INTERNATIONAL JOURNAL OF HIGH-ENERGY PHYSICS

CERN COURIER

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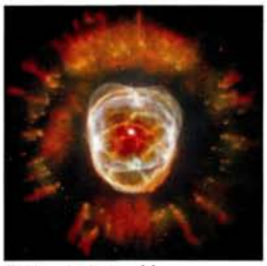
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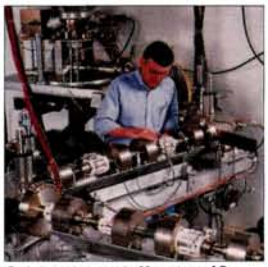
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Cover: Scene from *The Delphic Oracle*, a play on the theme of antimatter, by Geneva's Miméscope company in collaboration with CERN, which ran at CERN for a season this winter. p21.

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

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Korea and CERN make plans for future scientific collaborations

Following the signature of a Memorandum of Understanding recently at Korea University in Seoul, Korea. Left to right: K S Kim; J W Park; CMS resource manager D Blechschmidt; CERN research director R Cashmore; president J B Kim; CERN advisor on non-member state matters J Ellis; S K Park; and Y S Yoon.

A Memorandum of Understanding was signed recently in Seoul between a CERN delegation comprising the director of research Roger Cashmore, the advisor on non-member states John Ellis, the CMS resource manager Diether Blechschmidt and Korea University president Jung Bae Kim, on behalf of Korea.

The CERN representatives and Korean project leader, Sung Park, also met Korea's Minister of Science and Technology, and held discussions with Korean physicists and delegates from industry about the outline of plans for future R&D and the mass-production of the Forward Resistive Plate Chamber for the CMS experiment at CERN's LHC collider.

Over the past two years, Korea has played an active role in R&D for this major CMS component. In the summer of 1998 an actual-sized prototype was built and successfully tested at CERN, followed by the construction of a second actual-sized prototype. Intensive R&D continues, which is being coordinated by the Korea Detector Laboratory (KODEL; *CERN Courier* October 1998 p5).

Thirteen other Korean institutes are associated: Cheju National University, Chonnam National University, Chungbuk National University, Dongshin National University, Kangwon National University, Konkuk, Kyungpook National University, Seonam, Seoul National University, Seoul National University of Education, Sungkyunkwan, Wonkwang and Yonsei.

The signing of the Memorandum of Understanding represents a milestone for basic science research in Korea.

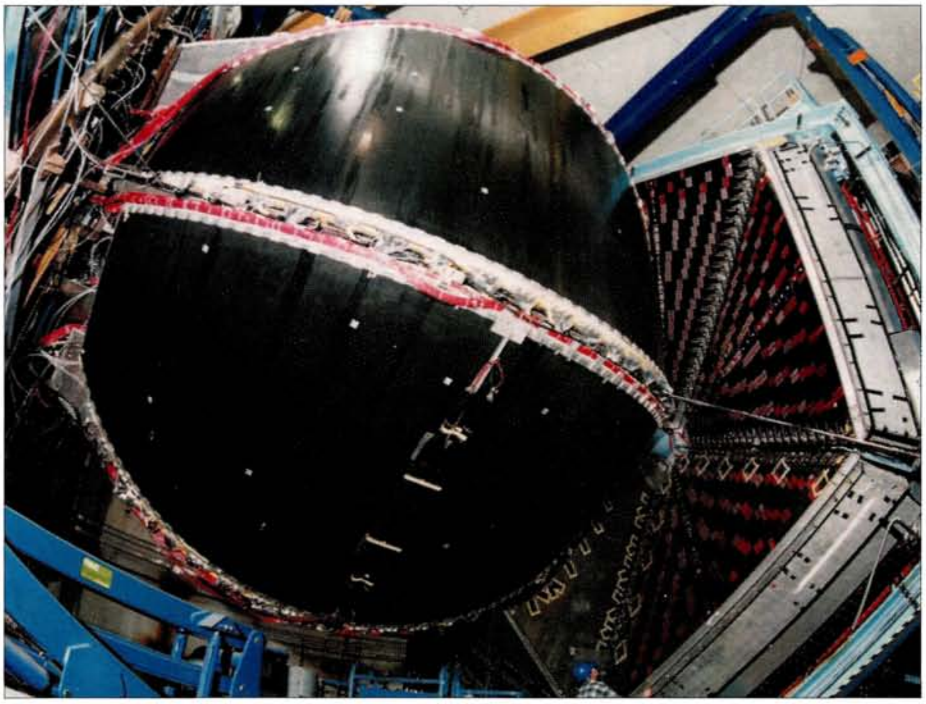
First major CMS production is over

The first major contract for the CMS experiment at CERN's LHC was completed last month when the last of 120 forged iron blocks rolled off the production line at the Izhora factory, St Petersburg. The blocks, weighing up to 41 tonnes, will make up the experiment's barrel magnet yoke. The occasion was marked by a ceremonies and a press conference in St Petersburg on 12 January.

Izhora won the contract following an international call to tender by CMS magnet contractor, German firm Deggendorfer Werft und Eisenbau GmbH. The contract, valued at DM 4 million, was for 3500 tonnes of forged and machined iron split into 120 blocks and produced in five batches for the five rings of the CMS barrel yoke. One of the reasons that Izhora won the contract is that there are few factories in the world that are capable of forging blocks on the scale required by CMS.

The blocks travel from St Petersburg to Deggendorf near Munich, where they are further machined and assembled. The trial assembly of the first ring was in September 1999 and the blocks for the final ring are now on their way to the German factory. After test assembly at Deggendorf, they will be shipped to CERN for final assembly in July.

Izhora has already supplied iron for experiments at Brookhaven, DESY and Fermilab, as well as for the Delphi experiment at CERN.



The CEBAF Large Acceptance Spectrometer in Hall B at the Jefferson Laboratory, Newport News, Virginia, provides a new view of the basic building blocks of matter.

CLAS at Jefferson offers a new subnuclear view

In Experimental Hall B at the Jefferson Laboratory, Newport News, Virginia, the CEBAF Large Acceptance Spectrometer (CLAS) has opened a new "window" on the building blocks of matter: mesons, nuclei and nucleons. CLAS enables detailed studies of the spectrum of nucleon-excited states. This is a source of vital information about the nucleon's constituents and the forces between them.

The large-acceptance CLAS serves experiments that require the simultaneous detection of several loosely correlated particles in the hadronic final state, and measurements at limited luminosity. It collects data at the unprecedented rate of 3000 events per second, which is substantially higher than its design goal of 1500 events per second. Six superconducting coils generate its toroidal magnetic field.

A seven-year collaboration between 34 institutions in the US, France, Italy, Armenia, Korea, the UK and Russia built CLAS for use in Hall B – the last of three experimental halls to become fully operational at Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF).

The superconducting radiofrequency CEBAF accelerator, which was originally designed for 4 GeV, but which is now delivering up to 5.5 GeV, provides three simultaneous continuous-wave beams of independent current and independent but correlated energies.

With Jefferson Lab seeking to bridge the gap between quark and hadronic descriptions of nuclear matter, CLAS's operation fits into a three-hall programme of complementary experiments guided by quantum chromodynamics, the fundamental theory of quark interactions. The laboratory's earliest experiments began in Hall C in late 1995.

CLAS enables particles to be tracked and identified, and their energy, momentum and initial direction to be defined. It does this by using information provided by drift chambers, Cherenkov counters, scintillation counters and electromagnetic calorimeters.

CLAS will be a crucial tool in Jefferson Lab's investigation of the quark–gluon structure of the nucleon and, in particular, will facilitate the detailed study of its spectrum of excited states. As in atomic physics, the spectrum of this system contains vital information about the nature of the nucleon's constituents and the forces between them.

It is not clear why the naive constituent quark model is so successful in explaining the particle spectrum discovered so far. CLAS will either support this model by discovering the complete pattern of states that it predicts, or it will reveal the model's shortcomings.

UK theorists investigate new trends

At the recent UK Rutherford Laboratory annual theory jamboree, speakers Subir Sarkar (left, Oxford) and Robertt Dijkgraaf (Amsterdam) discuss the introduction to Robertt's review of the promising area of string theory and quantum gravity.

The traditional annual UK theory meeting at the Rutherford Laboratory is a good showcase for new theory trends. One highlight was Robertt Dijkgraaf's review of the promising area of string theory and quantum gravity. He was effectively "selling" dictionaries to translate between any two out of three "languages" for describing the modern view of particle theory. D-branes, the large N-expansion and and non-commutative geometry provided the connection between the string theory and gauge theory descriptions, while renormalization group flow, holography and effective geometry provided the links between gravity and gauge theory. Sigma models allowed gravity to be related to the string theory language.

Martin Luscher presented a beautiful resume of Weyl fermions and chiral theory on the lattice. Jonathan Flynn gave the latest on the CP violation situation, both theoretically and experimentally. CP violation is poised on the threshold of a new era.

Subir Sarkar emphasized the excitement that exists in ultrahigh cosmic rays and how this is a clear indication of new physics just around the corner. The hot topic of extra dimensions and how to see a signal of their existence was authoritatively reviewed by Joe Lykken. Marcela Carena showed what we might expect at the Fermilab Tevatron and at CERN's LHC in Higgs phenomenology, while Martin Beneke described the impressive progress made during the last year in computing higher-order corrections to many quark-gluon processes and the impact that these will have in phenomenology.

Two talks took the audience to more distant horizons. Pierre Sikivie raised the exciting prospect of the possible existence of caustic rings of high-density dark matter in the galactic halo. Meanwhile, Chas Beichman, chief scientist of the origins programme at JPL, presented dramatic evidence for planets around distant stars and illustrated how we may be able to probe the conditions on these planets and determine whether such conditions would be favourable in supporting life.

Given the uncertain future of the theory group at Rutherford, it was heartening to see the traditions of this meeting, which has gone from strength to strength over the last 35 years, being kept.

Computing is put on the MAP

The University of Liverpool has just commissioned a major computer system that is dedicated to the simulation of data for current and future scientific experiments.

One of the largest in Europe, the system comprises three hundred 400 MHz PCs running under Linux. The primary role of the computer system is to simulate large numbers of events to help to optimize the design of the central vertex detector for the LHCb experiment at CERN's LHC proton collider.

Computing on the Liverpool MAP. Each rack carries 30 PCs and 2 ethernet hubs. Left to right: G Patel, E Gabathuler, A Moreton and T Bowcock. In the foreground is a prototype 1 TByte server on loan from Dell Computers UK.

The Monte Carlo Array Processor (MAP) is now fully commissioned and produces more than 250 000 fully simulated events per day.

All of the components of the system are low-price commodity items packed into custom rack-mounted boxes. The mounting ensures minimal space requirements and optimal cooling.

The power of MAP reflects the simplicity of its architecture, with essentially all of the PCs dedicated to one job. A custom control system and protocol written at the University of Liverpool has enabled very reliable communication between the "master" and the "slave" nodes on the 100BaseT internal network.

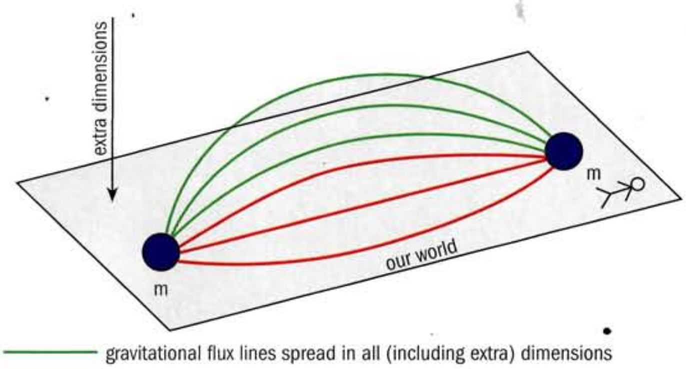
A small fraction of the system is reserved for system development and it is hoped to use this to test direct node to node communication. This would enable MAP to handle problems of much wider applicability than just event simulation.

The project will provide an insight into the operation of large-scale PC arrays planned for the LHC as well as providing the LHCb collaboration with sufficient computer power for its vertex detector optimization studies.

Despite its power, MAP is still a long way from being a general-purpose machine for analysing real or simulated data. A potential solution to the storage and analysis of large amounts of data is to store the output of the experiment on large disk servers.

The Liverpool team has tested a prototype 1 TByte server on loan from Dell Computers, UK. Unlike standard RAID architectures, there are no specialized hardware components but simply 1 Tbyte of SCSI disks attached to a high-performance server. This has the benefit of low cost compared with standard systems, and it is hoped to equip MAP with such a storage system to test its operation in such an environment.

Discovering new dimensions at LHC



New physics experience might reveal more dimensions in the Universe than meets the eye.

CERN's new LHC collider, which is scheduled to begin operations in 2005, aims to find the long-awaited "Higgs particle", which endows other particles with mass. In an entirely new energy range and with its special experimental conditions, the LHC could also discover other new physics effects.

Why is gravity so weak? The traditional answer is because the fundamental scale of the gravitational interaction (i.e. the energy at which gravitational effects become comparable to the other forces) is up at the Planck scale of around 10^{19} GeV – far higher than the other forces. However, that only raises another question: what is the origin of this huge disparity between the fundamental scale of gravity and the scale of the other interactions?

A possible explanation currently gaining ground in theoretical circles is that the fundamental scale of gravity is not really up at the Planck scale, it just seems that way. According to this school of thought, what is actually happening is that gravity, uniquely among the forces, acts in extra dimensions. This means that much of the gravitational flux is invisible to us locked into our three dimensions of space and one of time.

Consider, by analogy, what two-dimensional flatlanders would make of three-dimensional electromagnetism. To them, the flux lines of the force between two charges would appear to travel in their planar world, whereas in reality we know that most of the flux lines would spread out through a third dimension, thus weakening the force between the two charges.

Of course, if this third dimension were infinite in size, as it is in our world, then the flatlanders would see a $1/r^2$ force law between the charges rather than the $1/r$ law that they would predict for electromagnetism confined to a plane. If, on the other hand, the extra third spatial dimension is of finite size, say a circle of radius R, then for distances greater than R the flux lines are unable to spread out any more in the third dimension and the force law tends asymptotically to what a flatlander physicist would expect: $1/r$. However, the initial spreading of the flux lines into the third dimension does have a significant effect: the force appears weaker to a flatlander than is fundamentally the case, just as gravity appears weak to us.

Turning back to gravity, the extra-dimensions model stems from theoretical research into (mem)brane theories, the multidimensional successors to string theories (April 1999 p13). One remarkable property of these models is that they show that it is quite natural and consistent for electromagnetism, the weak force and the inter-quark force to be confined to a brane while gravity acts in a larger number of spatial dimensions.

The requirement of correctly reproducing Newton's constant, G, at long distances leads to the size of the extra dimensions in which gravity is free to act being related to the number of extra dimensions.

If there is just one extra dimension, then the model says that it should be of the order 10^{13} m, in which case solar system dynamics would be radically different and we would be taught a Newton's $1/r^3$ law in school rather than the $1/r^2$ law that we know and love.

So one extra dimension doesn't work. With two extra dimensions, the scale drops to slightly less than 1 mm and, small though that is, it at first seems surprising that extra dimensions of that size have not already been seen. However, because the extra dimensions only affect gravity, the most direct constraints come from experiments to measure G at short distances, and delving into the historical literature on the subject reveals that no measurements of G at the submillimetre scale have ever been made.

A team led by Aharon Kapitulnik at Stanford is currently in the process of accurately measuring G at submillimetre scales for the first time using a tabletop experiment.

