms as they dry. By cycling through many wetting and drying operations, they have found loops, hooks, coils and other shapes. In addition to the obvious interest in bent nanotubes as possible structural components for nano-devices, the expected change in their optical properties in response to bending also makes them possible candidates for sensors.



This image from an atomic force microscope shows part of an individual stripe of carbon nanotubes "woven" into a complex texture.

Further reading

V V Tsukruk, H Ko and S Peleshanko 2004 *Phys. Rev. Lett.* **92** 065502.

MOS structure points way to silicon optics

One of the big hold-ups on the development of optical (as opposed to electronic) circuits has been that there were no clear alternatives to silicon, which never seemed up to the job; certainly there was nothing with comparable fabrication infrastructure in place. However, this may have changed. Ansheng Liu of Intel in Santa Clara, California, and colleagues have shown that a MOS-type capacitor structure placed in a silicon optical waveguide can have its index of refraction varied by an applied voltage. The resulting device can provide phase-shift modulation with a bandwidth of more than 1 GHz, exceeding earlier speed records by a factor of about 50. Such progress, and the obvious ease with which electronics in silicon could be mixed with nascent silicon-optics technology, could lead to amazing devices in future.

Further reading

A Liu *et al.* 2004 *Nature* **427** 615.

Catalyst research takes off

This year is already proving good for research into new catalysts. John Shelnutt and colleagues at Sandia National Laboratories in Albuquerque, New Mexico, have shown that porphyrin molecules embedded in fatty droplets called liposomes can, in the presence of platinum ions and light, form foamy platinum nanostructures. These nanostructures turn out to be amazing catalysts that allow hydrogen atoms to be split off from water by light.

Meanwhile, Gregg Deluga of the University of Minnesota and colleagues have found a way to turn alcohol into hydrogen by simply passing it, together with air and water vapour, over a sequence of two catalysts. The first catalyst, made of rhodium and cerium oxide, makes hydrogen, carbon dioxide and carbon monoxide, and the second, made of platinum and cerium oxide, turns the carbon monoxide and water vapour into carbon dioxide and more hydrogen. The reaction takes place at over 700 °C, but once started it is exothermic so the process warms itself. This is exciting news as it offers a way to convert alcohol – which is easy to produce commercially in large quantities in a completely renewable and environment-friendly way – into a fuel whose only waste product on burning is pure water.

Finally, a new way has been found to split diatomic nitrogen, which is abundant in the atmosphere but almost inert chemically, into single nitrogen atoms, which can be made into important compounds of industrial and commercial value, such as ammonia. Paul J Chirik of Cornell University and colleagues have developed a novel semi-organic zirconium-based catalyst that does the job at 100 °C and atmospheric pressure. In contrast, the traditional Haber–Bosch process requires high temperatures between 400 and 500 °C and about 400 atmospheres of pressure.

Further reading

Y Song *et al.* 2004 *J. Am. Chem. Soc.* **126** 635.
G A Deluga *et al.* 2004 *Science* **303** 993.
J A Pool, E Lobkovsky and P J Chirik 2004 *Nature* **427** 527.

When fermions pair up and condense

A novel state of matter consisting of condensed fermions has been created by Deborah Jin and colleagues, Cindy Regal and Marcus Greiner, at NIST and the University of Colorado. The team showed that when fermionic potassium-40 atoms are held at microkelvin temperatures they pair up into bosons (rather as electrons form Cooper pairs in the BCS theory of superconductivity or He-3 pairs in superfluidity, but with much stronger binding) and then condense, forming a Bose–Einstein condensate, even though they're really fermions. The strength with which the pairing takes place can be tuned with a magnetic field, which makes this a very interesting experimental system. Even more excitingly, the small ratio between the Fermi and condensation temperatures relative to that observed in normal and even high-Tc superconductors could point the way to room-temperature superconductivity.

Further reading

C A Regal, M Greiner and D S Jin 2004 *Phys. Rev. Lett.* **92** 040403.

Compiled by Marc Türler

Star ripped apart by giant black hole

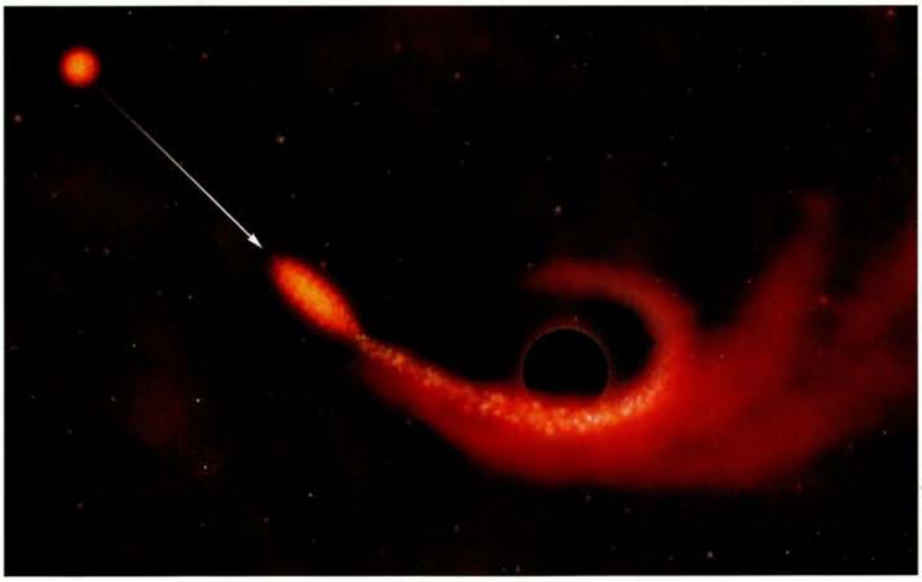
It has long been predicted that the very strong tidal forces of supermassive black holes at the centre of galaxies are able to disrupt stars venturing too close. Observational evidence for this phenomenon has now been obtained by two X-ray observatories – ESA's XMM-Newton and NASA's Chandra.

The story of this discovery goes back to July 1992, when the German Roentgen satellite (ROSAT) observed strong X-ray emission from an unknown source that happened to be in its field of view. This source, called RX J1242.6–1119, must have brightened by at least a factor of 20 during the previous one-and-a-half years, as it had not been detected between December 1990 and January 1991 during the ROSAT All-Sky Survey. Then in January 1999 the 1.5 m Danish telescope at La Silla, Chile, found two distant galaxies (redshift $z = 0.05$) within the X-ray position error circle, but surprisingly neither of them showed evidence for hosting an active galactic nucleus.

If the X-ray outburst was indeed associated with one of these non-active galaxies, the most likely interpretation of its origin was the tidal disruption of a star by a supermassive black hole. To test this hypothesis, the two galaxies were observed by the Chandra X-ray Observatory during March 2001, and a faint X-ray emission was detected at the centre of one of the two galaxies. Finally, in June 2001, a follow-up observation with XMM-Newton allowed the X-ray spectrum of this source to be obtained, although it was about 200 times dimmer than the outburst detected in July 1992 by ROSAT. The radiation was found to be widespread in energy – the characteristic emission of matter close to a black hole.

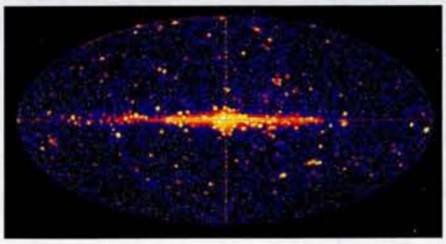
Like putting together the pieces of a puzzle in a detective story, these new observations now tell us what happened at the centre of this galaxy. A doomed star ventured too close to a massive black hole, and once close enough began to feel the extreme tidal forces exerted by the black hole. The difference in gravity acting on the front and back of the star first stretched it and then completely ripped it apart. Part of the stellar debris was pulled toward the black hole. In the extreme conditions close to the black hole's event horizon the gas heated itself up enormously, to millions of degrees, and before disappearing into the black hole forever, the gas emitted a brilliant flare of X-ray radiation – a "last cry for help" from the dying star. When re-observed with Chandra and XMM-Newton nine years later, the X-ray emission had dropped dramatically but not yet faded away completely. We can still see some of the afterglow emitted by the remaining gas that has not yet been swallowed by the black hole.

The data collected for RX J1242.6–1119 are the best evidence yet for such a tidal disruption event. Only two other suspicious flares that could be similar events have been found in other galaxies. Astronomers estimate that these events happen about once every 10 000 years in a galaxy. If this was going to happen around the black hole at the centre of our own Milky Way galaxy, it would become a hundred billion times brighter in X-rays than it is now, outshining every X-ray source in the sky, other than the Sun.



Artist's impression of a star (orange circle) that is being stretched and torn apart by the enormous gravity of a giant black hole. (Illustration: NASA/CXC/M Weiss.)

Picture of the month



This X-ray map of the entire sky is a beautiful example of recycling "trash" data from a satellite. It was constructed using 20 million seconds of data from the Proportional Counter Array of NASA's Rossi X-ray Timing Explorer (RXTE) when the satellite was moving between pointed observations. Because RXTE has been in operation for about eight years, it has now covered almost the entire sky with these "slew" observations, enabling the construction of the most precise map at X-ray energies between 3 and 20 keV. The plane of our galaxy is clearly seen, running horizontally along the middle of the image, and the map contains hundreds of clearly detected X-ray sources, including objects inside the Milky Way and beyond. (Credit: M Revnivtsev, S Sazonov, K Jahoda, M Gilfanov; NASA.)

Further reading

S Komossa *et al.* 2004 *ApJ* **603** L17.

The W and Z particles: a personal recollection

Pierre Darriulat, who was spokesperson for the UA2 collaboration between 1978 and 1985, looks back at the events surrounding the discovery of the W and Z particles at CERN in 1983.

As soon as it was known that the 1984 Nobel Prize for Physics had been awarded to Carlo Rubbia and Simon Van der Meer, a celebration was organized in an experimental hall at CERN. The happiness they radiate in this photograph was shared by the participants in the proton–antiproton project, who attended the event and drank a glass in their honour. Undoubtedly, this was one of the happiest days in the distinguished history of CERN.

The decade between 1967 and 1976 witnessed an impressive sequence of experimental and theoretical discoveries that changed the vision we had of the world – from the prediction of electroweak unification in the lepton sector (1967–1980) and the discovery of deep-inelastic electron scattering (1969), to asymptotic freedom and quantum chromodynamics (1973) and the discoveries of the J/Ψ (1974) and naked charm (1976). By 1976 the Standard Model of particle physics was in place, ready to confront experiments, and it was clear that a new accelerator was required to explore the electroweak unification sector. This is where the weak gauge bosons, W and Z, were expected, with approximate masses of 65 and 80 GeV/c^2, respectively. The arguments for the future LEP machine were already strong.

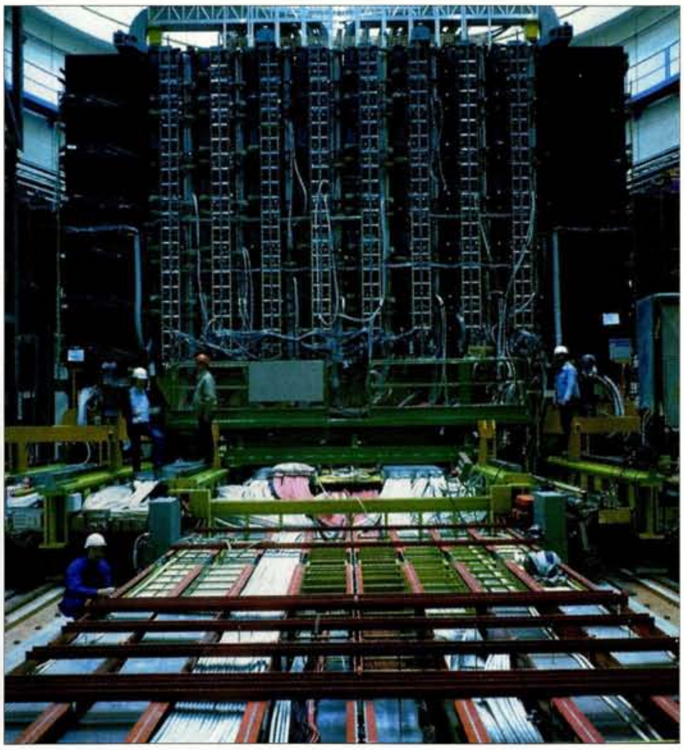
I remember being asked by John Adams (then executive director-general of CERN) to convene the Large Electron Positron Collider (LEP) study group in April 1976, and to edit the report. In practice this meant learning from theorists John Ellis and Mary K Gaillard all the beautiful new physics that was waiting for us, putting together some documents on the feasibility of the machine (which were available following Burt Richter's seminal paper), and wrapping it all up as quickly as possible together with some bread-and-butter experimental comments. It took only seven months to get it all done to the satisfaction of Adams, who wanted to push the LEP project in the wake of the success of the Super Proton Synchrotron (SPS), which was about to start operation.

The proton–antiproton choice

The situation in 1976 sets the context in which the proton–antiproton decision was made. The pressure to discover the W and Z was so strong that the long design, development and construction time of the LEP project left most of us, even the most patient, dissatisfied. A quick (but hopefully not dirty) look at the new bosons would have been highly welcome. But when proton–proton colliders such as the Superconducting Intersecting Storage Rings (SCISR) were proposed in this spirit, they were "killed in the egg" by the management at CERN, with the argument that they would delay – or even worse, endanger – the LEP project. This was accepted as a serious argument even by the proponents of such colliders.

The same argument did not apply to the proton–antiproton collider as it did not require the construction of a new collider ring and could be proposed as an experiment. One might object that this sounds like a bad joke, because it implied the construction of an antiproton source, and that turned out later to include a collector/accumulator accelerator complex (AC/AA).

However, it remains true that the existence of the SPS, which was soon shown to perform extremely well, was obviously an essential element of the success of the proton–antiproton project, for which ▷



The UA1 detector, shown here in its "garage" position, was a multi-purpose detector. It covered as large a solid angle as possible and could detect hadron jets, electrons and muons.

John Adams has to be credited. It is also true that he found it hard to swallow that his newborn baby should be tinkered with at such a young age and turned into a collider that had only a small chance of working. This was indeed the feeling of the vast majority of machine experts at the time, and much of Carlo Rubbia's merit is that he pushed his ideas for the proton–antiproton collider with an untiring determination in such an adverse climate. Indeed, he pushed not only with determination but also with a clear vision of what his proposals would lead to, and with a deep understanding of the machine-physics issues at stake.

A threat from Fermilab

Another argument also made it possible for the proton–antiproton project to break the LEP taboo. If CERN did not buy Carlo's idea, it was most likely that he would sell it to Fermilab. This threat was clear and had a great deal of weight when the decision was made at CERN. Despite the fact that the Fermilab machine was not performing well enough at the time to be used as a proton–antiproton collider, the threat very effectively accelerated the well known sequence of events that followed the publication in 1976 of the paper by Carlo Rubbia, Peter McIntyre and David Cline. In 1977, after the proposal had been made to CERN and Fermilab to produce the W and Z with existing machines, a feasibility study was undertaken by Franco Bonaudi, Simon Van der Meer and Bernard Pope that led to the Antiproton Accumulator (AA) design. At the same time a detector study was initiated under Carlo that led to the UA1 design, and the Initial Cooling Experiment (ICE) was proposed to the SPS Committee. The success of ICE was demonstrated in June 1978 and the approval for the UA1 detector followed immediately. Only six months later UA2 was also approved.

I strongly believe that if it had not been for Carlo, there would have been no proton–antiproton collider physics in the world for a long time, maybe forever. Whether the weak bosons would have been discovered at LEP, at the Stanford Linear Collider (SLC), or at some other collider is another matter, but it would have taken another six years at least. One might argue that six years is not really that long, but the top quark would not have been discovered either (other than indirectly from radiative corrections at LEP), nor would we have learned from the vast and rich amount of strong and electroweak physics data that have been collected at the SPS and Tevatron colliders – not to mention the low-energy LEAR physics, antihydrogen, glueballs, CP violation, antiprotonic helium atoms, etc.

