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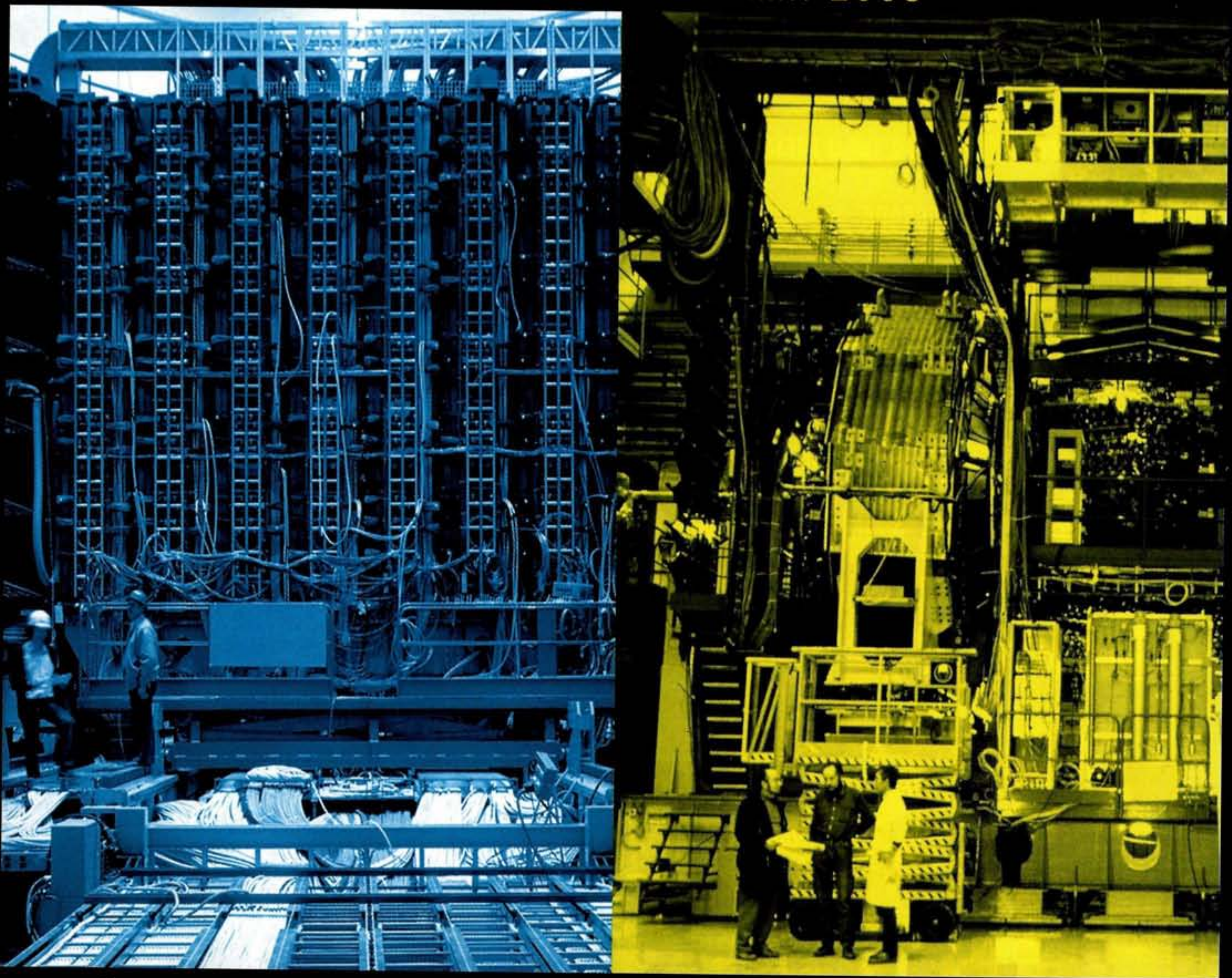

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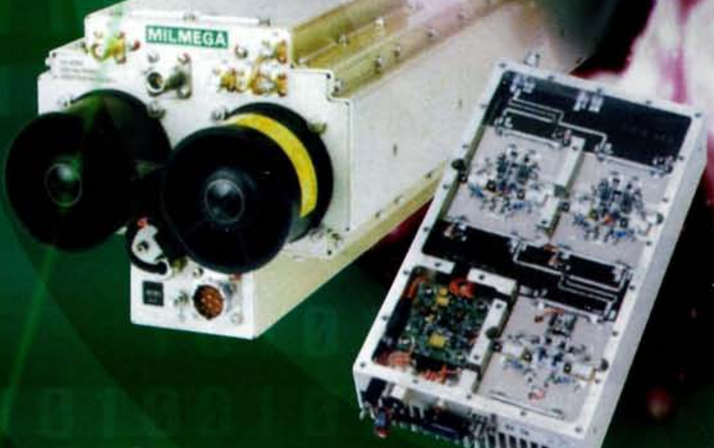

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Covering current developments in high-energy physics and related fields worldwide

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Editor Christine Sutton
CERN, 1211 Geneva 23, Switzerland
E-mail: cern.courier@cern.ch
Fax: +41 (22) 782 1906
Web: cerncourier.com

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Institute of Physics Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK
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Web: iop.org

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Tel: +44 (0)117 930 1031
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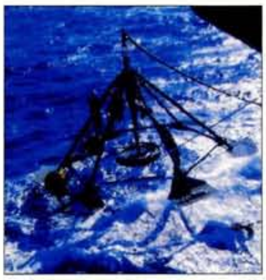
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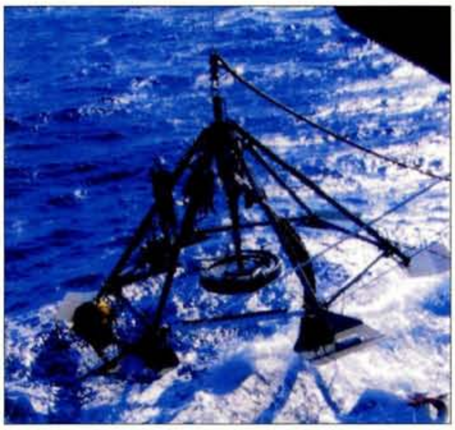
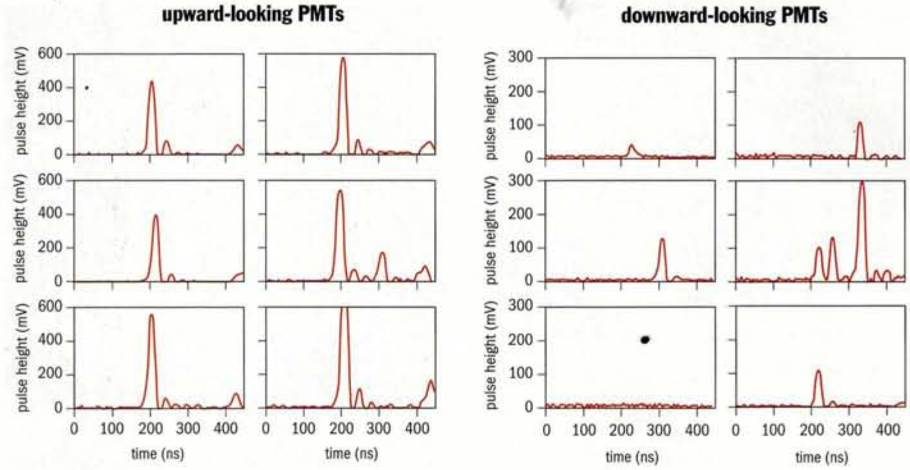
NEUTRINOS

NESTOR sees muons at the bottom of the sea



The NESTOR pyramid – the anchor unit with the environmental instrumentation – begins its journey to 4000 m below the surface of the Ionian Sea.



Waveforms from photomultiplier tubes (PMTs) in the same time frame show evidence in the upward-looking tubes for a downward-going muon.

On 29 March the NESTOR collaboration successfully deployed the first "floor" for a detector tower at its site 4000 m deep in the Ionian Sea. Data, including signals probably from downward-going muons, are being transmitted to the shore station in Methoni via a 30 km electro-optical cable laid on the sea-bed. This is the first time that continuous, real-time "physics" data have been obtained from such a depth, and represents a major step towards a kilometre cube neutrino detector.

The NESTOR (Neutrino Extended Submarine Telescope with Oceanographic Research) will ultimately consist of a tower with 12 floors of 32 m diameter, vertically spaced at 30 m. Each floor has 12, 38 cm diameter photomultiplier tubes (PMTs) mounted in pairs, looking upwards and downwards, at the ends of the six arms of a titanium "star". The PMTs detect Cerenkov light radiated by muons produced by the interactions of high-energy neutrinos near the detector. The read-out and control electronics are housed in a titanium sphere at the star's centre. With a total height of 410 m from the sea-bed, a tower will have an effective area of some 20 000 m^2 to neutrinos at 10 TeV.

The deployment site off the south-west tip of mainland Greece (Peloponnese) is an underwater plateau 65 km^2 in area at an average depth of 4000 m. This deep water, essential for a low cosmic muon background, is surprisingly close to shore, only 7.5 nautical miles (nm) from the island of Sapienza and 11 nm from Methoni. The NESTOR neutrino telescope is part of the scientific programme of the NESTOR Institute, in the town of Pylos on the bay of Navarino, 11 km north of Methoni.

The electro-optical cable from the shore station to the deep-sea site was laid in 2000. Then in January 2002 the end of the cable was brought to the surface by recovery buoy and connected to the junction box on the sea-bottom station, or "pyramid". The pyramid also houses the sea electrode (the electrical power-return), the anchor system and environmental monitors. Bad weather made it dangerous to attach a detector floor on this occasion, but useful data were transmitted to shore from the pyramid during the descent, and long-term variations in environmental parameters were measured at the sea-bed. Since then, the team has been awaiting the availability of a suitable vessel and good weather.

Only in March this year could the pyramid be brought back to the surface and the floor deployed. The titanium sphere at the centre of the floor was connected to the junction box and the detector floor lowered into the sea, 80 m above the pyramid. The operation was quite fast and posed no problems. The junction box and sphere were powered and monitored from the shore station throughout the deployment. There are LED calibration pulse modules positioned above and below the floor and the assembly is kept vertical by a buoy.

The titanium sphere contains a "housekeeping" board for control and monitoring of all systems and a "floor board" that performs the PMT pulse sensing, majority logic event triggering, coincidence rate scaling, waveform capture and digitization, as well as the data formatting and transmission. Parameters and functions can be downloaded over the optical link. The heart of the system is the Analog Transient Waveform Digitizer (ATWD), developed at Lawrence Berkeley Laboratory. Each ATWD has four channels with 128 common-ramp, 10-bit Wilkinson ADCs, and a present sampling rate of 282 MHz. A trigger is generated when the coincidence requirement for the floor is met and provides a time stamp for combining information from several floors.

Reconstruction and calibration have only just started but the data already obtained look very good. The plots show a typical event, with evidence of a downward-going muon. Even with a single floor, it may be possible to reconstruct tracks near to the horizon.

To avoid future delays the *Delta Verenike*, a large, self-powered floating platform with GPS dynamic positioning, has been designed for the deployment of NESTOR. Funded from within the Institute's infrastructure budget, construction is well advanced and delivery is expected later this year.

Further reading

For more details about the NESTOR Institute and neutrino telescope, see www.nestor.org.gr.

COLLIDERS

ACFA unveils plans for linear collider

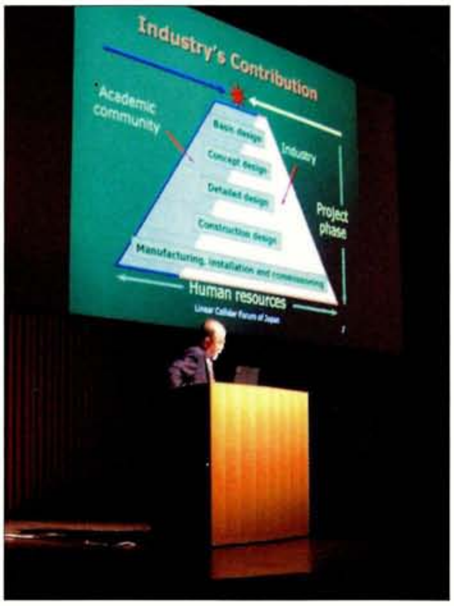
The Asian Committee for Future Accelerators (ACFA), together with the Japan Association of High Energy Physics (JAHEP) and the High Energy Accelerator Research Organization (KEK), have published a "roadmap report" for their linear collider project. The report was made public at the ACFA Linear Collider Symposium, held on 12 February at the international congress centre of Tsukuba in Japan. Nearly 400 people attended, not only from laboratories and universities around the world, but also from industry.

The linear collider project is an important one for ACFA. In statements in 1997 and 2001 ACFA strongly recommended that a linear collider should be constructed in the Asia-Pacific region with Japan as host for the worldwide international project, which should be operated concurrently with the Large Hadron Collider at CERN. The objective of the symposium was to explore the scope of the ACFA Linear Collider Project, including the overall design, cost, site and organizational aspects. The programme also included presentations on the viewpoints from the US, Europe and various ACFA countries, as well as from industry.

The initial goal of the ACFA linear collider is to perform experiments at a centre-of-mass energy (E_{cm}) of up to 500 GeV, with a luminosity of more than 10^{34} cm^{-2}s^{-1}. The design is based on a pair of linear accelerators installed in a straight tunnel about 30 km long. The main linacs will use X-band (11.424 GHz) RF technology, which has been developed in close collaboration with the NLC group in the US. This allows the electrons and positrons to be accelerated at 50 MeV/m or faster.

An important feature of the project is its energy-upgradability. The tunnel will be long enough for a machine eventually to reach E_{cm} = 1 TeV, but initially it would be only half-filled with RF accelerating structures. The energy could also reach beyond 1 TeV using the same technology – for instance, 1.25 TeV with one-third of the full luminosity.

Another option, presented by Kaoru Yokoya of KEK, would use C-band (5.712 GHz) RF technology from about 400 GeV, with X-band accelerating structures filling the remaining space in the tunnel at a future upgrade.



N Ozaki of the Linear Collider Forum of Japan presented the industry perspective.

A working group formed in 2001 listed eight candidate sites in Japan with the appropriate geology; an additional four sites are of interest because they are already national bases of scientific R&D. Atsushi Enomoto presented these options together with a description of the facility, including the underground tunnel structure, civil engineering processes, and systems for electric power and cooling. To maintain the accelerator complex continuously, the design foresees a double-tunnel structure – one for klystrons etc and the other running in parallel for accelerating structure.

Hirotaka Sugawara, KEK's director-general until the end of March, revealed that the total construction cost of the linear collider is estimated to be ¥495.1 billion (€3.86 billion) for the baseline case, in which the main linacs to support operation at E_{cm} = 500 GeV are built within tunnels that can eventually support operation at E_{cm} = 1 TeV. The cost also includes payment of all human resources other than accelerator scientists.

ACFA recommended in their statements that the linear collider should be built as an international facility open to all interested parties. Based on this recommendation, a committee formed in July 2001 has recently issued a report describing how the linear collider might be organized as a truly global project. As Sakue Yamada of KEK explained, the proposal is for a new international laboratory, the Global Linear Collider Centre (GLCC), to be created in Japan to facilitate the long-term commitment of participating partners, as well as open and transparent management. All partners would be on an equal footing although the contributions in financial and/or human resources may vary widely. In order to realize the GLCC quickly, the formation of a Pre-GLCC was proposed. A worldwide team would work together, irrespective of their preferences concerning the host, site or accelerator technology.

N Ozaki, the secretary-general of the Linear Collider Forum of Japan – a collaboration between the academic side and industrial companies formed in 2002 – discussed the linear collider from the industry point of view. Industry has a strong interest in the linear collider because its research may lead to business innovation.

Ozaki clearly described the importance of co-operation between researchers and industry from the beginning of the project. He emphasized that industry wants an early start for the linear collider project, and stressed that Japanese industry hopes to have industrial partners in other countries. The forum has plans to visit them in order to build up international collaboration.

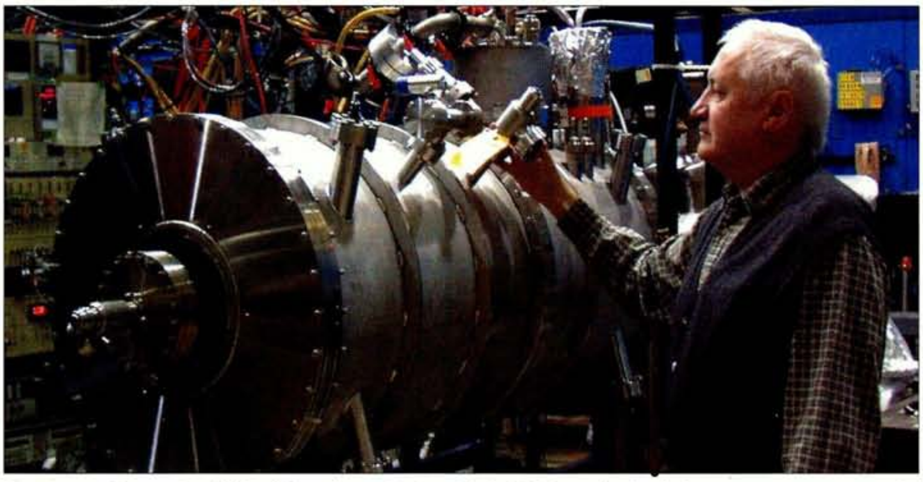
In concluding remarks, Sachio Komamiya from the University of Tokyo and the chairman of JAHEP spelt out the steps needed to realize the project. He emphasized that the final engineering design should be carried out by a global team under the Pre-GLCC, and should be completed by 2007. The construction of the machine is expected to take five years, including the excavation of tunnels and the installation of the accelerator, so commissioning could start in 2012.

Further reading

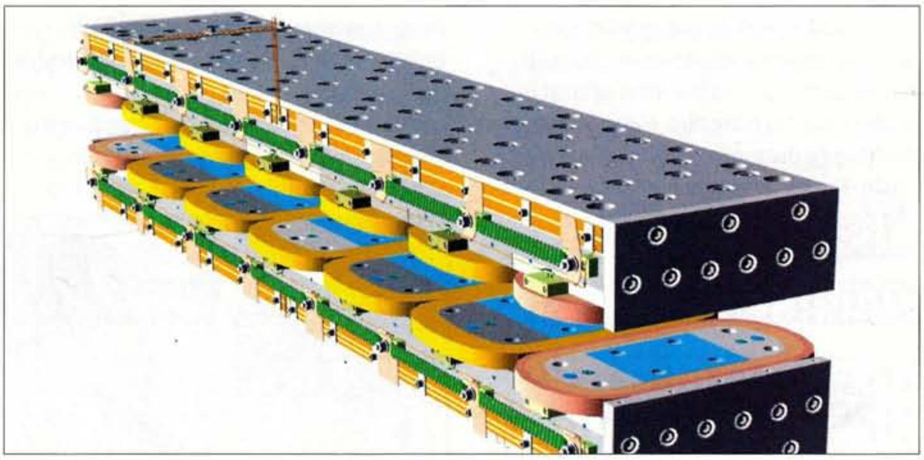
The ACFA linear collider roadmap report is available at http://lcdev.kek.jp/Rmdraft. The global laboratory report is at http://www.kek.jp/news/glcc_report.pdf.

CORNELL

Wigglers give CESR a new charmed life



Designer Alexander Mikhailichenko with the sixth CESR-c wiggler in its cryostat on a stand.



Assembly drawing of the CESR-c superferric wiggler magnets, vital for charm conversion.

In early March, after more than 23 years of continuous operation, the CESR staff and the CLEO collaboration at Cornell completed their programme of b quark physics. Now the conversion of CESR to operate in the lower-energy region of the c quark, or charm, threshold has begun, with the installation of the first new "wiggler" magnets, which are a key component of the conversion (*CERN Courier* January/February 2002 p13). The US National Science Foundation has approved the proposal for this new programme and awarded a five-year grant to support it. At the same time, the NSF approved the continuation of the CHESS facility, which supports the utilization of synchrotron radiation X-rays produced in CESR.

Conversion of CESR's e^+e^- storage ring to operate with sufficient luminosity in the charm-threshold region requires the installation of 18 m of wiggler magnets operating at magnetic fields of 2.1 T. Wiggler magnets have alternating north and south poles which induce rapid radial oscillations of the beams, increasing dramatically the emission of synchrotron radiation in the form of X-rays. Emission of synchrotron radiation "damps" the beams – that is, it decreases the sizes of the beams and increases the luminosity that the collider can provide.