For more than two extra dimensions their size begins to get quite small: 1 fm, for example, for six extra dimensions, outside the range of even the improved submillimetre gravity experiments. Nevertheless, the model still makes a number of dramatic predictions. If gravity does have extra dimensions at its disposal, they should manifest themselves at CERN's LHC proton collider, which is scheduled to come on line in 2005, no matter what the number of extra dimensions might be.

This is because the fundamental scale of the gravitational interaction should be around a few tera-electron volts, so, at TeV energies, gravitational effects will become comparable to electroweak effects. Consequently, gravitons will be produced as copiously as photons, with the difference that the photons will remain in our familiar dimensions while many of the gravitons will escape into extra dimensions, carrying energy with them.

More dramatically still, the LHC could produce fundamental string relations of our familiar particles, such as higher-spin relatives of electrons or photons. There is also a possibility that, owing to the now much stronger gravitational interactions, microscopically tiny black holes could be produced with striking signals.

Fortunately, such small black holes are not at all dangerous, being much more similar to exotic particles than large astrophysical black holes, and they decay quite quickly as a result of Hawking radiation. With the recent outburst of ideas in these directions, it is clear that extraordinary discoveries at the LHC may be just around the (extra-dimensional) corner.

Edited by Alison Wright

Except where otherwise stated, these news items are taken from the Institute of Physics Publishing's news service, which is available at "http://physicsweb.org".

Arrows of time run in reverse?

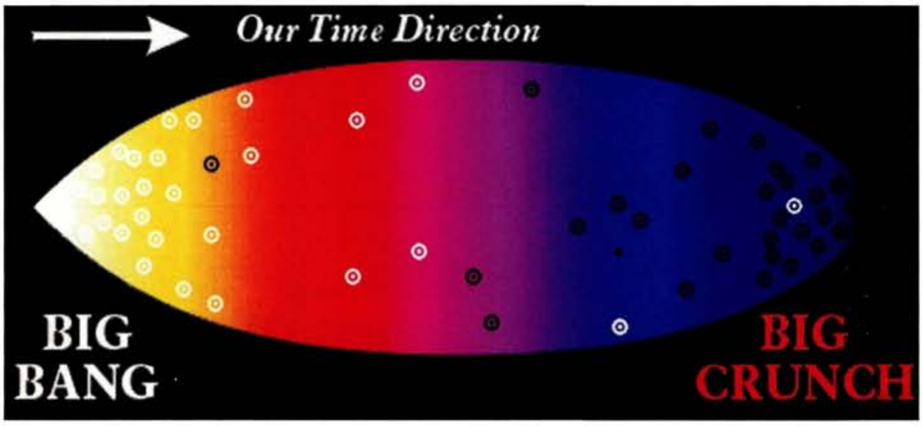
The laws of physics are mostly time-symmetric – they work whether time runs backwards or forwards. However, we certainly perceive an "arrow of time" whenever we smash an egg or drop a wineglass – the egg and glass will not reassemble themselves. Linking this arrow of time defined by thermodynamics to the cosmological arrow of the expansion of the universe defines, for us, a forward direction.

Why does the arrow point that way? Could there be pockets in the universe where the arrow points in the opposite direction, where time seems, to us, to run backwards?

Lawrence Schulman of Clarkson University in New York has been tackling this question. He claims that it is possible to have opposite-running time regions and that some "small" degree of contact between them will not destroy the arrows of time. However, on the question of causality (whether someone in a time-forward region could warn someone in a time-backward region that an event is about to happen), Schulman admits that his calculations rely on some assumptions to avoid paradoxes.

How could regions of opposite-running time have formed? In the same way that electrons and positrons run in opposite time directions, Schulman suggests a cosmological picture with a timeline running between the Big Bang and the "Big Crunch" – the massive contraction marking the end of our universe. Then what would appear to us as time-reversed regions are just matter following the timeline in reverse.

Although current cosmological thinking disfavours the Big Crunch scenario, if it does happen, it is still certainly a very long time away. Therefore, if there are galaxies with backward-running time, following the timeline from Big Crunch to Big Bang, at this instant they are very old and hence not very luminous, although they are still exerting a gravitational pull – exactly the hallmark of dark matter.



The direction of time follows the expansion of the universe, but perhaps there are regions of backward-running time (black circles), evolving in reverse from a possible Big Crunch at the end of our universe, and appearing to us like dark matter.

Photon teleportation achieved

Teleportation – the instantaneous transportation of an object (like Captain Kirk in *Star Trek*) across space – may seem to be solely the stuff of science fiction. However, at the quantum level, the dream has already become a reality.

Experiments in Austria and Italy pioneered "teleported" information about photon polarization (not the photon itself) from a sender to a receiver using the trick of "entanglement" – a deep quantum mechanical connection between particles that was first pointed out by Einstein, Podolsky and Rosen.

For example, with two entangled photons (A and B), determining the polarization of one of them (say, 0°) automatically defines the polarization of the other – the second photon must "collapse" into the complementary state (90°). Therefore to teleport the information "45° polarization", a messenger photon of 45° polarization is made to entangle with photon A, thus obliging A then to be in the complementary polarization state. This in turn means that photon B now has the same polarization as the messenger photon, which is complementary to that of A. Then measuring the 45° polarization of B means "message received".

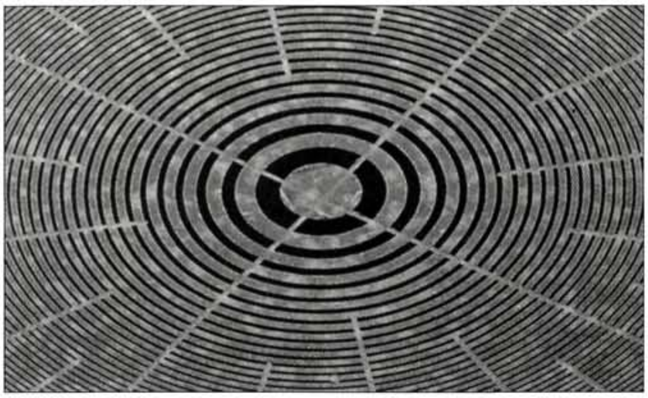
Experimenting with entangled photons is quite difficult, however. Now UK researchers are proposing a much simpler technique of conveying information – by teleporting the quantum state of an atom trapped in a cavity to a second atom in a distant cavity.

Laser traps electrons

Physicists at Rochester, New York, have trapped electrons in a laser beam. They make a laser "ring" by directing an intense beam through a half-wave plate to add a phase shift to the inner portion of the beam. Half of the incident field is shifted, causing destructive interference at the focus. With the central null field enveloped in the laser field, the trap is primed.

Electrons in the oscillating electromagnetic field drift under the ponderomotive force into low-intensity regions, becoming "trapped" in the centre ring. The force makes the electrons "quiver" – harmonic or anharmonic motion depending on whether they are non-relativistic or relativistic. The electrons emit light by Thomson scattering. Matching this radiation pattern to the results of computer simulations indicates the success of the trap.

Fresnel plate sharpens focus of helium beam



Exploiting wave-particle duality, researchers can focus beams of helium atoms to spots of 2 μm across by diffraction at a Fresnel zone plate. Imaged by a scanning electron microsope, the central zone of the plate is 10.4 μm in diameter, while the outermost slit is only 100 nm wide.

A team of German physicists has taken a step closer to the realization of an atomic de Broglie microscope. Exploiting the wave-particle duality of quantum theory, they have produced a highly focused and intense beam of helium-4 atoms.

Traditionally, imaging microscopes have used only electrons or photons, as either particle can be focused easily. However, imaging with helium atoms is an attractive alternative: at thermal energies (5–100 meV), chemically inert helium-4 atoms are non-penetrating and would not damage the subject of the imaging process. This is obviously useful in the imaging of biological samples. Also, the de Broglie wavelength of such atoms is only a few tenths of a nanometre, giving much better resolution than optical or electron microscopes for comparable energies of incident particles.

The problem is focusing a helium beam. Ground-state helium-4 atoms have low polarizability and no spin, so standard techniques cannot be used. However, wave-particle duality means that helium-4 atomics are diffracted by the slits of a grating just like waves. The effect is to focus the atoms into a narrow band – the central maximum of the diffraction pattern.

The researchers used a custom-made Fresnel zone plate – a grating of 100 nm slits in concentric rings. They saw a focused spot of less than 2 μm in diameter and of an intensity 1000 times as high as that achieved by any previous experiment.

Edited by Emma Sanders

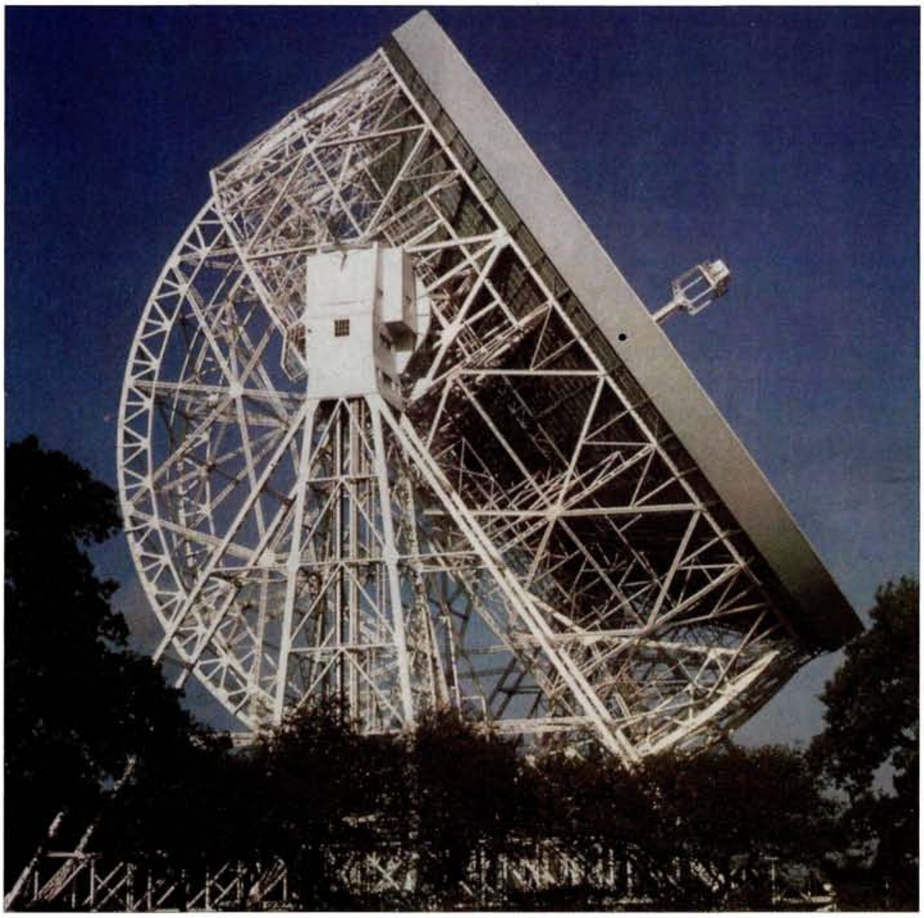
Pollution threatens observations

Two months from now the International Telecommunications Union will hold its World Radio Conference in Turkey. Radio astronomers are hoping for new regulations to curb emission from satellites that are polluting their observations.

Man-made radio emission has increased dramatically over recent years with the advent of satellite telecommunications and digital broadcasting – so much so that radio astronomy now finds itself under threat from the very technology that it nurtured. Even microwave ovens and car remote locking systems contribute to the rising noise that pollutes astronomical observations.

Radio astronomy has revolutionized our understanding of the universe, revealing, among other things, radio galaxies, quasars, pulsars and the cosmic background radiation. Indeed, radio is the only wavelength other than optical that is not blocked by the Earth's atmosphere. Radio waves pass through the clouds of gas and dust that block out light waves, revealing parts of the universe that would otherwise remain hidden.

Very long baseline interferometry links radio telescopes around the world to give the highest resolution available anywhere across the entire electromagnetic spectrum – 10 microarcsec – which is equivalent to the angle subtended by a golf ball on the moon, 400 000 km away.



The 72m Lovell radio telescope at Jodrell Bank, Manchester University. Man-made radiation is posing a serious pollution problem for radio astronomers. (NRAL)

Several organizations protect the interests of radio astronomy and negotiate with the governing bodies and communications giants. However, many compromises have to be made along the way. In May 1999 an agreement was concluded between radio astronomers and Iridium, which uses a network of satellites transmitting in the 1616–1626 MHz frequency range. These transmissions seriously pollute observations of the 1612 MHz spectral line of the hydroxyl radical, which gives a unique view of stellar evolution and galactic dynamics. The agreement, which was signed by the President of the European Science Foundation on behalf of the various radio observatories and their funding agencies, guarantees low interference from Iridium up to 50% of the time, which allows limited 1612 MHz research to continue.

ESO visits CERN

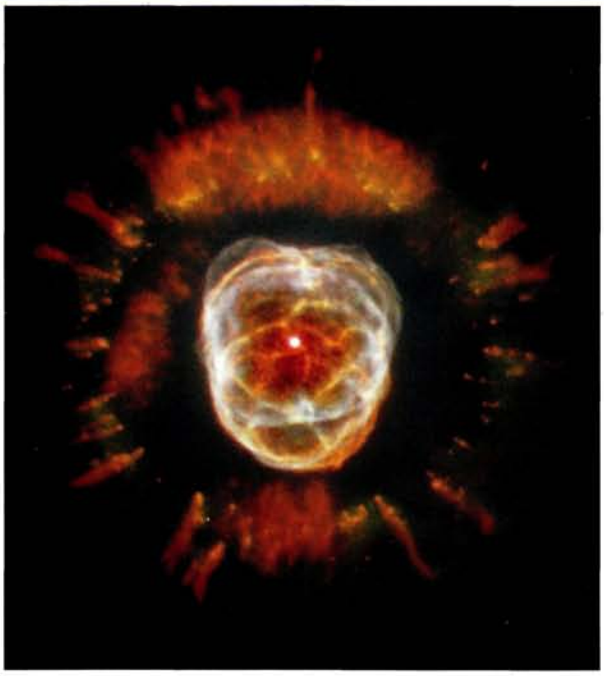
Catherine Cesarsky, director-general of the European Southern Observatory (ESO), visited CERN on 5 January. ESO has strong ties with CERN. Before the observatory moved to Garching in Germany, it was based at the CERN site. Shown here are CERN's LHC division leader Philippe Lebrun (right), Catherine Cesarsky and CERN physicist Daniel Treille, visiting the LHC magnet test hall.

Boomerang results suggest 'flat' universe

The ultimate fate of the universe depends on exactly how much matter it contains. It could expand forever, with galaxies drifting further and further apart. However, if there is enough matter, gravity's pull will slow the expansion down, or even reverse it, ultimately leading to a Big Crunch.

New results from a test flight of the Boomerang balloon experiment imply that there is just enough matter to stop the expansion, but not to reverse it. This scenario is known as a "flat" universe. Boomerang measures the Cosmic Microwave Background radiation (*CERN Courier* November 1999 p13). Fluctuations in this background are evidence for the first clumping of matter – the seeds of galaxies we see today.

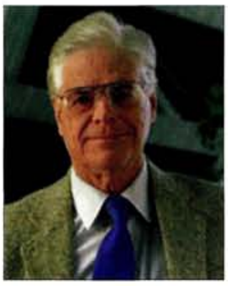
Picture of the month



This spectacular image shows the "Eskimo" Nebula, so-called because it resembles a face surrounded by a fur parka. The outside ring is really a disk of gas containing comet-shaped objects, with their tails streaming away from the central, dying star. It was first observed by William Herschel in 1787. This image was made on the 10 and 11 January during the Hubble Space Telescope's recommissioning phase. A recent repair mission replaced the telescope's gyroscopes and added new electronics. (NASA/ESA.)