The influence of the CERN ISR

I would like to say a word here about the CERN ISR and the seminal role that they played in the success of the proton–antiproton project. The ISR were the world's first hadron collider. This was the machine on which the young generation of machine physicists who designed, built and operated the antiproton source and the proton–antiproton collider (and later on, maybe to a lesser extent, LEP) gained their experience and their expertise. It worked superbly, exceeding its design goals in both energy and luminosity. It is the machine on which Van der Meer's ideas on stochastic cooling were tried for the first time, where they were studied and understood. It is also the machine with which a generation of physicists learned how to design experiments at hadron colliders.

When the first ISR experiments were being designed the strong interaction was still a complete mystery; when the machine was finally shut down QCD was in place. I do not mean to say that it is ISR physics that has taught us about QCD, but it contributed to the development of several of its ideas. ISR physics has helped us greatly in drawing a clear picture of hadron collisions, without which we would not have been able to design so effectively the UA experiments at CERN, and CDF and D0 at Fermilab. We, in UA2, were particularly indebted to the ISR, where many of us had previously been working and for whom this experience was an essential asset in designing a good detector.

I would also like to recall the extraordinary concentration of outstanding talents that the proton–antiproton project succeeded in attracting. One reason was of course that between the SPS and LEP projects – one completed and the other as yet unborn – its timing was in some sense ideal. But the other reason, possibly more important, was the challenging nature of the project, which attracted extremely bright engineers and physicists, both machine physicists and particle physicists.

The challenge of designing, constructing and assembling the antiproton source and detectors, and of getting them to work in such a short time, was enormous; as was that of digging and equipping the large experimental halls required for housing the new detectors that had to be alternately rolled in and out between collider and fixed target periods; and that of transforming the SPS into a collider. The amount of ingenuity that went into all these achievements was truly outstanding.

My best memory of those times may indeed be the good fortune I had to work with so many talents, and, in the case of UA2, to enjoy collaborating with such bright colleagues, senior physicists, post-docs, students or physicists of the same generation as mine.

The UA1/UA2 competition

The competition between UA1 and UA2 was real and lively, but relatively unimportant; it was more a kind of game, and we had a lot of fun playing it. There was no doubt that Carlo was the king of the proton–antiproton kingdom and was recognized as such by all of us. Undoubtedly, he would have had to take the blame if the proton–antiproton project had been a failure, but as it turned out to be a success he deserved to take the fame.

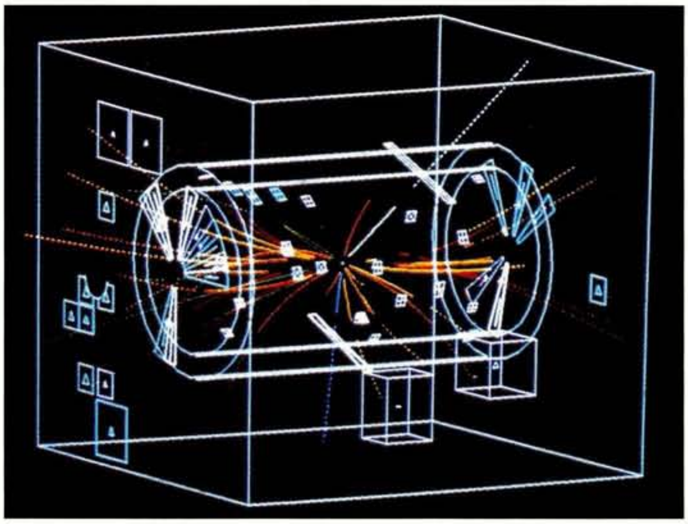
Personally, I had been working in Carlo's group for six years or so, mostly on K physics. I had joined him as a postdoc in the mid-1960s, coming from nuclear physics, and I had learned from him the basis of experimental particle physics. I had always been impressed by his brightness, by the readiness of his mind and by his far-reaching vision; and I respected him, as I do today, as someone of a clearly outstanding stature. To respect him as the king did not mean to belong to his court, however, and we in UA2 were particularly keen on finding occasions when we could proclaim that: "The king was naked." Such occasions were very rare – the king was usually dressed splendidly – so they were all the more enjoyable.

The design of the UA2 detector was a success and its construction and running-in went extremely smoothly. We were rightly proud of it. For only one-third the cost of UA1 – a condition of our approval was that UA2's cost should be significantly lower – we managed to build a detector that was ready on time, that saw the W and Z as soon as the collider luminosity made it possible (and at the same time as UA1 did), that measured the W and Z masses more accurately than UA1, and that was better than UA1 at detecting and measuring hadron jets. It was easier to design UA2 than UA1 because UA2 did not have to be a multi-purpose detector and could afford simply to ignore some of the physics, in particular to be blind to muons. While the main asset of the UA1 detector was its central detector, that of UA2 was its calorimetry.

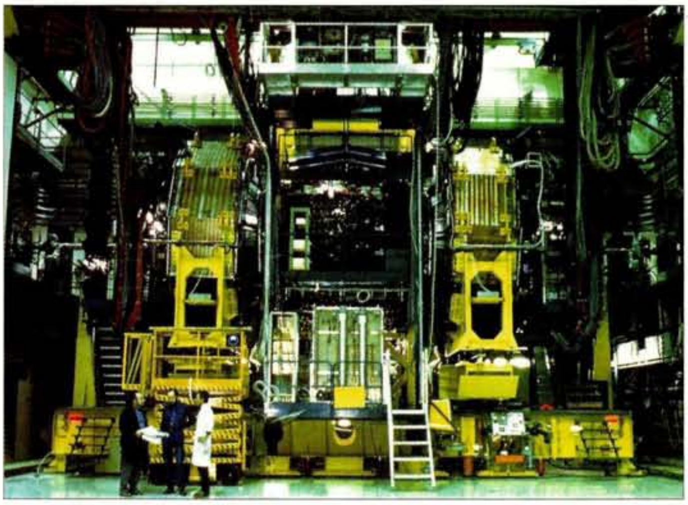
One difficulty in the design process had been judging how well the machine would perform, how long it would take to get going, and how noisy and hostile an experimental environment had to be expected. Sam Ting's detector (which was ultimately not approved) could have run in almost any background conditions, but could only see muons; the UA1 central detector required very clean conditions; UA2 was somewhere in between.

Expectations exceeded

The collider turned out to be an exceedingly clean machine and we had grossly underestimated how fast its luminosity would increase. In particular we had left an open wedge in our calorimeter, instrumented with a magnetic spectrometer, to do quietly (so we thought) some exploratory measurements while the machine was being tuned and run in. The wedge did not stay open very long, for the performance of the machine progressed at high speed, and we were able to tackle the first high-luminosity run with full calorimetric coverage.



The main asset of the UA1 detector was a large-volume, high-resolution central tracking detector, which was made according to an original and high-performance design.



The UA2 detector had a more limited scope than the UA1 detector: it could detect electrons but not muons, it focused on the central rapidity region, and it could not measure particle charges except for limited regions where the W decay asymmetry was maximal. But what it could do it did better than UA1. It provided the most accurate measurements of the W and Z masses and had excellent jet-detection capability.

I do not wish to repeat here the oft-told stories about the first seminars and the first publications reporting the UA1 and UA2 discoveries of the weak bosons (*CERN Courier* May 2003 p26), but I wish to comment on how we perceived these events. As I have already said, we were all expecting to see the weak bosons, we had no competition to fear from other laboratories and there was no question of UA2 "scooping" UA1 in the sense of stealing a Nobel prize or whatever. There was no doubt in our minds that Carlo and of course Simon deserved the whole credit for the success. The real outstanding achievement was the *production* of the weak bosons, not their detection. Without Carlo and Simon there would have been no proton–antiproton collider, but without UA1 and UA2 there ▷

would have been other experiments that would undoubtedly have done as good a job. The success of UA2 was largely due to the quality of the many physicists who had worked together very efficiently, with an excellent team spirit, and it was impossible to single out a few of them as deserving a larger part of the credit.

Of course there was competition; we enjoyed being faster or more clever than UA1 whenever we could afford to be, as when we were first at reporting to the 1982 Paris Conference the observation of very clear hadron jets, a breakthrough in the history of strong interaction physics. But this was not the dish, it was just the spices. The dish was serious business. It was reporting to the physics community what we had been finding. It was writing papers that would stay forever as important documents in the history of science.

In retrospect I am proud we resisted the pressure that was exerted on us to publish faster than we thought we had to. It would have been stupid and childish to give in, and would not have shown much respect for science. In fact this pressure made us almost overreact and, in the case of the Z, it caused a delay of nearly two months between the UA1 and UA2 publications because we preferred to wait for the imminent new run and collect more statistics before publishing. There was virtually no dissenting opinion in UA2 that we should have behaved differently – we all felt quite strongly about it. In particular the wiser and more experienced members of the collaboration (I mean the generation before mine) gave their full support to this line.

It is obvious today that there would have been no point in making a fuss about an event detected in 1982 that was most likely a Z, but one of its decay electrons was not identified because it hit a coil of our forward spectrometer magnets. We were wise to wait for more statistics before publishing the Z results. The issue at stake was not to bet on the truth, but to behave as if we were the only experiment.

Scientists of my generation are very fortunate to have witnessed such amazing progress in our understanding of nature, in phase with our own scientific life. It is remarkable that this has not only been the case in particle physics but also, and maybe to an even greater extent, in astronomy and life sciences. While many questions remain unanswered in each of these three fields, none can be put aside any longer as being a mystery inaccessible to science. Our vision of the world has changed dramatically. Having had an opportunity to contribute to this progress, however modest our contribution may have been, is very good fortune. May science be smiling on the next generation as kindly as it did on us, with the new physics that the LHC will soon reveal.

Further reading

Apart from the Nobel lectures of Rubbia and Van der Meer (see www.nobel.se/physics/laureates/1984), the interested reader may consult a list of relevant references in John Krige, *History of CERN*, volume III, chapter 6 (Elsevier, Amsterdam, 1996).

• This article is based on a talk given at the symposium held at CERN in September 2003, "1973: neutral currents, 1983: $W^{\pm}$ and Z^0 bosons. The anniversary of CERN's discoveries and a look into the future." The full proceedings will be published as volume 34 issue 1 of *The European Physical Journal C*. Hardback ISBN 3540207503.

Pierre Darriulat.

Bringing the heavens down to Earth

Recent developments and discoveries in astrophysics, particle physics and cosmology are creating an increasing synergy between astroparticle physics and particle physics at accelerators, as **Nikolaos Mavromatos** and **James Pinfold** explain.

As announced a year ago now, the Wilkinson Microwave Anisotropy Probe (WMAP) has measured anisotropies in the cosmic microwave background radiation to an unprecedented accuracy of 10^{-9} K. The vastly improved precision of these data, compared with the groundbreaking results of the earlier Cosmic Background Explorer (COBE) satellite, is clearly shown in figure 1. This is opening up a new era for astroparticle physics, as the accuracy of the WMAP data has allowed a determination of cosmological parameters that are of relevance to particle physicists. Specifically, data from WMAP have significantly constrained the dark-matter content of the universe. This in turn strongly implies model-dependent and stringent constraints on models in particle physics, especially in minimal supersymmetry. In addition, the current evidence for an accelerating universe has revealed a massive component of "dark energy" in the total energy of the universe. One can imagine a pie graph showing the breakdown of the energy budget of the cosmos: 4% ordinary matter, 23% dark matter and 73% dark energy.

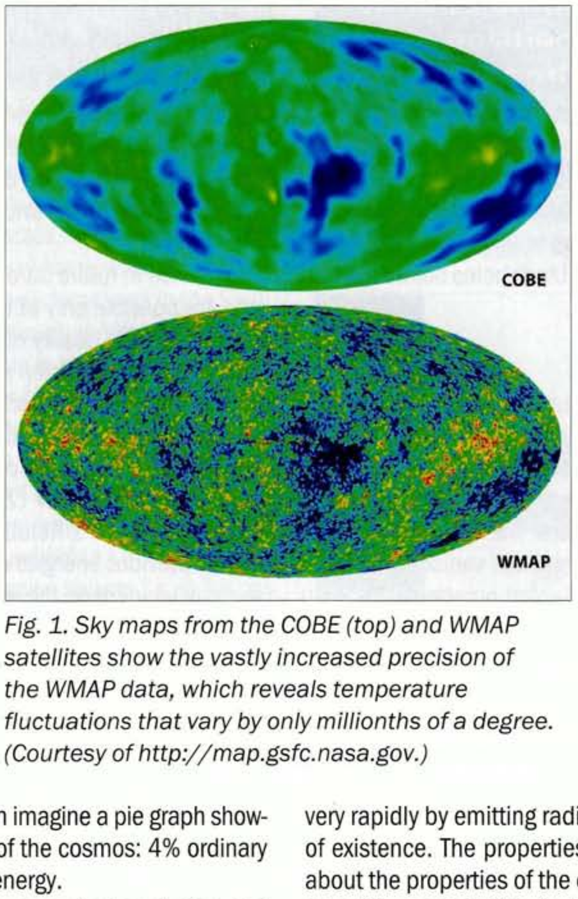


Fig. 1. Sky maps from the COBE (top) and WMAP satellites show the vastly increased precision of the WMAP data, which reveals temperature fluctuations that vary by only millionths of a degree. (Courtesy of http://map.gsfc.nasa.gov.)

Other examples of the interplay between accelerator physics and astroparticle physics are provided by the following areas: extra dimensions and mini-black-hole production; neutrino oscillations; electroweak baryogenesis; dark matter consisting of the lightest supersymmetric particle (LSP); magnetic monopole production; and ultra-high-energy cosmic rays (UHECR).

The new collider experiments, in particular at the Large Hadron Collider (LHC) at CERN, offer the unique possibility of exploiting the significant links between astrophysics and particle physics. Importantly, there are some astrophysical scenarios that can be tested decisively at high-energy colliders. In other cases input from collider experiments is required to sharpen predictions for future astroparticle physics experiments, for example: the LSP detection rate, the UHECR spectrum in "top-down" models, and the understanding of very-high-energy hadronic interactions. Alternatively, cosmic-ray astrophysics may point the way to new physics at accelerators.

In theories with large extra dimensions at sub-millimetre distances, for example, and/or high energies of the order of 1 TeV or more, gravity may become a strong force. Thus, hypothetically, the energy required to produce black holes is well within the range of the LHC, making it a "black-hole factory". As Stephen Hawking has taught us, these mini black holes would be extremely hot little objects that would dissipate all their energy very rapidly by emitting radiation and particles before they wink out of existence. The properties of the Hawking radiation could tell us about the properties of the extra spatial dimensions, although there are still uncertainties in the theory at this stage. Nevertheless, astroparticle and collider experiments should provide useful input to the theoretical work in this area. Indeed, the signatures are expected to be spectacular, with very high multiplicity events and a large fraction of the beam energy converted into transverse energy, mostly in the form of quarks/gluons (jets) and leptons, with a production rate at the LHC rising as high as 1 Hz. An example of what a typical black-hole event would look like in the ATLAS detector is shown in figure 2.

If mini black holes can be produced in high-energy particle ▷

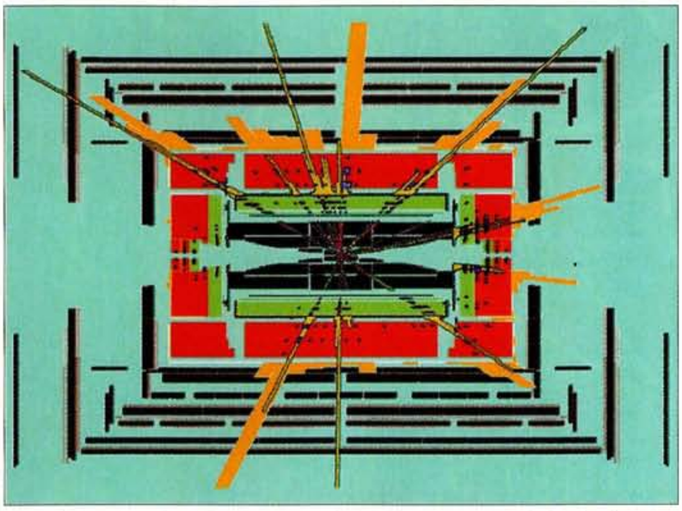


Fig. 2. Image showing how an 8 TeV black hole might look in the ATLAS detector (with the caveat that there are still uncertainties in the theoretical calculations).