When CESR was operating in the region of the upsilon particle, near 5 GeV per beam, the emission of synchrotron radiation in the collider's bending magnets was sufficient to achieve small beams and high luminosity. At the lower energies of the c quark threshold region, between 1.5 and 2 GeV per beam, a factor of 20 in the radiation damping rate is lost. The wigglers will make up for this loss and achieve the high luminosities required.

The wigglers for "CESR-c" are superferric magnets, with iron poles excited by superconducting coils. A prototype wiggler, constructed in early 2002, was placed in CESR last August. Beam tests showed that the effects from the wiggler are consistent with estimates based on computer tracking and dynamic aperture analysis. With the extra damping of this one wiggler, as well as two weaker wigglers from the CHESS synchrotron radiation source, the luminosity in CESR in the charm-threshold region approached $2 \times 10^{31}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, which is already above luminosities achieved at other colliders in this energy range. The final luminosity with all wigglers installed will be around $3 \times 10^{32}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.

Six wigglers, representing 8 m of the 18 m required, have already been built and will be installed during a machine shutdown from March through June. For cooling, these wigglers will use the cryogenic facilities in place for CESR's superconducting RF cavities. Space in the ring is being created by removing two dipole bending magnets, in the third of the circumference closest to the central lab, and increasing the field of adjacent magnets.

Other hardware changes are minor, such as using thinner windows in injection lines, improving the regulation of the power supply, and optimizing the superconducting RF field control for higher-field and lower-beam loading. The modifications of the CLEO detector are also modest. The main upgrade is replacing the silicon vertex detector with a small drift chamber.

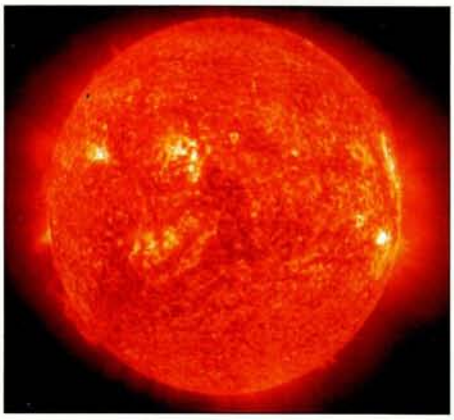
Because of the lower beam energy, synchrotron-radiation users will no longer be able to run in parallel with high-energy physics operation. Dedicated periods of operation with beam energies above 5 GeV will serve the needs of X-ray users. The higher-energy running also benefits the beam lifetime for high-energy physics operations by keeping the vacuum chamber clean thanks to the action of the higher-energy synchrotron radiation photons.

CESR will operate in the charm-threshold region during the second half of 2003, after a period of commissioning and synchrotron-radiation running. At the same time the remaining wiggler units will be built and tested, ready for installation when convenient, so that full-intensity operation for high-energy physics can follow shortly afterwards.

SOLAR NEUTRINOS

Neutrinos limit role of CNO cycle

The Sun burns through various nuclear reactions with the same net effect – the fusion of four protons to form a nucleus of helium, with the release of energy. The two main sets of reactions are the *p-p* chain, which involves the lightest nuclei, and the CNO cycle, in which the heavier nuclei of carbon, nitrogen and oxygen play a role. Calculations based on the standard solar model suggest that most of the Sun's energy comes from the *p-p* chain, with only 1.5% from the CNO cycle. This prediction is widely assumed to be correct, but can it be tested experimentally?



Neutrinos have shed light on element building in the Sun. (SOHO/EIT/ESA/NASA.)

This was indeed an early goal of solar neutrino experiments. However, the solar neutrinos that proved the least difficult to detect have been the high-energy neutrinos from the ^{8}B decays in a variant of the *p-p* chain. The low-energy neutrinos from ^{13}N and ^{15}O decays in the CNO cycle are much more problematic. Moreover, electron–neutrinos emitted by the Sun are now known to escape detection in many experiments through oscillation to another variety. Indeed, before the data from the Sudbury Neutrino Observatory (SNO) and SuperKamiokande became available, calculations in which the CNO cycle contributed as much as 99.95% of the solar energy would fit the data.

Now John Bahcall and Carlos Peña-Garay of the Institute of Advanced Study, Princeton, and M C Gonzalez-Garcia of CERN, SUNY and IFIC Valencia, have revisited the problem using all existing solar neutrino data, including that from SNO and SuperKamiokande, as well as the recent reactor data from KamLAND (*CERN Courier* March 2003 p7). Their extensive analysis involves 10 free parameters, which include neutrino oscillation parameters as well as various solar neutrino fluxes – including ^{13}N and ^{15}O decays. Their best fit indicates that the energy from the CNO cycle must be less than 7.3% at the 3σ level. To improve the limits to the 1.5% level of the solar model predictions will be very challenging, but would, say Bahcall and colleagues, provide a stringent test of the theory of stellar evolution.

Further reading

J N Bahcall, M C Gonzalez-Garcia and C Peña-Garay 2003 *Phys. Rev. Lett.* **90** 131301–1.

SYNCHROTRON RADIATION

BESSY shines bright in the far-infrared

The BESSY synchrotron light source in Berlin has developed a technique to provide intense, steady-state, broadband coherent radiation in the far-infrared – or terahertz (THz) – spectral range. This region of the spectrum, close to the microwave region, has so far been difficult to use because the available sources were very weak, but there are many potential applications, for example in medical imaging and chemical "fingerprinting". The breakthrough follows recent advances at the Jefferson Laboratory, where high-average-power broadband emission in the far-infrared was produced by synchrotron radiation from electron bunches in the free-electron laser (*CERN Courier* January 2003 p6).

BESSY can now produce terahertz radiation. (BESSY/Luftbild und Pressefoto Grahn, Berlin.)

Coherent far-infrared radiation can be produced as synchrotron radiation when the length of the electron bunches is comparable to that of the wavelength of the radiation. To produce these conditions the BESSY synchrotron must be run in a "low alpha" optics mode in which the length of the bunches and the shape are specially tuned. In this mode the bunches are typically 1 mm long, with up to 400 bunches stored in the ring at 2 ns bunch spacing. Measurements of the intensity of the coherent far-infrared radiation produced are 1000 times greater than a standard spectrometer mercury arc lamp, illustrating the advantage of the synchrotron source over a more standard thermal source.

Further reading

M Abo-Bakr *et al. Phys. Rev. Lett.* **90** 094801–1

PHYSICSWATCH

Edited by Archana Sharma

Muons bend to beat the smuggler

Physicists and astrophysicists at the Los Alamos National Laboratory, US, believe that cosmic-ray muons could join the armoury of cross-border surveillance techniques, because of their ability to create images of dense objects. The technique would be relatively inexpensive and harmless as it involves only natural background radiation, and the team says that it could be used to detect, for example, "a block of uranium concealed inside a truck full of sheep".

Cosmic rays in a spark chamber: could these muons help to catch smugglers?

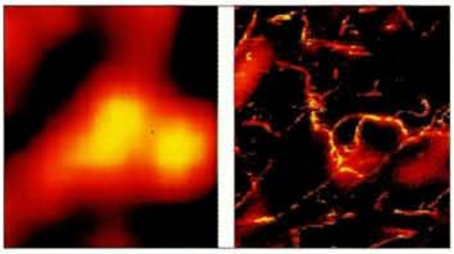
The process relies on the slight deflection in the paths of cosmic-ray muons as they pass through an object. By measuring the amount of deflection, the object's density can be reconstructed, rather as X-rays reveal varying density through differing amounts of absorption.

To investigate the potential of muon radiography, the team at Los Alamos placed pairs of drift chambers with an active area of 60×60 cm^2 above and below a test object of tungsten on steel supports. The reconstructed image clearly shows the tungsten, with some evidence for the steel. While one disadvantage of the technique is the relatively low flux of cosmic-ray muons, the team's simulations show that within only a minute they could detect a 10 cm cube of uranium in a large metal container full of sheep. The researchers conclude that the technique offers promise for the surveillance of commercial vehicles, cars and sea containers.

Further reading

K N Borozdin *et al.* 2003 *Nature* **422** 277.

New nano technique boosts microscopy



Two 2 μm square views of a carbon nanotube on a glass surface. One (left) was recorded using conventional optical microscopy, while the other was recorded with the near-field Raman technique, improving the resolution tenfold. (AIP Physics News Update.)

Single-walled nanotubes have become the focus of much interest thanks to their potential for nanotechnological applications. Now they have demonstrated the effectiveness of a new technique in high-resolution microscopy. Measuring below 50 nm with optical techniques has been a challenge, but researchers at Rochester, Portland State and Harvard have achieved just that with images of single-walled carbon nanotubes with a resolution of around 25 nm.

The team has extended the concept of "near-field optical microscopy" to develop "near-field Raman spectroscopy" in which a small probe – in this case a sharp 10–15 nm radius silver tip – is placed very close to a surface to enhance the Raman effect (the inelastic scattering of photons by molecules in the sample). The technique thus overcomes the diffraction limit, which in normal optical methods prevents details smaller than half the light's wavelength being clearly seen.

In the near-field Raman technique the researchers focus laser light on the sample close to the tip, which is kept only a few nanometres away from the surface. The field established at the tip increases the Raman scattering, and the scattered light can be collected to form an image as the tip is raster-scanned across the sample. The frequencies of the light also provide information on chemical composition and molecular structure.

The team has successfully produced images of individual carbon nanotubes with walls only a single atom thick. They now plan to determine structural details of carbon nanotubes, and hope to develop the technique to produce detailed pictures of proteins in cell membranes. Such images could offer hints for designing better drugs.

Further reading

A Hartschuh *et al.* 2003 *Phys. Rev. Lett.* **90** 095503-1.

Researchers reveal prime predictability

An interesting discovery may be imminent regarding whether prime numbers appear randomly in the sequence of whole numbers. It has not yet been shown that the occurrence of prime numbers – 2, 3, 5, 7, 11, 13, etc – follows a pattern, or that there is definitely no pattern. Now Pradeep Kumar and colleagues at Boston University have found that the increments in the distances between consecutive primes are not random, but have some rudimentary predictability. For the first few primes the distances are 1, 2, 2, 4 and 2 and the increments are +1, 0, +2 and −2.

The researchers find for example that positive values are almost every time followed by corresponding negative values. These studies, the researchers say, may have consequences for understanding patterns in nature that depend on prime numbers.

Further reading

Nature Science Update www.nature.com/nsu/030317/030317-13.html.

P Kumar, P C Ivanov and H E Stanley Information entropy and correlations in prime numbers http://xxx.lanl.gov/abs/cond-mat/0303110 (2003).

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ASTROWATCH

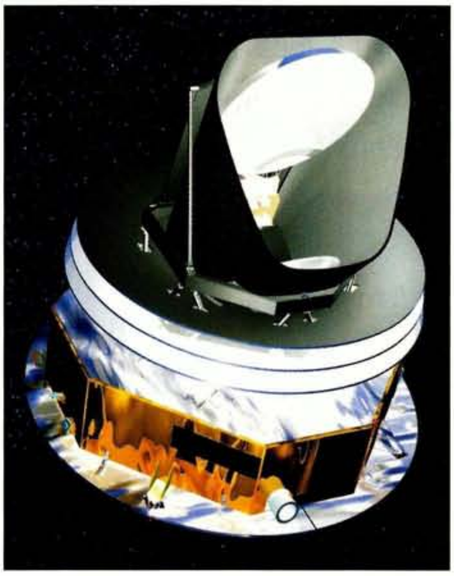
Edited by Marc Türler

Universe may end in a Big Rip

"Some say the world will end in fire, Some say in ice" wrote the poet Robert Frost in 1916. A third, even more fantastic possibility for the death of the universe has just been proposed. The acceleration of the expansion of the universe might eventually become so dramatic that in the foreseeable future galaxies, stars, planets and even atoms and nuclei are ripped apart.

The recent results of the Wilkinson Microwave Anisotropy Probe (WMAP) confirmed that the universe is mainly made of "dark energy" thought to be responsible for the current acceleration of its expansion (*CERN Courier* April 2003 p11). But what would happen if the rate of acceleration increased with time? A "Big Rip" is the answer according to Robert Caldwell, Marc Kamionkowski and Nevin Weinberg of Dartmouth University, New Hampshire. In this scenario, the acceleration of the expansion of the universe becomes infinite in finite time, finally overcoming all forces, including the nuclear force that binds the quarks in neutrons and protons together.

If and when this might happen depends on the equation-of-state parameter w describing the nature of dark energy, where $w = p/\rho$, the ratio of the spatially homogeneous dark energy pressure p to its energy density ρ. The simplest explanation of dark energy is a cosmological constant, in which case $w = -1$. Other possibilities are "quintessence" with $w > -1$ and "phantom energy" with $w < -1$.



Will the European Planck mission find evidence for the "cosmic doomsday" scenario of a Big Rip? (ESA.)

If dark energy is in the form of a cosmological constant or quintessence, the universe's expansion will accelerate, but at a constant or decreasing rate, respectively. This standard scenario of an ever-expanding universe would lead distant galaxies to disappear progressively behind the horizon of the universe (*CERN Courier* April 2002 p11). The anti-gravity force of such a kind of dark energy cannot disrupt galaxies. In the case of phantom energy, however, the force increases with time and becomes infinite in a finite time depending on the value of w. For $w = -1.5$ this might happen in only about 20 billion years.

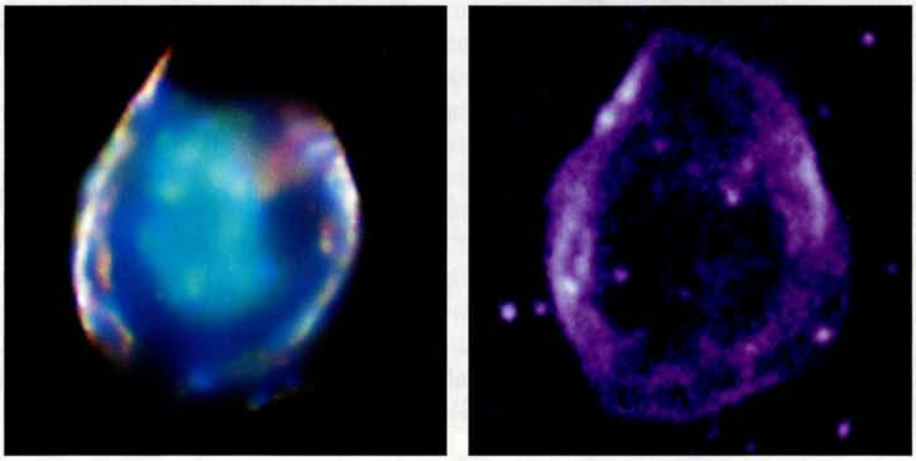
The countdown towards this Big Rip would be as follows: at 60 million years before the Big Rip, our galaxy is disrupted; at three months before, the solar system is unbound; at 30 minutes before, the Earth explodes; and at 10^{-19} seconds before, atoms dissociate.

This scenario cannot be excluded on the basis of observational constraints so far available. Current results from WMAP give only an upper limit of -0.78 for w, although its future observations may provide some additional constraints. Otherwise we will have to wait for the European Planck mission to be launched in 2007 to further constrain the nature of the dark energy that controls the ultimate fate of the universe.

Further reading

R Caldwell, M Kamionkowski and N Weinberg www.arxiv.org/abs/astro-ph/0302506.

Pictures of the month



The X-ray image (left) from NASA's Chandra satellite reveals many details of the supernova remnant DEM L71 located in the Large Magellanic Cloud some 180 000 light-years away. A hot inner cloud (light blue) is surrounded by an outer blast wave also visible in the optical image (right). The inner cloud is made of glowing iron and silicon at a temperature of 10 million degrees, suggesting that the star that exploded several thousand years ago was actually a white dwarf. Blowing apart these compact stars (typically the mass of the Sun for the size of the Earth) requires a gigantic thermonuclear explosion which arises when the white dwarf pulls too much material from a nearby companion star onto itself. These explosions are referred to as Type Ia supernovae to distinguish them from the more common Type II supernovae that end the life of massive stars. Because Type Ia supernovae have roughly the same luminosity, their detection in distant galaxies provided the first evidence in 1998 for the current acceleration of the expansion of the universe. (X-ray: NASA/CXC/Rutgers/J Hughes et al.; optical: Rutgers Fabry–Perot.)

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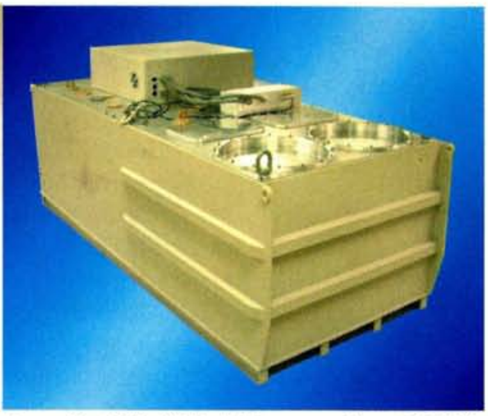

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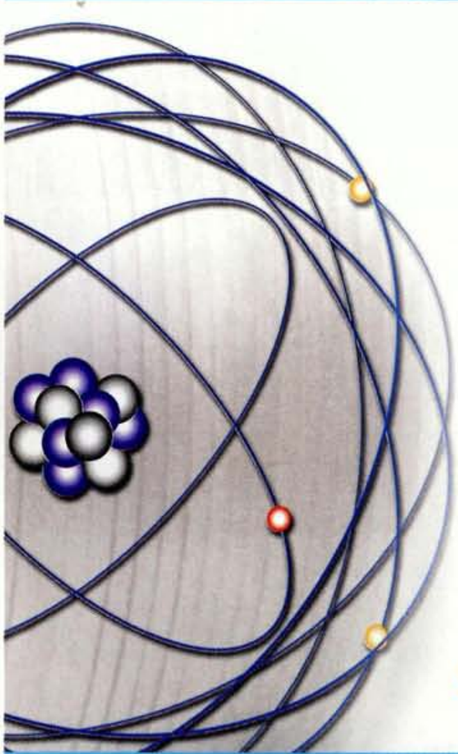

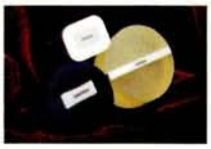

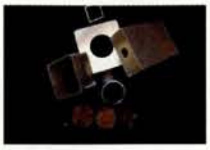

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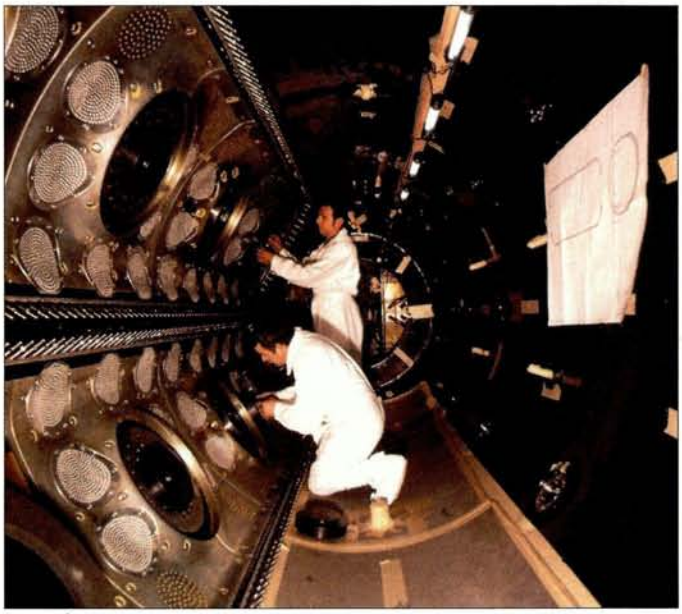
CERN and Saclay: 40 years of co-operation

The Saclay research centre opened its doors in 1952, just two years before CERN was founded. For much of the time since then, the two laboratories have enjoyed a fruitful collaboration, spanning the decades from the PS to the LHC.


The Gargamelle bubble chamber, which led to the discovery of neutral currents at CERN, was built at Saclay in the late 1960s.

The Saclay Research Centre near Paris is the largest of the French Atomic Energy Commission's research centres. Conceived from the start as a multi-purpose centre to bring together fundamental research and technical innovation, it has since expanded to explore many different aspects of nuclear physics and its applications, including, of course, particle physics. In 1963, when physicists from Saclay began experiments on the PS at CERN, it marked the start of a long and fruitful collaboration between the two laboratories. By the time the LHC is commissioned, this collaboration will have encompassed more than 30 different experiments, to which Saclay has brought its expertise in instrumentation, data acquisition and data analysis.