The magician: Robert Rathbun Wilson 1914–2000

Physicist, accelerator builder, artist, laboratory pioneer, visionary: Bob Wilson was admired all over the world. *Al Silverman* pays tribute to his extraordinary achievements.



Bob Wilson was a magician. Take, for example, his creation of Fermilab. This laboratory started as a proposal from the Lawrence Berkeley Laboratory for a 200 GeV accelerator to be built in seven years for $300 million. It was to be called the National Accelerator Laboratory. In due course the US Atomic Energy Commission (AEC) agreed to provide the funds but insisted that it should be built in Batavia, near Chicago. The Berkeley people refused, and the AEC turned to Wilson. He had already gone on record criticizing the Berkeley proposal as too conservative, too expensive and too long.

Wilson accepted the directorship and set out, more or less alone, to build the world's largest accelerator. So, with no staff, no laboratory and no buildings to work from, Wilson left for Batavia, a rural farm community in Illinois, to build the world's most sophisticated machine. Of course, he wasn't quite alone. Several people from Cornell and other accelerator laboratories joined, some permanent and some for a year or two. Accelerator builders were in short supply, and the existing laboratories worked hard to keep their people.

One of Wilson's first acts in his new task was to reset the goals: instead of 200 GeV, the design was for 400 GeV; instead of seven years, the construction time was shortened to six; and the price dropped to $250 million. In six years the machine was operating at 400 GeV and the cost was somewhat below the $250 million budgeted. How did he do it? That's the thing about magicians, you can't quite figure out how they do it.

Dreadful mistake

I don't mean to say it was all trouble free. Wilson and his group made one dreadful mistake. In his usual style, Wilson proceeded as fast as he could and found himself with a lot of magnets but no place to put them. He decided to store them in a part of the four-mile tunnel that had not yet been heated and was still pretty damp. The magnets stored there absorbed moisture through hairline cracks in the insulation, and, when the accelerator started operating, the magnets developed short-circuits. Wilson, a courageous magician, took a deep breath and, within about a year, during which time the accelerator was run as well as possible, slowly repaired the defective magnets as they failed. Boyce McDaniel, his longtime collaborator and successor as director of Cornell's Laboratory for Nuclear Studies, took a year's leave from Cornell to help to control the problem.

How important was it to reach 400 GeV? After all, 200 GeV was already about a factor of six greater than any other accelerator. In fact, this target was crucial. The two most important discoveries at Fermilab were the bottom and the top quarks – the two quarks making up the third and heaviest quark family. The bottom quark could not have been discovered at 200 GeV. I believe that Wilson could walk on water, but I don't believe that he foresaw this. I suspect it was pretty simple – 400 GeV was better than 200 GeV, and, in Wilson's judgement 400 GeV was possible with the allotted resources. Was it foolhardy? Was the risk too great? I don't think so. More could be learned from the more ambitious plan, so it was worth trying.

Superconducting magnets

That wasn't the end of the magic. He soon started a project, the Tevatron, to raise the energy to 1000 GeV. He certainly had the idea of the energy increase from the beginning and had built the tunnel with this in mind, but the tunnel's radius was too small to use conventional iron magnets, which saturated at 500 GeV. Also, the power for 1000 GeV conventional magnets was prohibitive. The answer was superconducting magnets, the fields of which could be greatly increased and whose power requirements were reasonable.

There was one small problem – no such magnet had ever been built. A few superconducting magnets had been used in experiments, but none reaching the stringent requirements of ▷

accelerator magnets. Also, one needed not a few but a thousand, very accurately made and highly reliable. Undeterred, he set to work building them. He set up an experimental facility at Fermilab, where he could build a magnet in a few weeks, test it, discover any problems and build an improved version, until he knew how to make them with sufficient accuracy and reliability. He did this himself, with his sleeves rolled up and his hands dirty. Of course, he had talented people working with him, particularly Alvin Tollestrup. It was a prodigious accomplishment and it was the new higher energy that made possible the discovery of the very heavy top quark. The third and heaviest family of quarks thus belongs to Fermilab and to Bob Wilson. The superconducting magnets also opened the door to a new accelerator era.

Art and science together

It wasn't only technically that Fermilab was beautiful; it was also beautiful to look at. Take, for example, the building now called Wilson Hall. Approaching Fermilab, you first see, about a mile away, an isolated tall building rising gracefully from the flat countryside. It looks more like a cathedral than a physics laboratory, and it's a surprising and exhilarating vision.

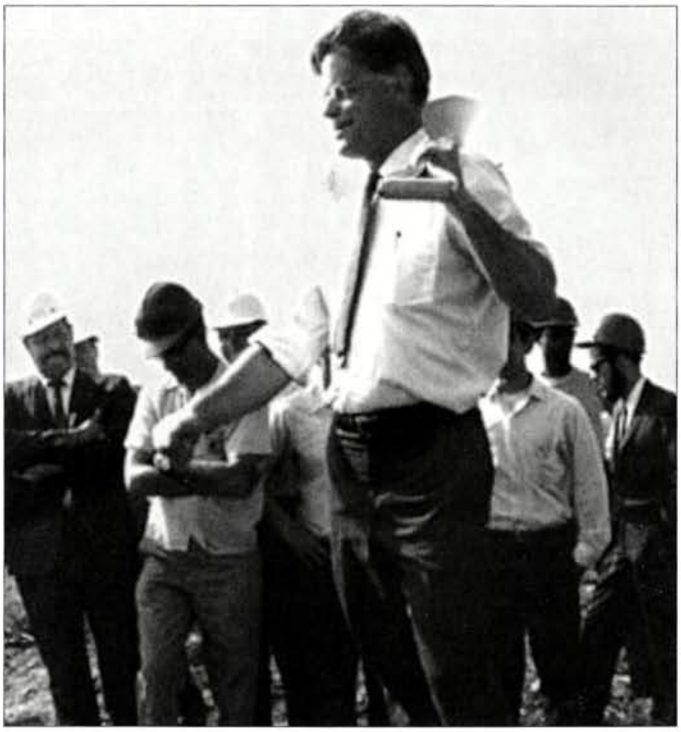
The aesthetics of Fermilab were important to Wilson. In an interview with Philip Hilts, published in the *Washington Post* of 20 February 1983, he spoke of these concerns. Among the features he mentioned were a 4 mile, 20 ft berm outlining the accelerator ring to mark the underground tunnel; a field planted with Illinois prairie grass, almost non-existent; and a herd of buffalo grazing inside the ring – a sight not seen in Illinois for 800 years. The grounds are dotted with sculptures, some by Wilson. Even the powerlines have a sculptural quality. These show the other side of Wilson – the artist who believed that science and art should blend to form a harmony that not only benefits scientific research and society but extends its culture.

This concern was eloquently expressed to Senator John Pastore on 17 April 1969 in testimony before the Joint Energy Committee of Congress:

Pastore: Is there anything connected with the hopes of this accelerator that in any way involves the security of this country?
Wilson: No sir, I don't believe so.
Pastore: Nothing at all?
Wilson: Nothing at all.
Pastore: It has no value in that respect?
Wilson: It has only to do with the respect with which we regard one another, the dignity of men, our love of culture. It has to do with whether we are good painters, good sculptors, great poets. I mean all the things we really venerate in our country and are patriotic about. It has nothing to do directly with defending the country except to make it worth defending.

Cornell

From 1947 to 1967, Wilson was the director of the Laboratory of Nuclear Studies at Cornell. I was his colleague for most of this period and experienced his magic. During his tenure we built four electron synchrotrons, each with some unique physics capability. Wilson cared about how his accelerators looked, but the reason he built them was that he wanted to do the physics that they made possible – he was first, and foremost, a physicist.



At the 1969 groundbreaking for Fermilab's Main Ring.

In 1948, shortly before the first synchrotron was put into operation, in his yearly report to the Office of Naval Research, which funded the accelerator, Wilson described what he thought the research programme would be:

"The most important problems of nuclear physics, to our minds, are: what are the elementary particles of which nuclei are made, and what is the nature of the forces that hold these particles together? A more general but connected problem concerns the general expression of electrical laws at such high energies as will be produced by our synchrotron. Our experiments are planned to attack all three problems. Thus we hope to produce artificial mesons which are supposedly elementary particles, and to study their interactions with nuclei. Further, we shall explore the electrical interactions of high energy electrons with electrons and protons in search of evidence pointing to a correct theory of electricity at high energy."

Wilson's vision about future research was right on target. One would be hard put to improve on it today. It is the statement of a physicist with a very clear notion of why he was building the accelerator and where he was going. Wilson built accelerators because they were the best instruments for doing the physics that he wanted to do. No-one was more aware of the technical subtlety of these machines, no-one was more ingenious in practical design and no-one paid more attention to their aesthetic qualities, but it was the physics potential that came first. And the clear ideas that Wilson had about the that physics he hoped to do is amply demonstrated in the almost prophetic statement quoted above.

So, for some 20 years as director of the Laboratory of Nuclear Studies, Wilson remained deeply embedded in the physics pro-


Loved and admired – Wilson at his Fermilab 80th birthday.

gramme, both as mentor and experimenter. He did important early experiments in pion photoproduction, which suggested to Bruekner the idea of nucleon excited states. He discovered the second nucleon excited state. He pioneered a class of experiments inside the synchrotron and with this technique did fundamental work on the structure of neutrons and protons, extending the pioneering work of Hofstadter at Stanford.

Machines

The first synchrotron, at 300 MeV, was designed and partly constructed before Wilson arrived at Cornell. It was a very productive machine, but by 1952 it was clear that the physics was urgently calling for higher energy, and Wilson initiated the construction of a 1 GeV (1000 MeV) synchrotron. It was characteristic that he insisted that the 300 MeV programme should continue without disturbance until the new machine was ready.

The following is a quotation from Wilson's 1953 report to the ONR describing the new project: "The Laboratory has indulged itself in some high adventure. A new synchrotron has been designed which is to give over a billion electron volts of energy. The design is highly controversial in that the new machine is exceedingly small and cheap for what it will do, hence there is considerable risk that it may not work at all. On the other hand, if we are successful, we shall have the largest electron accelerator in the world, and new areas of research will be opened to us. Our machine will cost us $200 000, while other machines giving much less energy have cost many millions of dollars."

This report tells us much about Wilson as an accelerator builder. Each new project was an adventure and an opportunity, and the more challenging the project, the more exuberantly it was embraced. It was pretty heady stuff, and we loved it and were inspired. The lab was a magical place. Despite Wilson's warning, the 1.2 GeV was a very successful machine. It not only did important physics, but its design paved the way to more compact, less expensive accelerators.

What is also revealing is the candour of Wilson's proposal to the ONR. There was no guarantee of success, only the guarantee of a scientifically exciting project worth the risk. It is a measure of the trust that the ONR had in Wilson that it unhesitatingly supported so modestly advertised a project.

The last machine Wilson built at Cornell was the 12 GeV synchrotron, at that time the world's highest-energy electron machine. This was the first accelerator to have the entire magnet (rather than just a vacuum chamber containing the beam) evacuated. This made it possible to reduce the vertical magnet aperture to 1 inch, simplifying the magnet construction and reducing the power demands. This idea was subsequently adopted for the Fermilab booster accelerator.

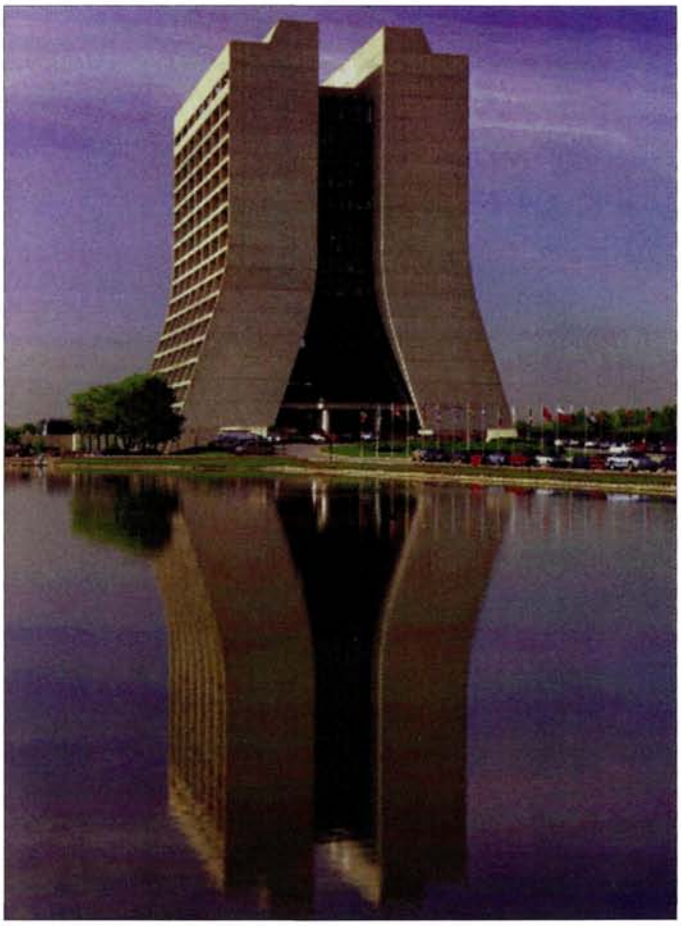
In the 1940s and 1950s, most of the accelerators were built at universities – perhaps 15 had frontline accelerators. The only one of which this is true today is Cornell. Cornell endured as an important centre of experimental high-energy research in this age of giant national and international laboratories, because it always had an accelerator with some unique physics capability built for a modest price. Wilson insisted on this during his tenure as director, and subsequent directors have continued in this "Cornell style".

Cancer therapy

A remarkable proposal of Wilson's, dating from the 1940s, has now assumed great importance. Making accurate measurements of the energy loss of protons traversing matter, he observed that protons deposit most of their energy near the end of their path, in what is called the Bragg peak. There was nothing unexpected about this measurement, but it led him to a happy and far-reaching idea – to use protons for cancer therapy. Wilson noted that, because of the Bragg peak, by carefully controlling the energy of a proton beam, most of its energy can be deposited in a cancerous tumour inside the body. This is in stark contrast with radiation treatment by electron or photon beams obtained from radioisotopes like cobalt, which attack both healthy and cancerous tissues indiscriminately.

It was this early interest in proton therapy that led Wilson first to provide a modest therapy facility at Fermilab, making use of the 200 MeV proton linac injector, and later to propose the use of the Harvard cyclotron for this purpose. Proton beams have now been used successfully for cancer therapy in a number of countries, usually as a secondary application on a machine designed for physics research. With the advent of Magnetic Resonance Imaging and Positron Emission Tomography, which can identify the positions of cancerous tumours with high precision, there has been an increased interest in the application of Wilson's ideas, and single-purpose hospital-based proton accelerators have been, and are being, built to extend this treatment. The first US single-purpose accelerator is at Loma Linda California Medical Center, having been built and tested at Fermilab.

The use of this technique is growing fast. New facilities are being built or planned in many places all over the world. The extent of this activity can be judged from the proceedings of the First International Symposium on Hadron Therapy at Como, Italy, in ▷



Cathedral of science - Wilson Hall at Fermilab.