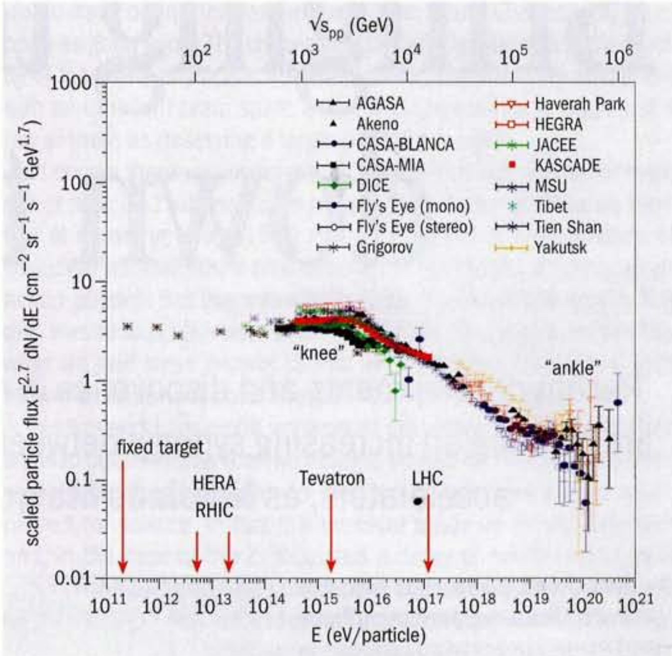


Fig. 3. The cosmic-ray energy spectrum showing the cosmic-ray energy equivalent to the centre-of-mass energy of currently operating and planned colliders. (Courtesy of R Engel, Xth Blois Workshop on Elastic and Diffractive Scattering, July 2003.)

interactions, they may first be observed in high-energy cosmic-ray neutrino interactions in the atmosphere. Jonathan Feng of the University of California at Irvine and MIT, and Alfred Shapere of the University of Kentucky have calculated that the Auger cosmic-ray observatory, which will combine a 6000 km^2 extended air-shower array backed up by fluorescence detectors trained on the sky, could record tens to hundreds of showers from black holes before the LHC turns on in 2007.

Crossing the divide

Neutrino astrophysics has also provided us with exciting new results on neutrino masses and has opened up another area of synergy between particle physics, astrophysics and cosmology. The Sudbury Neutrino Observatory and Super-Kamiokande detectors have shown that neutrinos oscillate into other flavours. The result is final: the minimal Standard Model is dead, as it predicted vanishing neutrino masses and thus separately conserved lepton numbers. This is an existence proof that astroparticle-physics experiments can indeed produce results that have a fundamental impact on accelerator-based particle physics.

Another area with important cosmological implications is the violation of discrete symmetries C (charge), P (parity) and T (time reversal), and their combination CPT, which may be violated in some models of quantum gravity. Such issues are associated with explanations of the observed matter–antimatter asymmetry in the cosmos. Neutrino factories could provide answers to such fundamental questions. There is also the possibility for direct detection of massive isosinglet neutrinos at the LHC, the existence of which would have an important astrophysical impact. No doubt the synergy between neutrino astroparticle physics and accelerator-based neutrino physics will continue to yield possibilities for more vital insights.

The current generation of collider experiments and in particular the LHC project at CERN offer the unique possibility to perform precise measurements of the properties of the hadronic interaction. The motivation is that very-high-energy particles will have central importance in future studies of cosmic-ray physics. Measurements that are possible only at the LHC will have the potential to improve significantly the quality of measurements of cosmic-ray air showers both in the "knee" region and especially for the very highest energies at the "ankle" and beyond (see figure 3). The Tevatron collider at Fermilab provides hadron collisions at a centre-of-mass energy approaching 2 TeV, which is equivalent to a cosmic ray with an energy of about 2 PeV (2000 TeV) colliding with a stationary proton. Brookhaven's Relativistic Heavy Ion Collider using nitrogen beams provides energies equivalent to that of a 5×10^{14} eV nitrogen nucleus incident on the atmosphere. The LHC will provide energies equivalent to roughly 10^{17} eV incident on a stationary proton. As can be seen from figure 3, these machines cover some of the important features of the cosmic-ray energy spectrum. It is worth noting that the energy flow in cosmic-ray air showers is within a few degrees of the incident particle – in effect the "beamline" – so it is vital that the LHC detectors have adequate forward detector systems.

New physics

Over the years cosmic-ray experiments have reported a remarkable spectrum of anomalies, observed at regions of pseudo-rapidity outside the range of existing accelerator observations. The class of inclusive phenomena include anomalous examples of mean free path or long flying component, heavy flavour production, attenuation of secondary hadrons, and the energy fraction of air showers in emulsion-chamber families. There are also anomalous individual exotic events, which contain unexpected features: Centauro and anti-Centauro events; Chirons and halo events; and muon bundles. While these anomalies could be due to "unrecognized" Standard

Model physics or an incorrect interpretation of the measurements, they could also be harbingers of new physics that would be manifest at the LHC and other future colliders. In 1971 K Niu and co-workers at Tokyo University, using balloon-borne emulsion chambers, reported evidence for decaying hadrons with unusual properties. After the discovery of charm in 1974, Tom Gaisser and Francis Halzen showed that the particles were in fact D-mesons; by then accelerator experiments had confirmed Niu's measurements of mass, lifetimes and other properties.

Another recent example of the use of timely astroparticle experiments to guide our search for new physics at future colliders is provided by the development of new detectors such as the satellite-based Gaseous Antiparticle Spectrometer. Proposed to search for cosmic antimatter, this could also probe for supersymmetric dark matter up to a neutralino mass of approximately 400 GeV. This would extend the range of immediate future terrestrial direct dark-matter searches such as the GENIUS (germanium detectors in liquid nitrogen in an underground setup) experiment at the Gran Sasso Laboratory.

The LHC will make available large underground detectors such as ATLAS and CMS with an unprecedented area of fine-grained detectors and magnetic field volume. Following in the footsteps of the COSMOLEP experiment at CERN's Large Electron Positron collider, these detectors could be used to determine precisely the direction and momentum of large numbers of penetrating cosmic-ray tracks within a very small area. One benchmark cosmic-ray phenomenon that can be studied is that of muon bundles, and another class of phenomena that can be studied in this way are upward-going showers, presumably from high-energy neutrino interactions in the Earth. In principle, trigger rates from the cosmic-ray phenomena mentioned above are low enough that they can be run in conjunction with standard trigger menus. In this way collider-physics experiments can make a direct contribution to astroparticle-physics experimentation.

In the "no man's land" just beyond the frontiers of our knowledge nothing is certain, and most of the recent discoveries, which must often be interpreted in a model-dependent way, are subject to interpretation and debate. For instance, the evidence for a dark-energy content of the universe, its origin and precise nature (i.e. is it a cosmological constant, a quintessence field or something else?), the nature of dark matter, the nature of the UHECR, the existence of supersymmetry or other new physics, the possibility for the existence of large extra dimensions, etc, are issues that are still not resolved. The synergies between particle physics, astrophysics and cosmology in the next 10 years should amplify our ability to make faster and deeper inroads in all of these areas. There is no doubt that a new frontier for fruitful collaboration is now before us.

Further reading

A website that provides online resources for those exploring the common issues of collider physics (based on the ATLAS detector) and astroparticle physics has been created at http://csr.phys.ualberta.ca/astroATLAS/index.htm. Most of the references used to prepare this article can be found on the site.

Nikolaos Mavromatos, *King's College London, and* **James Pinfold**, *University of Alberta.*

Highlights of SIGHAD03

The SIGHAD03 workshop in Pisa considered the challenges presented by different sources of low-energy hadronic cross-section data.

The SIGHAD03 workshop, held in the Italian city of Pisa last October, attracted around 60 participants.

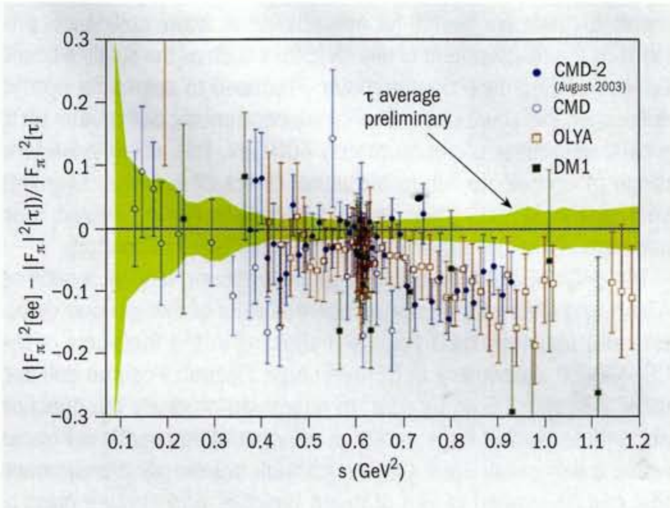


Fig. 1. Graph showing a comparison of the $\pi^+\pi^-$ spectral functions from e^+e^- annihilations and isospin-breaking corrected data from hadronic τ decays.

Can data on hadronic cross-sections from e^+e^- annihilations and τ decays be reconciled? This was one of the main topics discussed at the Workshop on Hadronic Cross Section at Low Energy – SIGHAD03 – which was held in Pisa, Italy, on 8–10 October 2003, and attended by about 60 participants from a variety of countries.

Despite its well known successes, the Standard Model still has a number of weaknesses, one of them being the prediction of the anomalous magnetic moment of the muon, a_μ. Participants at SIGHAD03 heard the whole story from the main protagonists: from the pioneering experimental work carried out more than 40 years ago, which was nicely summarized by Francis Farley of Yale, to the impressive accuracy reached in recent years on both the experimental and theoretical sides.

The main issue, however, still concerns the evaluation of hadronic contributions to a_μ below 2 GeV. These cannot be calculated by perturbative quantum chromodynamics, and so rely almost entirely on data. In the 1990s data from hadronic decays of the τ (from the ALEPH experiment) were used to add information to that obtained directly from electron–positron annihilations. This method – which was pioneered by Michel Davier of Orsay and presented by him at the workshop – allowed a substantial improvement in the theoretical evaluation of a_μ. In the meantime, the CMD-2 experiment at the VEPP-2M collider complex in Novosibirsk was able to improve the measurement of the two-pion annihilation cross-section (leading to a 0.6% systematic error), and both the OPAL and CLEO experiments came up with independent measurements of the τ spectral function.

These improvements led to a comparison between the $\pi^+\pi^-$ spectral functions from e^+e^- and τ data. However, after including isospin-violating effects, there is still a discrepancy of the order of 10 to 15% above the ρ resonance (see figure 1). The origin of this discrepancy, and more generally the results of the evaluation of a_μ using different approaches, was the central theme of one of the sessions at the workshop. Whether it is due to a missing correction in theory (the difference in mass and width between the charged and neutral ρ mesons, as discussed by Davier and Fred Jegerlehner of DESY) or whether it lies in the data, is still controversial.

SIGHAD03 also heard about the status of and the prospects for existing and planned colliders. Within a few years, upgrades of electron–positron colliders in Beijing (BEPCII/BESIII), Novosibirsk (VEPP-2000), Frascati (DAFNE-2) and Cornell (CLEO-C) should become operational and therefore provide new data. Results on τ spectra from B-factories are also expected; indeed, the first results from the Belle collaboration at KEK-B in Japan were presented at the workshop.

An improvement in the current situation will soon come from existing meson factories, with the KLOE, BaBar and Belle experiments. Here the use of the initial state radiation process (ISR), as recently proposed by the group of Johann Kühn in Karlsruhe, allows the whole available energy range to be scanned while working at a fixed energy. In particular, the KLOE collaboration at the DAFNE φ-factory in Frascati presented results on the hadronic cross-section below the φ peak, which agree with the Novosibirsk e^+e^- data and thus confirm the 2σ discrepancy with the τ approach. Preliminary data were also presented by the BaBar collaboration (at SLAC), showing the feasibility of the ISR method at B-factories, where there is the advantage that a much wider energy range can be covered. Recent theoretical developments on ISR were also reviewed, and during the workshop a round table was organized in order to discuss the status of radiative corrections for luminosity measurements in an attempt to provide a unified picture of the current situation.

Precise measurements of R, the ratio of hadronic to muon-pair cross-sections in e^+e^-, at low energy have a strong influence not only on the anomalous magnetic moment of the muon but also on the running electromagnetic coupling constant, whose uncertainty limits the prediction of the Higgs mass. The measurements also provide a test of the perturbative behaviour of the strong interaction and of low-energy effective field theories. The running of the electromagnetic and strong coupling constants, and the determination of charm and bottom masses, are two examples that were reviewed at the workshop, and whose progress has benefited from the latest experimental results from the electron–positron colliders in Beijing (BES) and Novosibirsk.

Despite its successes, the Standard Model still has a number of weaknesses, one of them being the prediction of the anomalous magnetic moment of the muon, a_μ.

In summary, this was a short but very intensive workshop. However, there were also two moments of relaxation, with a visit to the Piazza dei Miracoli, where the leaning tower is located, and a delicious dinner in the lovely ancient Villa Toscana. During the dinner, Simon Eidelman proposed organizing the next workshop in Novosibirsk two years from now. By then, new theoretical and experimental results, expected in particular from the g-2 experiment at Brookhaven, as anticipated by Lee Roberts (and now released, see *CERN Courier* January/February 2004 p6) will clarify whether the discrepancy observed in a_μ will vanish, or whether it will remain, so requiring new physics.

Further reading

For more information, see www.pi.infn.it/congressi/sighad03.

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Perspectives for nuclear-p

The Nuclear Physics European Collaboration Committee's recently published long-rang

In Vienna, Austria, in December 2001 the Nuclear Physics European Collaboration Committee (NuPECC) started to prepare a new long-range plan for nuclear physics in Europe. NuPECC's goal was to produce "a self-contained document that reflects on the next five years and provides vision into the next 10–15 years". The previous long-range plan had been published as a report, "Nuclear Physics in Europe: Highlights and Opportunities", in December 1997.

NuPECC first defined the active areas of nuclear physics that were to be addressed. Working groups were formed, spanning all the subfields of nuclear physics and its applications: nuclear structure; phases of nuclear matter; quantum chromodynamics; nuclear physics in the universe; and fundamental interactions and applications. Convenors for each of these groups were appointed and two liaison members of NuPECC were assigned to each of them. The working groups were then asked to provide recommendations for possible future directions and a prioritized list of the facilities and instrumentation needed to address them.

The next step in the process was a town meeting, organized at GSI Darmstadt on 30 January – 1 February 2003, to discuss the long-range plan. Prior to this, the preliminary reports of the groups had been posted on the NuPECC website. The town meeting was well attended with around 300 participants, including many young scientists, and the following summarizes the general trends and exciting ideas about modern nuclear physics that were presented at the meeting and given in the report.

Members of the nuclear-physics community at a town meeting held at GSI Darmstadt on 30 January – 1 February 2003. The participants discussed the long-range plan for nuclear physics in Europe prior to its finalization.

Progress in nuclear research

At a deeper level, nuclear physics is the physics of hadrons. Here, recent developments in lattice quantum chromodynamics (QCD) calculations have raised a great deal of interest in hadron spectroscopy. According to QCD, gluon-rich hadrons can be formed, as well as hybrid states of combinations of quark and gluonic excitations. There is also interest in quark dynamics, since in hadrons the polarization of gluons and the orbital angular momentum of quarks play an important role, together with a large transverse quark polarization. Nowadays the measurement of generalized parton distributions – which are generalizations of the usual distributions describing the momentum or helicity distributions of the quarks in the nucleon – receives much attention as the measurements will improve our knowledge of the structure of the hadron. Quark confinement and the study of phenomena in the non-perturbative regime of QCD will be addressed in future. Phase transitions of nuclear matter are being investigated in two regimes: at the Fermi energy, at which a liquid–gas phase transition is expected, and at very high energies and/or densities where a quark–gluon plasma (QGP) is expected. In the first phase transition interesting isospin effects turn out to play a role in the formation of exotic isotopes, whereas at the second phase transition the deconfinement of quarks is expected at very high temperatures and colour superconductivity at low temperatures and very high densities.