The bubble-chamber era

When researchers from Saclay first came to CERN in the 1960s, the majority of experiments in particle physics involved bubble chambers. Saclay was one of the pioneers of their construction and use at a number of accelerators: first Saturne at Saclay, then Nimrod – the Rutherford Laboratory's 8 GeV proton synchrotron – and then the PS at CERN and the 70 GeV accelerator at Serpukhov. The first series of experiments at the PS by physicists from Saclay's SPCHE (see "The early days of Saclay") involved the use of an 81 cm hydrogen bubble chamber. This was developed by the technical services at Saturne for the laboratory of the Ecole Polytechnique under the leadership of Bernard Gregory, who later became director-general of CERN. The chamber was used to study K^- p, K^- n, π^- p, π^+ n and $\bar{p}$-p scattering at energies of a few GeV, with the aim being to understand the collision mechanisms. The same theme was repeated, but at higher energies, in a second series of experiments at the PS on CERN's 2 m hydrogen bubble chamber.

The 1970s saw a further increase in collision energy, and bubble chambers became bigger and bigger in line with the increasing multiplicity and energy of the final particles. In 1971, André Lagarrigue led the construction of the Gargamelle bubble chamber at the Saturne laboratory. Exposed to the neutrino beam from CERN's PS, Gargamelle led to the discovery of neutral currents in 1973. This was followed by the Big European Bubble Chamber (BEBC) at the SPS, which involved energies approximately 10 times higher than at the PS. In addition to investigating strong interaction mechanisms and resonances, these experiments also explored neutrino–nucleon and antineutrino–nucleon scattering, the first stage in a better understanding of neutrino physics.

During its 30 years of bubble-chamber experiments, Saclay's DPhPE (Département de physique des particules élémentaires) – which the SPCHE had become in 1966 – built up strong teams, of around 150 people, that specialized in the scanning and measurement of images, before going on to develop automatic scanning techniques that allowed more than 10 million images to be analysed. As a result the DPhPE, together with CERN, had the greatest measurement and data-handling capacity of any European laboratory, and so was able to play a major role in the collaborations in which it participated. In developing bubble chambers, the DPhPE's technical services also acquired skills in the fields of magnetism, cryogenics and control systems, as well as experience in the design, construction and running of large projects. This expertise was to come in useful in the new generation of experiments at CERN in which the DPhPE took part.

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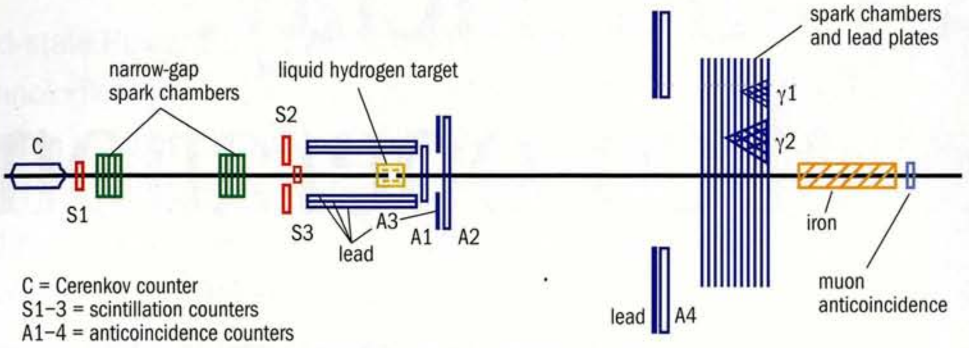
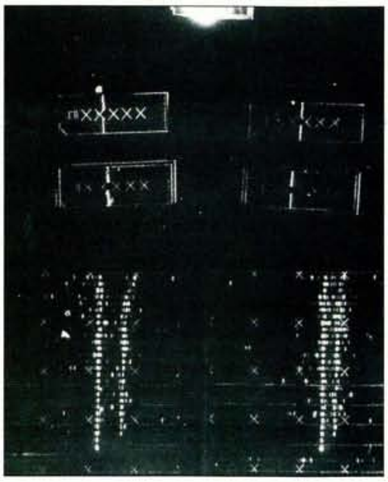
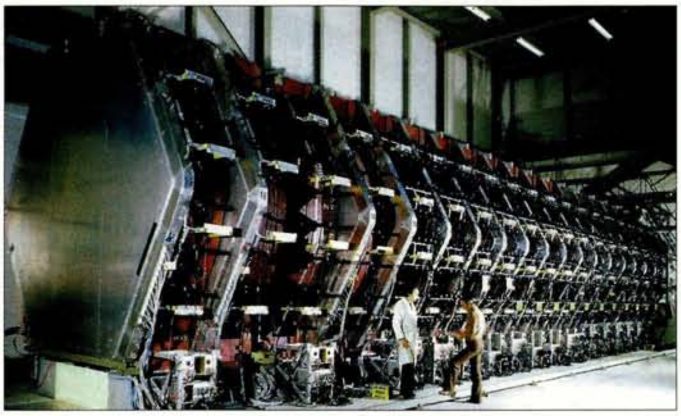
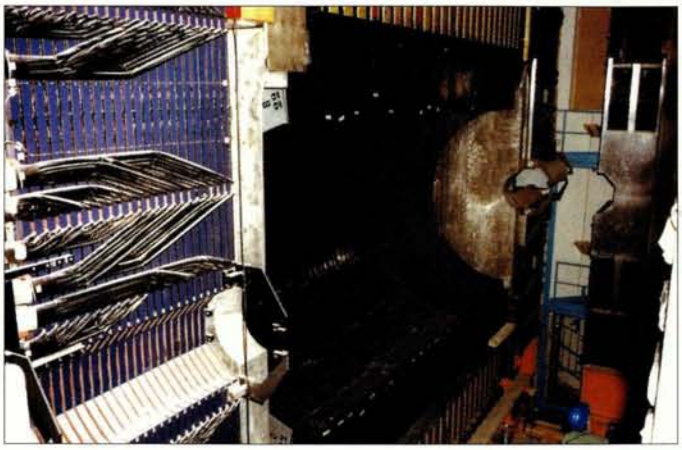




The layout of the first experiment with a spark chamber built by Saclay (left) on CERN's PS. The image on the right shows views from the top and side of a charge exchange event, $\pi^- p \rightarrow \pi^0 n$.



The CDHS experiment was designed to study deep inelastic neutrino scattering. The large hexagonal wire chambers seen here were built at Saclay.



The UA1 detector during construction, showing the electromagnetic calorimeter "gondolas" designed and built at Saclay.

The first electronic experiments

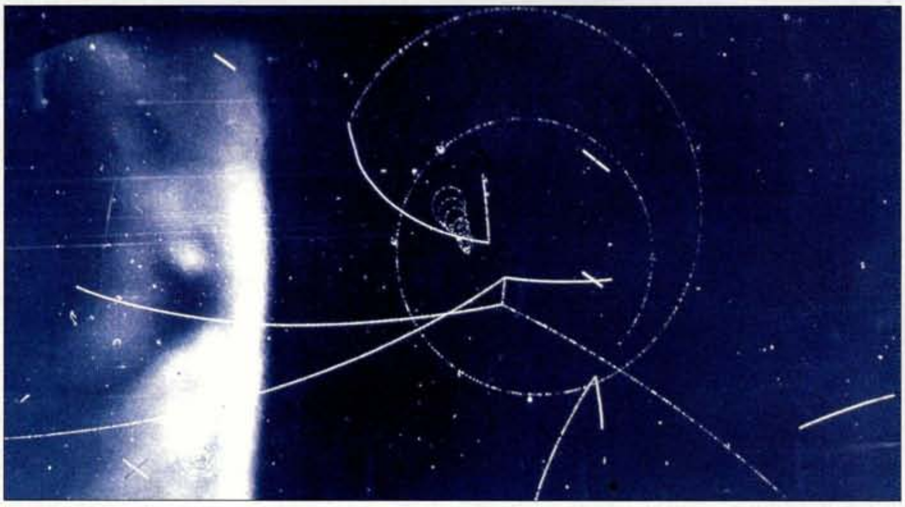
The spark chamber was invented at the beginning of the 1960s, and when used in conjunction with counters equipped with fast electronic read-out systems, it allowed events to be pre-selected – something that is impossible in bubble chambers. Spark chambers are also able to record signals much more quickly than bubble chambers, and their use became widespread in high-energy physics, marking the start of the "electronic" detector era. The SPCHE soon turned to this new technology. Its first electronic experiment at CERN, performed in 1964 by the team of Paul Falk-Vairant, involved the measurement of the high-energy charge exchange reaction $\pi^- p \rightarrow \pi^0 n$ at the PS, in an extension of an earlier experiment at Saturne. The equipment designed at the SPCHE consisted of scintillation counters and optical spark chambers to detect electromagnetic showers. Working first with a liquid hydrogen target, the experiment seemed to confirm the simple Regge pole theory favoured at the time; but when carried out with a polarised target, the results showed that a more complex interpretation was needed.

The DPhPE continued its extensive study of strong interaction mechanisms at the PS and also began to study strange particles following the 1964 demonstration of CP violation in the neutral kaon system, to which Réne Turlay, later a key figure at Saclay, contributed. In 1971, the start-up of the Intersecting Storage Rings (ISR) at CERN allowed matter to be explored at much higher energies, and physicists from the DPhPE took part in two experiments there. One of these was R702, whose purpose was to measure the production of particles with large transverse momentum, and whose results corroborated the theory of the granular structure of protons. In these early electronic experiments, the DPhPE contributed detector elements and the associated electronics commonly used at the time: scintillation counters for the trigger, Cerenkov counters for identifying particles, spark chambers for measuring trajectories, and polarised targets. The end of the 1960s saw the appearance of wire chambers for tracking, which were faster and more precise than spark chambers, and which allowed detectors to be built that were larger and easier to operate.

By 1977 when CERN's 200–400 GeV proton synchrotron, the SPS, was commissioned, the results from the previous 15 years had changed the perception of particle physics. In particular, the discoveries of neutral currents at Gargamelle in 1973 and of charmed particles in 1974 represented an initial experimental validation of the Glashow–Weinberg–Salam theory of the electroweak force and of quantum chromodynamics (QCD), the theory of strong interaction. The various experiments at the SPS set out to test these theories in more depth. The DPhPE played an active role, taking part in the deep inelastic scattering experiments with neutrinos (CDHS) and muons (BCDMS), as well as experiments in hadroproduction (WA11, NA3) and photoproduction (NA14). These brought a large

The early days of Saclay

The French Atomic Energy Commission (CEA) was created in 1945 on the orders of General de Gaulle, with the aim of harnessing nuclear energy in the areas of research, energy and defence. The first laboratory, led by Frédérick Joliot, was set up in the Châtillon fort near Paris, and the first nuclear reactor, Zoé, was built there and commissioned in 1948. The decision to build the Saclay nuclear research centre, which was to bring together fundamental and applied research, was taken in 1947. It was to house, in particular, a nuclear physics service firmly grounded in fundamental research and led by André Berthelot.



In this image from the Saclay 81 cm bubble chamber, an antiproton (lower of tracks to left) comes in and annihilates with a proton in the liquid, $p\bar{p}\rightarrow K^0K^-\pi^0$. The K^0 moves up the page and decays to $\pi^-\pi^+$; the $\pi^+\rightarrow\mu^+\rightarrow e^+$ decay creates the big spiral track.

The Saclay centre opened in 1952, and the following year it provided nuclear physicists with a 5 MeV Van de Graaff accelerator, followed in 1954 by a 25 MeV cyclotron. In the same period, the CEA installed a betatron at Villejuif near Paris, thus opening the way for electron and photon physics. Once his service had realised its full potential in nuclear physics, Berthelot sensed the advantages of higher energy physics of the kind already underway in the US at the time. In 1955 he played a crucial role in the decision to build a 3 GeV proton synchrotron at Saclay – known as Saturne – which was commissioned in 1958.

In the meantime, Berthelot set up a group within the nuclear physics service to prepare experiments on the future accelerator. The first heavy liquid and liquid hydrogen bubble chambers were built, the latest spark chamber technology – scintillation detectors or Cerenkov counters coupled with electronic devices – were used, and powerful electromagnets for the beams or bubble chambers were developed. In 1958 this group became a CEA service in its own right, known as the SPCHE (Service de physique corpusculaire à haute énergie), comprising around 100 people. Everything was then in place for the experiments at Saturne, as well as for the subsequent experiments at the higher energy accelerators, such as CERN's 28 GeV proton synchrotron, the PS. In 1966 the SPCHE became the DPhPE (Département de physique des particules élémentaires), which in turn became DAPNIA (Département d'astrophysique, de physique des particules, de physique nucléaire et de l'instrumentation associée) in 1991.

haul of results to which the DPhPE's physicists made significant contributions: measurement of nucleon structure functions, confirmation of violations of the scale-invariance predicted by QCD, precise measurements of $\sin^2\theta_W$ and α_s, and charm studies.

DPhPE built proportional chambers or drift chambers of various sizes and geometries for all of these experiments at the SPS. Given the large number of wire chambers that were needed, the assembly lines the laboratory had at that time were a valuable asset. In particular, large 4 m sided hexagonal chambers were designed for the CDHS, and were subsequently used in numerous detector tests under beam conditions before being integrated in the recent CHORUS experiment. The DPhPE also built its first large-scale calorimeter for the NA3 experiment. Comprising lead plates and scintillating tiles, its size (5 m × 2 m) necessitated the development of a new low-cost type of scintillator with a high attenuation length. Again the skills acquired through participation in these projects were put to good use in the next generation of experiments.

In the 1980s, CERN took the major step of converting its SPS into a 540 GeV proton–antiproton collider, which later ran at 630 GeV. Commissioned in 1981, the Sp$\bar{p}$S and its two general-purpose experiments, UA1 and UA2, led to the discovery of the $W^\pm$ and Z bosons, bringing resounding proof of the Glashow–Weinberg–Salam model for electroweak interactions (see p26). The DPhPE took part in both experiments, contributing not only through technical achievements but also in obtaining physics results, in particular regarding the $W^\pm$ and Z bosons, jets, and the search for the top quark. Building on its experience with NA3, the DPhPE became involved in calorimetry in both UA1 and UA2, with lead-sandwich electromagnetic calorimeters and scintillators for the UA1 and UA2 endcaps, followed by scintillating optical fibre detectors for the fibre tracker for the second phase of UA2. The scintillator "gondolas" of the UA1 calorimeter, a key component in identifying and reconstructing the decays of the $W^\pm$ and Z bosons based on electron decay, were one of the DPhPE's most significant achievements in terms of the specific developments and equipment needed, including the development of a new extruded polystyrene scintillator that allowed large thin leaves of uniform thickness to be made.

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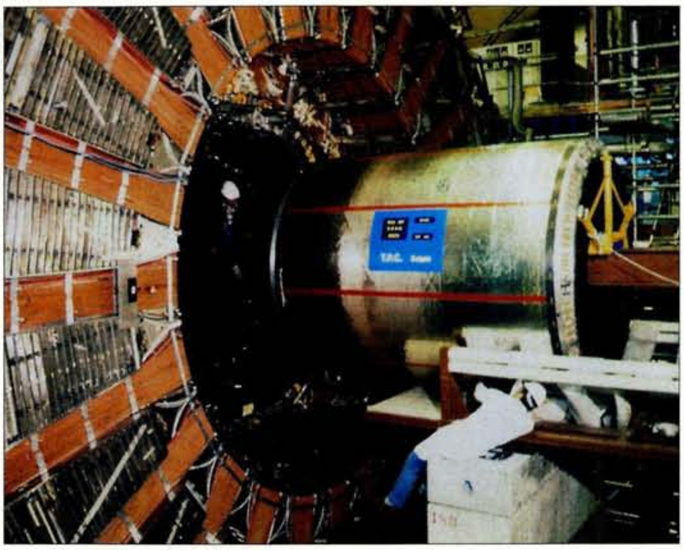
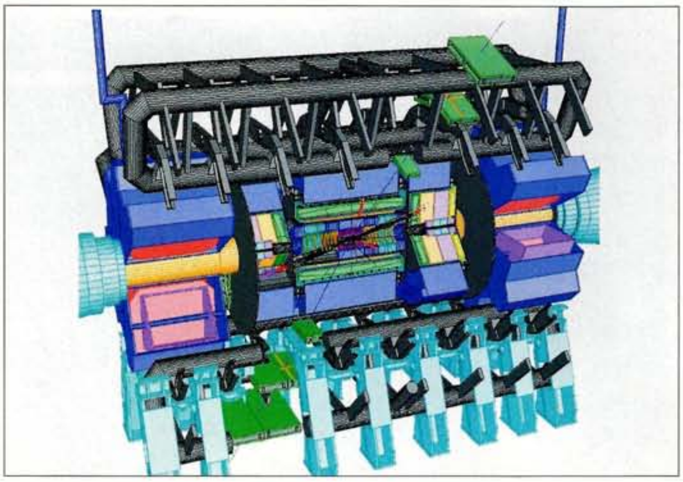


The TPC for DELPHI, seen here during installation, was built by Saclay in collaboration with the laboratories of the CNRS.



A schematic of the entire ATLAS detector, superimposed with a Higgs decay event. The software to reconstruct and display the muons, seen exiting at the top and bottom, has been developed by the group at DAPNIA.

The LEP era

The DPhPE was involved in LEP right from the outset, and participated in the ALEPH, DELPHI and OPAL experiments. In ALEPH, the contributions involved the superconducting solenoid – which was 5 m in diameter, 7 m long, with a field of 1.5 T – the lead-sandwich electromagnetic calorimeter that incorporated proportional tubes, and the silicon-tungsten luminosity calorimeter. For DELPHI, the DPhPE was involved with the tracker – a time projection chamber – and its associated data acquisition and read-out electronics. For OPAL, the contributions included the scintillator hodoscope for time-of-flight measurement and general trigger electronics. The 12 years of data taking at LEP contributed in many essential ways to refining the Standard Model. Physicists from DAPNIA, which the DPhPE became in 1991, were involved in this progress, taking part in, for example, beauty studies, the accurate measurement of the W boson mass, and the search for the Higgs boson and supersymmetric particles.

At the end of the 1980s, as the experiments at LEP progressed, the fixed-target programme began to focus again on the subjects for which this kind of experiment is still the most suited. The DPhPE decided to be involved in four experiments, namely CP violation in the neutral-kaon system (CP LEAR, then NA48), nucleon spin structure (NMC, SMC, then COMPASS), neutrino oscillation (NOMAD) and quark–gluon plasma (NA34). While most of these experiments have been completed, NA48 and COMPASS are still taking data.

Into the 21st century

Chambers are still the dominant instrument in particle physics but technologies have evolved, resulting for example in the "micromégas" (micromesh gaseous structure) chambers, which are able to absorb particle fluxes 1000 times more intense than conventional chambers, and which are also faster and more accurate. Developed by the DPhPE, together with the necessary state-of-the-art electronics, these chambers are used in COMPASS and have recently been adopted by the CAST experiment.

At the same time, the make-up of the Saclay teams has also evolved. The particle physicists no longer have a monopoly on experiments at CERN. They have been joined by teams of nuclear physicists from DAPNIA, studying the structure of the nucleus in the SMC and COMPASS experiments, for example, and in the neutron time-of-flight programme (nTOF). The future of the fixed-target programme at CERN also concerns DAPNIA, whose physicists and engineers are contributing to the proposal for a future Superconducting Proton Linac (SPL) accelerator complex at CERN, and to the design of experiments that would use the SPL's intense neutrino beams for the study of CP violation in the lepton sector (*CERN Courier* July/August 2001 p6).

From LEP to the LHC

CERN's latest machine, the Large Hadron Collider (LHC), will open up a new high-energy domain, and its experiments should clarify the precise nature of the electroweak symmetry breaking mechanism once and for all. DAPNIA is investing heavily in this future, with its particle physicists taking part in the ATLAS and CMS experiments and its nuclear physicists participating in ALICE. It is also involved in designing and monitoring the manufacture of the quadrupoles for the machine itself. Participation in ATLAS involves the design of the superconducting air-cored toroid magnet system, and the construction of the central electromagnetic liquid argon calorimeter. Involvement in CMS covers the on-line calibration system for the crystal electromagnetic calorimeter, which is based on the injection of laser light, as well as the general design and monitoring of certain components of the experiment's superconducting solenoid magnet, which is 6 m in diameter, 12.5 m long, and has a field of 4 T. In ALICE, DAPNIA is contributing the design and production of the wire chambers for the muon spectrometer. Muons, electrons and photons are all hints of the signals that these experiments hope to discover or measure, whether it be the Higgs boson at ATLAS and CMS, or the quark–gluon plasma at ALICE. What more promising subjects for the continuation of the 40 year long co-operation between Saclay and CERN could one hope for?