October 1993, to which more than 200 papers were contributed from Europe and the US. Wilson was honoured for his pioneering work in this area at an international conference at CERN in 1996.

There is much more to Wilson's career: his graduate work at Berkeley, where he did the first theoretical analysis explaining the stability of cyclotron orbits and tested his theory experimentally; his key role at Los Alamos as head of the Physics Research Division; his work for the civilian control of atomic energy, as chairman of the Federation of Atomic Scientists; his role in promoting international co-operation as one of the organizers of the International Committee on Future Accelerators (ICFA); and his very effective affirmative action programme at Fermilab, to choose a few examples.

Wilson's multifarious achievements did not go unrecognized. He was awarded honorary degrees from Notre Dame, Harvard, Bonn, and Wesleyan universities. He received the Elliot Cresson Medal from the Franklin Institute, the National Medal of Science, the Enrico Fermi award, the Wright prize, the del Regato Medal and the Gemant award, the last in recognition of his creative work in the arts and humanities. He was a member of the National Academy of Sciences, the American Academy of Arts and Sciences and the American Philosophical Society. In 1985 he was elected president of the American Physical Society.

Al Silverman, *Cornell.*

SESAME: a mini CERN for the Middle East

A new international centre for synchrotron radiation research could do for the science of the Middle East what CERN has done for science in Europe.

Science brings nations together, and synchrotron radiation facilities bring different kinds of science together. Thus SESAME (Synchrotron Light for Experimental Science and Applications in the Middle East) could help to strengthen valuable new ties and develop new ones.

In the aftermath of the Second World War, CERN was created under the auspices of UNESCO with two objectives: to promote science and to foster international co-operation. Both aims have been achieved spectacularly and CERN is not only considered to be a great European success, but also recognized worldwide as a leading international focus with enormous benefits for knowledge and technology transfer, providing a hub where scientists from different nations, races and creeds can work together peacefully.

This dream is now being renewed, this time in the Middle East, and again within the UNESCO framework. Important progress was made during a meeting of the SESAME Interim Council in December. There is now a good chance that the project will fly, with the participation of Armenia, Cyprus, Egypt, Greece, Iran, Israel, Jordan, Morocco, Oman, the Palestinian Authority and Turkey – a list that, hopefully, is not yet complete. In addition, some countries participate as active observers: Germany, Japan, the US, Sweden, Italy, Russia and Switzerland.

Discussing possibilities for the SESAME synchrotron radiation facility for the Middle East at a meeting in Ramallah on 1 October 1999. Right to left: Sa'id Assaf, director-general, Arafat Center (ANSAR); president of the Palestinian National Authorities, Yasser Arafat; former CERN director-general and chairman of the SESAME Interim Council, Herwig Schopper; and assistant UNESCO director-general for Natural Sciences Maurizio Iaccarino

BESSY 1 resurrected

This newest offspring of CERN goes back to an initiative of Sergio Fubini, who, enjoying the confidence of both the Israelis and the Arabs, started a Middle East Scientific Cooperation with the original aim of organizing seminars and workshops. During a meeting in Turin in autumn 1997, Herman Winick from SLAC and Gustav-Adolf Voss from DESY suggested that BESSY I, a Berlin synchrotron radiation machine scheduled to be closed down in 1999, could be upgraded as the core facility for a new laboratory in the Middle East. Remembering the origin and aims of CERN, I suggested bringing this project under the valuable political umbrella of UNESCO.

However, experience in elementary particle physics has shown that only viable projects with a sound scientific basis are worth pursuing as international ventures. Thus last spring a meeting was organized by Tord Ekelöf at Uppsala to discuss a possible scientific and technical programme and to ascertain whether there is sufficient interest in the region.

The outcome was very positive and the SESAME plan was brought to the attention of the director-general of UNESCO (at that time Federico Mayor), who expressed enthusiastic support and agreed to invite all governments in the Middle East and in the Mediterranean region to a meeting at UNESCO headquarters in June 1999. The delegations unanimously adopted a resolution to launch the project. An Interim Council (chairman Herwig Schopper) was created, advised by a Technical Committee (co-chairs G-A Voss of Germany and C Papanicolas of Greece), a Scientific Committee (co-chairs H Winick of SLAC and E Alp of Turkey/US), a Training Committee (co-chair M Virasoro of Argentina/Italy and R Mansouri of Iran) and a Finance Committee (co-chairs S Assaf of the Palestinian Authority and M Comsan of Egypt). The similarity of this structure to that of CERN is not accidental.

A detailed proposal has been tabled for upgrading BESSY I to a facility that is fully competitive with other machines. Some 10 beamlines are foreseen, with two superconducting wigglers, serving research that ranges from physics, material science, molecular ▷

biology, environmental, archaeological and medical studies through to the industrial production of micromechanical parts.

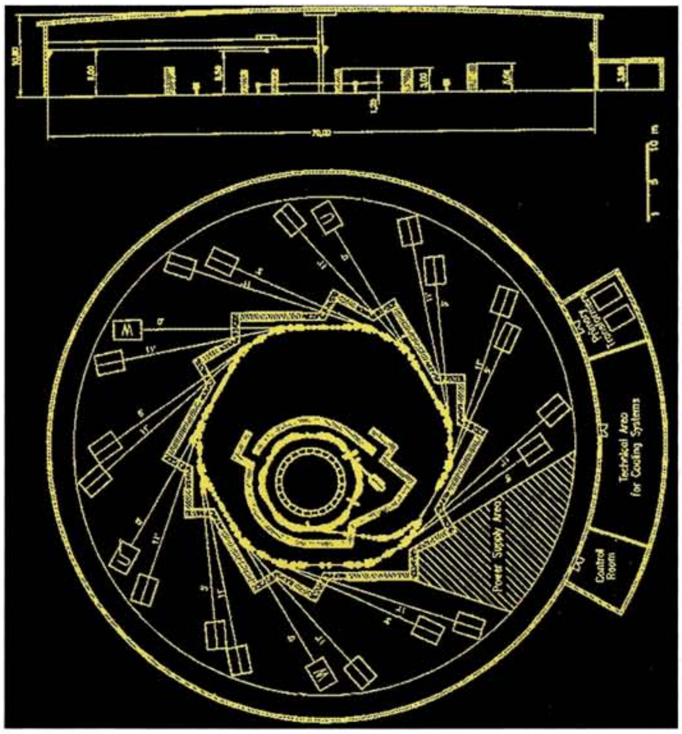
To explore and promote the project, assistant UNESCO director-general Maurizio Iaccarino and I recently visited Egypt, Israel, Jordan and the Palestinian Authority. The great interest that SESAME evokes in the region is not confined to scientists – we were received not only by several ministers but also by King Abdullah II of Jordan and President Arafat.

As with CERN, the next major problem to be solved is the selection of a site. All partners were asked to make site proposals. Some technical conditions had to be fulfilled, but, above all, free access to the laboratory for scientists from all over the world must be guaranteed. Proposals were received from Armenia, Egypt, Iran, Jordan, Oman, the Palestinian Authority and Turkey. Each proposal contained several possible sites.

Finding funding

A meeting of the Interim Council on 13 and 14 December agreed that political and financial criteria must be taken into account for a final site decision. A special committee chaired by the chairman of the Interim Council will meet this spring to prepare a proposal. In the meantime, discussions with and between governments will explore the possibility that one site might find support from several partners. The final decision should be taken before next summer.

The council meeting had to face a major problem. The German government had agreed to provide BESSY I as a gift – a decision that was much appreciated. However, at the same time, the funds for dismantling, packing and transport had to come from other sources and had to be found before the end of 1999, otherwise the components of BESSY I would be offered to other interested parties. To solve this problem, I asked each of the 11 SESAME partners to provide immediately US$20 000. This was agreed, with additional contributions coming from the US, Sweden and possibly Russia.



Proposed layout of SESAME. The next step is to find a site.

To complete the arrangements, I then had to beseech new UNESCO director-general, Koichiro Matsuura, who had been in office for only a few weeks, to underwrite an additional US$400 000.

With this initial funding in place, the dismantling of BESSY I can start. Experts from Armenia, Novosibirsk and from the region who will later install and operate the machine will be involved.

During all of the discussions, a remarkable and very pragmatic spirit of friendly co-operation prevailed, promising well for the future of the project. However, many problems remain, most notable of which is the funds for the creation of the laboratory and its operation. The installation and upgrading of the synchrotron are estimated at about US$20 million. Installing and equipping 10 beamlines within five years, together with putting in place the necessary infrastructure, will require a similar amount. Annual operating costs are estimated at US$3.5 million.

These hurdles will surely soon be overcome, and at the dawn of the century SESAME seems to be well on its way to becoming a "door opener" for a new wave of international co-operation, establishing a centre of excellence in a key region of the world.

Herwig Schopper, chairman, SESAME International Interim Council and former director-general of CERN (1981 to 1988).

Weapons abandoned in favour of detectors

The Cold War once absorbed a tremendous amount of resources and talent on both sides of the Iron Curtain. Particle physics is now at the forefront of a major, international effort that is refocusing these resources in more profitable directions.

Non-proliferation through scientific co-operation is the mission statement of the International Science and Technology Centre. The centre was established in 1992 under an agreement between the European Union, Japan, the Russian Federation and the US. Since 1992, other member nations have joined: Norway, Korea, Armenia, Belarus, Georgia, Kazakstan and Kirgizstan.

Based in Moscow, the International Science and Technology Centre (ISTC) provides ex-weapons scientists from former Soviet Union (FSU) countries with the opportunity to refocus their talents on peaceful activities. These activities may include helping to solve national and international technical problems; supporting the transition to market-based economies; contributing to basic and applied research; and encouraging the integration of other former weapons scientists into the international scientific community.

Particle physics in general and CERN in particular play a leading role in the work of the Moscow-based International Science and Technology Centre (ISTC). Its "swords into ploughshares" programmes redirect ex-Soviet weapons expertise towards more agreeable and profitable avenues. Left to right: ISTC executive director Alain Gérard, his assistant Alla Godunova and ISTC head of contracts and agreements, Norihiko Yokoyama, admire one of the calorimeter crystals provided by a major ISTC project for the CMS detector at CERN's LHC collider.

In the years 1992–9, ISTC programmes funded 830 projects worth US$230 million, providing grant payments to more than 30 000 workers. Particle physics and CERN played a valuable role in bringing together scientists and promoting understanding during the Cold War, and this role is continuing in the ISTC.

The main thrust of the ISTC programme is to support projects for FSU centres in collaboration with foreign firms or organizations. A significant proportion of the funding comes from ISTC sources. Each project is assigned to a CERN-familiar Russian "lead institute", which acts as a gateway to a frequently unfamiliar new supplier.

This traditional ISTC programme was extended in 1997 by the Partnership Programme, under which western organizations fund research and development to be conducted on their behalf at FSU centres via the ISTC. In this framework the outside funding is channelled by the ISTC, which also provides the necessary infrastructure and management inside the FSU region.

Overall, Partnership Programme contracts now exist with almost 60 partners, who work in the electrical, biomedical and chemical industries, as well as at research centres such as CERN. ISTC director-general Alain Gérard declared: "CERN–ISTC co-operation in high-energy physics continues to be a shining example of the unique and effective nature of the Partnership Programme, and it is a model for our future activities with CERN and other FSU institutes."

The ISTC "business", under both the traditional ISTC activities and the Partnership Programme, represents only a fraction of the total CERN–Russia collaboration. However, it signficantly extends its involvement to include additional institutes and a wider pool of expertise.

Case-studies

One of the first major projects under the ISTC banner began in 1994. This was a feasibility study of technologies for the accelerator-based conversion of plutonium and long-lived radioactive waste.

The Russian lead institute was Moscow's Institute for Theoretical and Experimental Physics (ITEP), with six other Russian centres also being involved. The partners were CERN and the US Los ▷

Alamos National Laboratory, both of which have demonstrated the feasibility of using particle beams from accelerators to transmute weapons-grade plutonium and to reprocess nuclear waste.

Overall, Partnership Programme contracts now exist with almost 60 partners, who work in the electrical, biomedical and chemical industries, as well as at research centres such as CERN

Directly involved in CERN's mainstream programme of research was an ISTC project for the design and construction of a cryostat and vacuum windows for a large liquid krypton calorimeter. The calorimeter is a key element of the NA48 CP violation experiment, which recently announced its initial results (*CERN Courier* September 1999 p6). Arranged through the Joint Institute of Nuclear Research (JINR) in Dubna, Moscow, the project involved the Khrunichev State Space Science and Production Centre, and ENTEK in Moscow. INFN Pisa was also a major partner.

Development work for experiments at CERN's future LHC collider is the theme of several major ISTC projects. Special computer systems to facilitate LHC detector design is the goal of VNIITF in Snezhinsk, with JINR also being involved. Recently the Snezhinsk institute assumed responsibility for the construction of major support structures for the ATLAS experiment, also involving JINR Dubna, IHEP Protvino and MPI Munich (*CERN Courier* January/February p6).

The inner tracker and forward multiplicity detector (FMD-MCP) for the ALICE experiment at CERN involves TsKBM of St Petersburg as the lead institute, together with JINR; the Nuclear Physics Institute in Gatchina, St Petersburg; the Kurchatov Research Centre, Moscow; the Mendeleev Institute of Metrology, St Petersburg; and several other St Petersburg concerns, as well as the university. On the CERN side, INFN Ferrara and Utrecht University provide the main interface.

For CMS, the production of lead tungstate crystals for the electromagnetic calorimeter was investigated by the Bogoroditsk Techno-Chemical plant. After this pilot study, mass-production of the 80 000 crystals will be shared by the Bogoroditsk plant and the Shanghai Institute of Ceramics (*CERN Courier* January/February p6).

For the endcap of the ATLAS hadron calorimeter, the main Russian partner is the Institute of High-Energy Physics (IHEP) in Protvino, Moscow, which is working with NPO Molniya of Moscow. The main collaborators are the Max-Planck Institut in Munich and CERN.

Several items for LHC detectors involve mass-production, such as the injection moulding for 0.5 million 200×400 mm transparent scintillation tiles to clad the ATLAS hadron calorimeter. IHEP in Protvino is the main Russian coordinator, with two specialist Russian concerns. For ATLAS, the project is handled by the Laboratorio de Instrumentacao e Fisica Experimental de Particulas, Lisbon. □

The Delphic Oracle and antimatter

This winter, CERN's LEP pit formed the backdrop for an unusual theatrical performance portraying Paul Dirac's mathematical discovery of antimatter symmetry.

Gripped by the intensity of original thought – Markus Schmid plays Paul Dirac, the spiritual father of antimatter.

Delphi revealed: at the play's end, the backdrop parts to show the experiment in the world's largest electron–positron collider.

A hundred metres underground in the pit that houses the Delphi experiment in the world's largest electron–positron collider, LEP at CERN – what better stage for a play about antimatter?

The Delphic Oracle by Geneva's'Miméscope company, in collaboration with CERN, ran for an extended season this winter. Each audience had to be limited to 60 because of the logistics of the LEP pit, and it was carefully divided into smaller groups – electrons, positrons, up quarks – each with its own CERN guide to usher them down, around and back up again.

The Delphic Oracle's action focused on Paul Dirac's mathematical discovery of antimatter symmetry, with Markus Schmid playing the role of the scientist gripped by the intensity of original thought and the profound implications of a discovery that went on to change our view of the universe. Such intellectual acrobatics were underlined by Yasmina Krim's graceful aerial ballet. The light show and backdrops illustrated matter and antimatter at work. At the end of the show, the audience was guided round the Delphi detector – a memorable experience, with even the access lift disguised as a time capsule.