A long-term and fundamental goal of nuclear physics is to explain low-energy phenomena starting from QCD. In a first step, the connection could be made through QCD-motivated effective field theories. This should go hand in hand with experimental investigations that allow tests of these models. Recently, new developments have taken place, raising interest in nuclear structure, and besides the development of equipment and refined detection methods, it is now possible to use exotic beams of unstable nuclei. Furthermore, due to the increase in computing capacity, *ab initio* calculations with two- and three-body forces up to mass 12 can be performed. Experimentally, it is now possible to broaden the research field of the 300 stable nuclei to the approximately 6000 atomic nuclei that are predicted to exist. This means that a number of questions can now be addressed, such as what happens in extreme conditions of the neutron to proton (N/Z) ratio, at a high excitation energy, at an extreme angular momentum, or at a very heavy mass – that is, at considerably more extreme conditions than those we have investigated so far. Phenomena to be addressed here include neutron halo structures, super-heavy elements, new magic numbers, hyperdeformation and many other exotic forms of atomic nuclei.

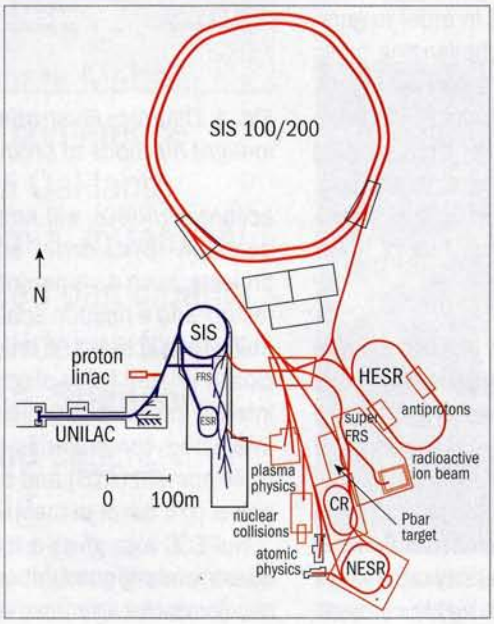
In the past 20 years nuclear astrophysics has developed into an

hysics research in Europe

ge plan looks forward to an exciting future with new facilities and challenging research.

The International Accelerator Facility for Beams of Ions and Antiprotons (IAFBIA)

The proposed IAFBIA facility at GSI Darmstadt will be based on the existing infrastructure (coloured blue on the schematic, right) of the linear accelerator, UNILAC; the heavy-ion synchrotron, SIS; the Fragment Separator, FRS; and the Experimental Storage Ring, ESR. The new accelerator facilities (coloured red) will consist of the superconducting synchrotrons, SIS100/200; the Collector Ring, CR; the New Experimental Storage Ring, NESR; the Superconducting Fragment Separator, Super-FRS; the Proton Linac; and the High-Energy Storage Ring, HESR. The site also houses buildings with target areas for plasma physics, ultra-relativistic nucleus–nucleus collisions, radioactive ion beams and atomic-physics experiments.



Primary beams
10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$.
Factor 100–1000 over present in intensity.
2(4) × 10^{13}/s 30 GeV protons.
10^{10}/s $^{238}U^{73+}$ up to 25 (35) GeV/u.
Secondary beams
Broad range of radioactive beams up to 1.5–2 GeV/u; up to factor 10 000 in intensity over present.
Antiprotons 3–30 GeV.
Storage and cooler rings
Radioactive beams.
e–A collider.
10^{11} stored and cooled antiprotons (0.8–14.5 GeV).
Key technical features
Cooled beams.
Rapidly cycling superconducting magnets.

important subfield of nuclear physics. It is a truly interdisciplinary field, concentrating on primordial and stellar nucleosynthesis, stellar evolution, and the interpretation of cataclysmic stellar events such as novae and supernovae. It combines astronomical observation and astrophysical modelling with research into meteoritic anomalies, and with measurements and theory in nuclear physics. With the use of new methods, as well as the availability of radioactive-ion-beam (RIB) accelerators, astrophysically relevant nuclear reactions are already being measured. In future, this research will be intensified with the new generation of RIB facilities.

In the past, research on symmetries and fundamental interactions (and the physics beyond the Standard Model) has made large steps with the development of techniques that facilitate precision measurements. In this subfield, research on the properties of neutrinos (mass measurement), time-reversal and charge–parity violation (through measurements of electric-dipole moments of molecules, atoms and nucleons as well as correlations between electrons and neutrinos in β-decay), and the determination of fundamental constants, is in progress.

Finally, there has been progress in the applications of nuclear-physics techniques and methods. These cross over into several disciplines, such as life sciences, medical technology, environmental studies, archaeology, future energy supplies, art, solid-state and atomic physics, and civilian safety.

Research facilities

Several new research facilities are now being developed or built. The most ambitious is the International Accelerator Facility for Beams of Ions and Antiprotons (IAFBIA) in Darmstadt (currently GSI) (see box above). This will be available for experiments after 2010. For nuclear structure and related studies with extreme N/Z ratios, RIB facilities are required and can be realized by means of the in-flight fragmentation (IFF) technique, as aimed at with the IAFBIA, or the isotope-separation online (ISOL) method (see figure 1, p24). In Europe, a plan to build the European ISOL (EURISOL) facility, which would be ready after 2013, exists, and intermediate to this are the ISOL facilities already operational at CERN, GANIL and Louvain-la-Neuve, and the upgrades at REX-ISOLDE and SPIRAL2, as well as the future facilities SPES in Legnaro and MAFF in Munich.

Recommendations

The first of NuPECC's recommendations is to exploit fully the existing and competitive lepton, proton, stable isotope and radioactive ion-beam facilities and instrumentation. In addition to their physics-research potential, they will serve as important training sites and facilities where major beam-production development and detector R&D can be performed in the next 5 to 10 years. In its previous long-range plan, NuPECC gave high priority to the ALICE experiment at CERN, which has an extensive programme to investigate QGP in ▷

the framework of the large and active heavy-ion programme at the Large Hadron Collider (LHC) in the near future. A huge European effort is already underway to build the ALICE detector in time for the LHC. In accordance with the high priority given to ALICE in the previous long-range plan, NuPECC strongly recommends its timely completion to allow early and full exploitation at the start of the LHC.

Support of the university-based nuclear-physics groups, including their local infrastructure, is seen by NuPECC as essential for the success of the programmes at the present facilities and at future large-scale projects. Furthermore, NuPECC recommends that efforts should be taken to strengthen local theory groups in order to guarantee the development needed to address the challenging basic issues that exist or may arise from new experimental observations. NuPECC also recognizes the positive role played by the ECT* centre in Trento in nuclear theory, especially in its mission of strengthening unifying contacts between nuclear and hadron physics. In addition, NuPECC recommends that efforts to increase literacy in nuclear science among the general public be intensified.

Priorities for the future

The specific recommendations and priorities follow on from the new experimental facilities and advanced instrumentation that have been proposed, or are under construction, to address the challenging basic questions posed by nuclear science. NuPECC supports, as the highest priority for a new construction project, the building of the IAFBIA. This international facility (see IAFBIA box, p23) will provide new opportunities for research in the different subfields of nuclear science. Envisaged for producing high-intensity radioactive ion beams using the IFF technique, the facility is highly competitive, even surpassing in certain respects similar facilities that are either planned or under construction in the US or in Japan. With the experimental equipment available at low and high energies, and at the New Experimental Storage Ring with its internal targets and electron collider ring, the facility will be a world leader in research in nuclear structure and nuclear astrophysics, in particular for research performed with short-lived exotic nuclei far from the valley of stability. The high-energy, high-intensity stable heavy-ion beams will facilitate the exploration of compressed baryonic matter with new penetrating probes. The high-quality cooled antiproton beams in the High-Energy Storage Ring, in conjunction with the planned detector system, PANDA, will provide the opportunity to search for the new hadron states that are predicted by QCD, and to explore the interactions of the charmed hadrons in the nuclear medium. In short, this facility is broadly supported since it will provide almost all fields of nuclear science with new research opportunities.

After the construction of IAFBIA, NuPECC recommends the highest priority to be the construction of the advanced ISOL facility, EURISOL. The ISOL technique for producing radioactive beams has clear complementary aspects to the IFF method. First-generation ISOL-based facilities have produced their first results and have been shown to work convincingly. The next-generation ISOL-based RIB facility EURISOL aims at increasing, beyond 2013, the variety of radioactive beams and their intensities by orders of magnitude over what is available at present for various scientific disciplines, including nuclear physics, nuclear astrophysics and fundamental interactions. EURISOL will employ a high-power (several MW) proton/deuteron (p/d) driver accelerator. A large number of possible projects, such as a neutrino factory, an antiproton facility, a muon factory and a neutron spallation source, may benefit from the availability of such a p/d driver, and synergies with closely and less closely related fields of science are abundant. Considering the wide interest in such an accelerator, NuPECC proposes joining with other interested communities to do the Research and Technological Development (RTD) and design work necessary to realize the high-power p/d driver in the near future.

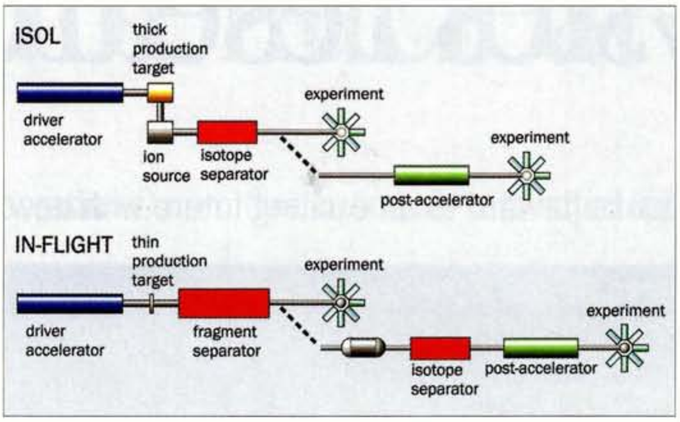


Fig. 1. Diagram illustrating the difference between the ISOL and in-flight methods to produce radioactive ion beams.

NuPECC also gives a high priority to the installation at the Gran Sasso underground laboratory of a compact, high-current 5 MV accelerator for light ions, equipped with a high-efficiency 4π array of germanium detectors. Such a facility will enhance the uniqueness of the present facility at Gran Sasso, and its potential to measure astrophysically important reactions down to relevant stellar energies.

On a longer timescale, the full exploration of non-perturbative QCD, e.g. unravelling hadron structure and performing precision tests of various QCD predictions, will require a high-intensity, high-energy lepton-scattering facility. NuPECC considers physics with a high-luminosity multi-GeV lepton-scattering facility to be very interesting and of high scientific potential. However, the construction of such a facility would require worldwide collaboration, so NuPECC recommends that the community pursues this research from an international perspective, incorporating it into any existing or planned large-scale facilities.

To exploit the current and future facilities fully and most efficiently, advanced instrumentation and detection equipment will be required to carry on the various programmes. The AGATA project for the construction of a 4π array of highly segmented germanium detectors for γ-ray tracking will benefit research programmes in the subfields of nuclear science at the various facilities in Europe. NuPECC gives its full support to the construction of AGATA, and recommends that the R&D phase be pursued with vigour.

- For more information about NuPECC, see www.nupecc.org.

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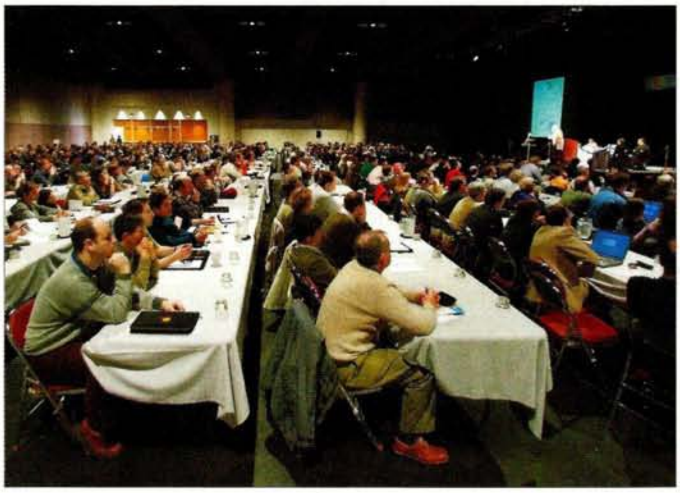
Quark Matter brings heavy ions to Oakland

The Quark Matter 2004 conference, held in Oakland, California, in January, provided participants with evidence for the elusive quark–gluon plasma. **Spencer Klein** and **Joakim Nystrand** describe the highlights of the meeting.



The 700 participants at Quark Matter 2004 fit comfortably into the cavernous exhibit hall of the Oakland Convention Center.

Held every 18 months, Quark Matter is the major conference covering relativistic heavy-ion collisions. The latest in the series – Quark Matter 2004 – took place on 10–17 January at the Oakland Convention Center in California and was co-chaired by Hans Georg Ritter and Xin-Nian Wang from Lawrence Berkeley National Laboratory (LBNL). The meeting featured a flood of new data from the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, along with continuing analyses from experiments at CERN's Super Proton Synchrotron (SPS) and reports from the HERA-B and HERMES experiments at DESY.

The conference – which was preceded by two well-attended and well-received workshops, one for graduate students and the other for local high-school teachers – was officially opened by Jerry Brown, Oakland's mayor and ex-governor of California. Reinhard Stock of IFK Frankfurt opened the scientific programme with a historical overview of heavy-ion collisions, which was followed by theoretical and experimental introductions by Urs Wiedemann of CERN and Tom Hemmick of SUNY, Stony Brook, respectively. So began five days of parallel and plenary sessions, and while everything cannot be described here in detail, the following aims to provide a flavour.

The biggest question at recent Quark Matter conferences has been: have we found the quark–gluon plasma? Although the collaborations working at RHIC have made no definitive statements, the sense among the participants this year was that for the first time the answer is "yes". A broad range of measurements painted a picture that most attendees found convincing: strong suppression of high transverse momentum (p_T) particles, the absence of back-to-back jets, anisotropies consistent with strong, hydrodynamic flow, and many other observations. The data show that a dense medium is produced in the collisions and that particles interact strongly and lose energy as they traverse it. The observed energy loss requires a very dense medium, which seems incompatible with the presence of hadrons. The observed anisotropies (in flow) for different particle species indicate that the medium behaves like an almost perfect fluid, as expected from a quark–gluon plasma (QGP). A comparison of the anisotropies of different species suggests that equilibration is rapid and thus likely occurs during the partonic stage.

Many of these effects were already seen at the Quark Matter 2002 conference, held in Nantes, France (*CERN Courier* October 2002 p11). Since then RHIC has taken and analysed data on deuterium–gold (dAu) collisions, providing a key control. In dAu collisions the number of nucleon–nucleon collisions is small and the energy density is expected to be too low to form a QGP. The putative QGP signatures were absent in the dAu data, showing that the phenomena are final-state effects. These effects were also absent (in the case of high-p_T particle suppression) or greatly reduced (for flow) in lower energy collisions.

Hard probes of ion collisions

Perhaps the most striking result to come out of RHIC so far is the strong suppression of mesons with high p_T observed in central nucleus–nucleus collisions (i.e. collisions where the nuclei fully overlap). The production of hadrons with p_T above approximately ▷

2–3 GeV/c in proton–proton collisions is well described by perturbative quantum chromodynamics (QCD). If heavy-ion collisions were mere superpositions of individual nucleon–nucleon collisions, the particle yield at high p_T would scale with the number of binary collisions. David d'Enterria of Columbia reviewed RHIC data showing that particle production is suppressed by about a factor of five relative to a nucleon–nucleon superposition. This suppression is not seen in dAu or lower energy ion–ion collisions. Carsten Greiner of Frankfurt discussed hadronic final-state interactions and concluded that hadronic interactions alone could not explain the data.