Vanina Ruhlmann-Kleider, **Monique Neveu** *and*
Serge Palanque, *DAPNIA, Saclay.*

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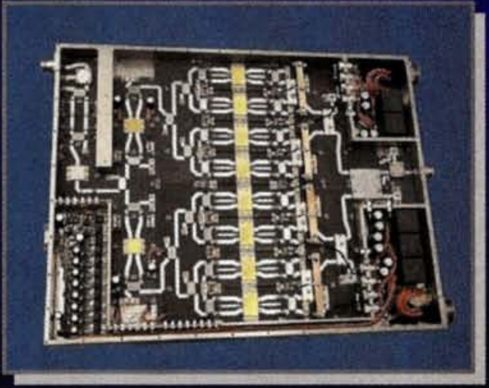

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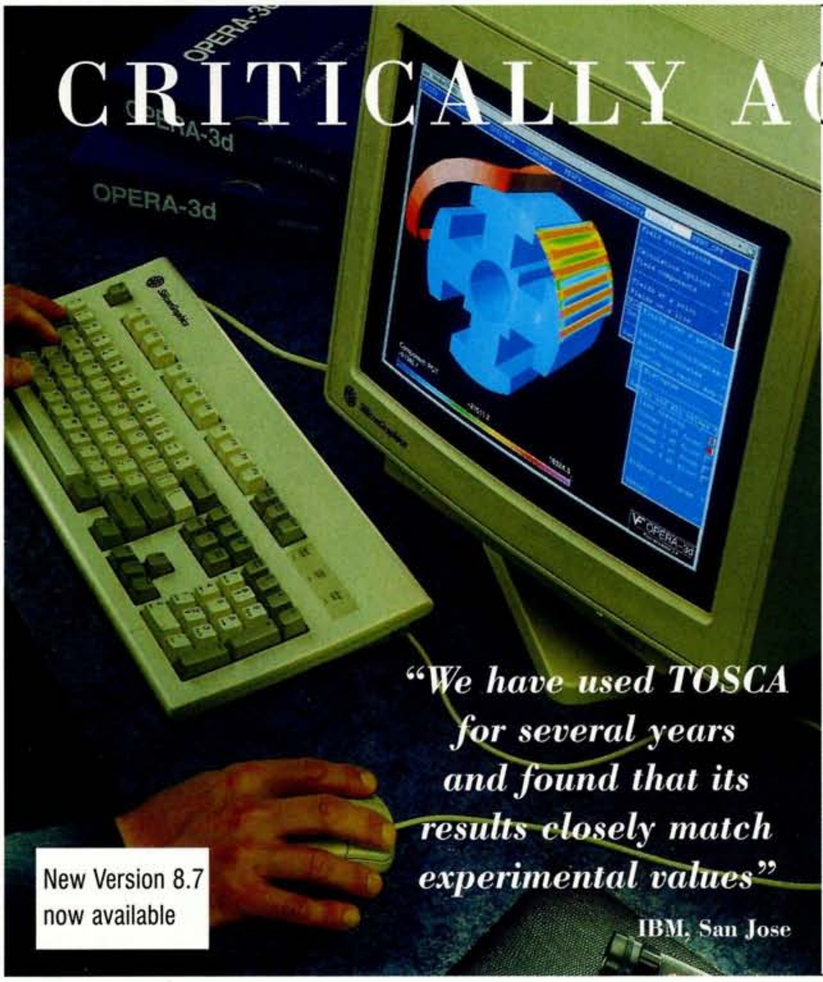

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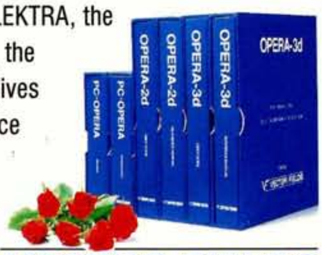

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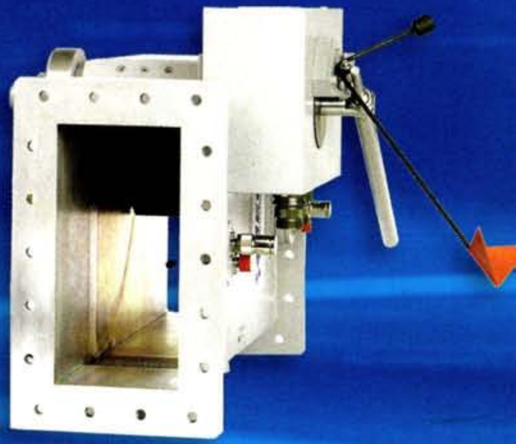

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MACRO delivers its final word on monopoles

The MACRO experiment searched for magnetic monopoles throughout the 1990s. It found none but set stringent limits.

The MACRO detector at the Gran Sasso Underground Laboratory during the construction phase (left) and when completed (right).

MACRO, the Monopole, Astrophysics and Cosmic Ray Observatory detector, ceased operation two years ago. As its name makes clear, one of MACRO's main aims was to search for magnetic monopoles, and recently the MACRO collaboration published the final results of their direct monopole search. It found none, but set the most stringent upper limits on their existence so far, and at the same time set upper limits on nuclearites.

MACRO was located in Hall B of the Gran Sasso Underground Laboratory, under about 1400 m of rock, which reduced the cosmic ray flux to about 1 muon per square metre per hour, or about one million times less than the flux at the Earth's surface. The detector had a modular structure, with a total volume of $76.5 \times 12 \times 9.3\ \mathrm{m}^3$ and a total acceptance of about $10\,000\ \mathrm{m}^2$ sr. It used three types of subdetectors – liquid scintillation counters, limited streamer tubes and nuclear track detectors – and was operational from 1989 until the end of 2000.

The magnetic monopole is a hypothetical particle with a single magnetic charge. Classically, such particles are expected in analogy with electrically charged particles, and in order to symmetrize Maxwell's equations. However, experiments indicate that in nature magnetic effects are due only to magnetic dipoles, which are created by moving electric charges.

Nevertheless, in 1931, while attempting to find a theoretical motivation for the quantization of electric charge, Paul Dirac found a relationship that quantizes the product of a basic electric charge e, times a basic magnetic charge g – namely, $eg/c = nh/4\pi$, with $n = 1, 2, 3,...$. In this case, the quantization of electric charge follows from the existence of a magnetic charge. Moreover, if the basic electric charge is that of the electron, in the symmetric cgs system of units, then the basic magnetic charge is $g = 68.5e$. This is a large value, and it introduces a numerical asymmetry between electric and magnetic phenomena; it also leads to a large magnetic coupling constant. Such "classical Dirac magnetic monopoles" have been searched for at every new higher energy accelerator, but without success.

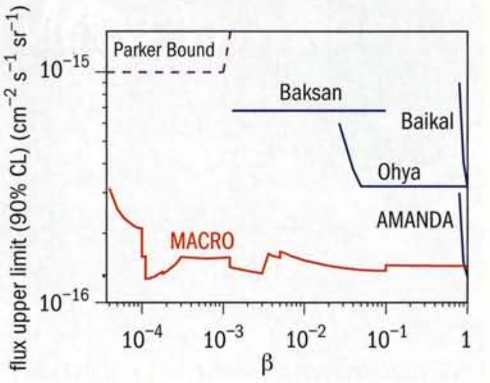
During the 1970s, monopoles appeared on the scene again, when theorists found that electric charge is naturally quantized in gauge theories that unify the strong and the electroweak interactions (GUTs). These theories require magnetic monopoles of very large mass, $\sim 10^{17}$ GeV. Such a mass cannot be produced at any of our accelerators, existing or planned, but the heavy monopoles could have been produced in the early universe, and could still exist as relic particles in the penetrating cosmic radiation.

MACRO searched for superheavy magnetic monopoles using its three types of subdetectors, either on a stand-alone basis or in combination. It also used different and redundant electronics, which allowed searches in different velocity ranges, cross checks and background studies. No candidate monopole was found, with an upper limit at the 90% confidence level of a flux level of ▷

1.4×10^{-16} cm^{-2} s^{-1} sr^{-1} for monopoles with velocity between 4×10^{-5} c to c and magnetic charge with $n \geq 1$ (Ambrosio *et al.* 2002a). Some indirect searches may yield stronger limits, but only after making several hypotheses that can't be checked.

The GUT monopole is a complicated object with a very small core and different surrounding regions. If a proton were to hit a monopole core it would catalyse the decay of the proton ($Mp \rightarrow Me^{+}\pi^{0}$). Because of the smallness of the monopole's core this should be a very rare phenomenon, but if there are baryon number violating terms in the four-fermion virtual condensate around a GUT monopole of up to 1 fm radius, the cross-section could be large and the phenomenon could be observed. MACRO made a dedicated search for this using the streamer tube system and looking for a fast track originating from a slow ($10^{-4} < \beta < 10^{-3}$) incoming particle – the possible monopole. The search excluded large cross-sections and again obtained the best existing limits (Ambrosio *et al.* 2002b).

As a by-product of these searches for magnetic monopoles, MACRO has also set stringent limits for other exotica, in particular nuclearites. Nuclearites (strangelets or strange quark matter) should consist of aggregates of *u*, *d* and *s* quarks. They would be colour singlets and could be the ground state of QCD. The overall electrical neutrality of strange quark matter would be insured by an electron cloud. Nuclearites could have been produced shortly after the Big Bang, at around the hadronization time, and may have survived as remnants to form part of the cold dark matter. When hitting the Earth with typical galactic velocities ($\beta \sim 10^{-3}$) they would not ionize, but excite atoms and molecules along their trajectories and should be easily detected in scintillators and nuclear track detectors. MACRO established upper limits at the level of 1.4×10^{-16} cm^{-2} s^{-1} sr^{-1}. Nuclearites, like magnetic monopoles, could exist at lower levels than we can at present detect, if indeed they exist at all.



The 90% confidence level global MACRO direct upper limit for GUT monopoles with one unit Dirac charge, compared with previous direct limits and the Parker astrophysical bound.

Further reading

M Ambrosio *et al.* 2002a *Eur. Phys. J.* **C25** 511.
M Ambrosio *et al.* 2002b *Eur. Phys. J.* **C26** 163.

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Hadronic interactions in Slovakia

The Hadron Structure 2002 conference covered topics ranging from spin studies to relativistic nuclear physics, as **Dusan Bruncko** and **Jozef Urbán** report.

Participants at the Hadron Structure 2002 conference, which was held in Herľany, pose for the traditional conference photo.

The old spa area of Herľany in Slovakia welcomed more than 50 physicists from over 30 countries last September for the 2002 Hadron Structure conference, which took place in the Educational Centre of the Technical University. The area is famous for its cold-water geyser, which is unique in Europe, and which did not disappoint as it erupted four times during the conference. Nor did the conference itself disappoint, with its mix of theoretical talks and experimental reviews.

The Hadron Structure conferences, which have become one of the major events in the Slovak high-energy physics community, are based on a tradition of more than 30 years. The origins of the conferences can be traced back to the late 1960s, when informal meetings of theoreticians from Bratislava, Budapest and Vienna – the so-called Triangle Meetings – were organized three to six times a year and moved between the different locations. The meetings held in Slovakia were called the Hadron Structure meetings and they gradually developed into a series of conferences.

Although the Triangle Meetings were predominantly devoted to theoretical topics, at Hadron Structure 2002 the theoretical reports were balanced by impressive experimental review talks. The following is only a brief report of the scientific programme, which involved a wide range of high- and medium-energy particle physics and heavy-ion physics.

The LEP experiments presented reports on W boson physics, Higgs boson mass limits, and on the searches for neutralinos and large extra dimensions, as well as electroweak, heavy flavour and QCD measurements at LEP. The results are in good agreement with the Standard Model expectations. The H1 and ZEUS experiments at HERA reviewed results on proton structure functions, inclusive diffraction measurements, open charm and beauty, as well as ▷

vector meson production. The beauty results seem in general to be above perturbative QCD predictions. Recent spin physics results from HERMES, as well as the latest results from the HERA-B experiment, were also presented.

In B physics, the two dedicated spectrometers BaBar and Belle presented their results on CP violation in B^0 decays, the B^0 lifetime and branching fractions. Their measurements of the unitary triangle angle β are found to be consistent with the expectations of the Standard Model and can be used to constrain extensions of the model.

Moving on to heavy-ion collisions at RHIC, in Brookhaven, the STAR collaboration reported results on transverse momentum distributions, hadronic yields and correlations. The azimuthal correlations at moderately high transverse momenta demonstrate the existence of hard scattering processes at RHIC, while the disappearance of di-jets and the suppression of single inclusive particle production are consistent with the jet-quenching scenario. PHENIX presented results on high-p_t charged-particle azimuthal correlations, which may indicate a novel particle production mechanism.

In relativistic nuclear physics, selected problems studied at the Veksler and Baldin Laboratory of High Energies at JINR, Dubna, were reported. These studies make use of the Synchrofasotron Nuclotron acceleration system. A plan to upgrade the Nuclotron and organize a user centre for relativistic nuclear physics and applied research with ions of a few GeV energy is foreseen.

Two review talks at the conference were presented on behalf of the ATLAS collaboration. One of these concerned the overall detector concept, the status of the subsystems and the magnet. The second talk was an overview of the ATLAS physics potential for searches at the LHC for the Higgs boson(s), supersymmetric particles, quark and lepton compositeness, new gauge bosons and extra dimensions.

The conference was organized by the Nuclear Physics Department in the Faculty of Sciences at P J Šafárik University in Košice, in association with the Department of Subnuclear Physics, Institute of Experimental Physics, Slovak Academy of Sciences, Košice, the Physics Institute, Slovak Academy of Sciences, Bratislava, the Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, and the Physics Department, Faculty of Electrical Engineering and Informatics, Technical University, Košice.

Further reading

The conference proceedings will be published, and when available the details will be found on the conference website at http://hep.science.upjs.sk/~hs02/.

Dusan Bruncko, *Department of Subnuclear Physics, Institute of Experimental Physics, Slovak Academy of Science, Košice, and* **Jozef Urbán**, *P J Šafárik University, Košice.*

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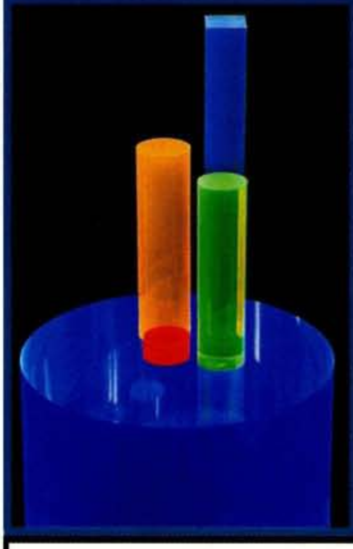

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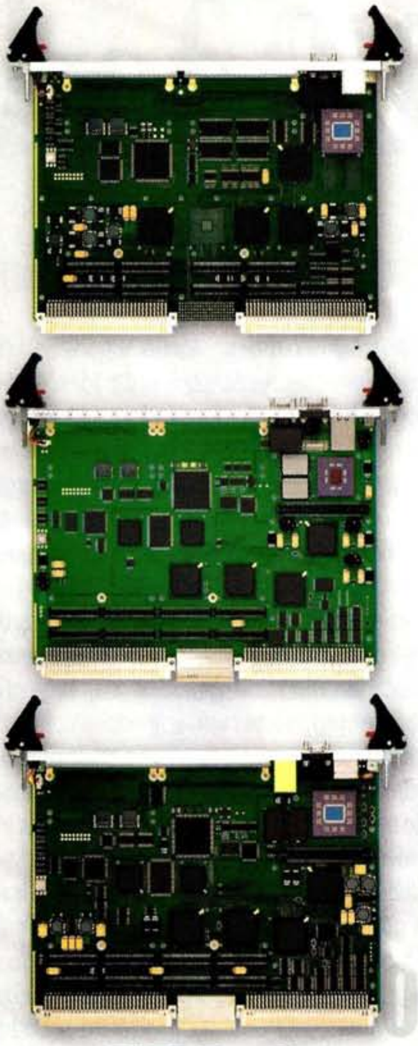

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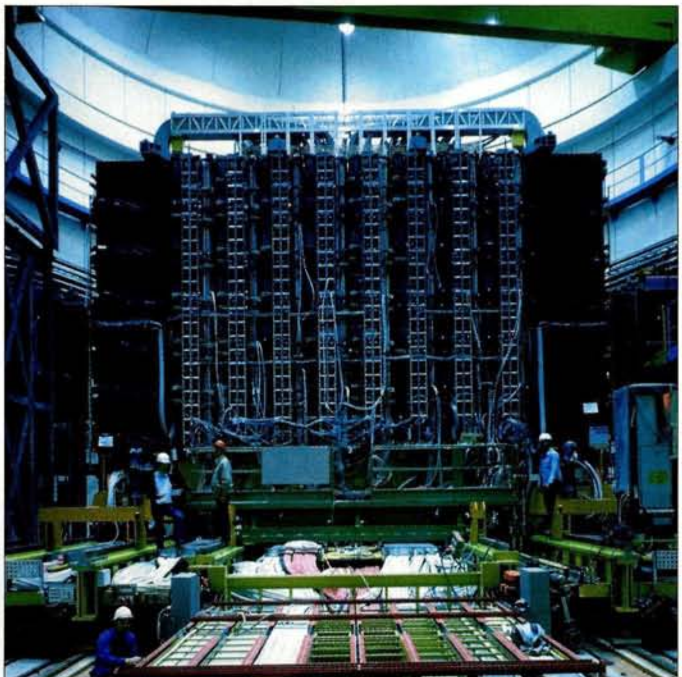
When CERN saw the

The W and Z particles were first observed at CERN 20 years ago by the UA1 and UA2

The Antiproton Accumulator, seen here in October 1980, was essential for providing the antiproton beam in the SPS.



The UA1 was a huge and complex detector for its day. It was designed as a general-purpose detector.

In 1966/7 Steven Weinberg, Abdus Salam and John Ward proposed a local gauge theory, $SU(2) \times U(1)$, for a unified description of electromagnetic and weak interactions, with a Higgs mechanism to give mass to the (weak) field quanta. When I arrived as a student at Johns Hopkins University in 1966, Ward was a professor there. I could understand that something exciting was going on from the discussions at the physics seminars, but could not appreciate the importance it would subsequently acquire.

The most striking feature of the weak interactions is their very short range of less than around 10^{-15} cm, i.e. less than 1% of the size of a nucleon. This is compared with a range of around 10^{-13} cm for nuclear (strong) forces, and is in stark contrast to the "infinite" range of the electromagnetic force. The short range of the weak interactions implied very massive mediating particles or quanta, W^+ and W^-, for the charged current, the only known weak interactions at the time. However, the unified description of Weinberg, Salam and Ward had four field quanta, two charged and two neutral, implying that a new type of "neutral current" weak interaction should exist. This would be mediated by the Z^0 – a particle that is closely related to the massless photon, in fact it is almost identical except for being very massive. The renormalizability of the theory, shown in 1971 by Gerard 't Hooft and Martin Veltman, and by the discovery of the weak neutral currents at CERN in 1973, made this unified electroweak scheme appear plausible. But what could the mass of the W and Z particles be?

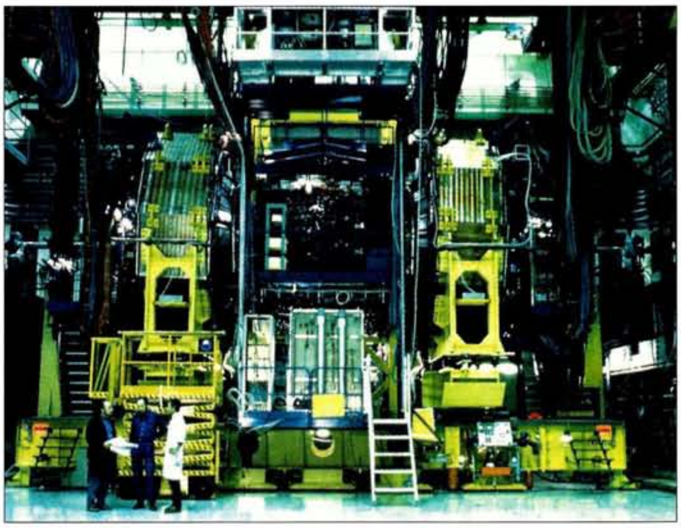
Where and how?