Underground setting, lights and acrobatics apart, the strict scientific focus and the stark table-and-chair props were redolent of Michael Frayn's play *Copenhagen* about Niels Bohr and Werner Heisenberg (*Cern Courier* May 1999 p26), which all goes to show that physics can make good theatre.

In *The Delphic Oracle*, Heisenberg did not appear but was the addressee of the letters that Dirac laboriously compiled on stage. Unlike *Copenhagen*, where Frayn had scrupulously done his homework, physics purists might react to the liberal interpretation of Dirac's work in *The Delphic Oracle* and its scientific message. Although Dirac saw the need for symmetry between positive and negative charges in his famous 1928 relativistic treatment of the electron, for several years the proton was identified as the corresponding positive charge. Dirac himself said so in a letter to *Nature* in October 1930.

Others (notably Oppenheimer and Weyl) began to worry about a particle as heavy as the proton partnering a light electron in a theory that was supposed to be absolutely symmetrical. In May 1931, Dirac grasped the bull by the horns and finally proposed what his equations had been saying all along: "We may call such a [positively charged] particle an anti-electron. We should not expect to find any of them in nature, on account of their rapid rate of recombination with electrons, but if they could be produced experimentally in high vacuum, they would be quite stable and amenable to observation." These would have been fine words with LEP only a few metres away.

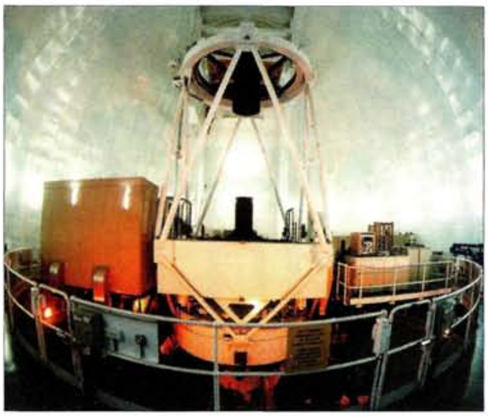
As an introduction to antimatter and as a spectacle, *The Delphic Oracle* was memorable, displaying Dirac's torment at having constructed a theory so perfect that its implications were unthinkable. Dirac suspected that antimatter had to exist, but it took him three tortured years to summon the courage to say so.

Like champagne, antimatter is always stimulating, however it is served.

Gordon Fraser, *CERN*.

• *Gordon Fraser's new book* Antimatter: the ultimate mirror *is soon to be published by Cambridge University Press.*

Physics in space



Viewing the universe through high technology detectors – the William Herschel Telescope, La Palma. (The Isaac Newton Group of Telescopes, La Palma.)

Superconducting tunnel junctions have been developed as photon-counting spectroscopic detectors for ground- and space-based astrophysical research. Arrays of tantalum-based junctions have now reached a state of maturity such that serious space-based applications can be considered over a range of wavelengths.

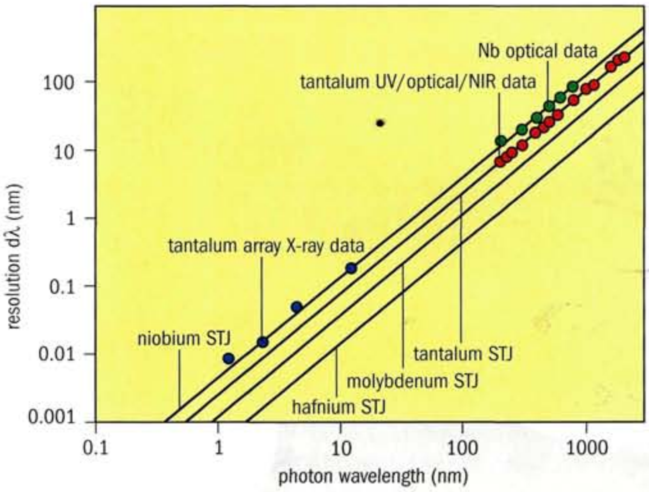


Fig. 1: Superconducting tunnel junctions (STJs) have been developed as photon counting spectroscopic detectors for ground- and space-based astrophysical research. This shows the tunnel-limited resolution of a number of elemental superconductors as a function of wavelength from the X-ray to the near infrared. The experimental data derived from niobium and tantalum STJs is also shown.

Experimental astrophysics is all about detecting photons from distant objects, and over an increasingly wide range of wavelengths. Progress in the field advances hand in hand with advances in photon-detection technology, particularly superconductors (April p11).

The absorption of a photon in a superconductor is followed by a series of fast processes that involve the breaking of Cooper pairs by energetic phonons created by the hot electrons produced as the atom relaxes after the initial photoabsorption. The result of this cascade is that the photon's energy is converted into a population of free charge – quasiparticles – in excess of any thermal population.

For typical transition metals, this conversion process ranges from nanoseconds (niobium) to microseconds (hafnium). At sufficiently low temperatures (typically about an order of magnitude lower than the superconductor's critical temperature) the number density of thermal carriers is very small while in a superconductor, such as tantalum, the initial mean number of free charge carriers created is much greater (April 1999 p11).

Limiting resolution

The quasiparticles produced through photoabsorption can be detected by applying a DC potential across two such films separated by a thin insulating barrier, forming a superconducting tunnel junction (STJ). This potential bias favours the transfer of quasiparticles from one film to the other via quantum mechanical tunneling across the barrier. The detector signal is therefore represented by the current developed by this tunnel process.

After initial tunnelling, a quasiparticle can, moreover, tunnel back, contributing many times to the overall signal before it is lost. This also boosts performance.

The overall limiting resolution for a STJ depends on the characteristics of the superconductor, but it is predictable. Figure 1 illustrates this resolution for a number of elemental superconductors.

Observations at X-ray wavelengths...

High -resolution X-ray spectroscopy provides the ability to determine the electron and ion temperatures, the electron density and the relative abundance of the elements, as well as establishing the degree of thermal and ionization equilibrium in a hot plasma.

It is the ability to resolve the satellite lines that can determine the key characteristics of the X-ray-emitting plasma in a model-independent manner

While the measurement of the intensity of the hydrogenic and helium-like lines from the same element is an important ion temperature indicator, it is the ability to resolve the satel-

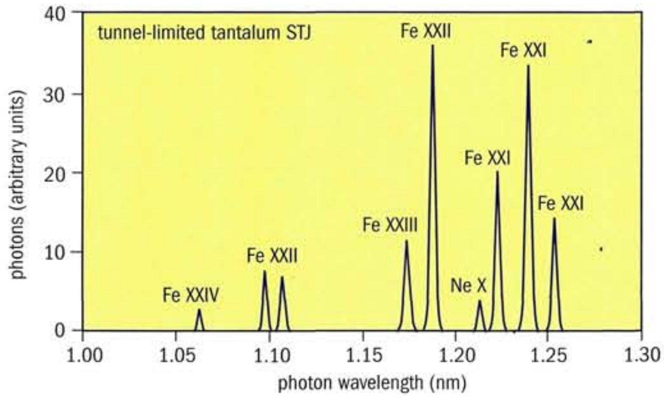


Fig. 2: The simulated response of a tantalum-based STJ to the Fe-L complex of lines around 1 nm from a hot optically thin plasma at 107 K. Practically all of the lines are resolvable by such a detector.

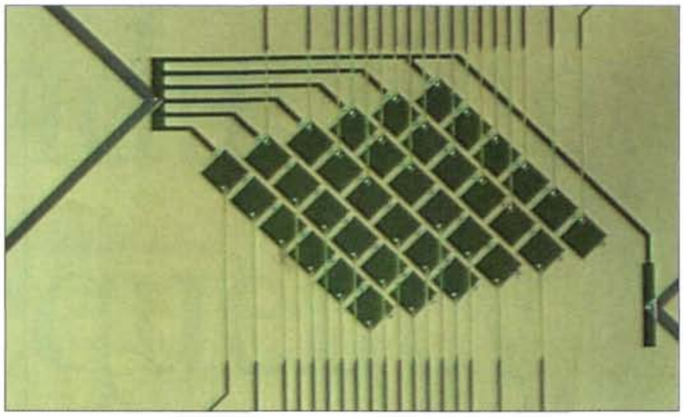


Fig. 4: A microscope image of a 6×6 pixel array of tantalum STJs prior to testing at ESA/SSD. Each device is 25 μm across and consists of two films, each 100 nm thick.

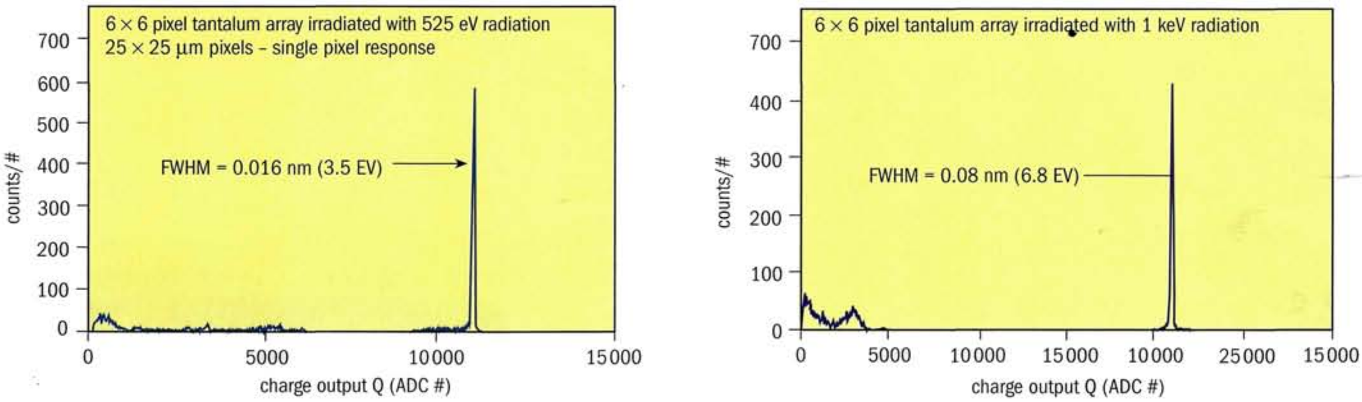


Fig. 3: The spectra from a single pixel of a 6×6 tantalum array illuminated by monochromatic soft X-rays.

lite lines that can determine the key characteristics of the X-ray-emitting plasma in a model-independent manner.

Figure 2 shows the response of a tantalum STJ to the large complex of lines (the Fe-L complex) around 1 nm, which is expected to be radiated from an optically thin plasma having a temperature of approximately 107 K. In this example, continuum emission has been suppressed for clarity. As the majority of lines are easily resolvable with such a tantalum STJ, measurement of the relative intensity of the lines from the same ion enables the temperature to be uniquely determined. In addition, through the relative intensity of lines from different elements, their relative abundances can be established.

Note that the intensity ratio of resonance lines from different ions of the same element, together with line centroids, allows one to deduce either the degree of ionization equilibrium or possibly the distance to the object via the determination of the redshift. A high spectral resolution is required for such observations. This resolution can be achieved using a tunnel-limited tantalum STJ but is impossible with conventional solid-state devices.

...and at ultraviolet and optical wavelengths

In optical and ultraviolet spectroscopy, a high resolution normally implies a resolving power of 10^4. From figure 1 it is clear that none of the classical superconductors forming the basis of current STJs under development (based on niobium, tantalum, aluminium, molybednum or hafnium) could achieve such resolving power.

In fact, a superconducting critical temperature well below 100 μK is implied to achieve such resolving power, leading to the development of STJs based on such elemental superconductors as rhodium. Of course, things are not quite this simple, with the temporal characteristics associated with the production of the free excess charge carriers being a function of the critical temperature, while phonons have wavelengths that are significantly larger than the thickness of the film. Thus such low-temperature superconductors may respond significantly slower.

Given that the resolution of a typical STJ based on tantalum is not appropriate for high- or even medium-resolution spectroscopy, what are the alternative key attributes of such a device for optical/ultraviolet astronomy?

Timing precision (below 10 μs), coupled with the broadband spectral capability, may make this the ideal spectrophotometer. Objects such as pulsars and flare stars may be ideal objects to observe with narrowfield small arrays. In addition, the efficiency at ultraviolet wavelengths, coupled with a large-format array (a panoramic detector), may allow for the development of an efficient broadband imaging spectrometer to determine the low-resolution spectra of faint objects, allowing for deep field surveys.

Such surveys could allow the determination in a single exposure of the broadband spectra and possibly therefore the redshift (and thus age) of all objects through the measurement of the Lyman edge and the Lyman emission lines – the "Lyman forest". ▷

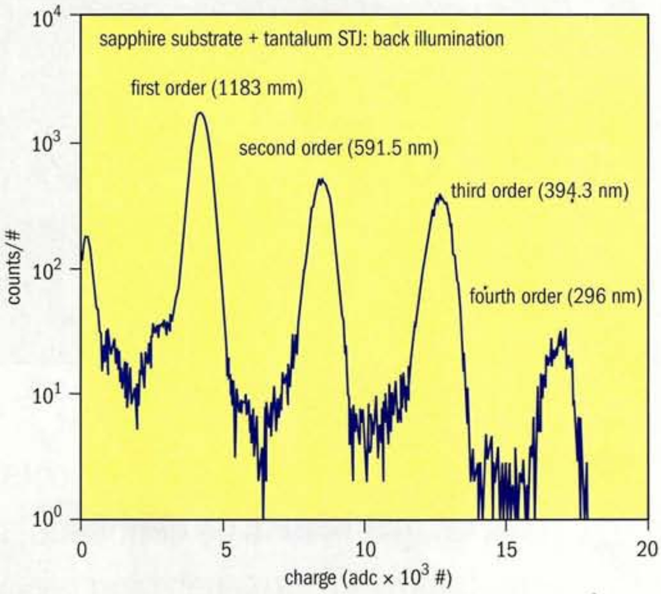


Fig. 5: The charge spectrum from the irradiation of a tantalum STJ by photons of 1183 nm wavelength. The various orders from the grating monochromator are easily discernible and provide an excellent technique for establishing the linearity of the device.

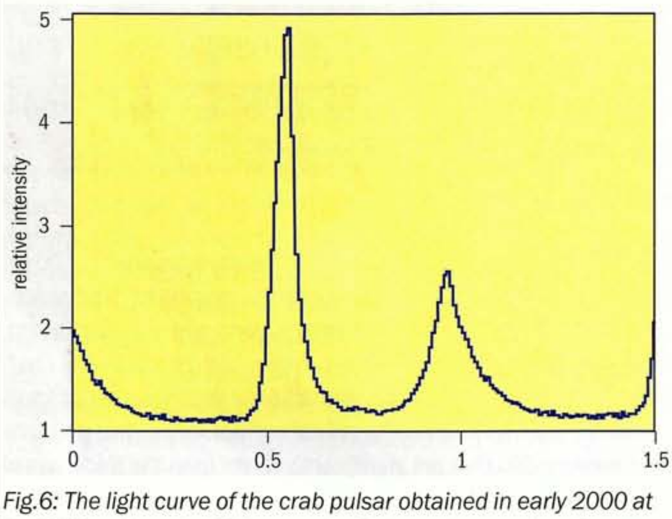


Fig.6: The light curve of the crab pulsar obtained in early 2000 at the William Herschel Telescope, La Palma. The waveband is 300–700 nm and each photon from the pulsar has its colour and time of arrival recorded with an accuracy of around 5 μs.

Owing to redshift, the Lyman edge is close to the optimum performance for a tantalum-based STJ with an efficiency of some 70% and a resolution of 20 nm.