Julia Velkovska of Vanderbilt reviewed measurements of high-p_T particle suppression for different particle species. Above 6 GeV/c all particle species show comparable suppression. However, at intermediate momenta ($2 < p_T < 5$ GeV/c) only mesons are suppressed. In hydrodynamic models bulk radial expansion equalizes velocities, boosting the number of heavy particles at intermediate p_T. In this model the ϕ meson and the proton would therefore have the same suppression. Rainer Fries of Minnesota presented an alternate scenario, where the baryons are produced by recombination of already existing quarks. This recombination may explain the intermediate-p_T data.

With the dAu data ruling out initial-state effects, the study of high-p_T particles in nucleus–nucleus collisions has largely evolved into "jet tomography", where the jets probe the matter produced in the collisions. The experimental and theoretical aspects of this technology were reviewed by Mike Miller of Yale and Ivan Vitev of Iowa State, respectively. In proton–proton collisions jets are usually created back-to-back; this back-to-back topology is observable as correlations between high-p_T particles. In gold–gold collisions the correlations disappear, perhaps because one of the produced jets is absorbed in the medium. Transverse-momentum conservation requires that the energy in the quenched jet does not disappear but is redistributed. This redistributed energy may have been seen in low-momentum particles.

Both the STAR and PHENIX collaborations at RHIC have studied the quenching of the away-side jet relative to the reaction plane – the plane spanned by the beam axis and the impact parameter (see figure 1). This study used data from glancing collisions, where some back-to-back correlations remained. As expected, if the suppression is caused by energy loss in the dense nuclear medium, the quenching is strongest when the jet is perpendicular to the reaction plane (long path through medium) and weaker when the jet is in the reaction plane (short path through medium). The results from STAR are shown in figure 2.

The dense matter produced in the collisions can also be studied through direct photons, which are emitted as the system cools. There is, however, a huge background from photons produced in hadronic decays, particularly from π^0 and η mesons. This background must be carefully measured and subtracted. Justin Frantz of Columbia presented results from PHENIX on direct photons (see figure 3). For $p_T > 5$ GeV/c the yield agrees with a calculation based on perturbative QCD, another strong indication that high-p_T parton production is well understood, and that the suppression of high-p_T hadrons is indeed due to interactions in the dense matter. Direct photons at intermediate p_T may also be emitted from the QGP, as was discussed by Guy Moore of McGill, but current results are not precise enough to probe this region.

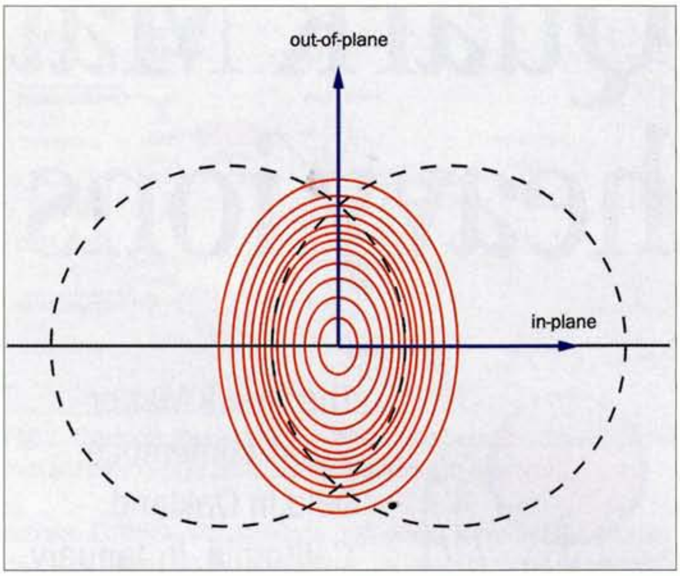


Fig. 1. In a non-central heavy-ion collision, as shown here, the collision region (the overlap between the two nuclei) is elliptical. High pressures can convert this spatial anisotropy into a momentum anisotropy, which leads to non-isotropic particle emission. The blue arrows refer to the reaction plane.

Suppression of J/Ψ production was one of the first proposed signals for the QGP, and has long been studied at CERN's SPS. Goncalo Borges of LIP, Lisbon, presented the latest results from NA50. Again proton–ion or deuteron–ion data are important references to measure both the hadronic absorption in ordinary nuclear matter and the effects of modifications to the gluon distribution function in heavy nuclei (shadowing). The PHENIX collaboration presented data on J/Ψ production in dAu collisions at RHIC, supporting moderate gluon shadowing and little hadronic absorption. An Tai of the University of California, Los Angeles, presented the first measurements of fully reconstructed open charm at RHIC made by the STAR collaboration, and Melynda Brooks of Los Alamos National Laboratory also reviewed charm measurements at RHIC and the SPS.

Soft particle production

Most of the particles observed in a detector are produced very late in the collision, at a time known as "freezeout". Federico Antinori of INFN Padova showed that the particle abundances are generally well described by a thermal model, with no strangeness enhancement or suppression. The particle ratios depend only on the particle mass and temperature. The enhanced strangeness production compared with proton–proton collisions could be due to the difference between global strangeness conservation in a large system (i.e. a grand canonical distribution) and local conservation in a small system (the canonical distribution). Global conservation allows single strange-quark production (with strangeness conservation imposed on the final state), while in a small system strange quarks are produced in pairs. The properties of the final state were discussed by Gunther Roland of MIT and Andrzej Rybicki of Krakow.

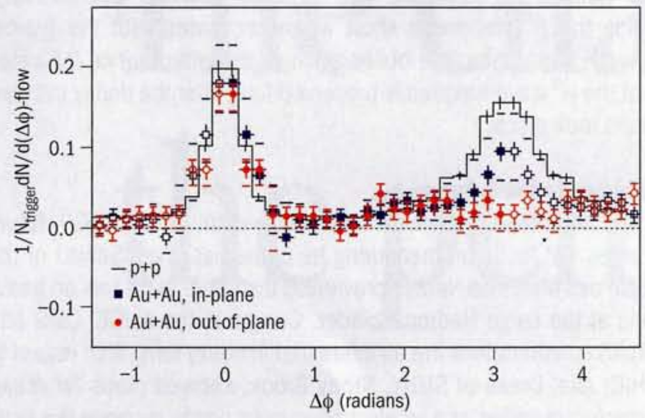


Fig. 2. Results from STAR on high-p_T charged-particle angular correlations, showing the angular separation between a high-p_T trigger particle and a lower p_T probe. The solid line is from proton–proton collisions, showing near-side (same jet, $\Delta\phi$ ~0) and away-side (back-to-back jets, $\Delta\phi$ ~π). The squares represent the correlations in gold–gold collisions, where the trigger particles are aligned in-plane (see figure 1), and the diamonds represent particles aligned out-of-plane. Greater dissipation is observed out-of-plane, where the path length is longer.

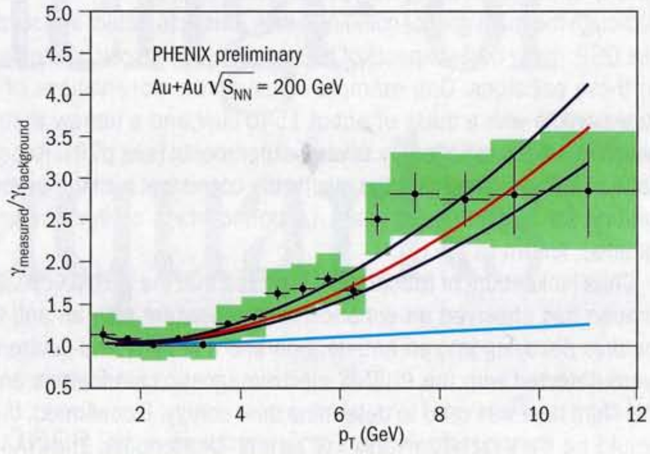


Fig. 3. Measurement by PHENIX of the ratio of photons detected to those expected from meson decays in the most central gold–gold collisions at RHIC. If all observed photons came from decays of hadrons, then the ratio would be 1. The direct photon yield agrees with perturbative QCD calculations, shown by the red curve; the purple curves show the theoretical uncertainties. The blue curve is the expectation assuming that there is no suppression of high-p_T mesons.

The spectra of the short-lived resonances (K*, ρ, f_0(975), Δ, Σ*(1385), and Λ(1520)) were presented by Patricia Fachini of Brookhaven. Some short-lived resonances may be less abundant than the thermal-model predictions. This could happen when daughter particles rescatter during the period between chemical freezeout, when particle production stops, and thermal freezeout, when elastic scattering stops. The PHENIX collaboration has compared the hadronic (K^+K^-) and leptonic (e^+e^-) decays of the ϕ-meson and sees no evidence for a shift in mass or branching ratio.

One striking phenomenon observed at RHIC is non-isotropic flow. The overlap between two colliding ions forms an elliptical region (see figure 1). Tetsufumi Hirano of the Riken BNL Research Center explained how high pressure turns this spatial anisotropy into an anisotropy in momentum space. Some years ago it was expected that this flow would be negligible at high energies; it is in fact stronger at RHIC than at lower energies. Fabrice Retiere of LBNL compared data from all four RHIC experiments, showing that the observed flow of different particle species is consistent with thermodynamic models that treat the system like an almost perfect fluid. The Λ and kaon flow are particularly interesting: the Λ flow is the same as the kaon flow at two-thirds of the momentum; an observation clearly pointing to interactions involving partons. Much time was spent discussing how to reconcile these macroscopic approaches with microscopic pictures based on hadronic or partonic shower simulations.

The size of the interacting system can be measured by studying correlations among identical particles. The enhanced production of bosons with similar momenta can be used to measure the source size via Hanbury-Brown Twiss (HBT) interferometry. Dan Magestro of Ohio State noted that HBT studies are perhaps the least-understood measurement made at RHIC. The experiments at RHIC have found that the system is small, with a Gaussian radius of around 6 fm and a lifetime of 8–10 fm/c. This small size and short lifetime is difficult to reconcile with the observed collective flow. Measurements by the STAR collaboration of HBT parameters with respect to the reaction plane show that the initial eccentricity of the reaction volume survives to the final-state HBT measurements.

Jeff Mitchell of BNL reviewed studies of the event-to-event variations of a variety of observables. Most of the fluctuations can be understood as normal statistical variations, but non-statistical fluctuations have also been confirmed, e.g. in mean p_T. These may be due to jet production.

Do gluons condense?

A secondary theme at the conference was the study of parton distributions at low-x (fractional parton momentum) and a postulated new state of matter, the "coloured glass condensate" or CGC. Jamal Jalilian-Marian from the University of Washington explained that the condensate may form at very high gluon densities, i.e. at low-x, especially in heavy nuclei. When gluons saturate the available transverse phase space, they recombine and their density is reduced. These gluon fields might be describable classically. Measurements at HERA of low-x gluon densities and the surprisingly low multiplicities seen at RHIC were previously cited as evidence for the CGC. The BRAHMS collaboration presented two pieces of evidence regarding the CGC. Their charged-particle rapidity distribution for dAu collisions does not match the CGC predictions. Ramiro Debbe of Brookhaven showed that forward production of high-p_T particles in dAu collisions is suppressed, as expected for a CGC. However, despite strong advocacy by proponents of the CGC, many at the conference felt that more quantitative studies are needed before alternative explanations can be ruled out. ▷

And now for something completely different

Although the main goal of colliding heavy ions is to detect and study the QGP, many other aspects of high-energy physics can be studied in these collisions. One example concerns the observations of a new particle with a mass of about 1540 MeV and a narrow width, which has been reported by several experiments (see p29). Robert Jaffe of MIT explained that the results are consistent with the expectations for a pentaquark state (a bound state of five valence quarks), known as the Θ^+.

Chris Pinkenburg of Brookhaven reported that the PHENIX collaboration has observed an enhancement consistent with an anti-Θ particle decaying into an anti-neutron and a K^-. The anti-neutrons were detected with the PHENIX electromagnetic calorimeters and the flight time was used to determine their energy. If confirmed, this would be the first observation of an anti-pentaquark. The NA49 experiment at CERN's SPS has found a signal for the doubly strange Ξ^{--} pentaquark in the decay $\Xi^{--} \rightarrow \Xi^- + \pi^-$. However, the HERA-B experiment at DESY has searched for the Θ^+ particle in proton–nucleus collisions, but found no signal.

In addition to studying the hadronic reactions, the STAR collaboration has also investigated the photoproduction of ρ^0 mesons in gold–gold collisions at RHIC. In contrast to the electron–nucleus reactions, the photoproduction in a heavy-ion reaction can occur at either of the two beam nuclei. For very small transverse momenta the amplitudes from the two sources interfere destructively. Since the ρ^0 lifetime is short when compared with the typical ion–ion separation, the observation of this interference indicates that the ρ^0 wave function is preserved long after the decay into two pions took place.

Looking to the future

With fairly broad agreement that we have finally seen QGP, future studies will focus on measuring its properties. Yves Schutz of the École des Mines de Nantes previewed the future in his talk on heavy ions at the Large Hadron Collider. Groups in the ALICE, CMS and ATLAS collaborations are all interested in heavy ions. With regard to RHIC, Axel Drees of SUNY, Stony Brook, showed plans for major detector upgrades and an electron cooling ring to increase the luminosity by a factor of 40. Around 2015–2020 RHIC could add an electron ring to study electron–ion collisions. In the nearer future, however, we can look forward to Quark Matter 2005, which will be held on 1–6 August 2005, in Budapest, Hungary.

Further reading

The talks presented at Quark Matter 2004 are available on the conference website at http://qm2004.lbl.gov.

Spencer Klein, *LBNL, and* **Joakim Nystrand**, *University of Bergen.*

The challenge of the pentaquarks

Volker Burkert reports on Pentaquark 2003, the first topical workshop on exotic baryons, which was held at Jefferson Lab in November.

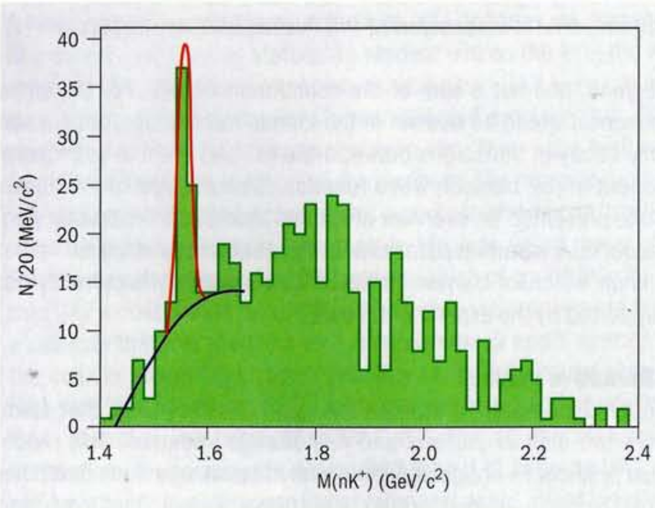


Fig. 1. The missing mass spectrum for the $\Theta^+(1540)$, as observed by the CLAS experiment at Jefferson Lab.

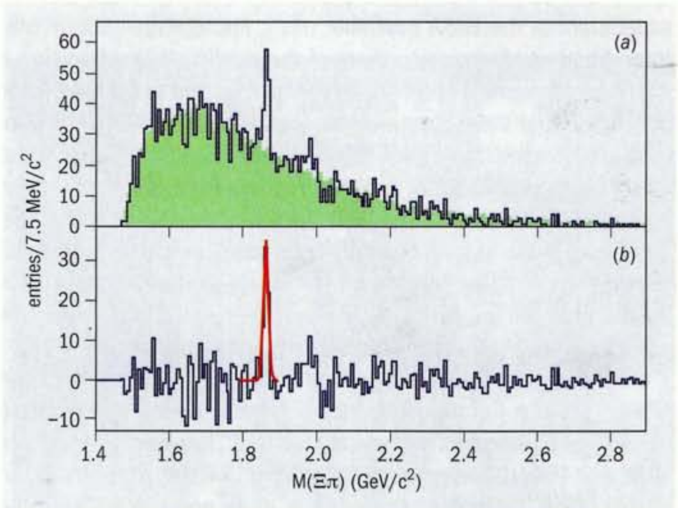


Fig. 2. The mass spectrum for the Ξ^{--}, as observed by NA49 at CERN. [(b) has combinatorial background subtracted.]