The observed linear increase of the neutrino–nucleus cross-sections with incident energy up to $E_\nu \sim 350$ GeV, which was consistent with the (old) Fermi four-fermion point interaction, could not last forever. At a neutrino–nucleon (or rather, neutrino–quark) centre-of-mass energy of the order of 300 GeV the cross-section would reach the S-wave unitarity limit, so the effects of W-exchange had to come in, in order to modify this unacceptable behaviour. The non-deviation from linearity in the measured cross-section indicated $m_W > 50$ GeV, and was consistent with infinite m_W. Meanwhile, the charged current and neutral current data from neutrino interactions, when incorporated into the Weinberg–Salam–Ward scheme, were giving a weak mixing angle $\sin^2\theta_w \sim 0.3–0.6$, which implied $m_{W,Z} \sim 60–100$ GeV. Subsequently, measurements of $\sin^2\theta_w$ narrowed its value down to around 0.23, providing by 1982/3 a much better estimate of $m_W \sim 80$ GeV and $m_Z \sim 90$ GeV to within a few GeV. In the late 1970s and early 1980s the forward–backward angular asymmetry, due to γ–Z interference, in $e^+e^- \rightarrow \mu^+\mu^-$ at the top PETRA energies ($\sqrt{s} \sim 30–40$ GeV) also indicated $m_Z < 100$ GeV rather than an infinite m_Z. So, the question was where could these W and Z intermediate vector bosons be produced and how could they be detected?

end of the alphabet

experiments. Daniel Denegri, who worked with UA1, recollects the spirit of discovery at the time.

In 1976 CERN's SPS began operating with particle beams of energies up to 350–400 GeV onto a fixed target, i.e. with centre-of-mass energies of $\sqrt{s} \sim 30$ GeV, which was insufficient for W and Z production. The same year David Cline, Carlo Rubbia and Peter McIntyre proposed transforming the SPS into a proton–antiproton collider, with proton and antiproton beams counter-rotating in the same beam pipe to collide head-on. This would yield centre-of-mass energies in the 500–700 GeV range. Provided the antiproton intensity was sufficient, the W and Z particles could be produced through their couplings to quarks and antiquarks, and detected through their couplings to leptons as prescribed by the Weinberg–Salam–Ward model. Then, in 1979, Weinberg, Salam and Sheldon Glashow were awarded the Nobel prize for electroweak unification and the prediction of weak neutral interactions, which implied the existence of the Z particle. (Ward was no doubt of the same class, but the Nobel prize can only be awarded to three people at most.) This indicated that the theoretical community was more convinced of the existence of the W and Z than most of the experimentalists at the time.



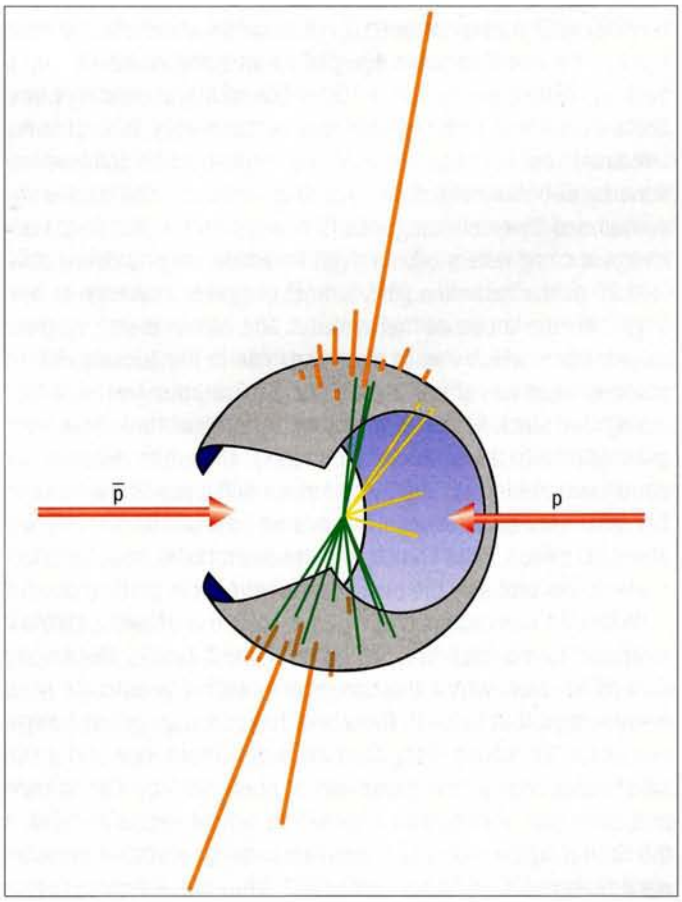
The UA2 detector, which had a more focused design, was more compact than the UA1 detector.

The proton–antiproton collider

CERN meanwhile went ahead with the proton–antiproton collider, and by the summer of 1981 the heroic endeavour of transforming the SPS into a proton–antiproton collider had been accomplished, despite the many uncertainties, including unknown unpredictable beam–beam effects. There is no doubt that Carlo Rubbia, with his enthusiasm, power of conviction and charisma, played a key role in this phase of the project. The first proton–antiproton collisions occurred on 9 July 1981, almost exactly three years since the project had been officially approved. Within hours, the first events that had been seen, detected and reconstructed in UA1's central tracker were shown by Rubbia at the Lisbon conference (UA1 collaboration 1981).

The PS proton beam at 26 GeV was used on a fixed target to produce antiprotons at ~3.5 GeV, creating about one antiproton per 10^6 incident protons. The antiprotons were then stacked and stochastically cooled in the antiproton accumulator at 3.5 GeV, and this is where the expertise of Simon Van der Meer and coworkers played a decisive role. With a few times 10^{11} antiprotons accumulated per day, the cooled (phase-space compactified) antiprotons were reinjected into the PS, accelerated to 26 GeV and injected into the SPS, counter-rotating in the same beam pipe with a proton beam. Both beams were then accelerated to 270 GeV and brought into collision in two interaction regions at $\sqrt{s} = 540$ GeV. Sufficient luminosity remained for about half a day. The initial luminosity in November/December 1981 was about $10^{25}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, but subsequently increased by a factor of 10^5 over the following years.

The UA1 (Underground Area 1) detector was conceived and ▷



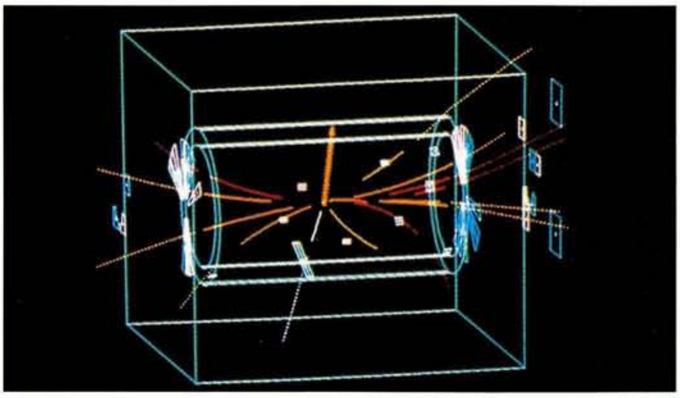
A spectacular, early two-jet event in the UA2 detector.

designed in 1978/9, with the proposal submitted in mid-1978. At that time we were in barracks on the parking lot in front of building 168, at the same time and place that CDF was designed, for Alvin Tollestrup was spending a year at CERN. UA1 was approved in 1979, and was constructed and essentially functional – including the reconstruction software – by the summer of 1981 (although part of the tracker electronics was still missing). At the time of approval there was a general incredulity in the particle physics community (although not obviously in UA1) that UA1 could be built – and even less operated – in time when compared with the much more focused design and modest size of the UA2 detector. That this was possible was largely thanks to Rubbia's enlightened absolutism (or more diplomatically to his unrelenting efforts), and to his unbelievable intellectual and professional capabilities and stamina.

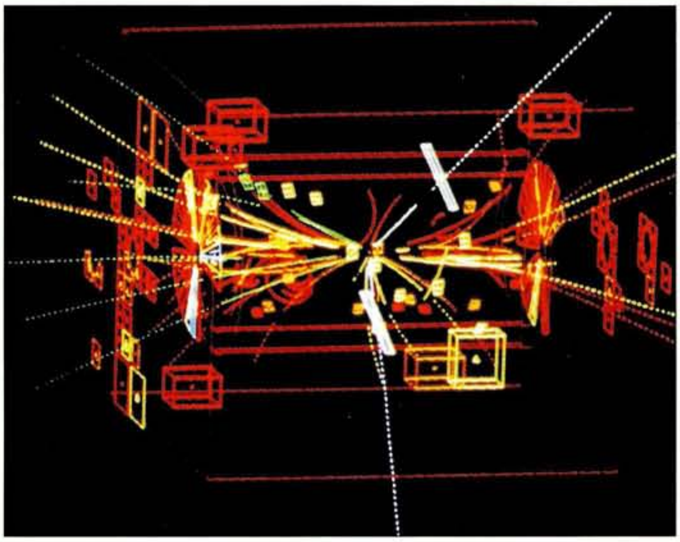
The two detectors

UA1 was a huge (~10 × 6 × 6 m^3, ~2000 tonnes) and extremely complex detector for its day, exceeding any other collider detector by far. The design was simple, beautiful, economical and, as it turned out, very successful. In the days of initial construction, the collaboration counted around 130 physicists from Aachen, Annecy, Birmingham, CERN, College de France, Helsinki, London/QMC, UCLA–Riverside, Rome, Rutherford, Saclay and Vienna. There was a large, normally conducting dipole magnet with a field of 7 kG perpendicular to the beamline. The collision region was surrounded by a central tracker – a 5.8 m long, 2.3 m diameter drift chamber with 6176 sensitive wires organized in horizontal and vertical planes. Tracks were sampled about every centimetre and could have up to 180 hits, with a resolution of 100–300 μm in the bending plane. This detector was at the cutting edge of technology; it was the first "electronic bubble chamber" and the reconstruction software was done by ex-bubble chamber track reconstructors. The tracker was surrounded by electromagnetic (27 radiation lengths deep) and hadronic calorimeters (about 4.5 interaction lengths deep) down to 0.2° to the beamline. This almost complete coverage in solid angle became known as "hermeticity". The central electromagnetic calorimeter – which was to play a key role in the subsequent discoveries – was very effectively and economically designed as a lead-scintillator stack in the form of two cylindrical half-shells each subdivided into 24 elements (gondolas). The entire detector was doubly surrounded by ~800 m^2 of muon drift chambers with a spatial resolution of ~300 μm. The overall cost of the detector was about 30 million Swiss Francs, and the central ECAL about 3 million – which was probably the best ever investment in particle physics.

While UA1 was designed as a general-purpose detector, UA2 was optimized for the detection of $e^\pm$ from W and Z decays. The emphasis was on calorimetry with a spherical projective geometry – much simpler than that in UA1. There was full coverage in solid angle, except for 20° cones along the beamlines. There were about 500 calorimeter cells with a granularity of about 10° by 15° in polar and azimuthal angles, with a three-fold segmentation in depth in the central region (40–140°) and two-fold segmentation in the forward regions (20–40° and 140–160°) to allow electron–hadron separation. The central calorimetry was, in total, about 4.5 interaction lengths deep, while the forward one was about 1 interaction length (two sections of 18 and six radiation lengths). There was no central magnetic field, but the two forward regions were equipped with magnetic spectrometers (two sets of 12 toroid coils). In the central part there was a vertex detector made of coaxial drift and proportional chambers to detect charged tracks and the collision vertex. Preshower counters improved electron identification through the spatial matching of tracks and clusters. The collaboration counted about 60 physicists, with groups from Bern, CERN, Copenhagen, Orsay, Pavia and Saclay.



The decay of a W particle in the UA1 detector, showing the track of the high-energy electron towards the bottom. The yellow arrow marks the direction of the missing transverse energy and hence the path of the unseen neutrino.



One of the first Z particles observed in UA1. The two white tracks (towards the top right and almost directly downwards) reveal the Z's decay into an electron–positron pair that deposit their energy in the electromagnetic calorimeter.

The jet run

The first real physics run was in December 1981. Known as the jet run, it was devoted to the search for jets arising from the hard scattering and fragmentation of partons as expected from QCD. The integrated luminosity was about 20 events per μb. The main initial effort in UA1 was based on the tracker, i.e. the measurement

Carlo Rubbia (left) and Simon van der Meer celebrate the news that they have been awarded the Nobel prize in October 1984.

of high-momentum tracks and the correlations in azimuth and rapidity between charged particles. Within the collaboration, not enough attention was paid to the searches based on energy clusters in the calorimeters. The UA2 search, based exclusively on calorimetry, was simpler and gave more telling results. At the Paris conference in the summer of 1982, UA2 had clear back-to-back two-jet events, one of which was particularly spectacular with a total transverse energy (E_t) of about 130 GeV. The UA1 result was somewhat less elegant. The subsequent studies by UA1 and UA2 were based on calorimetric jet algorithms and the data were selected by total E_t or localized E_t depositions. This gave an excellent confirmation of QCD expectations in terms of cross-sections, fragmentation functions, angular distributions, etc. But what about the W and Z particles?

On the trail of the W

In the case of the W particle, both experiments looked for Drell–Yan production – that is $\bar{u}d \rightarrow W^-$, $u\bar{d} \rightarrow W^+$ with the antiquarks, $\bar{q}$, largely from the valence antiquarks in the incident antiprotons, and the quarks from the incident protons, with a fractional momentum $x \sim m_{W,Z}/\sqrt{s} \sim 0.2$. This identification of incident partons was to facilitate the unambiguous identification of a possible resonance mass peak with the expected properties of the $W^{+/-}$ – namely the spin of 1 and the V–A nature of weak interactions – which should manifest themselves through characteristic forward–backward asymmetries in the decays of the W to a charged lepton and neutrino ($W \rightarrow l\nu$). For the running period at the end of 1982 we expected a luminosity in excess of $10^{28}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and an experimental sensitivity of $> \sim 10$ events/nb – an increase of 1000 compared with the previous run. The theoretical predictions for the cross-section for $W \rightarrow l\nu$ were ~0.5 nb, so few events were expected.

In the run in November/December 1982 the collider attained a peak luminosity of $5 \times 10^{28}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. UA1 collected $18\,\mathrm{nb}^{-1}$ of data, with the total number of recorded triggers about 10^6 for 10^9 interactions in the detector. The electron trigger in UA1 was two adjacent gondolas or bouchon petals with > 10 GeV, with a rate of $\sim 1\,\mathrm{s}^{-1}$. The criteria that in December allowed UA1 to select the first five $W \rightarrow e\nu$ candidates unambiguously, required an ECAL cluster of > 15 GeV, a hard isolated track of $p_t > 7$ GeV/c roughly pointing to the cluster, missing $E_t > 14$ GeV, and no jet within 30° back-to-back in the plane transverse to the electron candidate. This became known as the Saclay missing E_t method. This selection in fact gave six events, five of which turned out to be fully compatible with $e^\pm$. In these five events, the electron had an E_t of ~25 GeV in one case and between 35 and 40 GeV in the others, closely balanced event-by-event by the missing E_t. Thanks to the hermeticity of the UA1 design, the resolution on missing E_t in UA1 was 7 GeV in hard/jetty events, so the observed missing E_t was highly significant in each event ($> 5\sigma$). The sixth event had 1.5 GeV of leakage in the HCAL and, upon detailed inspection, turned out to be a case of $W \rightarrow \tau\nu \rightarrow \pi^\pm\pi^0\nu$.

In the first weeks of January 1983 an independent search – not based on a missing E_t selection, but on stringent electron selection requirements – was performed at CERN. It found the same events, without the tau event, but with an additional event in the endcaps that was below the Saclay/missing E_t selection cuts. These events were announced later the same month at the Rome conference and went in the publication announcing the discovery of the W (UA1 collaboration 1983a). The key to this success was the built-in redundancy of UA1 – which allowed the same events to be found by two largely independent methods, resulting in clean samples with no nearby background events – and the fact that the reconstruction software was ready and working. The already perceptible Jacobian peak behaviour giving $m_W = 81 \pm 5$ GeV clinched the day.

In the same run UA2 had four $W \rightarrow e\nu$ candidates (UA2 collaboration 1983a). The electron identification was based on a calorimetric cluster of more than 15 GeV, with longitudinal and transverse shower profiles consistent with $e^{+/-}$, track–preshower–calorimetric cluster spatial matching, and electron isolation within a cone of 10°. In the forward–backward regions, where there was a magnetic field, momentum/energy (p/E) matching was enforced but the electron was not required to be isolated. Moreover, events with significant E_t opposite to the electron were rejected. These events also had missing E_t, but the 20° forward openings resulted in poorer resolution, and thus the separation of events from the background was not so good. In fact one of the consequences of UA1's hermeticity and the selective power it provided for $W \rightarrow l\nu$ events, was that the D0 detector at Fermilab, which was designed in 1983/4, was made as hermetic as possible.

Catching the Z

In April/May 1983 came the next run with $118\,\mathrm{nb}^{-1}$ of integrated luminosity for UA1. This gave an additional sample of 54 $W \rightarrow e\nu$ events, giving $m_W = 80.3 + 0.4 - 1.3$ GeV – and the angular asymmetry in the W decay due to the V–A coupling was unmistakable. The first $W \rightarrow \mu\nu$ events were also seen, but most importantly the first $Z \rightarrow e^+e^-$ events and one $Z \rightarrow \mu^+\mu^-$ were found. An express line selected events with two electromagnetic clusters of $E_t > 25$ GeV with small HCAL deposition, and also muon pair events, thereby allowing very fast analysis. The selection of $Z \rightarrow e^+e^-$ was much ▷

easier than the W selection. The additional requirement of track isolation in the tracker, track-cluster spatial matching and < 1 GeV in the HCAL cell behind the cluster, selected four $Z \rightarrow e^+e^-$ events with no visible experimental background in 55 nb^{-1} of data. At this stage UA1 decided to publish its evidence for the Z. The first mass determination gave $m_Z = 95.5 \pm 2.5$ GeV and the cross-section for Z decay to lepton pairs was about one-tenth that of the W, as theoretically expected (UA1 collaboration, 1983b).

UA2 accumulated a comparable integrated luminosity during April/May 1983. In the UA2 selection for Z events, while one electron candidate again had to satisfy the same stringent requirements as in the $W \rightarrow e\nu$ search, the requirements on the second electron candidate were much looser, essentially a narrow electromagnetic cluster and a cluster–cluster invariant mass of more than 50 GeV. This procedure selected eight events altogether, all clustering in mass around 90 GeV. For three out of these eight events, the second electron candidate in fact also satisfied all the tight electron requirements (UA2 collaboration 1983b). With results from UA1 and UA2, the Z particle was definitely found.

This period, around the end of 1982 and throughout 1983, was an amazing time from both a professional and personal point of view. It was an unforgettable time of extreme effort, tension, excitement, satisfaction and joy. Subsequent runs allowed us to nail down the properties of the W and Z better and initiate other searches that were not always as successful but still extremely interesting and exciting.

The discovery of the W and Z particles was a definitive vindication of the idea of gauge theories as appropriate descriptions of nature at this level, and the unified electroweak model combined with QCD became known as the Standard Model. In the 10 years of experimentation at LEP, this Standard Model became one of the most thoroughly tested theories in physics, down to the level of a part in a thousand. However, in the $SU(2) \times U(1)$ scheme with spontaneous symmetry breaking, one of the four scalars that did not disappear into the $W^\pm$ and Z masses has still to be found – and the discovery of the Standard Model Higgs, in the ATLAS and CMS detectors at CERN should eventually complete this story. The discovery of the W and Z at CERN also signalled that the "old side" of the Atlantic regained its eminence in particle physics. "...L'espoir changea de camp, le combat changea d'âme...." (Victor Hugo, "Waterloo".)

Further reading

UA1 collaboration 1981 G Arnison *et al. Phys. Lett.* **107B** 320.
UA1 collaboration 1983a G Arnison *et al. Phys. Lett.* **122B** 103.
UA1 collaboration 1983b G Arnison *et al. Phys. Lett.* **126B** 398.
UA2 collaboration 1983a M Banner *et al. Phys. Lett.* **122B** 476
UA2 collaboration 1983b P Bagnaia *et al. Phys. Lett.* **129B** 130.