However, it is clear that STJ devices based on lower-temperature superconductors such as hafnium would allow the clear evaluation of redshift. Of course, the response of the STJ in the ultraviolet is particularly attractive for future space-based astronomy missions.

Current performance

Tantalum-based STJs build on earlier work with niobium. The predictability of both tantalum and niobium devices (*cf.* figure 1) give some confidence in the ultimate successful development of lower-temperature elemental superconducting tunnel junctions, such as those based on hafnium.

Figure 3 illustrates the measured spectra from a tantalum STJ forming part of a 6 × 6 array illuminated by monochromatic radiation of various wavelengths. The array is shown in Figure 4, where each device was 25 × 25 μm and consisted of two films each 100 nm thick. Only those photons absorbed in the base film, separated from top film and substrate events by their distinct signal risetime, are shown. Typical resolutions of 0.015 nm (3.5 eV) at 2.4 nm (~500 eV) were measured and are indicated in figure 1.

Not only are the various orders well resolved, but the charge output as a function of wavelength can be precisely determined leading to a high wavelength linearity

At optical and ultraviolet wavelengths, where the photon energy is small, spatial effects, which degrade the response below 0.5 nm, are unimportant. Here it is rather that the signal is low, so the signal-to-noise ratio is the dominant factor governing the resolution.

At these wavelengths the photons enter the detector through the substrate, which can be either sapphire or magnesium fluoride, depending on the short wavelength cut-off required. The theoretical efficiency of a tantalum device deposited on a sapphire substrate with this mode of illumination is high. All photons are absorbed in the high-quality epitaxial tantalum base film. Efficiencies of 70% from 200 – 600 nm are expected, limited at short wavelengths by the cut-off of the sapphire substrate, and these have been experimentally confirmed.

To illustrate the broadband response of this type of detector, figure 5 shows the charge spectrum from a single tantalum-based device illuminated with optical light via a grating monochromator. This response ranges from 296 to 1183 nm – from the ultraviolet to the near-infrared.

Precise determination

Not only are the various orders well resolved, but the charge output as a function of wavelength can be precisely determined leading to a high wavelength linearity. This allows wavelength resolution to be determined across a broad waveband, and this is shown for both tantalum- and niobium-based devices in figure 1.

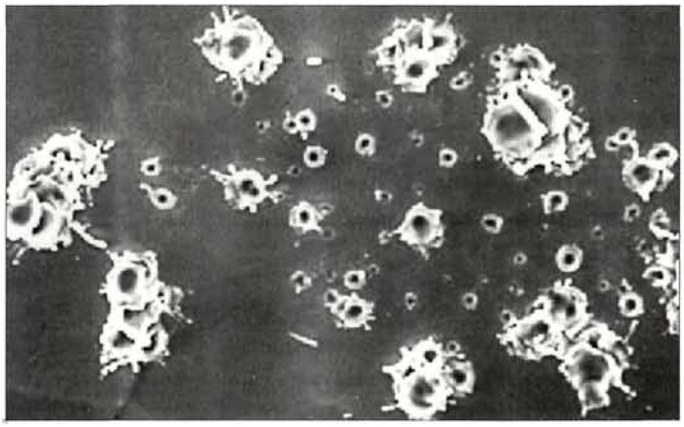
The astronomical capabilities of this unique detector have now been demonstrated. Figure 6 shows the light curve of the Crab pulsar obtained from a 6 × 6 pixel optical array installed in early 1999 at the William Herschel Telescope, La Palma.

All photons are detected individually from this pulsar, a spinning neutron star with a period of 33 ms some 6000 light-years away, and their energy (wavelength) and arrival time recorded. This opens up the pulse phase spectroscopy of exotic objects, and demonstrates the feasibility of the technique on space-based missions, covering a range of wavelengths – from 0.5 nm to 2 μm (approximately 0.5–2500 eV).

A Peacock, Astrophysics Division of the European Space Agency, ESTEC, Noordwijk, The Netherlands.

Superconducting radiofrequency

Accelerators are increasingly turning to superconducting technology to transfer power to the particle beams. The biennial workshop is a shop window for progress.



In the quest for improved performance, precision techniques monitor the "diseases" of superconducting materials.

Prototype cryomodules containing superconducting accelerating cavities for CERN's LHC collider.

Radiofrequency is the motive power of particle accelerators and, in the continuing bid for higher energies, superconducting techniques are increasingly being used to squeeze out the maximum number of electron volts from the available power.

The biennial Radiofrequency Superconductivity Workshop reflects this progress and focuses attention on new goals. The ninth workshop was organized by Los Alamos on 1–5 November 1999 at Santa Fe, New Mexico, under chairman Brian Rusnak. About 180 participants registered, a little fewer than the previous workshop, but with an ever-increasing participation of representatives from industry. The latter also presented their latest high-tech products – cavities, couplers, high-quality niobium and related fabrication tools.

The workshop began with operations and laboratory review talks. It opened with the achievements of the superconducting radiofrequency (RF) system for CERN's LEP2 electron–positron collider, which is currently the largest system in the world with about 3500 MV of "superconducting voltage".

The niobium film on copper (Nb/Cu) cavities clearly outperform the specified field gradient. This performance gives LEP beams of up to 102 GeV, a level that not even optimists could dare to dream of when the first modules were installed. Even above design specifications, the system runs very reliably and about 15 MW of RF power is regularly transmitted to the beam.

CEBAF, the continuous-wave electron-recirculating linac at the Jefferson Laboratory, Newport News, routinely delivers beams at 5.5 GeV, well above the 4 GeV that was originally specified.

ATLAS, the versatile heavy-ion accelerator in operation and extension at Argonne, the more recent ALPI at Legnaro and other smaller machines regularly accumulate superconducting cavity hours.

In Cornell's CESR electron–positron collider, the four existing copper five-cell cavities have been replaced by four single-cell superconducting cavities, with strong higher-order mode damping to allow the beam current and luminosity to be increased significantly.

The international TESLA project

Many advances in production and material testing result from the international TESLA project and its test facility at DESY (working as a free electron laser).

R&D continues to yield dividends. The spinning of a whole multicell cavity from a seamless tube, and non-destructive metal sheet probing (for example, to detect a foreign metal by the tiny magnetic field of the thermocurrent produced when a localized area of a niobium sheet is heated), were reported.

The stiffening of cavities – to reduce Lorentz force deformation and detuning – with external thermal copper spraying was examined. Controlling these pulsed cavities in amplitude and phase to maintain beam quality is not trivial. However, a working system, using digital controllers with feedback and feed-forward, has been built and tested successfully.

A more difficult task will be the control and operation of the proposed superstructure of four seven-cell cavities, connected by short beam pipes and driven by a single power coupler at one end.

The nine-cell TESLA design accelerating gradient of 25 MV/m has become routine at the test facility. Even better, single-cell lab tests at different places approach gradients of close to 40 MV/m.

Until recently, electropolished and buffered chemically polished cavities seemed to show the same performance, the latter method being simpler. However, already advertised by the Japanese KEK Lab at the last workshop, electropolishing shows higher gradients and the "holy" heat treatment at about 1400 °C becomes redundant.

High-pressure water rinsing has become a standard finishing surface treatment, and other liquids – for example, detergents – have been proposed. Also, a weak bakeout at only 145 °C improved a cavity significantly. The progress is still encouraging.

These achievements are complemented by a better understanding of the superconducting surface. A major effort for the Nb/Cu cavities at CERN has given a better picture of the influence of RF and external magnetic fields responsible for the decrease of the resonance Q-value with higher RF field (Q-slope). This Q-slope makes today's Nb/Cu cavities – the thermal stability of which is otherwise very attractive – non-competitive for very high gradients.

A parallel effort correlated copper surface treatment and film production parameters – for example, using different noble gases for sputtering – with their composition and RF performance.

A quadrupole-resonator test cavity has been built to probe surface resistance. The Q-slope is also present in a weaker form for the solid niobium cavities, so several models have been proposed to explain the effect. However the jury is still out.

Improvements

High-power couplers – several with adjustable coupling – have been improved at many laboratories. All of them reach the several hundred kilowatt range in continuous-wave operation at frequencies between 350 MHz and 1.3 GHz.

After a successful application in LEP, most coaxial couplers include an option for DC bias voltage to suppress multipacting. Despite their increased performance, power couplers remain the bottleneck in high-current machines, limiting the useful cavity gradient to far below today's possibilities.

For CERN's LHC 400 MHz single-cell cavities, the operational gradient is only 5.5 MV/m. All 21 bare cavities have been fabricated by industry with proven LEP2 Nb/Cu technology. They have all been tested successfully (*CERN Courier* July 1999 p7), ready for assembly into cryomodules.

Accelerated electrons become relativistic very soon in a linac, but the much heavier protons are significantly slower than the velocity of light in much of the machine. Thus, modified spherical cavity shapes with reduced cell length (reduced beta cavities) have been designed, built and successfully tested at several laboratories for high-current proton machines. (At CERN's LHC, the protons will already become relativistic in the injection chain.)

The Q-value and accelerating gradient of these cavities is intrinsically lower compared with cavities for fully relativistic beams. Despite lower accelerating gradients, a high-quality superconducting surface is as important here as it is for high-gradient cavities.

There are several studies for new high-current proton linacs in the range of a few hundred mega-electron volts to 1–2 GeV – for spallation sources or nuclear waste transmutation – that have a normal conducting and a superconducting option. The proven reliability of today's large superconducting RF systems – running for many months without real interruption – should help to convince funding agencies of the value of the latter option.

The last day of the workshop looked at projects like the TESLA linear collider proposal and an upgrade of CEBAF to 12 GeV, and possibly to 30 GeV. After LEP is closed, the LEP2 RF system could be recommissioned in an Electron Laboratory for Europe recirculating-electron linac project. Even a possible muon collider with superconducting RF was presented.

The tenth workshop will be held in 2001 in Japan and will be organized jointly by JAERI and KEK. The chairperson will be Shunichi Noguchi from KEK. The community is already convinced that there will be a lot more to report.

Joachim Tückmantel, *CERN*.

What's new in particles and cosmology?

The 1999 DESY Theory Workshop concentrated on the growing symbiosis between particle physics (particularly neutrinos) and cosmology.

Japanese experimenter Yoji Totsuka (right) and Lawrence Krauss.

Georg Raffelt (left), Edward Kolb (centre) and Valery Rubakov.

The latest round of the traditional annual theory workshop at DESY focused on the interplay between particle physics and cosmology, a theme of increasing interest to specialists in both domains. Two experiments and observations highlighted topical interest: Y Totsuka reported the strong case for the observation of neutrino (ν) oscillations at the Superkamiokande underground experiment in Japan, while B Leibundgut overviewed the recent results on the "Hubble diagram" for 1a type supernovae, which point towards a cosmological constant (Λ).

Both topics are both very immediate and fundamental - they affect the question of what the universe is made of, the possible need for modifications of standard cosmology, the generation of masses and scales in grand unified field theories or even deeper theories, and the issue of hidden generation symmetries that may explain the observed patterns of elementary particle masses. And both issues are not yet understood.

Results that began to emerge in 1998 make it clear that not all muon-neutrinos produced in the atmosphere arrive in underground detectors - in transit they appear to switch to another type of neutrino. Superkamiokande has reported a dependence of this neutrino "extinction" on the path length between production and detection. Such a dependence is characteristic of neutrino oscillations and implies that such neutrinos must have mass.

At the DESY meeting, theorists tried to understand the resulting neutrino mass and mixing implications. The debate centred on a consistent determination of the neutrino masses and mixing angles from the various experimental observations. New effects and experiments were proposed to resolve the issue.

On the more theoretical side, most specialists agreed that we understand why the neutrino masses are so much smaller than the electron or quark masses. In the standard model, renormalizability forbids neutrino masses - having no mass is consistent with the gauge symmetries. To introduce masses means going beyond the standard model. After years of searching for "physics beyond the standard model", it has now arrived.

Grand unification

Neutrino masses are most likely due to the violation of lepton conservation in an extension of the standard model, which could happen in the vicinity of the remote grand unification scale. The results are effective non-renormalizable couplings between neutrinos and Higgs scalars. The Higgs mechanism then relates a typical neutrino mass to the Fermi scale - a mere fraction of an electronvolt.

A concrete manifestation of these general aspects is the "seesaw mechanism", in which the non-renormalizable interaction is generated by the exchange of superheavy singlet neutrinos. Another is the induced vacuum expectation value of a superheavy scalar triplet.

The need for neutrino masses thus gives direct experimental evidence that the standard model needs to be extended, hinting towards grand unification or similar ideas. Even though less spectacular, the theoretical implications of the neutrino oscillations ▷

may turn out to be of comparable importance to proton decay – a process long thought to be inevitable but yet to be observed.

Particularly intriguing are the possible consequences of these effects for the generation of matter asymmetry in the early universe. Our very existence demands processes that produce more matter than antimatter.

The precise mass and mixing pattern for the neutrinos is not well understood. It may be as rich as for the quarks, but with a completely different generation structure. Why is the mixing angle for the muon neutrino maximal? Generation symmetries and their spontaneous breaking are the prominent candidates for possible explanations of the mass patterns.

Hubble diagrams

The other basic question debated at the workshop hinged on basic cosmology. A 'Hubble diagram' of brightness versus redshift (related to velocity of recession) of very distant type 1a supernovae suggests that the expansion of the universe is accelerating. This could be the effect of a cosmological constant (Λ), proposed long ago by Einstein. Some doubts remain in the interpretation of the data. The main uncertainty is the lack of understanding of how the average brightness of supernovae has evolved. These are explosions that happened in quite early stages of the evolution of the universe.

On the other hand, K Gorski and J Silk compared the anisotropy of the cosmic microwave background radiation with structure formation in the universe. This indicates that the background energy density seems to participate in the formation of the structure. There seems to be some homogeneous component, and the cosmological constant would be a candidate.

At DESY, specialists admitted to being quite puzzled by these findings. Theorists still have no good explanation of why the cosmological constant should vanish, and even less why it should have a tiny non-zero value. The energy density in radiation or matter decreases with the second inverse power of time, so a true constant Λ that influences today's evolution of the universe would have been completely negligible at early stages of the universe.

A significant role for Λ "today" – and neither earlier nor later in the history of the universe – seems to require an unacceptable matching or "fine-tuning" of numbers. Some say that the "natural guess" for the value of Λ is off by 120 orders of magnitude – probably the worst failure of an educated guess ever made. Already Einstein was worried about his constant, and we still are.

Popular alternatives are models with a cosmological evolution of a scalar field, often named "quintessence" today (June 1999 p13). In these models the homogeneous part of the energy density varies with time in such a way that it is relevant today.

In a class of these models, "cosmic attractor" solutions avoid the fine-tuning problem. And some of them mimic the effects of a cosmological constant on the supernovae Hubble diagram. One of these models could finally lead to a cosmology consistent with observation. Nevertheless, a satisfactory explanation from fundamental particle physics or string theories is still missing. Much remains to be done and understood.