Pentaquarks – baryons made from five quarks – have been postulated and searched for in hadronic processes for decades. They are allowed by quantum chromodynamics (QCD), the theory of quarks and gluons, but until recently all searches for pentaquark states had been inconclusive. The breakthrough came in 1997 in a paper by three Russian physicists, Dmitri Diakonov, Victor Petrov and Maxim Polyakov. Within a chiral soliton model, they predicted an anti-decuplet of 10 ground-state pentaquarks, three of which had exotic-flavour quantum numbers, meaning that their quantum numbers cannot be constructed from only three quarks. One of the states was predicted to be long-lived, and with a mass near 1530 MeV. It took another five years before a state close to this mass was reported from several experiments (*CERN Courier* September 2003 p5). This state, initially known as the Z^+, is now called the $\Theta^+(1540)$.

The discovery took the community by surprise. However, within only four months of the broad public announcement in July 2003, more than 60 theoretical papers appeared on the subject. It was therefore timely for the Department of Energy's Thomas Jefferson Laboratory (JLab) to organize the first topical workshop on the subject. While around 30 to 35 physicists were originally expected to attend, almost 120 experimentalists and theorists from all over the world participated in the two-day workshop, which was organized into plenary and focus sessions. The latest results were presented by representatives from a number of experimental groups: GRAAL in France; COSY, ELSA and HERMES in Germany; SPring-8 in Japan; ITEP in Russia; JLab and RHIC in the US, and CERN.

Experimental evidence

Takashi Nakano from Osaka discussed the original finding of the Θ^+ in the photoproduction of K^+K^- pairs off a plastic scintillation counter that happened to be installed in the beamline as a veto counter. He also presented very preliminary new data using a linearly polarized photon beam and a deuterium target. Representing the CLAS experiment, Valery Kubarovsky presented new experimental evidence for the Θ^+ from JLab. The CLAS collaboration observed a signal with a significance of about 7.8 σ for the ▷

production on proton targets, the highest significance for this state to date (see figure 1). These data also show some evidence for production of the Θ^+ through an intermediate excited nucleon, N*, with a mass near 2400 MeV. Such a state is also likely to be a pentaquark baryon, though with non-exotic quantum numbers. If this result is confirmed, it will be the first hint of a connection between the Θ^+ and the spectroscopy of non-exotic baryon states.

New evidence has also come from the mining of old data. The re-analysis of neutrino bubble-chamber data presented by Mikhail Kubantsev of Fermilab shows a clear signal at the Θ^+ mass in pK^0_s, as does the HERMES experiment at DESY, which studied the same channel, as reported by Wolfgang Lorenzon. While this channel measures the absolute strangeness quantum number $|S| = 1$, it does not determine the sign. Although the exotic nature of the signal is not uniquely identified in this reaction, the absence of known Σ states that could mimic a pentaquark in this mass range is used to identify the state indirectly as the Θ^+.

Michael Ostrick from Bonn presented data from the SAPHIR experiment at the ELSA machine, using photoproduction on protons. This included a re-analysis of the published results using a different technique to identify the K^0_s, which is used to tag the Θ^+. He concluded that there is no obvious discrepancy between the published results and the re-analysed data. Carlo Schaerf of INFN Roma reported on searches for the Θ^+ at the GRAAL detector at the European Synchrotron Radiation Facility using a photon beam on a deuterium target and a non-magnetic detector with a large BGO (bismuth gemanate) calorimeter. Although the reported statistics are currently too low to conclude much, the search in the exclusive channel with a $\Lambda\Theta^+$ in the final state looks promising.

Other searches are also underway at the COSY synchrotron at the Jülich Research Centre using proton–proton scattering, where the Θ^+ may be produced in association with a Σ^+ hyperon, and with the STAR and PHENIX detectors at Brookhaven's Relativistic Heavy Ion Collider (RHIC). For central gold–gold collisions at the RHIC, one expects about one Θ^+ per collision accompanied by thousands of other particles.

Cascade particles

The Θ^+ is not the only pentaquark state that the models predict. In the chiral soliton model the Θ^+ is an isosinglet member of an anti-decuplet of 10 states that, in a quark picture, are made of four quarks and one antiquark. The model predicts nine other pentaquark states, two of which have exotic-flavour quantum numbers. These are the cascade particles, Ξ^{--} and Ξ^+. Indeed the Ξ^{--} may have been observed at CERN in the NA49 experiment. Representing NA49, Kreso Kadija reported evidence for a narrow cascade Ξ^{--} at a mass of 1862 MeV and with a width of less that 18 MeV (figure 2). Such a state must have exotic-flavour quantum numbers requiring at least five quarks (*CERN Courier* December 2003 p5). These data lend support to the symmetry properties of pentaquark states as predicted in the chiral soliton model, or in the quark-cluster picture.

Representatives of all theoretical persuasions were present at the workshop. Dmitri Diakonov of NORDITA in Copenhagen presented reasons why the Θ^+ might be so light. In the chiral soliton model, it is a collective excitation of the mean chiral field that binds the

From left to right: Dmitri Diakonov, Harry Lipkin and Robert Jaffe in discussion at the Pentaquark workshop.

baryons, and not a sum of the constituent quarks. For the same reasons it would be narrow. In the infinite momentum frame it can only decay in transitions between the Θ^+ and the five-quark component of the nucleon wave function. Simon Capstick of Florida State presented an overview of various theoretical models for pentaquarks. A natural explanation for the narrowness of the Θ^+ is that it is an isotensor baryon. However, this possibility is currently not supported by the experimental data.

Alternative models

Robert Jaffe of MIT presented the quark cluster model that starts from two diquark clusters and one strange antiquark. This model also predicts an antidecuplet but with mass assignments that differ from the one predicted by the chiral soliton models. One unresolved problem is that this model needs a narrow nucleon-like five-quark state, which is identified with the Roper resonance at 1440 MeV. However, this state has a width of more than 300 MeV. Marek Karliner of Cambridge University discussed an alternative quark cluster model, developed with Harry Lipkin of the Weizmann Institute, where the five-quark states are composed of triquark–diquark clusters. They predict that narrow five-quark states analogous to the Θ^+ should also occur in the charm and bottom sector.

Michal Praszalowicz of Brookhaven discussed pentaquarks in the SU(3) Skyrme and chiral quark soliton models. The first lattice QCD results presented by Kei-Fei Liu of Kentucky University and Tamas Kovacs of Wuppertal do not present a consistent picture. Two groups (Kovacs and Shoichi Sasaki) measured a pentaquark signal consistent in mass with the experimental observation, while a third group (Liu) saw no resonant signal. The groups with a positive result predict the parity of the $\Theta^+(1540)$ to be negative, while both the chiral soliton and quark cluster models require positive parity.

Discussions in the focus sessions addressed questions of how to obtain more information on properties such as spin/parity and the natural widths of the $\Theta^+(1540)$, as well as new experiments that can identify other predicted pentaquark states. Expected new data

Old 'new particles' – a new kind of hyperon?

Two high-statistics bubble-chamber experiments using negative kaon beams have seen a new hyperon at 3.17 GeV with a width of not more than 20 MeV.

The first evidence came from a Birmingham–CERN–Glasgow–Michigan State–Paris collaboration, which studied the interaction of 8.25 GeV negative kaons with hydrogen in the CERN 2 m bubble chamber. The result was confirmed by a Cambridge–Michigan State collaboration that used 6.5 GeV negative kaons in the Argonne 12 foot hydrogen bubble chamber.

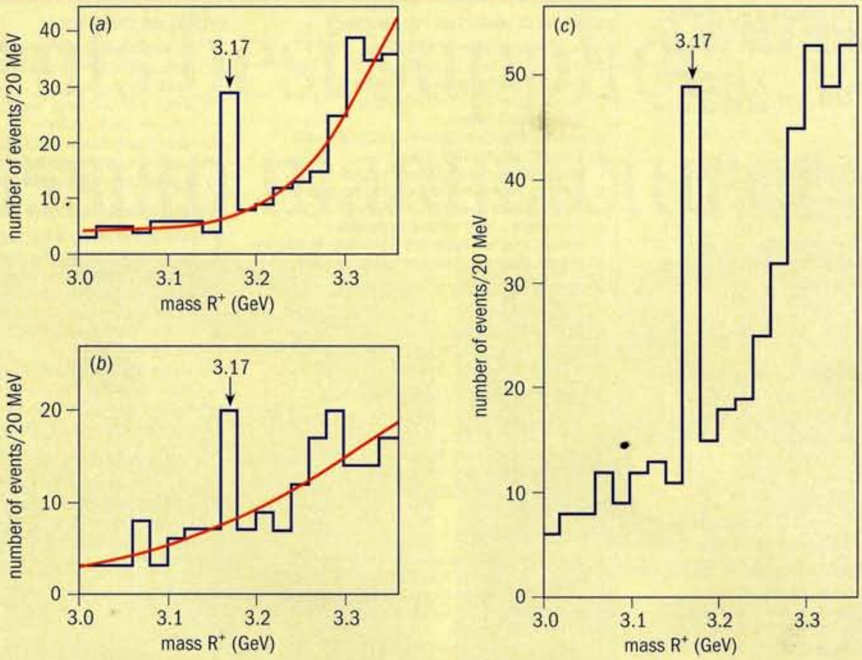
Both experiments looked for reactions where the kaon hits a proton, producing a pion and a hyperon that then decays into many particles, of which more than one carries strangeness.

A sharp signal was seen in the five-body and six-body decays at a mass of 3.17 GeV, while no corresponding effect was seen with just one strange particle in the final state. The new heavy particle also appears to come out forwards, which to the initiated suggests that baryon exchange is responsible.

The dominance of final states containing many strange particles, together with the exceptionally narrow width of the signal, suggests that the new hyperon could have an unusually complex internal structure.

Recently, theoreticians have predicted the existence of "exotic" baryons containing a quark–antiquark pair in addition to the usual complement of three quarks, and which would not behave like normal baryons. The new hyperon could be one of these exotic states.

• Reprinted from *CERN Courier* January/February 1980.



Observations of a new heavy hyperon in negative kaon interactions in (a) the CERN 2 m bubble chamber and (b) the Argonne 12 foot bubble chamber. The smooth curve in (a) and (b) shows the estimated background, and (c) shows the effect of combining the two sets of data from the different experiments. This narrow state, which decays into many strange particles, could be an "exotic" baryon containing more than three quarks. [R^+ is the system recoiling against a π^- in the reaction $K^-p \rightarrow \pi^-R^+$.]

Further reading

The data in this article were published in: J Amirzadeh *et al.* 1979 *Physics Letters* **89B** 125. Further data were collected in both experiments and presented at the Baryon 1980 conference, see J Amirzadeh *et al.* 1980 *Proc. IV Int. Conf. on Baryon Resonances*, Toronto, Canada.

from JLab should have sufficient statistics to measure full angular distributions and determine the spin. Identification of the parity, meanwhile, may require measurements using linearly polarized photon beams or experiments with hadron beams.

The mass of the $\Theta^+(1540)$ is not as well established as one might expect from a narrow state, and ranges from 1528 to 1555 MeV, which is outside the uncertainties given by the experiments. It was emphasized that this issue should be addressed urgently as it has impact on mass predictions for other five-quark states.

The question: "why have pentaquark states not been seen before?" was asked frequently and some answers were given. For example, data on K^+n phase shifts are quite poor in the corresponding mass range and have obvious holes. At the end of the workshop one piece of early evidence was shown from data on K^+p scattering from the 2 m bubble chamber at CERN. The data show a small but significant peak at a pK^0 mass of 1540 MeV, however only at the highest K^+ beam momentum.

In the final session Kim Maltman of York University, Toronto, put the experimental evidence and theoretical approaches into their proper perspectives and discussed the relative merits of the different theoretical concepts. A second workshop on pentaquarks is planned for July 2004, and will be held at SPring-8 in Japan. A Program Advisory Meeting held at JLab from 12–16 January 2004 also accepted four additional pentaquark experiments, which will continue to add to the collective knowledge about this baryon system.

• For the full programme, including all the talks, see: www.jlab.org/intralab/calendar/archive03/pentaquark/program.html.

Volker Burkert *is Hall B leader (CEBAF Large Acceptance Spectrometer) at Jefferson Lab.*

AWARDS

ATLAS presents best supplier award to Russian manufacturer

ATLAS spokesperson Peter Jenni (right) presents the award for best ATLAS supplier to Anatoly Kryuchkov, the deputy general director and technical director of Molniya.

ISTC proposal group leader Elena Ryabeva holds the award presented to the ISTC for their contribution to the Molniya project.

The Russian machine-building plant Molniya has been awarded a best ATLAS supplier prize for excellence in the construction of 29 modules for the ATLAS liquid argon Hadronic End-Cap Calorimeter (HEC). To manufacture the unique copper plates and module structures required, the company set up a dedicated production process and developed stringent quality-control criteria. Molniya completed the task on time, within budget and the completed modules surpassed required quality standards. Of the 29 modules, 13 are series modules that have already been integrated into the four wheels of the detector; the remaining 16 are calibration modules designed for the ATLAS beam tests.

The project, which ran from 1998–2004, was executed within a collaboration of the International Science and Technology Centre (ISTC), involving CERN, MPI Munich and IHEP Protvino, together with Molniya, and was led by Serguei Denisov from IHEP Protvino. In presenting the award to Anatoly Kryuchkov, deputy general director and technical director of Molniya, Peter Jenni, the ATLAS spokesperson, emphasized the value of high-quality components to the HEC, as it will play a central role in the physics of the LHC. He went on to acknowledge the contribution made by the ISTC to the project by presenting a second award to the ISTC proposal group leader Elena Ryabeva.

CERN SPSC

Special meeting to consider future fixed-target plans

A special meeting of CERN's SPS and PS Experiments Committee, the SPSC, will be held in Villars, Switzerland, from 22–28 September 2004. The purpose of this special meeting is to review both the present and future activities and opportunities in fixed-target physics, and to consider the possibilities and options for a future fixed-target programme at CERN.

The chairman of the SPSC would like the groups that are currently working on fixed-target experiments at CERN, and those who have the submission of proposals for such experiments in mind, to forward to the SPSC secretariat a short report indicating their ideas and plans for the future. These submissions will only be for the purpose stated here; they will in no way be considered as binding with respect to the subsequent preparation and submission of letters of intent and proposals to the SPSC.

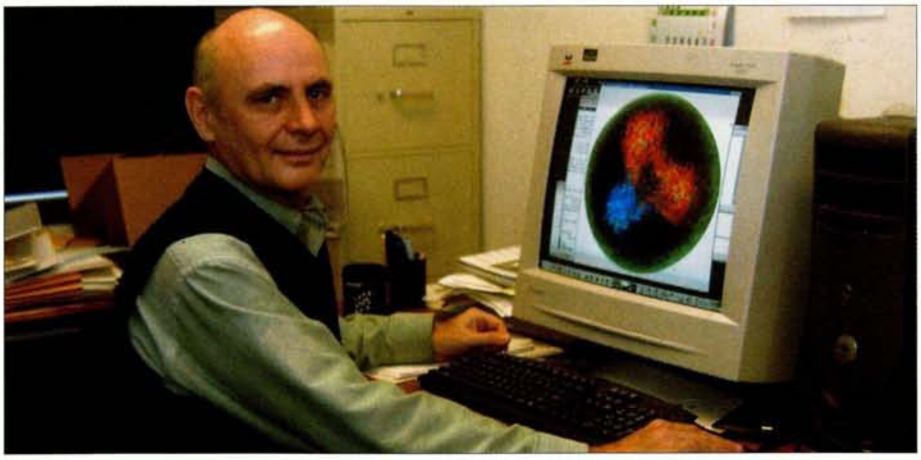
Further details concerning the meeting and the important dates leading up to it will be available soon on the SPSC website at: http://committees.web.cern.ch/Committees/SPSC/WelcomeSPSC.html.