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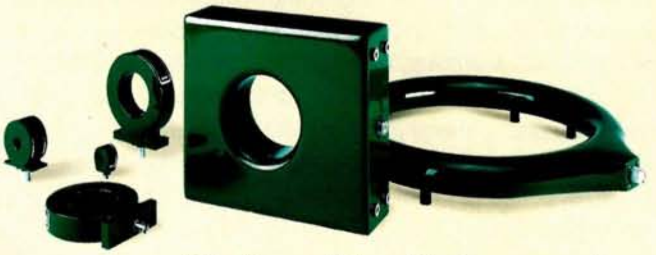

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Japanese use phonons to cool neutrons

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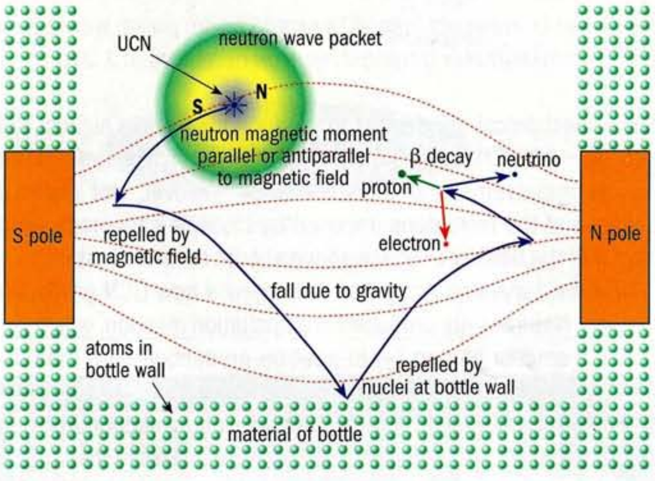

Fig. 1. The various kinds of behaviour of ultracold neutrons (UCN) in an experimental bottle.

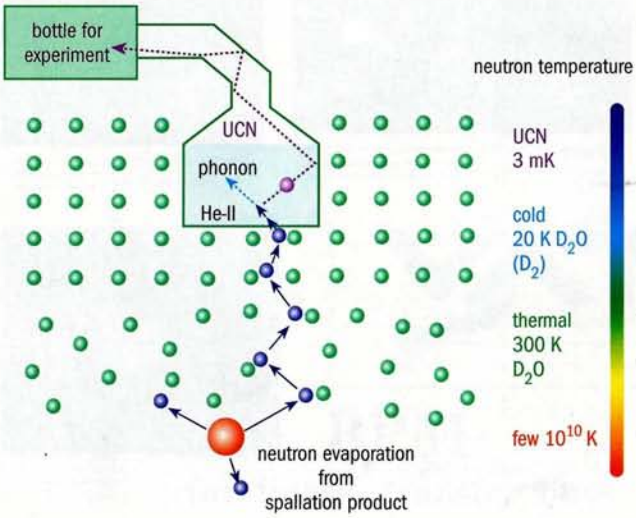

Fig. 2. The spallation production process for ultracold neutrons.

Physicists working at the spallation neutron source at the Research Centre for Nuclear Physics at Osaka University in Japan have for the first time produced ultracold neutrons using phonon excitations in a quantum liquid. A group led by Yasuhiro Masuda of KEK succeeded in the efficient production of ultracold neutrons in superfluid helium, which is free from the limitations of previous ultracold neutrons sources, imposed by Liouville's theorem.

Ultracold neutrons (UCN) are important experimentally because, although neutrons are very small when compared with the interatomic distances in a material, UCN can be confined in a material bottle due to their wave properties. The attractive nuclear force inside a nucleus in a material distorts the wave associated with a neutron, pushing it back from the centre of the nucleus. Moreover, neutrons of long wavelength (low energy) see the nuclear force of many nuclei in a material. As a result, neutrons below a critical energy – UCN – are completely reflected from a material surface and can be confined in a bottle. UCN are also confined by the magnetic potential in a magnetic bottle (figure 1).

As neutrons are a fundamental constituent of the universe, confined neutrons can be used in various experiments to study the creation of matter in the universe, nucleosynthesis after the Big Bang, and the burning of the Sun. The energy available at the time of the Big Bang created a huge number of particle and antiparticle pairs, which annihilated and transformed back to energy. However, a CP-violating interaction broke the balance of particle and antiparticle numbers, and in due course quarks and leptons were formed. The quarks then condensed into protons and neutrons, and the protons and neutrons formed the nuclei of heavier elements in the process of nucleosynthesis. The nuclei later joined with electrons to form atoms, and eventually stars were born.

The neutron lifetime and the neutron cross-sections of nuclei together played a crucial role in nucleosynthesis immediately after the Big Bang. The neutron lifetime is also relevant to the proton–proton chain in the burning of the Sun. In addition, the same CP violating that created the imbalance between matter and antimatter in the early universe induces an electric dipole moment (EDM) in the neutron. UCN are used for precision measurements of both the EDM and the lifetime of the neutron, and can be used in neutron cross-section measurements. They are also useful for other precision experiments on neutron beta-decay and gravity, and are used in research in surface physics.

In any of these experiments, a high UCN density is very desirable. At the reactor at the Institut Laue-Langevin (ILL) in Grenoble, France, UCN have been extracted from a cold neutron source using gravity ▷

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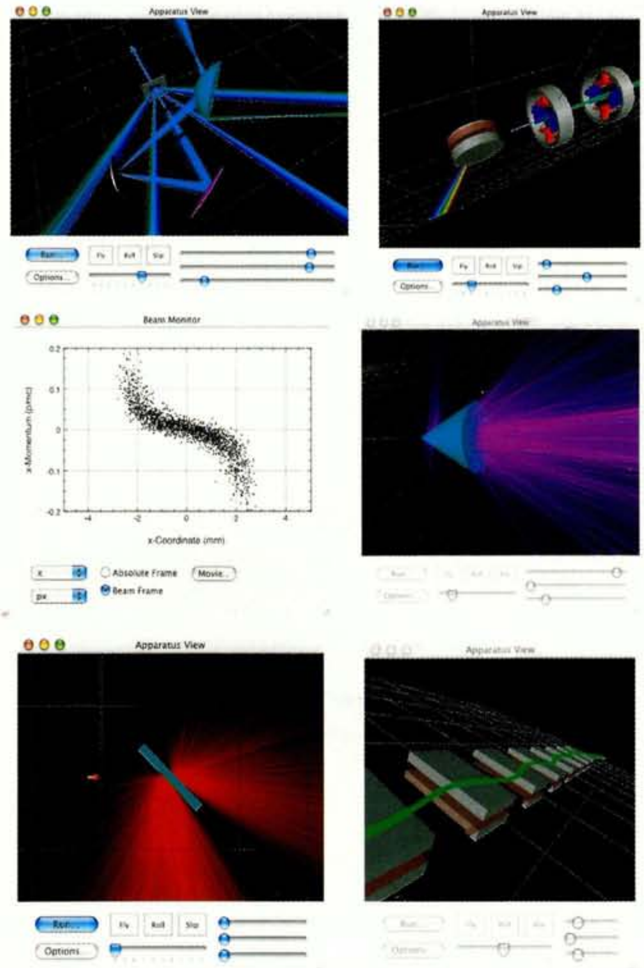

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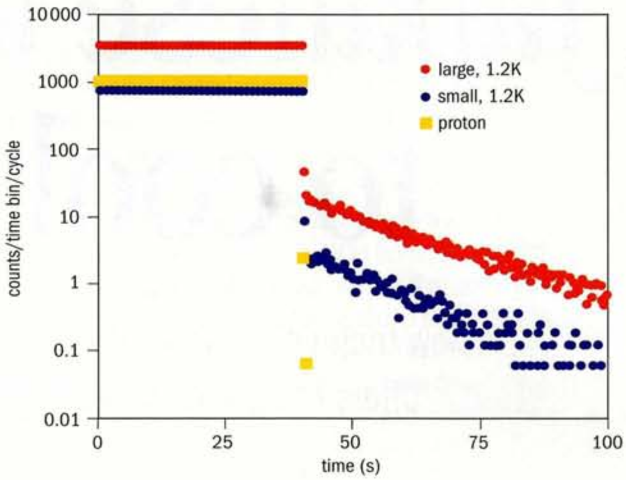

Fig. 3. Neutron counts for a 40 s proton beam pulse, with 1.5 cm and 2.4 cm diameter ultracold neutron detectors at 1.2 K.

and a mechanical decelerator to produce the world's highest UCN density – 10 UCN per cubic centimetre in an experimental bottle. Further improvement in the density is, however, not expected because of the limitations imposed by Liouville's theorem, which says that the density in phase space should remain constant.

Now the Japanese group has employed a new UCN production method. Neutrons are produced in a spallation reaction, which generates a smaller photon (γ) to neutron production ratio than in a reactor. A pulsed proton beam, with a typical pulse width of 40 s and a power of 78 W, was used for the spallation reaction. The spallation neutrons, with energies in the MeV region, were then moderated down to cold neutron energies by collisions in thermal (300 K) and cold (20 K) heavy water (figure 2). The cold neutrons were further cooled down to UCN velocities through phonon interactions in 1.2 K superfluid helium. This cooling process is not limited by Liouville's theorem because the decrease of neutron phase space is compensated by the increase in phase space of the phonons.

The UCN were then extracted, with negligible losses, through a guide tube into an experimental bottle, where the number of UCN was counted using two (15 and 24 mm diameter) solid-state detectors behind a ^{6}Li film. A typical UCN count time was 60 s, and the UCN were found to remain in the bottle with a decay time constant of 14 s (figure 3). The UCN density was 0.7 UCN per cubic centimetre at the beginning of the counting, and this doubled to 1.4 UCN per cubic centimetre when the proton beam power was doubled.

The new UCN source is expected to produce a UCN density of greater than 10 000 UCN per cubic centimetre, through improvements in the proton beam power, the UCN lifetime in the bottle, etc. The main limitation comes from the ability of the cryostat cooling to remove γ heating in the superfluid helium after the spallation reaction. The above expectation is based on practical values of superfluid helium temperature (0.8 K) and proton beam power (30 kW).

Further reading

Y Masuda *et al.* 2002 *Phys. Rev. Lett.* **89** 284801.

Yasuhiro Masuda, *KEK.*

Swiss Headquarters
Tel ++41 81 771 615 61
Fax ++41 81 771 48 30
Email reception@vat.ch

VAT France
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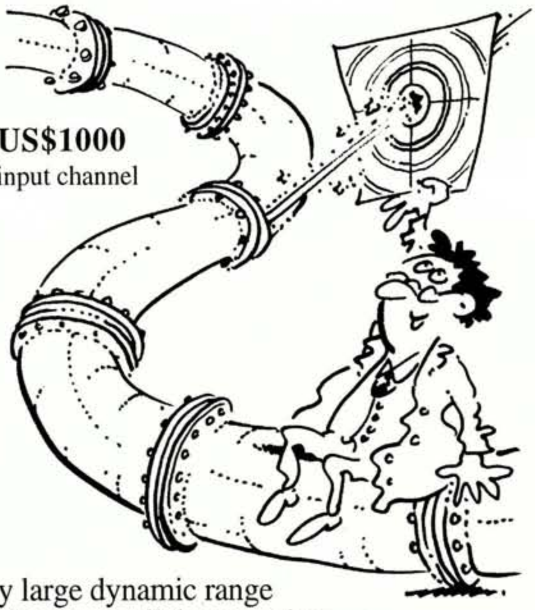

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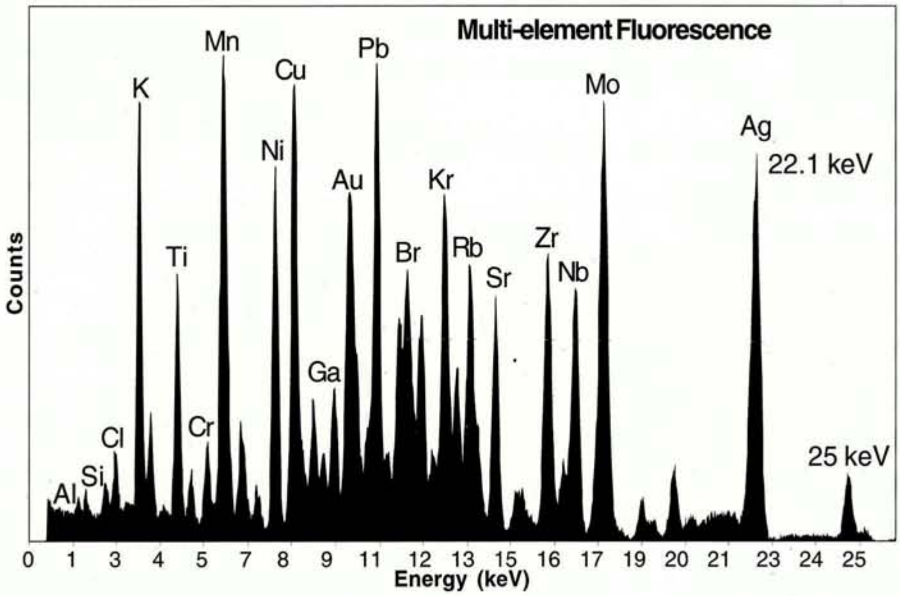

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UNITED STATES

Major change in leadership at the DOE's high-energy physics division...

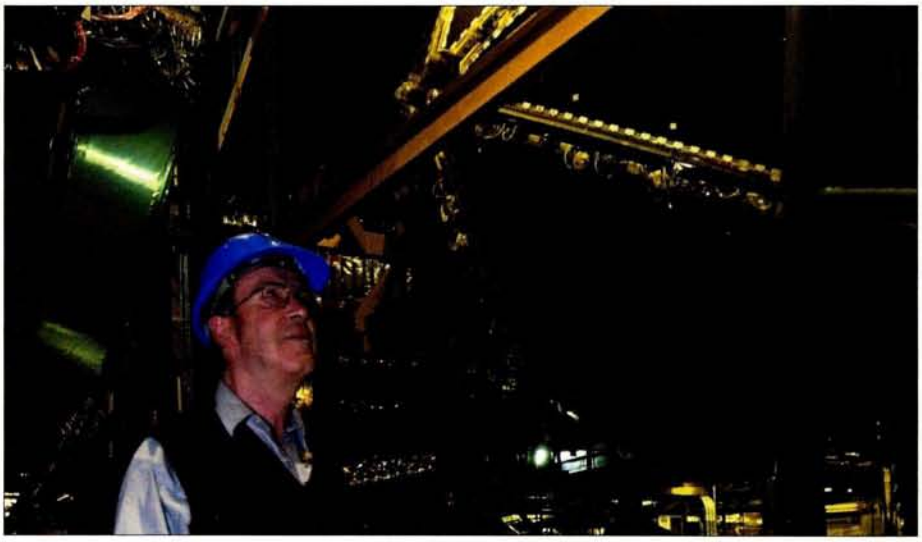
John O'Fallon (pictured right), who was director of the Division of High Energy Physics for 15 years, has moved to a new position in the US Department of Energy (DOE). On 24 March he became executive assistant for international and interagency planning in the office of the associate director for High Energy and Nuclear Physics (HENP). In his new position, O'Fallon's responsibilities will centre around two major activities in the DOE's high-energy physics programme. These include designing, planning and implementing policies regarding US involvement with the LHC at CERN, and establishing the framework necessary for other international projects the global high-energy physics community proposes to pursue. In addition, he will lead a DOE initiative designated as Streamlining Departmental Grants Processing, which is part of the DOE's E-Government Strategic Action Plan.

Particle physics in the US has seen several major achievements during O'Fallon's time as director of the Division of High Energy Physics. These include the discovery of the top quark and the first observation of the tau neutrino at Fermilab, the first observation of CP violation in the B-meson system and the precision measurement of sin2β at SLAC, and convincing evidence for atmospheric neutrino oscillations at SuperKamiokande. After the demise of the SSC, O'Fallon played an instrumental role in setting the framework for US scientists to continue research at the high-energy frontier, by laying the groundwork with CERN and by orchestrating the shift to research at the LHC.

With O'Fallon's change of post, Robin Staffin is now serving as acting director of High Energy Physics, as well as continuing in his present capacity as deputy associate director for HENP. Staffin, who has been deputy associate director for two years, received his PhD in high-energy theory under Sidney Drell at SLAC. Prior to coming to HENP, he served as deputy assistant secretary for research and development in the DOE's Office of Defense Programs, and was later appointed senior policy advisor for science and technology and scientific advisor to the secretary of energy.

...and at Jefferson Lab's Experimental Hall B

On 1 February 2003, Bernhard Mecking stepped down as leader of Hall B to return to full-time research at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia. Mecking came to Jefferson Lab from the University of Bonn 18 years ago, before Hall B even existed. He had a vision for the CEBAF Large Acceptance Spectrometer (CLAS), a remarkable instrument that he led from its conception through the design and construction phases, and finally to commissioning and experiments. Mecking, seen here with CLAS, will now work on extracting physics from the terabytes of data that CLAS has accumulated. Fellow veteran Jefferson Lab physicist Volker Burkert succeeds him as the new Hall B leader.



AWARDS

CMS suppliers receive Gold and Crystal awards

Four years after its inception, the awards ceremony to honour CMS's top suppliers has become a regular fixture in the collaboration's calendar. This year, in three separate ceremonies, eight companies received the Gold Award and four the prestigious Crystal Award.

On 10 February, the visit to CERN of the director and deputy-director of the Snezhinsk All-Russian Institute of Scientific Research for Technical Physics (VNIITF) of the Russian Federal Nuclear Centre (RFNC) provided an occasion for the first ceremony. The VNIITF received a Gold Award for exceptional performance in the assembly of steel absorber plates for the CMS forward hadron calorimeter. The institute has developed a special welding technique, allowing a high-quality detector to be produced at relatively low cost.

The main ceremony took place on 24 February during the CMS week at CERN, when eight firms collected their awards. Four of them – Techmeta, Doosan Heavy Industries & Construction, Hamamatsu Photonics and Polymicro Technologies – received the Crystal Award. Techmeta, a French firm specializing in electron-beam welding, was rewarded for its assembly of the three components of the CMS solenoid conductor. Korean firm Doosan Heavy Industries & Construction manufactured the device for swivelling the CMS coil into a horizontal position for insertion into the vacuum vessel. The company managed to produce and deliver this complex, custom-built piece of equipment in just one year. Hamamatsu Photonics developed and produced the avalanche photodiodes for the electromagnetic calorimeter. The Japanese firm introduced a number of innovations to enhance the radiation hardness and magnetic field resistance of the photodiodes so that they could withstand the challenging conditions of the LHC environment. The fourth Crystal Award winner, Polymicro Technologies of the US, produced the 1115 kilometres of quartz plastic optical fibres for the forward hadron calorimeter, which are designed to withstand the extreme radiation levels in the forward region of CMS.

At the same ceremony, Gold Awards were presented to four firms – Franc-Comtoise Industrie, Dembiermont, MFK and EAE. French firm Franc-Comtoise Industrie was rewarded for its on-site assembly of the two CMS magnet end-cap yokes, which are made up of six iron disks 15 metres in diameter, weighing between 300 and 700 tonnes. A second French company, Dembiermont, manufactured aluminium alloy rings for the flanges of the external mandrels of the CMS coil. These 7 metre diameter seamless rings are probably the largest of their type currently in existence. Finally, Turkish companies MFK and EAE joined forces to produce components for the hadron forward calorimeter. The components were produced with great care and in only 10 months, well in advance of the agreed schedule.

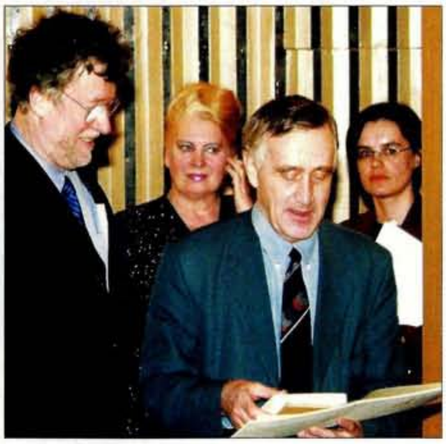
In the third ceremony on 7 March, CMS handed out further Gold Awards to three Russian and Bielorussian companies on the occasion of a visit by dignitaries from the two countries. The three awards were made to the Russian firms ENTEK and the Myasishchev Design Bureau, and the Bielorussian company MZOR. MZOR and ENTEK designed, produced and assembled the mechanical parts for the CMS hadron calorimeter end-caps. The MZOR machine-tools company fabricated the absorber plates and interfaces, and also produced special assembly tooling. In addition, ENTEK manufactured components for the calorimeter and took responsibility for its final assembly at CERN. The Myasishchev Design Bureau was responsible for the carbon fibre structures in which the fragile lead tungstate crystals of the electromagnetic calorimeter end-caps are to be embedded. These lightweight structures must support a weight of 22.9 tonnes in each end-cap.

Felicitas Pauss (left) hands a CMS Gold Award to Georgy Rykovanov, director of Russia's RFNC–VNIITF Institute.

The winners of eight CMS suppliers' awards during their visit to the CMS assembly site on 24 February.

Directors of the three Russian and Bielorussian firms that received awards on 7 March at the CMS assembly site, where they stand in front of the hadron calorimeter together with visiting dignitaries from their countries and CMS collaboration leaders.