From **Christof Wetterich**, *Heidelberg.*

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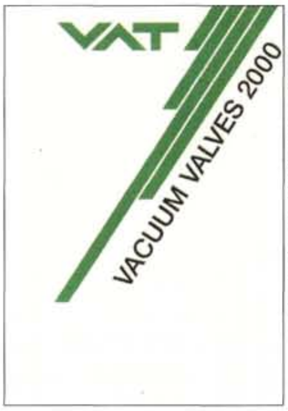

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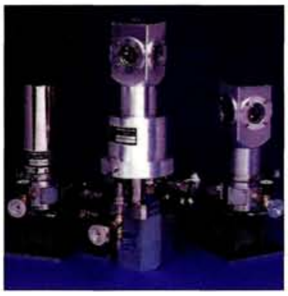

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- B: Si Front-End Processing—Physics and Technology of Dopant-Defect Interactions II
- C: Gate Stack and Silicide Issues in Silicon Processing
- D: Materials, Technology, and Reliability for Advanced Interconnects and Low-*k* Dielectrics
- E: Fundamentals and Materials Issues in Chemical-Mechanical Polishing of Materials
- F: Magnetic Materials, Structures, and Processing for Information Storage
- G: Polycrystalline Metal and Magnetic Thin Films
- H: Corrosion of Metals and Alloys
- I: New Methods, Mechanisms, and Models of Vapor Deposition
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- K: Morphological and Compositional Evolution of Heteroepitaxial Semiconductor Thin Films
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- M: Morphology and Dynamics of Crystal Surfaces in Complex Molecular Systems
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The 2000 MRS Spring Meeting will serve as a key forum for discussion of interdisciplinary leading-edge materials research from around the world. Various meeting formats—oral, poster, round-table, forum and workshop sessions— are offered to maximize participation.

990099

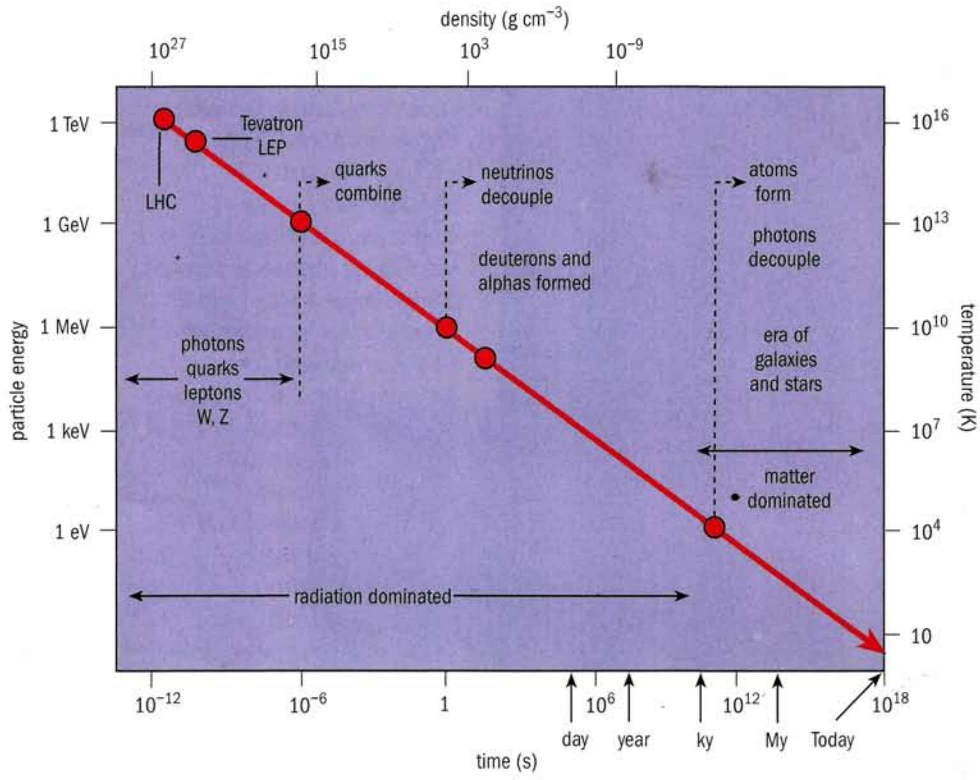
The field round Supernova SN1987A in images from the Anglo Australian Telescope. The image of the star that exploded to create the supernova (arrow) is clearly elongated. This does not indicate any particular peculiarity or a close companion; it is the effect of stars being aligned by chance along similar lines of sight. Several other examples can be seen here and other, different, blended images are seen in the photograph of the same field taken two weeks after the supernova appeared. The difference in image quality ("seeing") is an effect of the Earth's atmosphere, which was steadier on the first occasion. (David Mailin).

A brief history of the universe

During 1998–9, Peter Kalmus of London's Queen Mary and Westfield College lectured on "Particles and the universe" in 43 UK locations to 10 000 high-school students. Readers of *CERN Courier* will be familiar with the particle physics aspects of his story. A version of the first part, dealing with the universe, is published here.

On 23 February 1987 an explosion that was a billion billion billion times as powerful as a hydrogen bomb was detected on Earth. It was Supernova 1987A, the first exploding star visible to the naked eye since the one that was detected by Kepler in 1604. The star, 170 000 light-years away in the Large Magellanic Cloud, ran out of nuclear fuel, collapsed under the influence of its own strong gravity and, in a few seconds, released a hundred times as much energy as our Sun has poured out in its entire lifetime.

However, even before a Canadian astronomer on a mountain in Chile first noticed the light of Supernova 1987A, ghostly messengers called neutrinos were registered in two huge underground particle detectors in the US and Japan. These detectors, consisting of a few thousand tonnes of very pure water, equipped with photomultipliers and electronics, had been built for a quite different purpose. They were designed to check whether protons were stable or whether they might undergo a very slow radioactive decay. No proton decays have yet been seen, but the detection of supernova neutrinos gave information both about these particles and about stellar collapse, and it was a dramatic illustration of the interplay between astronomy and particle physics. ▷



Big physics machines can reproduce the conditions of the early universe.

Of course, the biggest explosion of all was the Big Bang – the creation of the universe about 12 billion years ago. The early universe was incredible – a dense primordial soup of elementary particles, colliding repeatedly at tremendous energies – a brilliant fireworks display. Indeed, the present universe with all its beauty and complexity is merely the wisp of smoke remaining after the fireworks show.

Today's particle physics allows us, in a way, to recreate some conditions of the early universe. Readers who have spent many hours learning history, spanning perhaps a mere few thousand years, may be pleased to see the history of the universe displayed on a rather simple graph. The temperature of the universe in Kelvin is plotted on the right *y*-axis against time in seconds on the bottom *x*-axis. Both axes are logarithmic . On the left *y*-axis is plotted the average energy per particle, which is proportional to the temperature. The energy-mass density of the universe is plotted on the top *x*-axis, in units of equivalent mass density relative to the density of terrestrial water.

The CERN LEP and Fermilab Tevatron colliders have energies of around 100 GeV per elementary constituent (quark or lepton), and such energies were normal when the universe had a temperature of 10^{15} K, around 10^{-11} s after the Big Bang. The constituent particles – even neutrinos – were in almost perfect equilibrium with each other. Annihilation and creation were in balance. The universe then, as now, contained vastly more photons than quarks, and the energies per quark or lepton were then much greater than the rest masses, so the universe was accurately described as "radiation dominated". As the universe expanded, it stretched the wavelength of radiation so that the photons had lower energies. The concentration of elementary objects was also reduced, thus the universe cooled. As we follow this thermal history, a number of remarkable events occur, leading to our present world.

Annihilation

At around 10^{-6} s the average energy had dropped to a few giga electron-volts, and quarks could combine into hadrons, and a bit later into the stable protons and (relatively stable) neutrons. At around 1 s, although the density was still several hundred thousand times that of water, collisions of neutrinos became rare – they could no longer be in thermal equilibrium with other particles and effectively decoupled for ever from the rest of matter and radiation. After a few more seconds, when the energy dropped below the mega electron-volt level, electrons and positrons could no longer be created, so they annihilated, leaving just sufficient electrons to balance the charge of the protons.

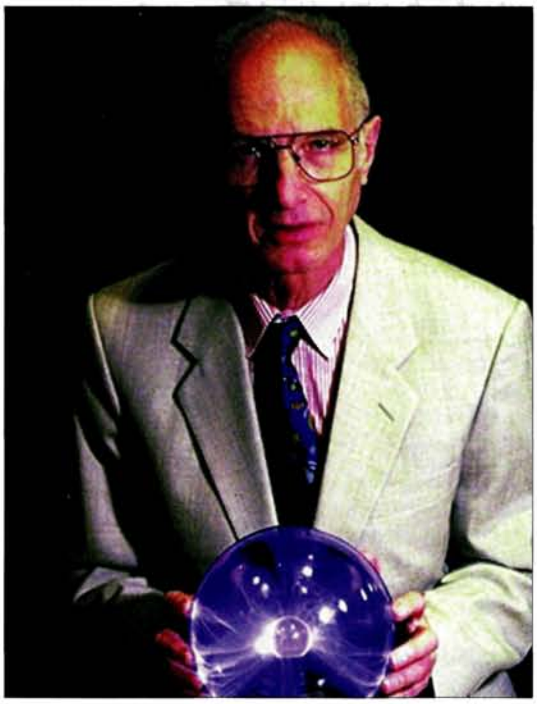
Some of the protons and neutrons could combine into deuterons, and then alpha particles, before the density and collision rate became too low. Then any remaining unbound neutrons decayed in the following hours. The amounts of deuterium and helium, which can be measured today, are a sensitive test of the conditions at that time, and hence of the Big Bang model. Tiny traces of isotopes of lithium could have been formed, but the absence of stable nuclei of mass 5 and mass 8 prevented the creation of further nuclei. This nucleosynthesis occurred at around 3 min.

After some 300 000 years the temperature had dropped to around 10^{4} K and the average energy to around 1 eV, below the ionization potential of atoms. Neutral atoms of hydrogen and helium were formed. Photons were no longer

The early universe was incredible – a dense primordial soup of elementary particles, colliding repeatedly at tremendous energies – a brilliant fireworks display...the present universe with all its beauty and complexity is merely the wisp of smoke remaining after the fireworks

Peter Kalmus – particles and the universe

Peter Kalmus has carried out particle physics experiments for more than 40 years in the US, the UK, Germany and CERN. He shared, with John Dowell, the Institute of Physics' 1988 Rutherford Medal for contributions to the 1983 discovery of the W and Z particles at CERN. He is vice-president of the Institute of Physics and chairman of the Particles and Fields Commission of IUPAP. Since his notional retirement in 1998, he has been devoting much of his time to the public understanding of science by contributing to organizations such as the Royal Institution and the British Association for the Advancement of Science, and by giving public talks. A written version of his talk was published in Physics Education (1999 34(2)).



gen and helium were formed. Photons were no longer impeded by frequent interactions with matter (they couple to charged particles), and the universe, which had until then been opaque, became transparent. Photons thus decoupled from matter. The dominant energy density after this was in the form of matter (including dark matter, the nature of which has not yet been determined), having previously been in the radiation. However, the temperatures and energies shown in the diagram, even in the matter-dominated era, represent those of the radiation. With the expansion of the universe, this radiation has now cooled to 2.7 K, the cosmic microwave background (CMB).

The observations can be explained by invoking Einstein's cosmological constant – a kind of cosmic repulsion or negative vacuum pressure, which Einstein later regarded as his "biggest mistake"

Star material

Gravity, acting on density ripples that have now been detected as tiny anisotropies in the CMB, caused matter to form clumps, which later became galaxies and stars. Thus the objects of astronomy finally make their appearance in the bottom right corner of the diagram. The first stars were composed of hydrogen and helium only. Fusion processes and other nuclear reactions in the cores of stars created all of the remaining elements.

The more massive stars had shorter lifetimes, and some exploded as supernovae, thereby polluting the local cosmos with these chemicals, and contributing to the mixture of elements out of which later stars, including our Sun and its solar system, could be formed. Every carbon and heavier nucleus in the Earth and in our bodies was formed at the centre of some now exploded star. We are all made of star material!

Until recently, cosmological measurements were consistent with the Big Bang expansion, opposed by the attraction of gravity. Depending on the mean mass-energy density of the universe, this could lead to continuous expansion or to ultimate contraction: the Big Crunch. Most cosmological measurements were rough. A few years ago, measurements indicated that the age of the universe was a bit less than the age of some stars, but, because of the observational uncertainties, a factor of less than two did not cause undue concern.

However, observations are getting much better. Results in the last year from two collaborations indicate that the expansion may actually be accelerating: very distant supernovae appear fainter than expected, indicating that they may be further away than implied from their redshifts. Careful checks on the supernova analyses are in progress, and additional distant supernovae are within the range of existing telescopes.

The observations can be explained by invoking Einstein's cosmological constant – a kind of cosmic repulsion or negative vacuum pressure, which Einstein later regarded as his "biggest mistake". Variations, such as "quintessence" – a fifth force that changes with time, – are also receiving attention. The energy density associated with a cosmological constant would affect the early structures in the universe and hence the angular anisotropy of the CMB – the ripples in the universe.

The CMB fluctuations are being measured with good precision at smaller angular scales, and their analyses show better consistency with supernovae and other observations if an additional cosmic repulsion is allowed. The energy density associated with the cosmological constant appears to be greater than that of matter. New CMB anisotropy results from the balloon-borne Boomerang project are about to be released, and these will be followed in the next few years by the NASA MAP and ESA Planck missions. The era of precision cosmology is about to begin, and its symbiosis with particle physics will result in more exciting science in the new century.

Peter Kalmus.

RECRUITMENT

For advertising enquiries contact *CERN Courier* recruitment/classified, IOP Publishing Ltd, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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NIELS BOHR INSTITUTE, UNIVERSITY OF COPENHAGEN

Postdoctoral position in Relativistic Heavy Ion Physics

A postdoctoral position is available with the High Energy Heavy Ion (HEHI) group at the Niels Bohr Institute, University of Copenhagen. The position is initially for one year with a possibility of prolongation for a second year. The position is expected to start on (or about) June 1, 2000.

The HEHI group is involved in experimental relativistic heavy ion physics at RHIC and LHC. The group plays a central role in the BRAHMS experiment at RHIC, which is expected to start data taking in the spring of 2000 and is involved in planning the ALICE detector for LHC. The successful candidate is expected to participate in data taking at RHIC, analysis of data from BRAHMS and detector development for ALICE. An extensive travel activity to Brookhaven National Laboratory and CERN must be expected.

Candidates should have a PhD. in experimental nuclear physics, relativistic heavy ion or particle physics. Applications should contain curriculum vitae, publication list, references or list of referees to contact (3), a statement of research interests and previous experience, and copies of degree certificates.

Salary is set by agreement between the Ministry of Finance and AC (The Danish Confederation of Professional Associations).

Deadline for applications is April 14, 2000.

Applications should be sent to:

Dr. J.J. Gaardhøje, The Niels Bohr Institute
Blegdamsvej 17, DK- 2100 Copenhagen, Denmark.
E-mail: gardhoje@nbi.dk Phone: +45 35325309

The University of Iowa
Postdoc Position on BABAR

The experimental HEP group of University of Iowa working on BABAR is looking for a postdoctoral fellow with a Ph.D. in particle physics. The BABAR experiment has already collected 2 fb-1 data since June 1999, and expects to collect 10 fb-1 leading to the first hint of CP violation. The Iowa group has had major responsibilities in BABAR DAQ system and primary responsibility for trigger online. The group, which presently consists of three postdocs and two graduate students, has successfully implemented the Level 1 trigger (DAQ/Online) and major parts of the Dataflow and Level 3, and is now mounting a serious effort on physics analysis. A basic knowledge or experience with C++/OOAD is desirable. S/He is expected to take a leadership role in analysis. An excellent leadership opportunity also exists in the trigger upgrade effort of BABAR. The successful candidate is expected to be stationed at SLAC, and can start soon. Salary will be commensurate with experience.