The Budker Institute of Nuclear Physics (BINP) in Novosibirsk, Russia, recently played host to a visit from CERN's director-general, **Robert Aymar**. The purpose of the visit was to introduce the new director-general to the institute and to allow him to see the substantial contribution to the Large Hadron Collider that BINP is making in the framework of the CERN/Russia agreement. Aymar is seen here, on the left of the picture, together with **Alexander Skrinsky** (centre), the director of BINP, and **Lyn Evans**, the LHC project leader.

HONOURS

Virginia honours parton theorist Radyushkin

Anatoly Radyushkin, of the Department of Energy's Thomas Jefferson National Accelerator Facility and Old Dominion University, has been named as one of three Outstanding Virginia Scientists for 2004. Radyushkin, who received his PhD from Moscow State University in 1978, is also a permanent staff member of the Laboratory of Theoretical Physics in Dubna, Russia. He is a pioneer in developing generalized parton distributions, and in 1991 came to Virginia, where experiments measuring generalized parton distributions form an essential part of the long-term physics programme at Jefferson Laboratory.



Frampton's work celebrated at Coral Gables conference

Paul Frampton (right) talks over dinner with Gerard 't Hooft (left) and Sheldon Glashow.

Paul Frampton, of the University of North Carolina at Chapel Hill, was honoured recently at the Coral Gables 2003 Conference in High Energy Physics and Cosmology. The meeting was held on 17–21 December in Fort Lauderdale, Florida, and the first two days were dedicated to Frampton's contributions to the field in honour of his 60th birthday. Speakers at the birthday "fest" included frequent collaborators Tom Kephart of Vanderbilt University and Y Jack Ng of Chapel Hill, as well as Alan Guth of MIT, Pham Quang Hung of UVA-Charlottesville, Holger Nielsen from the Niels Bohr Institute, Copenhagen, and Mark Wise of Caltech. Attendees included former students Marcelo Ubriaco from Puerto Rico and Otto Kong from Taiwan; former Chapel Hill postdocs Osamu Yasuda and Tadashi Yoshikawa, who made the trip from Japan; and Nobel laureates Sheldon Glashow, Gerard 't Hooft and Martinus Veltman.

CERN was host to the meeting of the International Advisory Panel of the Center for Advanced Mathematical Sciences of the American University of Beirut on 16 January. This external review and advisory committee meets once a year to follow up on the centre's activities and to advise on appointments etc. The panel is currently chaired by Fields Medallist **Sir Michael Atiyah**, who is seated second from the right next to **Sir James Mirrlees**, the recipient of the 1996 Nobel prize in economics (second from left).

MEETINGS

The International Ticer School 2004, formerly known as the International Summer School on the Digital Library, has announced courses for June and August. In these high-standard courses, experienced international lecturers deal with several interesting and current topics. The first of the latest courses, on "Digital Libraries and e-Publishing for Science, Technology and Medicine", will be held at CERN on 13–18 June. For further information, see www.ticer.nl.

The Australia–New Zealand Semiconductor Instrumentation Workshop will be held at the Royal Society of New Zealand in Wellington from 16–18 June. The workshop will be dedicated to semiconductor instrumentation for particle physics (e.g. the ATLAS and CMS experiments at CERN), medical physics and astrophysics. It is expected to create synergies between the high-energy particle, medical and astrophysics communities of New Zealand, Australia and the rest of the world. For more information, see http://hep-project-anz-workshop.web.cern.ch.

The Sixth International Workshop on Radiation Imaging Detectors will take place at the University of Glasgow, UK, from 25–29 July. Registration is now open and the deadline for submission of abstracts is 1 June. For more details, see www.iworid2004.ph.gla.ac.uk.

The 5th Rencontres du Vietnam 2004, "New Views in Particle Physics" will be held from 5–11 August in Hanoi, Vietnam. The aim of the Rencontres has been to extend the successful scientific international collaboration between Europe, Russia, Japan and the United States to the emerging Pacific Rim countries. As a natural continuation of the series, two parallel conferences, one on particle physics and the other on astrophysics, will be organized in 2004. For more information, see http://vietnam.in2p3.fr/2004.

The 10th International Symposium on Particles, Strings and Cosmology (PASCOS04) will be held at Northeastern University, Boston, Massachusetts, on 16–22 August. It will bring together leading experts in the three disciplines to discuss interconnections, assess current progress and possible future directions. There will also be a strong experimental component. This year the symposium will include a special programme in honour of Pran Nath on his 65th birthday. For further details, see www.pascos04.neu.edu.

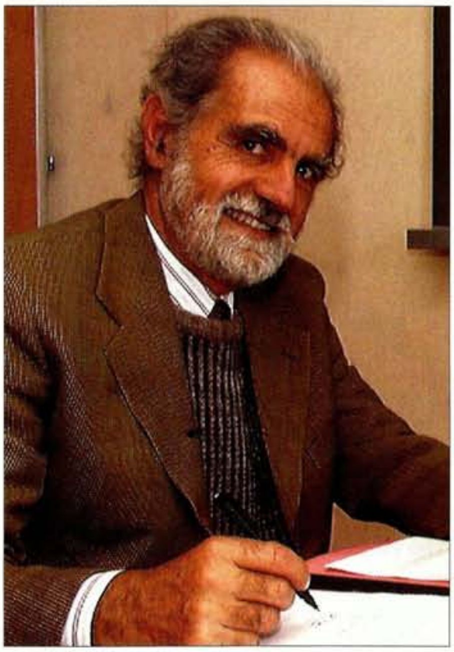
The 11th Euro Summer School on Exotic Beams will be held at the University of Surrey, Guildford, UK, on 19–27 August. This EU-funded school is intended for students and young postdocs starting to work in fields related to radioactive ion beams. It consists of six lecture courses given by specialists in exotic beams, starting from a basic level. The deadline for registration is 1 June; an online registration form can be found on the web at www.ph.surrey.ac.uk/cnrp/euroschool04. Further information is also available by e-mail from euroschool@surrey.ac.uk.

The 8th International Workshop on Tau–Lepton Physics, Tau04, will be held in Nara, Japan, on 14–17 September. This workshop is organized every two years to discuss recent progress in physics of the tau lepton and its associated neutrino. For further information, see www.hepl.phys.nagoya-u.ac.jp/public/Tau04/, e-mail tau04@hepl.phys.nagoya-u.ac.jp, or fax +81 742 20 3390.

Cosmo04, the annual Cosmo International Conference on Particle Physics and Cosmology, will be hosted by the Canadian Institute for Theoretical Astrophysics in Toronto on 17–21 September. The conference, which will be devoted to the modern interfaces between fundamental and phenomenological particle physics and physical cosmology and astronomy, will take place at the downtown campus of the University of Toronto. Topics covered will include inflation, cosmological fluctuations, astroparticle physics, neutrino astrophysics, dark matter, the cosmological constant and cosmic microwave background. For further information, see www.cita.utoronto.ca/~cosmo04.

OBITUARIES

Luis Masperi 1940–2003



Luis Masperi, who was director of the Latin American Centre for Physics (CLAF), passed away on 2 December 2003 after a short illness. Born in Spoleto, Italy, Masperi was raised in Argentina and became an Argentinean citizen. Following a doctorate from the National University of Cuyo in 1969, he became a theoretical physicist of international renown. From 1982 to 1984 he served as president of the Argentinean Physical Society, but he also maintained links with his native Italy through numerous visits and in particular a lifelong relationship with the International Centre for Theoretical Physics in Trieste. From 1998, as director of CLAF, he worked tirelessly to promote links between Latin American physicists and the global physics community. A notable success was the organization of the first CERN–CLAF School of High Energy Physics in 2001.

Masperi's international reputation rested not only on his research, but also on his dedication to world peace. In 1992 he shared the American Physical Society's Forum Award with fellow Latin American physicists Luis Pinguelli Rosa, Alberto Ridner and Fernando de Sousa Barros, for efforts in persuading Argentina and Brazil to abandon their nuclear weapons programmes; and from 1999 to 2002 he was a member of the Pugwash Council.

His boundless energy and enthusiasm for what he believed in will be sorely missed by all of those who worked with him and shared his ideals.

Juan-Antonio Rubio, CERN.

John Harry Adlam 1924–2004

John Harry Adlam, one of the early contributors to accelerator design, died on 4 February. A colleague and great friend of mine for many years, John was contemporary with John and Mary Bell, and many other illustrious personnel at the British/American Laboratory based in The Lees, Great Malvern. This had been home to some of the early British scientific advances in accelerator physics. In 1952 John and I worked as a small team on dielectric measurements of titanium and barium oxide disks that had formed part of the structure of a dielectric loaded linear accelerator, which was designed by R B R Shersby-Harvie *et al.* Sadly, this was before the phenomenon of multipactor had been discovered and the accelerator failed.

Interest had begun in accelerating protons in a linear accelerator structure and work moved to Harwell in 1954, where there was a project for a 300 MeV proton linac in conjunction with teams from several British universities. The project was truncated from 300 to 50 MeV following a major improvement in the efficiency of beam extraction from synchrocyclotrons.

There were difficulties in finding a solution to the focusing of protons in an accelerator as the known method in use relied on grid structures in the beam path that were lossy. John and I developed a system for cavity field measurement that was based on perturbation of the field with metallic and dielectric objects. At about the same time he produced a paper that turned out to describe the forerunner for the radiofrequency quadrupole, whose development came much later from the United States. That development revolutionized the difficult part of heavy-particle acceleration, namely the low-energy end of the spectrum where Cockcroft–Walton generators formerly held sway.

In 1955 John was moved from his previous work to join a team that was developing the "Dain" valve, a continuously pumped triode for use with the 50 MeV accelerator. The triode was used successfully on the accelerator at the Rutherford Laboratory, which came into being as a laboratory alongside Harwell but outside the security fence, as the work was open to all.

Later on, in 1963, John moved to Culham, where a fusion laboratory had been set up with John Adams as director, between his days at CERN as leader of the PS project and thereafter as leader of the SPS project.

John retired in 1989 and lived in Summertown, Oxford. He slipped on ice this year and was hospitalized. He died in hospital as a result of an internal haemorrhage from an untreated hernia.

Frank James, CERN 1954–1960 and 1969–1985.

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Director

Fermi National Accelerator Laboratory

The Fermilab Board of Overseers of Universities Research Association, Inc. (URA) has initiated a search for a new Director of the Fermi National Accelerator Laboratory in Batavia, Illinois. The position, for a term of five years with the possibility of extension for a mutually agreed time, will be available July 1, 2005. The Search Committee welcomes applications and nominations for this position. It is recommended that applications be accompanied by curriculum vitae and other information bearing on the candidates' qualifications for the Directorship. Relevant qualifications include scientific stature, leadership capability, and management skills. The membership of the Search Committee and its charge are posted at **http://www.fnal.gov/directorsearch**.

Communications should be sent as soon as possible, preferably before May 15, 2004, and should be addressed to:

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TECHNISCHE UNIVERSITÄT DRESDEN

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C4 - Professur für Teilchenphysik

(Nachfolge Prof. K. R. Schubert) zu besetzen. Der/Die Stelleninhaber/in soll die Teilchenphysik in Forschung und Lehre vertreten. Er/Sie soll herausragende Erfahrungen in der Planung, Leitung und Auswertung von Experimenten an Beschleunigern vorweisen können. Die Weiterführung der erfolgreichen Dresdner Beteiligung am BABAR-Experiment ist erwünscht. Darüber hinaus wird ein starkes Engagement für ein neues und zukunftsträchtiges Projekt der Teilchenphysik erwartet. Der/Die Stelleninhaber/in soll die Experimentalphysik in der Lehre im Studiengang Physik sowie in anderen Studiengängen der Naturwissenschaften, Ingenieurwissenschaften und Medizin vertreten. Eine angemessene Beteiligung an allgemeinen Aufgaben der Fachrichtung Physik wird erwartet.

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MAX-PLANCK-GESELLSCHAFT

2 Postdoctoral Positions 1 Software Developer Position in Experimental High-Energy Particle Physics

The Max-Planck-Institut für Physik (MPI) is one of the world's leading research institutes focused on particle and astroparticle physics from both an experimental and a theoretical perspective. Our research activities comprise participation in the H1 and ZEUS experiments at HERA, the STAR experiment at RHIC and the ATLAS experiment. ATLAS is presently under construction to operate at CERN's Large Hadron Collider (LHC) starting from 2007. The scientific focus of the ATLAS collaboration is the search for the Higgs boson (the particle at the origin of particle masses), precision measurements of top- and b-quark physics, and the search for new physics beyond the Standard Model, e.g. Supersymmetry. The MPI contributes to the construction of three sub-detectors for ATLAS, the Liquid Argon Calorimeter (LAr), the Monitored Drift Tubes for the muon system (MDT) and the SemiConductor Tracker (SCT).

The MPI invites applications for **two postdoctoral positions** in experimental elementary particle physics to strengthen our MDT and SCT Groups. We are seeking for candidates to contribute both to the construction, testing, quality assurance and installation of detector modules, and to preparations of the physics analyses. Candidates should have a PhD in experimental physics with a solid background in elementary particle science. The positions are limited to three years, with the possibility of extension within the rules of the German Hochschulrahmengesetz.

Applications are also invited for the position of a **software engineer** or a **physicist** who will participate in developing software for calibration, integration, alignment, readout and reconstruction within the ATLAS project. The candidate should contribute both to sub-detector specific tasks at our institute and to the development of the ATLAS core software at CERN. The candidate must have significant development experience with an object-oriented environment, with the UNIX operating system in a scientific environment and with the C++ programming language. Experience in relational database systems like ODBC, Oracle or MySQL, knowledge of other programming languages like Perl or Python and experience and interest in GRID computing will be of additional advantage. The candidate should at least have an M.S. degree in computer science, physical science or mathematics. The position is initially limited to two years.

Salaries for all positions are according to the German federal pay scale (BAT). Applications from women are particularly welcome. The Max Planck Society is committed to employing more handicapped individuals and especially encourages them to apply.

For more information on the institute and its research see our internet homepage http://www.mppmu.mpg.de.

Interested individuals should send their application, including statements of interest, CV, list of publications and the names and addresses of three suitable referees, to

Max Planck Institute for Physics
(Werner Heisenberg Institute)
Prof. Dr. Siegfried Bethke
Föhringer Ring 6,
80805 München, Germany

The Lawrence Langer Research Fellowship

This special research fellowship is named after Lawrence Langer who performed pioneering research on beta decay and neutrino mass measurements. The fellowship is awarded to an outstanding post-doctoral scientist who is at an early point in a promising career.

Candidates for this fellowship must have displayed outstanding potential in subatomic physics research, and must show definite promise of becoming leaders in the academic research community. A Ph.D. in experimental subatomic physics is required. Fellowships will be awarded for a three-year term. Langer Fellows, who will be competitively selected, are given the freedom of associating with IUCF faculty members in a research area of common interest.

The I.U. subatomic physics group has an active program with experiments to study nucleon structure, nuclear dynamics, and the properties of the weak interaction. The wide range of questions being addressed by 11 faculty members involve leadership roles in studies of parity violation and quark mixing matrix unitarity with low-energy neutron beams at LANSCE, NIST and SNS; flavor and spin structure of the nucleon at RHIC with the STAR detector; neutrino oscillations and scattering with the miniBooNE experiment and proposed follow-ups at Fermilab. Local facilities include a 200 MeV cyclotron, a 240 MeV synchrotron, and a new cold Neutron Source currently under construction. While the major programs on the first two of these no longer include nuclear physics, they do provide excellent facilities for development and testing. The laboratory also provides excellent personnel infrastructure to enable strong participation in major off-site projects. Opportunities are available on all major research projects. For further information, please access our Web site at **http://www.iucf.indiana.edu.**

The Lawrence Langer Research Fellowship carries a stipend of $55,000 per annum, with an additional allocation of up to $20,000 per annum for research support and travel.

Send résumé, bibliography and contact information for three references by June 30 to

Dr. John M. Cameron, Director
Indiana University Cyclotron Facility
2401 Milo Sampson Lane, Bloomington, IN 47408
FAX: 812-855-6645 Email: cameron@iucf.indiana.edu

IU is strongly committed to achieving excellence through cultural diversity.
The university actively encourages applications and nominations of women, persons of color, applicants with disabilities, and members of other underrepresented groups.
Indiana University is an Affirmative Action/ Equal Employment institution.