PRIZES



On 19 March, **Alexander Skrinsky** (right), director of the Budker Institute of Nuclear Physics in Novosibirsk, received the 2002 Karpinsky Prize, which is awarded by the Alfred Toepfer Foundation and Russian Academy of Sciences. The prize was instituted in 1979 as a memorial to the Russian scholar Alexander Karpinsky, who in May 1917 became the first elected president of the Russian Academy of Sciences. The Karpinsky Prize is awarded bienially to a Russian researcher for achievements in natural sciences, ecology and humanities. This year it was presented to Skrinsky, seen here with **Albrecht Wagner**, in acknowledgment of his outstanding pioneering work on particle accelerators and accelerator technologies. These include new fundamental concepts on storage rings, linear colliders and electron cooling. The prize is accompanied by a scholarship of one year's research in Germany for a young scientist nominated by the laureate.

Gerardo Herrera Corral (left), of the Centro de Investigación y de Estudios Avanzados del IPN (CINVESTAV) in Mexico City, has been awarded the 2001 research prize of the Mexican Academy of Sciences for his experimental studies in high-energy physics. This major award is given every year to a young scientist who has made a distinguished contribution to any area of pure science. This is the first time that this prize has been given to an experimentalist in high-energy physics, and is an important sign of the growth of experimental high-energy physics in Mexico. Herrera Corral, seen here receiving the prize from the Mexican President **Vincente Fox**, leads the team of six Mexican institutes in the ALICE Collaboration at CERN. (Erik Meza.)

RETIREMENTS

Ted Wilson (right), a well known figure in accelerator physics, retired from CERN in March. After an earlier year at CERN, he came to the laboratory in 1967, where he worked on the SPS and collaborated closely with John Adams on the design and commissioning of the accelerator. In 1980 he joined the PS and worked on the antiproton accumulator. Later he became a member of the LHC Committee and was entrusted with the task of writing a report on the design of the future accelerator. Drawing on this experience Wilson, seen here with his assistant **Suzanne von Wartburg** during an EPAC meeting in 1994, took over as head of the CERN Accelerator School (CAS) in 1992. In this capacity he was responsible for organizing around 25 schools, not including special schools in India and China, and in particular he took part in the development of joint schools with Japan. Although now retired and having handed over the reigns of CAS to Daniel Brandt, Wilson will continue to pursue his interests in accelerators.

MEETINGS

SUSY 2003, "Supersymmetry in the desert", the 11th Annual International Conference on Supersymmetry and Unification of the Fundamental Interactions, will be held on 5–10 June at the University of Arizona in Tucson. Conference topics will include phenomenological aspects of SUSY and SUSY breaking; experimental searches, constraints and bounds; string phenomenology, extra dimensions and the brane world; formal aspects of SUSY, SUGRA and string theory; and astrophysical and cosmological connections. Full details are available on the web at http://newton.physics.arizona.edu/susy2003.

PHYSTAT2003 will be held at SLAC in Stanford, California, on 8–11 September. It will cover statistical issues in the fields of particle physics, astrophysics and cosmology. This is the fourth conference in the series that started at CERN with the "Confidence Limits Workshop" in January 2000. More information about this year's conference at SLAC can be found on the web at http://www-conf.slac.stanford.edu/phystat2003.

The EuroConference on Hadron Structure Viewed with Electromagnetic Probes, a conference on electromagnetic interactions with nucleons and nuclei, will take place on 7–12 October at Santorini, Greece. The conference programme will include QCD structure of hadrons, nucleon form factors and polarizabilities, highly exclusive processes, and nucleon correlations in nuclei. The conference is part of the 2003 Euresco Conference Programme, and further information is available from the website at http://www.esf.org/euresco/03/pc03117.

CENTENARY

Florida symposium fetes Paul Dirac

When Paul Dirac, one of the founders of modern physics, retired from Cambridge University in 1970, he joined the Department of Physics at Florida State University (FSU), where he continued to work on problems in fundamental physics and taught a variety of courses. He died in Florida in 1984 and is buried in Tallahassee's Roselawn Cemetary. So it was fitting that one of the last events to celebrate Dirac's centenary in 2002 was the Dirac Centennial Symposium organized by the FSU.

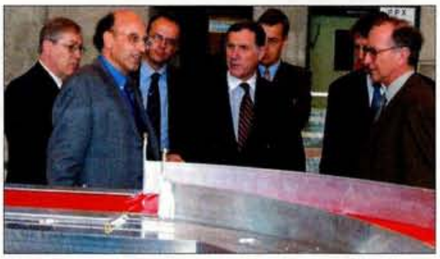
Participants at Florida State University's Dirac Centennial Symposium, including, second from left, Pierre Ramond, then moving right, Paul Langacker, Brian Serot, Laurie Brown, Monica Dirac, Leo Halpern, Joe Polchinski and Howie Baer.

The symposium, organized by Howie Baer and colleagues, was a one-and-a-half day celebration of Dirac's achievements and their continuing impact upon research at the frontiers of physics. More than 150 participants heard talks by a variety of eminent speakers, including Laurie Brown and Leopold Halpern, who provided some historical perspective; Pierre Ramond, who generalized Dirac's equation and introduced fermions into string theory; Brian Serot, on building atomic nuclei using the Dirac equation; Paul Langacker, who dealt with one of Dirac's pet ideas in a talk on time variation of physical constants; and Joe Polchinski, who brought monopoles up to date with duality and string theory. In the keynote banquet speech, Dirac's daughter Monica presented a personal portrait of her father. A commemorative volume summarizing the talks is to be published by World Scientific.

VISITS

Hundreds of school students from around Europe visit CERN each year, but not many come all the way from the US. Yet 15 students from the class of **Ken Wester** (at left rear of picture), a physics teacher at Columbus High School, Mississippi, made the trip. Wester participated in CERN's High School Teachers Programme last year, and was so enthralled that he organized for his final-year students to visit CERN. The 18-year-olds arrived on 10 March and spent two days at the laboratory, visiting the CMS construction site and the AD antimatter factory, before leaving on a tour of Switzerland and Germany. The students are seen here with their teacher by the model of CMS in Building 40, together with CMS spokesman **Michel Della Negra** (front).

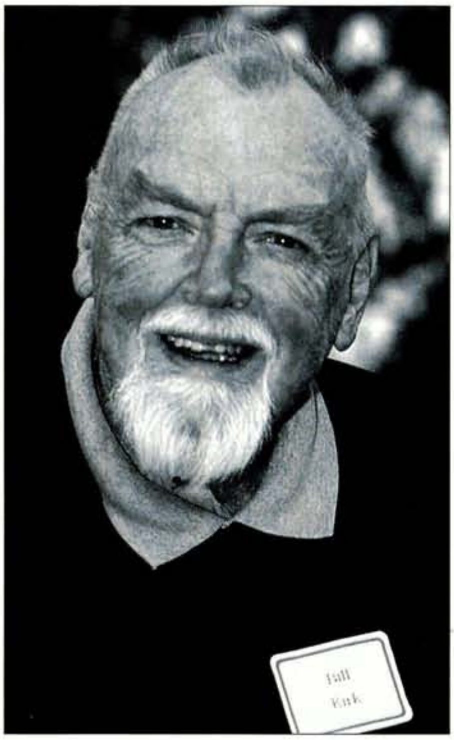
The TESLA test facility was one of the highlights of a recent visit to DESY by **John Marburger** (left), director of the US Office of Science and Technology Policy (OSTP). Marburger, a physicist and former director of the Brookhaven National Laboratory, was at the laboratory to learn more about the status of the TESLA X-ray laser and the TESLA linear collider, as well as international collaboration at DESY. As the scientific advisor to the US President, Marburger plays a critical role in the development of the country's scientific strategy. His office is currently working with other partners to produce guidelines for a possible decision-making process to build an international linear collider. Marburger is seen here with **Susan Elbow** (centre), American consul general in Hamburg, **Albrecht Wagner**, director of DESY, and **Hans Weise**, coordinator of the linear accelerator of the TESLA Test Facility.



David Syz (centre), state secretary for economic affairs in Switzerland, visited CERN on 3 March with his board of directors. During the visit Syz heard about Technology Transfer at CERN and the openlab project, and visited the assembly area for ATLAS, where the ATLAS spokesman **Peter Jenni** (second from left) described the progress with various components, including the toroid magnet coils seen here.

OBITUARIES

William T Kirk 1927–2003



In 1956 Edward L Ginzton, the then director of the Microwave Laboratory at Stanford University, advertised for an assistant. William "Bill" Kirk, a history graduate of Cornell in 1952, who was working in industry after graduation, responded to the ad and moved to Stanford. He remained there until his death, from cancer, on 14 February 2003.

Kirk became much more than an administrator and assistant to SLAC's directors. He was a problem solver, a mediator, a guardian of the Queen's English, and an invaluable bridge between all members of the SLAC community – technical workers, administrators and scientists. He later ably directed all of SLAC's information activities.

Kirk is probably most widely remembered for creating SLAC's particle-physics magazine *Beam Line* in 1974. Until 1988 he was the *Beam Line*, performing all the work from writing to composition, layout and typesetting. After 1988 he remained as co-editor until his retirement in 1993, when he continued as an informal advisor to the editor.

While Kirk was a history major and novelist, he understood high-energy physics and high-energy physicists. His writings on high-energy physics, such as the article "High Energy Physics – An Introduction" that among other topics compared the technology and purpose of storage rings and fixed-target machines, have become classics in popular science writing. Kirk also wrote lucid articles on the operation of PEP, the discovery of the J/Psi particles and many others. He became very much in demand as an editor of the many international conference proceedings of meetings in high-energy physics, a task he always undertook with great skill and a drive for perfection.

Bill was a very humble person, notwithstanding his major contributions to high-energy physics. Most of the verbiage in the 1957 proposal to government agencies, which led to the creation of SLAC, largely originated from Kirk's pen, yet his name does not appear among the profuse acknowledgments in the document.

Throughout his career, Kirk divided his interests in high-energy physics and writing with a dedication to athletics. He was a member of several of Cornell University's successful football teams, an avid golf player, and the instigator of and slugger in the annual baseball game between theorists and experimentalists at SLAC. Kirk's contributions to SLAC and to high-energy physics will be long remembered. He was a great man, always available, always constructive and always helpful. We will miss him.

Pief Panofsky, SLAC.

Viktor S Rumyantsev 1945–2003

Viktor Rumyantsev, who died on 28 February 2003, began his scientific career at the Institute of Physics, National Academy of Sciences in Minsk, Belarus, where he performed experimental research in the field of particle physics. In 1974 he started working in close collaboration with colleagues from the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, where he investigated multi-particle production in pion–nucleus collisions.

In 1994 Rumyantsev was elected deputy director of the Dzhelepov Laboratory of Nuclear Problems at JINR, and became active in the ATLAS Collaboration, especially in the construction of the Tile Calorimeter Barrel, and also the Liquid Argon Calorimeter and the MDT chambers. He also contributed to the WA-102 experiment at the OMEGA spectrometer at CERN, in the search for exotic mesons in double pomeron exchange processes.

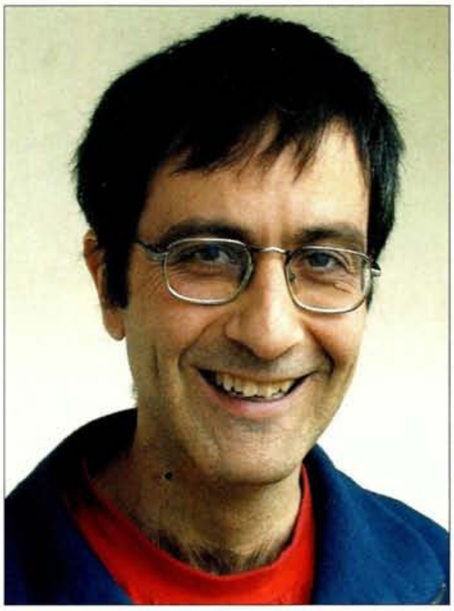
From 1999, Viktor headed the Particle Physics Laboratory of the National Centre for High Energy and Particle Physics in Minsk. His scientific activity here, with the exception of the ATLAS project, essentially concentrated on the application of micro-channel aluminium oxide plates in particle detectors.

For all his colleagues he was, and remains, a beloved and admired scientist and friend.

Nikolai A Russakovich, JINR.

OBITUARIES

Aris Angelis 1954–2003



On 5 February, our colleague and dear friend Aris Angelis left us at a moment when we all believed he could win the battle for his life.

Aris graduated from the University of Athens in 1975. He went on to Oxford University where he received his doctorate in 1984. During this period he suffered his first attack of the illness that was eventually to claim his life, which he saw off through a combination of aggressive treatment and the determination that was so much a part of his character. As a result of the treatment at the time, his doctors told him that he would not be able to take part in competitive sport again. However, he went on to represent Oxford at karate in the varsity match against old-rivals Cambridge, and was a regular performer in mountain marathons around Switzerland.

Aris worked on several experiments at CERN, starting at the ISR. He developed a taste for heavy-ion physics through the experiments NA34, WA93/98, SIGAPO, ALICE and finally CMS. He had a nomadic career, holding positions at University College London, McGill University, the University of Geneva and CERN. Since 1997 he had been attached to the University of Athens.

Aris left his mark on CERN's heavy-ion programme from the early days at the SPS to the very end, preparing for the future at the LHC within ALICE and CMS. Those of us who knew and worked with Aris appreciated him both as an enthusiastic colleague and as a warm and helpful friend. Younger colleagues thought of him as their mentor during their crucial and difficult first steps in science. Others looked forward to working with him at the LHC.

Aris was also an effective communicator. Very aware of the need for the public communication of our field, he became a CERN guide in 1999 and was consistently voted one of CERN's best. His explanations of the science in English, French, Italian and Greek were greatly appreciated and the CERN visits service received many complimentary letters following his tours. He also took part in many special events, such as CERN open days and the Oracle of Delphi theatrical event staged in an experimental hall, and always with the same enthusiasm, dedication and competence. Aris was also an active and enthusiastic member of the European Particle Physics Outreach Group, where he represented ALICE, and he acted as secretary of the LHC Outreach Group.

Aris's dogged determination, his sense of right and wrong, and his stubborn persistency left no-one indifferent. These characteristics earned him respect and made him a reliable friend, who was always ready and willing to help. His untimely and unjust departure came as a shock to us all – Aris was not the kind to give in. To suffer a life-threatening illness once is cruel, twice is a tragedy. On both occasions, however, Aris faced his illness with a courage and dignity that set an example for us all.

Apostolos D Panagiotou, University of Athens, and James Gillies, CERN.

NEW PRODUCTS

Electron Tubes has launched a counter timer module with upgraded software for PCs. The CT2 is designed to respond directly to all TTL photon and pulse counting systems, and with Active X it interfaces with Lab View and Visual Basic, and is Windows 98, 2000 and XP compliant. For further information, call +44 (0)1895 630 771, or see the website at http://www.electrontubes.com.

Polytec PI has introduced a new generation of digital piezo nanopositioning and nanoscanning controllers for use in metrology, surface profiling, scanning microscopy, etc, with an improvement in linearity of two orders of magnitude. The new PI E-710.SCN controllers use a smart digital controller that reduces nonlinearity, phase lag and tracking errors. For further information, call Jim Gareau on +1 508 832 3456, e-mail info@polytecpi.com, or see the website at www.polytecpi.com.

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Microwave Amplifiers has recently introduced the AM84 and AM85 series of amplifiers, designed specifically as klystron drivers for both pulsed and CW applications. Available in the 1.1–3.1 GHz band as narrowband or wideband units, and using the latest GaAsFET technology, the amplifiers provide high linearity at powers up to 1.2 kW. For further details call Neil Richardson on +44 (0)1275 853 196, or e-mail nrichardson@maltd.com.

CORRECTION

An error crept into the report on the Pomeranchuk Prize on p29 of the April edition. The prize winner was of course Bryce DeWitt (not Bruce DeWitt). Many apologies.

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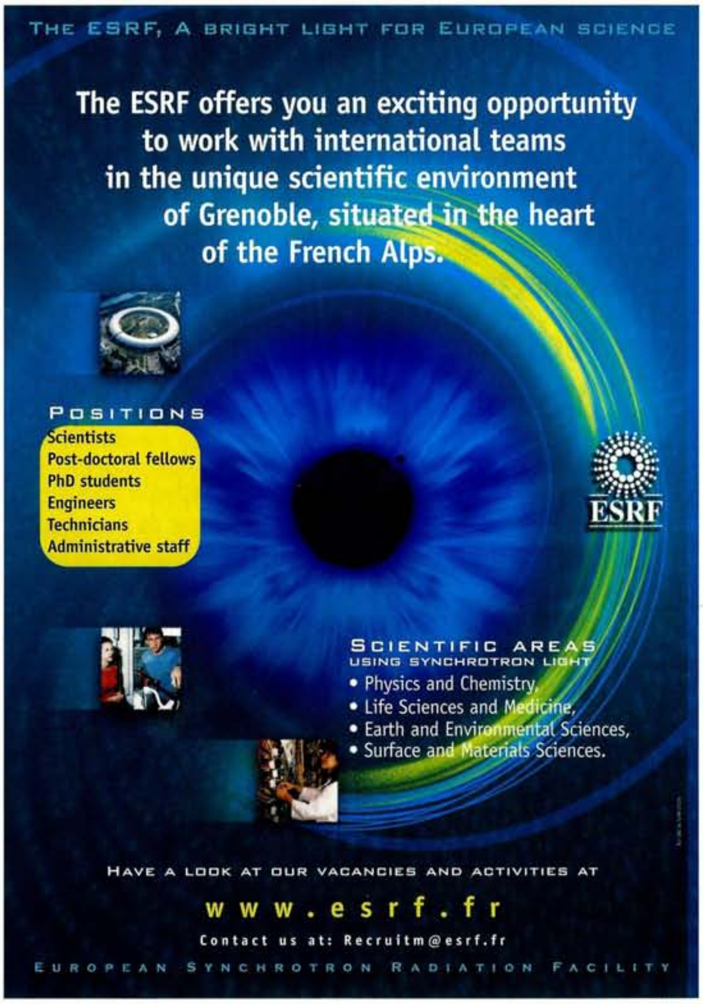

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Foundation FOM

The Foundation for Fundamental Research of Matter (FOM) stimulates and coordinates fundamental physics research in the Netherlands. For that, she is enabled by grants from the Dutch government through the Dutch Organisation for Scientific Research (NWO). FOM receives funds from NWO, Euratom, EU and several companies.
The 1000 employees approximately, mainly scientists (including Ph.D. - students) and technicians, are divided over five laboratories and approximately 100 departments at general and technical universities. FOM - founded in 1946 - is a foundation recognized by NWO.

FOM

NIKHEF is the national institute for subatomic physics in the Netherlands, in which the funding agency FOM, the Universiteit van Amsterdam, the Vrije Universiteit Amsterdam, the Katholieke Universiteit Nijmegen and the Universiteit Utrecht participate. The academic staffs consist of about 120 physicists of whom more than half are Ph.D. students or postdoctoral fellows. Technical support is provided by a well-equipped mechanical workshop and an advanced electronic, engineering design and IT group with a total staff of about 100. The design and construction of detectors and the analysis of data take place at the Institute in Amsterdam as well as at the participating universities.

The institute coordinates and supports major activities in experimental subatomic physics in the Netherlands. The experiments are performed with accelerators at CERN (Geneva), DESY (Hamburg), FNAL (Batavia), SLAC (Paolo Alto) and Brookhaven (Upton).

NIKHEF also participates in the European project in high-energy neutrino astroparticle physics ANTARES. A detector, consisting of 1000 optical modules, is currently under construction. It will be deployed over the next two years in the Mediterranean Sea at a depth of 2.5 km. NIKHEF provides the read-out system based on modern optical data transmission technology. The NIKHEF group is involved in developing filtering and reconstruction software running on a PC farm in the shore station.

For its Antares programme, NIKHEF is searching for an outstanding

Experimental Physicist

with a strong record of accomplishment and leadership in experimental research, preferably in high energy physics.

Requirements
Candidates will be considered for a permanent position when they have at least several years of post-doctoral experience. They should have a broad and deep knowledge of experimental particle physics and a keen interest in the field of astroparticle physics. Further qualifications include: pragmatism, creativity, competence in detection techniques, and knowledge of modern information technology. The candidate should have excellent communication skills, ability for teamwork and leadership capability.

Information
General information and information about the scientific and educational activities at NIKHEF can be found at: http://www.nikhef.nl/. Further information can be obtained from the leader of the ANTARES programme, Dr. M. de Jong, telephone: +31 (0) 20 592 21 21/e-mail: mjg@nikhef.nl, or the chairman of the search committee, Prof. Dr. Ing. J.F.J. van den Brand, telephone: +31 (0) 20 592 20 15/e-mail: jo@nikhef.nl.

Applications
Letters of application, including curriculum vitae, list of publications and the names of three referees are to be sent before June 1st. 2003 to Mr. T. van Egdom, P.O. Box 41882, 1009 DB Amsterdam, the Netherlands. NIKHEF is an equal opportunity employer.

NIKHEF

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The Paul Scherrer Institute (PSI) is looking for a strategically thinking and communicative personality for the position of

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The Paul Scherrer Institute is a multi-disciplinary institute for research in the natural and engineering sciences. PSI is active in research in condensed matter physics, materials science, elementary particle physics, astrophysics and the life sciences, and also in energy and the environment. The research is carried out in collaboration with universities, research laboratories and industry from around the world. The Institute develops and operates large and complex research facilities for its own and external researchers. Among these are a synchrotron light source, a 1 MW spallation neutron source, a zero power reactor and a hot laboratory.

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Prof. Ralph Eichler will answer your professional questions: telephone +41 (0)56 310 32 16, e-mail: ralph.eichler@psi.ch

Please send your written application before 14 June 2003 to Paul Scherrer Institut, Mrs Ursula Schmid, Department of Human Resources, code no. 4000, 5232 Villigen PSI Switzerland

Further job opportunities at PSI may be found at: www.psi.ch

Experimental Physicist

The Physics Department of Brookhaven National Laboratory presently has an excellent opportunity for an Experimental Physicist to work with the PHENIX Group under the direction of M.J. Tannenbaum. The rank will be at Assistant Physicist although a higher rank or a professional appointment could be considered, depending on experience. The position requires a Ph.D. in nuclear or elementary particle physics, experience with data acquisition in large, modern high energy or nuclear physics experiments, and the ability to work in a large collaboration and participate in projects that cross institutional boundaries as part of a team. Should be able to demonstrate expertise in one or more of the following areas: programming in C++ and Java, CORBA, operating systems including Linux, VXWorks, and Windows 2000, Ethernet and Gigabit Ethernet networking, real time data acquisition electronics, or high speed trigger electronics.

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Interested candidates should submit a CV, three letters of reference indicating position # MK 2847 to M. Kipperman, Brookhaven National Laboratory, Bldg. 185, Upton, New York 11973-5000. BNL is an equal opportunity employer committed to workforce diversity.

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The Indiana group is involved in various aspects of the muon and fiber tracker detectors and is active in the areas of muon identification, *b*-jet tagging, *B*-physics analyses, and new particle searches including Higgs boson searches in the future.

Applicants should send a curriculum vitae, a list of publications, a statement of research interests and at least three letters of recommendation to:

Ms. Donna Martin
Physics Department
Indiana University
Bloomington, IN 47405
Fax: (812) 855-0440

For more information, please contact Prof. Rick Van Kooten (rvankoot@indiana.edu, 812-855-2650) and/or visit http://hep.physics.indiana.edu/~rickv/postdoc.html

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Further details can be found at www.diamond.ac.uk

Applications for DLS0038, 39, 40 must be received by 2nd May 2003, and DLS0041, 42, 43, 44, 45 16th May 2003.

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The Physics Department at SMU is seeking an outstanding individual at the Assistant or Associate Professor level (more senior level may also be considered). We are looking for an individual with significant accomplishments and promise of future achievements who will take a leadership role in enhancing our current activities and in setting future directions.

The SMU group has major responsibilities on the CLEO III, ATLAS, CLEO-c and BTeV experiments. The group has excellent mechanical and electronics facilities and enjoys a strong university support.

Applications will be reviewed beginning in October 1, 2003. Please submit a CV, statement of research interest, and at least 3 letters of recommendations to:

Prof. Richard Stroynowski,
Department of Physics, Southern Methodist University,
Dallas, Texas 75275-0175 U.S.A.

SMU

Stockholm University

invites applications for a permanent position as

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The research group at Stockholm University works on the digitizing electronics of the ATLAS hadron calorimeter and electronics for the first level calorimeter trigger. The group is active in studies of the top quark at the DO experiment, and simulation studies of beyond the standard model physics, in particular Higgs and SUSY for ATLAS. The successful candidate is expected to play a leading role in the preparation for physics studies and supervision of PhD students in the ATLAS experiment.

The application should arrive no later than May 5th 2003. Full description of the application procedure and more information about the research group can be found at URL: **http://www.physto.se/bubnet/Atlas/position.html**

More information can be obtained from Prof. Sven-Olof Holmgren, e-mail: soh@physto.se, telephone: +46 8 5537 8660.

NEED TO RECRUIT?

E-mail: Reena Gupta: reena.gupta@iop.org

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Applications including the curriculum vitae, the list of publications, and research and teaching records should be sent within **6 weeks** after publication of this advertisement to:

Wissenschaftliche Geschäftsführung der Gesellschaft für Schwerionenforschung mbH, Planckstraße 1, 64291 Darmstadt, Germany

Massachusetts Institute of Technology
Laboratory for Nuclear Science
Cambridge, Massachusetts 02139-4307

Research Scientist Position in the area of High Energy Physics

Applications are invited for a Research Scientist position to work on the Data Acquisition system and High-Level Trigger of the CMS Experiment at the Large Hadron Collider. The Laboratory for Nuclear Science at MIT is participating in both the High Energy and the Heavy-Ion programs of CMS and the MIT group in CMS is planning to expand the effort at CERN within the next few years.

We seek a PhD physicist with a strong interest in High Energy Physics at the LHC and with experience in the area of Data Acquisition (DAQ) and/or Computing. Experience with real-time systems, especially on the software side is desirable and a solid knowledge of Object-Oriented programming techniques is necessary. CMS is expected to start taking data in 2007. The successful candidate will be stationed permanently at CERN in Geneva, Switzerland and will work with the CERN CMS DAQ Group. The Research Scientist Position is initially for 3 years with the possibility of renewal. The physicist appointed will not only have an opportunity to play an important role in both the development of the DAQ system and physics studies but will also have the possibility to participate in physics analyses after the startup of the LHC.

Applicants should submit curriculum vitae, publication list and request that 3 recommendation letters are sent to:

Professor Bolek Wyslouch, c/o Ken Hewitt, Room 26-516, Massachusetts Institute of Technology, 77 Massachusetts AV, Cambridge MA 02139-4307, Email khewitt@mit.edu

Applications will be accepted until the position is filled. MIT is an Affirmative Action/Equal Opportunity employer and especially solicits applications from qualified women and minorities.

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Postdoctoral Position Synchrotron Research

We are seeking a postdoctoral fellow (m/f) to conduct research in the framework of the experimental subprogram of the Laboratory for Waste Management and the Project Team of the microXAS beamline at the Swiss Light Source (SLS). The research activities of the involved groups are directed towards the use of synchrotron-based spectroscopic techniques to investigate retardation processes in (nuclear) waste repositories on the micro scale. The doctoral study will focus on the speciation of selected radioelements incorporated into highly heterogeneous waste repository materials (cement, iron corrosion products) and will involve (micro) X-ray absorption spectroscopy (XAS) measurements and (micro) X-ray fluorescence (XRF) experiments at the microXAS beamline at the Swiss Light Source (SLS) and other synchrotron sources in Europe or the USA.

Your Qualifications

Candidates should possess a Ph.D. in physics, geochemistry, chemistry, mineralogy, environmental sciences or related fields. The successful candidate should have good experimental and technical skills, the ability to integrate spectroscopic and geochemical/mineralogical data, and the ability to work well in a collaborative setting. Experience in synchrotron-based techniques is required.

For further information contact PD Dr. A. Scheidegger, Tel. +41 56 310 21 84.

Please send your application to PAUL SCHERRER INSTITUT, Human Resources, Mr. Thomas Erb, ref. code 4402, 5232 Villigen PSI, Switzerland.

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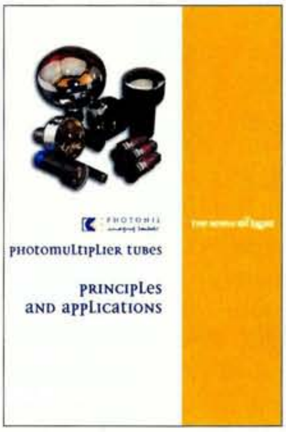

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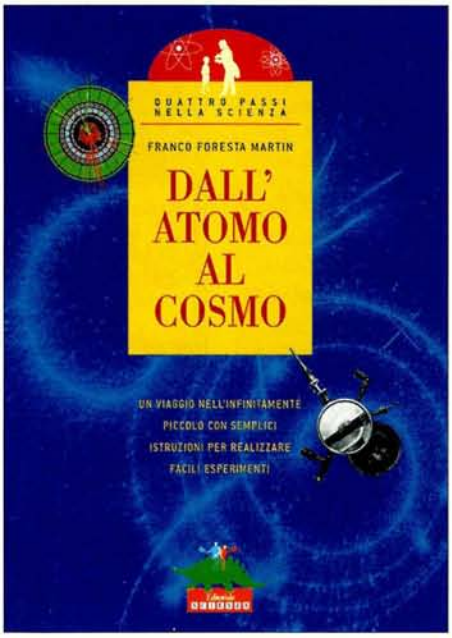
Dall'Atomo al Cosmo (From Atoms to the Cosmos) by Franco Foresta Martin, Editoriale Scienza. ISBN 8873072305, €12.90.

From the title it might seem that this book is a scientific voyage from the infinitely small to the infinitely large, but in fact it's more like a historic trip from the origin of science to today's research in particle physics. From the Greek philosophers to the Standard Model, it introduces the reader to the most important contributors to today's physical description of the constituents of matter. Although cosmology and astrophysics are not discussed, the book explores the history of particle physics in 12 chapters. It chronologically presents the most important challenges and breakthroughs, and includes some fascinating anecdotes, which make reading the book more pleasant.

The layout of the book looks inviting, especially (in the reviewer's opinion) for a younger audience, and no formulae are used. Simple experiments presented at the end of almost every chapter can be easily performed at home or at school. The book is produced in collaboration with the Italian National Institute for Nuclear Physics (INFN), which is distributing it free to schools in Italy. The final chapter describes the activities of the INFN and thereby shows how Italian researchers contribute to physics. In this way, students are informed about the opportunities they can expect if they study physics at university.

The author, Franco Foresta Martin, is a well known science journalist and popularizer. His personal experience as a writer, as well as good scientific accuracy, come out throughout the book. However, it is not clear whether the historic approach and the (often too?) simple experiments can be really effective with today's young people, in the era of the Internet and high technology. Sometimes the difficulty in finding the right level of explanation is particularly apparent, as the reader can easily get lost between the history and life of the scientists and some of the deep notions of the physics they performed. The chapter on radioactivity shows this very well: Rutherford's theory about atoms is introduced at the same time as ions and natural radioactivity. On the other hand, the experiment proposed at the end of the same chapter – radioactivity seen on a TV screen – seems potentially more tailored to today's young generation, and therefore more appropriate.



The "Quarkoscopio", or quarkoscope, is the activity proposed at the end of the last chapter, which is about the Standard Model and the use of fundamental particles in medicine. With this simple instrument, which can be built using cardboard, one can easily find out the quark constituents of the most common particles. The quarkoscope is quite an original idea and could turn out to be useful even to more experienced physicists!
Antonella del Rosso Vite, CERN.

Books received

Cohesion: A Scientific History of Intermolecular Forces by J S Rowlinson, Cambridge University Press. Hardback ISBN 0521810085, £65.

A detailed historical account of how leading scientists of the past 300 years have tried to understand why matter sticks together, this book will interest physicists and physical chemists, as well as historians of science.

Theory of Optical Processes in Semiconductors by P K Basu, Oxford University Press. Paperback ISBN 0198526292, £39.95.

Now out in paperback this book, aimed at graduate students in physics and engineering, and other beginners in the field, provides a simple quantum mechanical theory of important optical processes in semiconductors.

Plasma Waves: Second Edition by D G Swanson, Institute of Physics Publishing. Hardback ISBN 075030927X, £48 ($75).

This extended and revised edition encompasses waves in cold, warm and hot plasmas and relativistic plasmas. Written as a textbook for students, it also provides essential reference material for researchers.

Online publications

A Brazilian feast of cosmology and gravitation. www.cosmologia.cbpf.br.

The Brazilian School of Cosmology and Gravitation celebrated its 25th anniversary in 2002 by launching a website that contains all 93 lectures and seminars of the nine schools that have been organized since the first school in 1977. The site, set up by the Cosmology and Gravitation Group at the Brazilian Center of Scientific Research (CBPF), which organizes the schools, contains an impressive collection of talks by many of the most important scientists in the areas of cosmology, gravitation, astrophysics and field theory. It is an important resource for students and researchers, which also shows the evolution of these areas of physics during the past 25 years. The material, which is in PDF format, can be accessed via the website of the Cosmology and Gravitation Group at the CBPF (www.cosmologia.cbpf.br).

The proceedings of the 10th school, which was held from 29 July – 9 August 2002, will be published this year by AIP.

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IoP

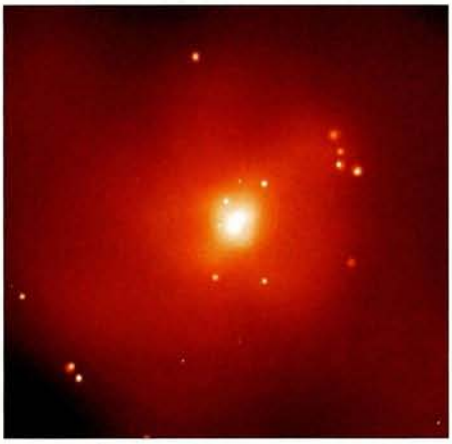
Let the data free!

Three researchers working in the new field of astroparticle physics argue the case for making the data from astroparticle experiments public.

Making astronomical data from the telescopes in space or on Earth freely available is common practice. A first step in this direction for particle physics data has been undertaken recently with QUAERO, a scheme developed at Fermilab to make high-energy data from the D0 experiment generally available (*CERN Courier* November 2001 p8, Abazov *et al.* 2001). This kind of "experimental transparency" allows any physicist in the world to test a new theoretical idea or evaluation algorithm. However, the practice does not exist for data taken from dark-matter experiments, although the most natural approach for this relatively new cross-disciplinary field of astroparticle physics should be that the data do not remain the private property of each experimental collaboration, but become public, as in the case of astronomical data.

We do not believe that the continuing secrecy in experimental astroparticle physics has been introduced intentionally. On the contrary the reason most probably lies in the lack, as yet, of any direct signature for dark-matter particles, which are believed to dominate the gravitational mass of the universe strongly. This situation has existed for decades, but despite this the challenging experimental question of the nature of dark matter is now fascinating more and more physicists across different disciplines. To our knowledge, there is no other similar example in the past.

As long as dark-matter physicists believe they have a zero result with their data, they will focus on improving detector performance to stay at the forefront of their field of research. Who then, has the time and the courage to consider releasing data collected over several years, which have become downgraded at best to measurements of background? There is no lack of data coming out of the underground dark-matter experiments worldwide, but these data have already been quasi disqualified because they do not fit the widely accepted picture of dark-matter interactions at the Earth.



A cloud of X-ray emitting gas surrounding galaxy NGC 720, extending well past the optical image, provides astronomical evidence for dark matter, as the gravity of the visible matter is not sufficient to bind such a hot gas. Could dark matter searches contain an overlooked signature, of interest to particle physicists and astrophysicists alike? (NASA/CXC/UCI/D Buote et al.*)*

However, in the past even dark-matter data have been re-evaluated following a new (theoretical) approach from inside as well as outside the collaboration, and this is exactly why astroparticle physicists should release their data. Most, if not all, dark-matter experiments are not complex, and their data can easily be formatted for non-experts. Scientific problems know no frontiers, and certainly not those as defined by a collaboration, even an international one. The dark-matter problem itself might also require some kind of synergism, or even a cross-correlation, between different experiments that have been declared – or even not declared – as dark-matter experiments.

As in particle physics, astroparticle physics theory is far ahead of experimental performance. However, it could be that the generally accepted theoretical picture does not point the experimentalists in the right direction. After all, there have been plenty of unanticipated discoveries in the past. For example, if the recently widely discussed theory of extra dimensions reflects reality, at least some of the approaches of the dark-matter searches must be revised because the particles they are aiming to detect have completely different properties from those assumed so far. Obviously, we must be sure that a signature in dark-matter data from previous experiments has not been overlooked, otherwise the broken dreams of dark-matter physicists will become their nightmares.

Making the data from astroparticle physics public will certainly promote scientific collaboration and will increase the many numbers of "amateurs" working in this field. Scientific transparency can only be beneficial to the science we are supposed to serve, and we have therefore suggested to the astroparticle physics community that it releases its data (Hoffmann *et al.* 2003). CERN, with its astroparticle physics programme, could once more be the pioneer of a new approach.

Further reading

V M Abazov *et al.* 2001 *Phys. Rev. Lett.* **87** 231801.

D H H Hoffmann, J Jacoby, K Zioutas 2003 *Astroparticle Physics* (in press).

Dieter Hoffmann, TU-Darmstadt, Joachim Jacoby (University of Frankfurt) and Konstantin Zioutas (University of Thessaloniki) are members of the CAST collaboration at CERN.

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S-Band and L-Band SYSTEMS

Typical Electron Beam Energy (MeV)	1 to 20
Typical Electron Beam Power (kW)	1 to 30
Typical Electron Beam Head Mass (kg)	500
Typical Characteristic Dimensions (mm^3)	1500 x 1200 x 1200
Scan Horn	As required

MEDIUM AND HIGH POWER, EASY TO OPERATE, SMALL FOOTPRINT

OPTIONS:

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

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

AS&E High Energy Systems Divisions, 3300 Keller Street, Bldg 101, Santa Clara, CA 95054
Phone# (408) 980-9729 Fax# (408) 980-8605
Web Address: www.as-ehesd.com

TOOLS FOR DISCOVERY

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LHC experiments:

Magnetic Field (up to 7 kGauss) and Radiation Tolerant HV & LV boards

Catalog products:

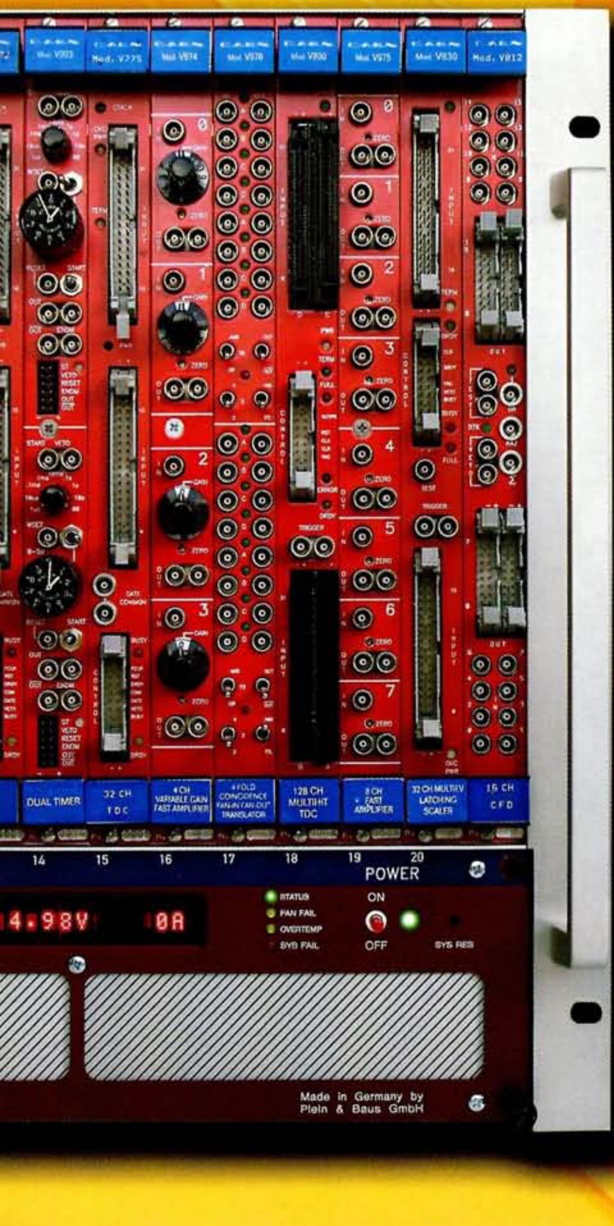
wide range of HV & LV Power Supplies (for all detectors)

Catalog products:

FE, DAQ & Trigger Units (VME, CAMAC, NIM)

Custom Design:

FE, DAQ, HV, LV & Trigger Units



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More than 20 years experience.
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