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- Nucleus-Nucleus Collisions
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SENIOR APPLIED PHYSICIST
FOR X-RAY DETECTOR DEVELOPMENT

Praesepe is a Netherlands-based company which specialises in data analysis and instrumentation for X-ray and gamma-ray astronomy (see www.praesepe.com). We currently have a vacancy for a Senior Applied Physicist to lead a programme to develop compound semiconductors for use as hard X-ray and gamma-ray detectors. The work will be undertaken as part of the laboratory research programme of the Advanced Concepts and Science Payloads Office of the European Space Agency (ESA). The project will be based in the ESTEC laboratory of ESA in Noordwijk, The Netherlands.

The ideal candidate will have sufficient experience to lead a solid-state detector project both from a scientific and an engineering point of view. In addition a knowledge of general techniques in X-ray and gamma-ray radiation analysis, are essential. The candidate should be able to plan and execute measurement campaigns without supervision. The ability to analyse data in support of device physics interpretation is important. The candidate must also have the ability to specify and coordinate work undertaken by industrial contractors and academic collaborators. Familiarity with cryogenic equipment, computer interfaces to experiments, radioactive source handling and measurement campaigns and national accelerator facilities would be valuable.

Applications with CV to
Praesepe B.V., Lorentzplein 7, 2012 HG
Haarlem, The Netherlands.

Preferably by email (info@praesepe.com) or by FAX +31-23-5510910.

Peoples Fellows Program

The Peoples Fellowship Program at Fermilab supports accelerator scientists and high energy physicists early in their careers by providing unique opportunities for self-directed research in accelerator physics and technology. The Fermilab accelerator complex provides beams for collider physics at the energy frontier, and high intensity beams for neutrino physics and other fixed target programs. Current areas of accelerator research include stochastic and electron cooling, muon cooling, superconducting magnet R&D, superconducting RF R&D, linear colliders, large hadron colliders, advanced acceleration methods, accelerator controls and feedback, and computational physics and modeling.

The fellowships are awarded on a competitive basis to Ph.D. physicists of exceptional talent as evidenced by their graduate or postdoctoral work. Peoples Fellowships are open to accelerator scientists within three years of receiving their Ph.D. and to high energy physics post-docs within 5 years of their Ph.D. Fellows will work at Fermilab in areas of accelerator physics or technology of their choice. Peoples Fellowships are tenure track positions with an initial term appointment of three years.

Applicants should submit a statement describing a proposed research program, a curriculum vitae, and the names of at least four references no later than April 30, 2004. Applications, either in paper or electronic form, and requests for information should be sent to:

James Strait, Chair, Peoples Fellows Committee
Fermi National Accelerator Laboratory, MS 343
P.O. Box 500, Batavia, IL 60510-0500
e-mail: strait@fnal.gov

http://www.fnal.gov/pub/forphysicists/fellowships/peoples.html

Fermilab

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BOOKSHELF

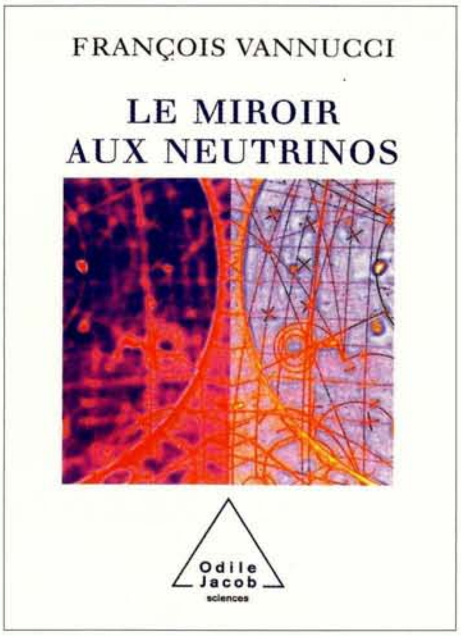
The Global Approach to Quantum Field Theory by Bryce DeWitt, Oxford University Press (vols I and II). Hardback ISBN 0198510934, £115 ($230).

It is difficult to describe or even summarize the huge amount of information contained in this two-volume set. Quantum field theory (QFT) is the more basic language to express the fundamental laws of nature. It is a difficult language to learn, not only because of its technical intricacies but also because it contains so many conceptual riddles, even more so when the theory is considered in the presence of a gravitational background. The applied field theory techniques to be used in concrete computations of cross-sections and decay rates are scarce in this book, probably because they are adequately explained in many other texts. The driving force of these volumes is to provide, from the beginning, a manifestly relativistic invariant construction of QFT.

Early in the book we come across objects such as Jacobi fields, Peierls brackets (as a replacement of Poisson brackets), the measurement problem, Schwinger's variational principle and the Feynman path integral, which form the basis of many things to come. One advantage of the global approach is that it can be formulated in the presence of gravitational fields. There are various loose ends in regular expositions of QFT that are clearly tied in the book, and one can find plenty of jewels throughout: for instance a thorough analysis of the measurement problem in quantum mechanics and QFT, something that is hard to find elsewhere. The treatment of symmetries is rather unique. DeWitt introduces local (gauge) symmetries early on; global symmetries follow at the end as a residue or bonus. This is a very modern point of view that is spelt out fully in the book. In the Standard Model, for example, the global symmetry (B–L, baryon minus lepton number) appears only after we consider the most general renormalizable Lagrangian consistent with the underlying gauge symmetries. In most modern approaches to the unification of fundamental forces, global symmetries are quite accidental. String theory is an extreme example where all symmetries are related to gauge symmetries.

There are many difficult and elaborate technical areas of QFT that are very well explained in the book, such as heat kernel expansions, quantization of gauge theories, quantization in the presence of gravity and so on. There are also some conceptually difficult and profound questions that DeWitt addresses head on with authority and clarity, including the measurement problem mentioned previously and the Everett interpretation of quantum mechanics and its implications in quantum cosmology. There is also a cogent and impressive study of QFT in the presence of black holes, their Hawking emission, the final-state problem for quantum black holes and a long etcetera.

The book's presentation is very impressive. Conceptual problems are elegantly exhibited and there is an inner coherent logic of exposition that could only come from someone who had long and deeply reflected on the subject, and made important contributions to it. It should be said, however, that the book is not for the faint hearted. The level is consistently high throughout its 1042 pages. Nonetheless it does provide a deep, uncompromising review of the subject, with both its bright and dark sides clearly exposed. One can read towards the end of the preface: "The book is in no sense a reference book in quantum field theory and its applications to particle physics...". I agree with the second statement but strongly disagree with the first.
Luis Alvarez-Gaume, CERN.



Le miroir aux neutrinos (The Neutrino Mirror) by François Vannucci, Odile Jacob. ISBN 2738113311, €23.50.

Neutrinos have excited scientists since 1930 and have allowed some important discoveries: Gargamelle's 1973 observation of neutral currents in fact constituted the first manifestation of the Z boson, and as such marked the experimental foundation of the Standard Model. More recently, the beautiful phenomenon of neutrino oscillations has demonstrated that the Standard Model needs to be enlarged to account for neutrino masses. In a nutshell, neutrinos are in the spotlight.

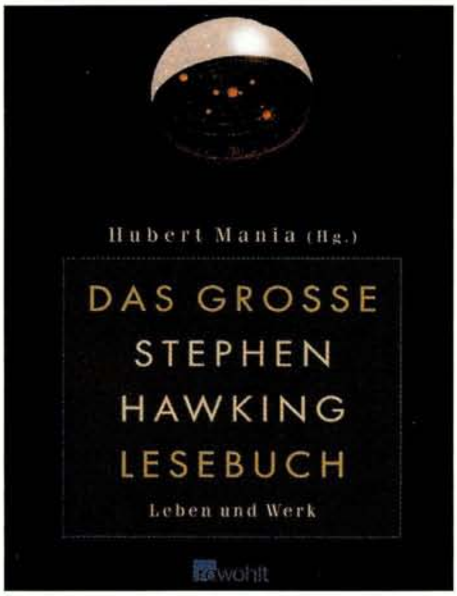
For this reason it is very pleasant to see one of our colleagues undertake to communicate to a broad public his enthusiasm and excitement for these particles that are so hard to detect. The "mirror" through which Vannucci invites us to discover these neutrinos is, in the end, that of his own personality. The reader finds a typically French character, profoundly cultured, who revels in the company of literary quotes that mirror his thoughts and that enrich them with a touch of melancholic beauty. Marcel Proust and Oscar Wilde top his favourite author's list, which extends from Saint Augustine to Daniel Pennac, via Jean-Paul Sartre and the medical dictionary. Sometimes a school-boy's wink, and often a sensuous shiver, express themselves through these quotations, which is testimony to the fact that science speaks not only to the brain but also the heart. I am not sure that I have grasped what these quotations are supposed to explain, but they certainly carry a form of emotion.

The book tells the story of neutrinos, at a level that is meant to be accessible to pupils in the final years of high school (15–18 years old), as well as scientifically cultivated adults. It begins with a discussion of perception and detection, first of ordinary objects and then of particles. Then we arrive at Pauli and his "radioactive ladies and gentlemen", followed immediately by UA1 and the discovery of the W. (Sartre and Le Verrier are quoted...but no word of Carlo Rubbia. This will soothe the feelings of all those who felt they should have appeared.) Then we go back to the experiments to measure the neutrino mass followed by neutrinoless double-beta decay, and the detection of the first neutrino interactions by Fred Reines. As one can see, the experiments that have established the properties of neutrinos are listed thematically and not necessarily historically, something that I appreciated.

With occasional irony towards his colleagues (or himself?), Vannucci takes us around the experiments that made history in neutrino physics; those that were right and those that were wrong, those that made us understand and those that got us confused. This is followed by a discussion on uncertainties and the scientific method. I am not sure I agree fully when what we don't know yet but are striving to know and will hopefully understand ("the big bang cannot be considered a physical event"), is compared with medieval legends ("angels, archangels and cherubim of the middle ages"). However, do read carefully and you will find the definition of the "miroir aux alouettes", which inspired the title of the book and is taken from a quotation in...a dictionary.

It is not obvious for whom this book is best suited. For whom would I buy it? It seems more for our fathers – and mothers – or our colleagues than for teenagers, who may be discouraged by the unlikely mix of literature and science.
Alain Blondel, Geneva University.

Das große Stephen Hawking Lesebuch, Leben und Werk (The Big Stephen Hawking Reader) by Hubert Mania (ed.), Rowohlt Verlag. Hardback ISBN 3498044885, €17.90.



The Big Stephen Hawking Reader includes excerpts from books written by Hawking, as well as information about his life and work. This naturally divides the book into two parts: the first half is a short biography of Hawking interspersed with sections explaining the basic physics of his work. In this way it not only introduces Hawking himself, but also his thoughts and ideas.

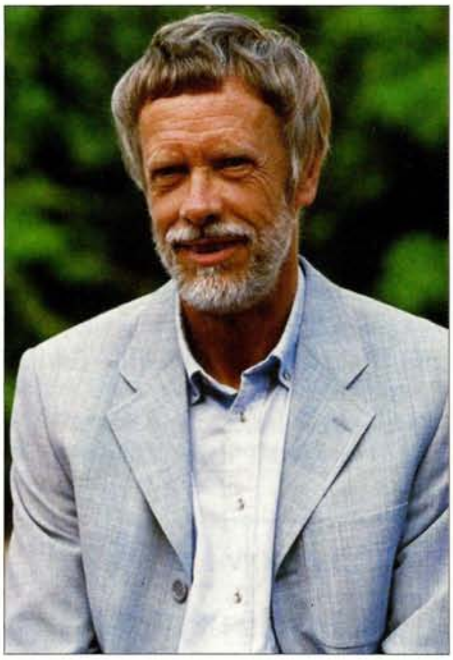
Mania admits in the prologue that he wrote the biography from a "respectful distance", honouring Hawking's wish to be remembered for his work and not his "involuntary presence in the gossip columns". Because of this, Mania sometimes leaves out things that could shed a less favourable light on Hawking. For example, Hawking's treatment of his first wife is only mentioned very briefly. Nevertheless there are some nice anecdotes about Hawking, such as when he was thinking about *A Brief History of Time*. "If he was going to neglect his research to write a popular book, then it should be profitable for him."

The second half of the book is made up of excerpts from *A Short History of Time*, *The Illustrated Short History of Time* and *Einstein's Dream*. The chapters are well chosen and understandable with the help of Mania's comments.

Even if Mania's book is sometimes a little sketchy, I enjoyed reading it and would recommend it to anyone who wants a short introduction to Stephen Hawking's life and work – and it whets the appetite for more books about and by this well known scientist.
Hannelore Hammerle, CERN.

The importance of funding outreach

Outreach should be recognized as a natural part of scientific research, and hence of its funding, argues **Erik Johansson**.



Science and technology play an increasingly important role in our everyday lives, and many of life's decisions now depend on some sort of scientific or technical knowledge. At the same time, advances in modern science occur quickly as each subject evolves and entirely new subjects are created, so it is often difficult for the general public and for teachers to keep up with scientific discoveries and technological innovations. However, science can be made more accessible and interesting to students, teachers and the public if they are exposed to the exciting ideas and discoveries of the latest research, for example in the field of high-energy particle physics.

Research in particle physics involves advanced technology, such as the large-scale use of superconductivity, precision particle detectors, and state-of-the-art electronics and computing systems. The technology of particle accelerators and detectors can also be applied to medicine and many other areas of science and industry, bringing alive the "appliance of science" to everyday life. Moreover, research has led to advances in information technology, such as the World Wide Web, which can bring about a "high tech" approach to learning about science. Aspects of classical physics, such as electromagnetism, optics and kinematics, can also be given a new lease of life through examples from modern physics, as compared with traditional teaching.

It is now generally agreed that education and awareness in science have to be strengthened in modern society. Indeed during the past few years increasing efforts have been made to improve awareness in the general public – especially young people in schools – of the importance of natural science to everyone. Scientific outreach, which promotes awareness and an appreciation of current research, has become an essential task for the research community and for many scientists.

As a result of an increased awareness of the importance of outreach activities, the European particle-physics community created the European Particle Physics Outreach Group (EPOG) in 1997 to promote outreach activities in particle physics. EPOG members represent the particle-physics communities of the 20 member states of CERN and, more recently, the US, together with the major laboratories of CERN, DESY and INFN. The group has received its mandate from the High Energy Particle Physics (HEPP) division of the European Physical Society (EPS) and the European Committee for Future Accelerators (ECFA). EPOG aims to help make scientific results and discoveries accessible to schools and the general public, and to introduce modern science into the school curricula.

Since its inception, the members of EPOG have both learned from each other and worked together on joint activities. There are many particle physicists active within their own countries who are working on a variety of initiatives, such as the development of new teaching materials, the translation of materials, workshops and masterclasses for both students and teachers, and visits to CERN. This work is often undertaken on a voluntary basis, with little or no official funding, and is dependent on the goodwill of the hardworking contributors and their institutions.

To be really successful though, outreach activities have to be done in a professional manner. Leading scientists who have a specialist knowledge in their subjects can form a powerful team with educators and those familiar with modern techniques in disseminating information to large groups of people. However, as we are competing with television and other leisure pursuits, outreach activities also require proper funding to be able to produce an attractive and engaging image of the natural sciences.

For this reason EPOG, together with ECFA and the EPS HEPP division, has written to a number of science research councils and other funding bodies in various countries to encourage them to recognize scientific outreach as an important and natural part of the research process, and to make financing available to the scientists for professional outreach activities. As we say in the letter, we realize that in some countries the importance of scientific outreach activities has already been recognized and is regarded as a natural part of the research activity. A particularly good example is the awareness in the US, which has resulted in organized funding. In many other countries, however, this is still not the case, and we believe that proper funding is crucial for an increased interest in and awareness of science and technology.

In summary, it is important that outreach activities are taken seriously by the bodies that fund our research. They should be recognized as a natural and logical part of research, and as an important link between research and society. With appropriate funding we could have the opportunity to make our mark and, who knows, to make a real difference.

Erik Johansson, Stockholm University and chair of EPOG.