Applicants should initially send a short summary (by e-mail or telephone) of their interest, past experience, and names of at least three referees to:

Professor Usha Mallik, [usha-mallik@uiowa.edu]
Dept of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242, (319)335-0499.

N.B. The University of Iowa is an equal opportunity employer; women and minorities are encouraged to apply.

HELSINKI INSTITUTE OF PHYSICS

DIRECTOR

Helsinki Institute of Physics, Finland, invites applications for the position of the Director of the Institute. The appointment will be made for a period of up to five years starting not later than Jan. 1, 2001. Helsinki Institute of Physics is a joint national research institute governed by the Universities of Helsinki and Jyväskylä, and the Helsinki University of Technology.
The research fields include theoretical physics, experimental particle physics and technology related to accelerators. The Institute has also the responsibility to coordinate Finland's relations with CERN and other international accelerator centres.

The Director belongs to the staff of the University of Helsinki. Familiarity of the research fields and experience in directing research is required. Salary conditions will be based on those applied at Finnish universities. For further information please contact: Vice-Rector Ilkka Niiniluoto, Chairman of the Board, tel. +358 9 19123365, e-mail: Ilkka.Niiniluoto@helsinki.fi.

Applications should include a curriculum vitae with a brief account of the applicant's qualifications and activity relevant to the position. The applications should be addressed to the Board of Directors, Helsinki Institute of Physics and mailed to the Registrar of the University, P.O. Box 33 (Yliopistonkatu 4), FIN-00014 University of Helsinki, Finland, fax +358 9 19122527. The deadline for receiving the application is March 15, 2000, 3.45 p.m.

SUDBURY NEUTRINO OBSERVATORY
Research Associate Position
Centre for Research in Particle Physics
Carleton University, Ottawa, Canada

A vacancy exists for a research associate to work with the CRPP group on the Sudbury Neutrino Observatory. The SNO detector is now in full data taking mode. The CRPP group's main responsibility is to determine the radioactive background contributions to the SNO signals. The RA will collaborate with a team to develop techniques for the purification and assay of water to ultra low levels of radioactivity and to implement these techniques on the full scale systems. The RA would be based in Sudbury, and would be expected to contribute to the on-site data analysis effort as well. Candidates should have a Ph.D. degree. The position would be for two years in the first instance. Further information can be found at http://www.sno.phy.queensu.ca. Applicants for this position are invited to send a resume and to have three letters of reference forwarded to:

Dr. Tony Noble, SNO Project Office, P.O. Box 159, Lively, Ontario, Canada, P3Y 1M3, Fax: 705-692-7001, e-mail: noble@physics.carleton.ca.

Applications received prior to March 31, 2000 will receive first consideration. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents.

Universität Heidelberg

The Kirchhoff Institute for Physics (KIP) at Heidelberg University has two immediate openings for a

Scientific Staff Position in Technical Computer Science

(Wissenschaftlicher Angestellter/PostDoc) at the Lehrstuhl für Hardware Informatik. Activities of this group include the design of high-performance trigger processors for LHC experiments, which includes as the implementation of trigger algorithms in both hard– and software. Heidelberg is one of the most beautiful German cities, located at the Neckar, in an area with particularly mild micro climate.

The successful applicant is to work in the TRD group developing a trigger system for the approved ALICE Transition Radiation Trigger. Here trigger processor ASIC and various FPGA systems are being developed. The final setup will include 75000 of the Heidelberg trigger chips, which will all be networked. The research group has access to a well equipped, in-house ASIC laboratory. Participation in the educational activities of a German Lehrstuhl is expected.

Candidates should have experience with hardware design. In particular experience with modern digital design methodology (VHDL, Verilog synthesis, Synopsys) is very favorable. The candidate should be familiar with common operating systems such as Window NT and Unix and should have knowledge of C or C++.

The position requires a Ph.D and includes a substantial benefits package. The appointment will be initially for two years with a possible extension up to 5 years. Provided superior performance the position offers the possibility to confer qualification as a university lecturer (Habilitation). Disabled applicants with equal qualifications will be preferred. The Heidelberg University encourages especially women to apply. Interested applicants are invited to send their application before 31.3.00

Ruprecht-Karls-Universität Heidelberg, Institute for High Energy Physics, Ref.: VOLI_TRD, Schröderstrasse 90, D-69120 Heidelberg, Germany,

For additional information, please contact
Prof. Volker Lindenstruth, e-mail: ti@kip.uni-heidelberg.de, phone: +62 21 / 54 - 43 03

Imperial College

OF SCIENCE, TECHNOLOGY AND MEDICINE

Research Associate Position in Experimental Particle Physics

The High Energy Physics group at the Blackett Laboratory, Imperial College, London, has a vacancy for a Research Associate to work on the initial design of a high intensity neutrino source for use in studies of neutrino oscillation. This new, PPARC-funded, position is available now for an initial period of two years which may be extended.

A high intensity muon storage ring would be an ideal source of neutrino beams and would allow detailed studies of neutrino oscillation to be carried out. To realise such a facility requires that a series of challenging problems be overcome. Research and development aimed at tackling these problems is in its infancy worldwide. The Imperial group is working closely with particle physicists and machine physicists at Rutherford Appleton Laboratory and elsewhere to establish a team of people to be in the forefront of the design for a future muon storage ring, neutrino beam and neutrino detectors. The successful applicant will be expected to take a leading role in the studies of the physics opportunities afforded by such a facility as well as taking an active part in the design and implementation of a series of experiments designed to measure important characteristics of the proposed design.

Salary, according to experience, will be in the range £18,420 - £26,613, including London allowance. Applications, comprising a curriculum vitae, a list of publications and the names and addresses of two referees, should be sent to

Professor Ian Butterworth, Blackett Laboratory, Imperial College, London SW7 2BW, UK.

Applications will be accepted until the position is filled. **Informal enquiries can be made to Dr K. Long at the above address, or via email to k.long@ic.ac.uk.**

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

POSITIONS IN ACCELERATOR PHYSICS at MICHIGAN STATE UNIVERSITY

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University is seeking several highly qualified accelerator physicists or engineers to join the Accelerator Physics Group. We seek to strengthen specific areas related to high-intensity beam dynamics and superconducting rf technology.

The NSCL is presently upgrading its facility to increase the intensity of primary heavy-ion beams in the 10-200 MeV/nucleon energy range by several orders of magnitude and produce world-unique secondary beams of rare isotopes for research in nuclear physics and nuclear astrophysics with scheduled completion mid-2001. A design effort for an accelerator system of an advanced rare isotope accelerator facility capable of producing high intensity (>100 kW) primary beams from hydrogen to uranium with energies per nucleon up to at least 400 MeV will be the primary emphasis in the near term.

Accelerator physicists and engineers with specific and extensive experience in the general areas of particle beam dynamics and superconducting rf accelerating systems are sought. Priority is given to applicants with experience in one or several of the following areas: space-charge dominated beams; RFQ design; linac dynamics particularly for heavy ions; superconducting accelerating cavity characterization, design, and fabrication; superconducting accelerating cavity rf system design and implementation including appropriate stabilizing rf feedback systems.

Depending on the successful applicants' qualifications, appointments will be made at any of three ranks in the NSCL Continuing Appointment System that approximately parallels the university tenure stream faculty system (see CA Handbook at http://www.msu.edu/unit/facrecds/policy/nscl01.htm). Interested individuals should send a CV and arrange for three letters of reference to be sent directly to:

Professor Richard York,
National Superconducting Cyclotron Laboratory, Michigan State University
East Lansing, MI 48824-1321.
For more information, see our website at http://www.nscl.msu.edu.

MSU is an equal opportunity/ affirmative action institution.

University of Colorado, Boulder
Post-Doctoral Research Position on BaBar

The experimental high-energy physics group at the University of Colorado has an opening for a person with a strong computing background and with a strong interest in experimental High Energy research. The person is to participate in the BaBar experimental program at the Stanford Linear Accelerator Center. The applicant should have a Ph. D. degree and is expected to have a strong C++ software language background.

Applicants should send a Curriculum Vitae and arrange to have three letters of recommendation sent to

Prof. Uriel Nauenberg, Department of Physics, Campus Box 390 University of Colorado, Boulder, CO 80309-0390

All applications should be received by May 31, 2000. You can communicate via e-mail, uriel@cuhep.colorado.edu.

The University of Colorado at Boulder is committed to diversity and equality in education and employment.

Physics Division
ATLAS Experiment
Lawrence Berkeley National Laboratory

The Physics Division at **Lawrence Berkeley National Laboratory (LBNL)** has several immediate openings for scientific positions with the ATLAS experiment at the Large Hadron Collider at CERN. The successful candidates will have important roles in the development and construction of the silicon pixel and/or silicon strip detector elements of the ATLAS tracking system.

STAFF SCIENTIST

Expected to take an immediate leadership role in the development and later construction and operation of the ATLAS silicon tracking systems. There will be opportunities to participate in the analysis of data from the ATLAS detector. A minimum of two years of hands-on experience with silicon detector systems is required. Depending on the experience and qualifications of the successful candidate, this will be a term position with expectation of becoming a career appointment or, for very well qualified candidates, an immediate career appointment. The current job location is at LBNL with frequent travel to CERN but with the expectation of residency at CERN during the final assembly, commissioning and initial operation of the ATLAS silicon tracking system. A PhD in experimental particle physics or equivalent experience is required. Applications must be received by May 1, 2000. **Job #PH011639/JCERN**

POSTDOCTORAL FELLOW

The successful candidates will have key roles in the development and later fabrication of the silicon pixel detector system or the silicon strip system for ATLAS. In either case, the immediate emphasis will be on laboratory and test beam measurements of silicon detector/electronics assemblies and preparations for production of these assemblies at LBNL. Experience with silicon detector systems or other complex electronics/detector systems is preferred. A PhD in experimental particle physics or equivalent experience is required. **Job #PH011637/JCERN** and **PH011638/JCERN**

For more information visit: **http://www.lbl.gov or http://www-atlas.lbl.gov**. Applications, including CV, list of publications, description of research interests, and three letters of recommendation should be submitted via email (our preferred method) to: **employment@lbl.gov** (no attachments). Reference appropriate Job# in your cover letter. Or mail to: **Lawrence Berkeley National Laboratory, One Cyclotron Road, MS 937-0600, Berkeley, CA 94720**. Or fax: **(510) 486-5870**. If you have questions, email them to: **KRPrintup@lbl.gov** or call: **(510) 486-7532**. Berkeley Lab is an AA/EEO employer.

BERKELEY LAB

TECHNICAL OPPORTUNITIES

Jefferson Lab, located in Newport News, VA, is a world-class scientific laboratory centered around a high-intensity, continuous wave electron beam, which provides a unique capability for nuclear physics research. We are located near Colonial Williamsburg, the Chesapeake Bay and the resort area of Virginia Beach.

Our Accelerator Development Department currently has a number of openings for Scientists, Engineers, and Technicians to contribute to the development of the superconducting RF technology and its application to accelerator projects at Jefferson Lab and to other national or international accelerator projects:

- Superconducting RF Physicists (AR2107, AR2120)
- Superconducting RF Post-Doctoral Fellow (AT2101)
- Applied Surface Scientist (AR2104)
- Accelerator Physicists (AR2116, AR2123)
- RF Engineers (AR3106, AR3116)
- Manufacturing Engineer (AR3204)
- Testing, Instrumentation and Measurement Engineers (AR3108, AR3117, AR3224)
- Facilities Engineer (AR3229)
- Prototyping Engineer (AR3118)
- I&C Computer Scientist (AR2013)
- RF/Electronics/Programming Technicians (AR7001, AR7222, AR7209)
- Mechanical Technicians (5 positions) (AR7336)
- QA/QC Coordinator (AR4007)

Further information and complete descriptions of the positions can be found by visiting our web site at http://www.jlab.org/div_dept/admin/HR/jobline/jobline.html or by calling our jobline at 757-269-7359.

Proud to Be An Equal Opportunity, Affirmative Action Employer

Jefferson Lab

DEPARTMENT *of* PHYSICS *and* ASTRONOMY

PHYSICIST PROGRAMMER
PARTICLE PHYSICS EXPERIMENTS

Available from April 2000 for a period of two and half years to be involved in primarily the development of software for the ATLAS experiment at the LHC. Experience in Object-Oriented design and programming in C++ is desirable.

You will also contribute to data analysis of the BaBar experiment at SLAC which began taking data in May 1999 and already has a significant sample of BB events. Experience gained from using the BaBar software and the Objectivity database will be valuable for the design of the ATLAS software.

You should hold a Ph.D or equivalent. The starting salary will be in the range £18185 - £19869 p.a.

Please quote *REF: 306018CC*

Further particulars including details of the application procedure should be obtained from **THE PERSONNEL DEPARTMENT, THE UNIVERSITY OF EDINBURGH, 1 ROXBURGH STREET, EDINBURGH EH8 9TB. Tel: 0131 650 2511 (24 hour answering service). http://www.personnel.ed.ac.uk/recruit.htm**

Closing date: 24 March 2000

THE UNIVERSITY OF EDINBURGH

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FACULTÉ DES SCIENCES
SECTION DE PHYSIQUE
DÉPARTEMENT DE PHYSIQUE NUCLÉAIRE
ET CORPUSCULAIRE
24, quai Ernest-Ansermet | CH-1211 Genève 4
Tel. +44 22 702 63 69/62 73
Fax +41 22 781 21 92

UNIVERSITÉ DE GENÈVE

The Department of Nuclear and Particle Physics has an opening for a

Research Associate
(Post-Doctoral position)

This position is available for participation in the ATLAS experiment at CERN. Some participation in future accelerator projects (the neutrino factory) could also be envisaged. Candidates for this position should not be more than 32 years of age, and should have a PhD degree, or equivalent, in physics with appropriate experience in particle physics. Previous experience in detectors or data acquisition techniques would be an advantage. The position will involve some teaching duties at the University. The position is available for a period of 4 years. The closing date for applications is 31st March 2000.

Candidates should forward a curriculum vitae and the names of two referees to:

Prof. Alain Blondel
Département de physique nucléaire
et corpusculaire
24, quai Ernest Ansermet
CH - 1211 Genève 4

Additional information can be obtained by e-mail from:
Alain.Blondel@cern.ch

University of California, San Diego
Postdoctoral Research Positions in
Experimental High Energy Physics

The Department of Physics at the University of California, San Diego, invites applications from outstanding candidates for Postdoctoral Research positions in experimental High Energy Physics. The UCSD group participates in the CLEO experiment at Cornell, the BABAR experiment at SLAC, and the upcoming CMS experiment at the LHC. The successful applicants will participate either in the ongoing CLEO physics program, the initial program of data taking and CP physics analysis with the BABAR detector, or development of the CMS data acquisition, software, and computing systems. Candidates with interest and experience in the areas of drift chambers, tracking and vertexing software, and in data analysis are particularly encouraged to apply. A Ph.D. in particle physics or a related field is required. Experience in C++ would be an asset. The appointments will initially be for two years with the possibility of an extension to a third year. Applicants should send a copy of their curriculum vitae, including a statement of physics interests, and arrange for three letters of recommendation to be sent to:

Postdoc Search Committee c/o Bernie Camberos
University of California, 0319, 9500 Gilman Drive
La Jolla, CA 92093-0319
e-mail: pdsearch@ucsd.edu
phone: +1 (858) 534-1943 fax: +1 (858) 534-0173

The nominal deadline for the receipt of the application is April 15, 2000, although the search will continue until the positions are filled.

FACULTY POSITION IN EXPERIMENTAL PARTICLE PHYSICS
University of California, Irvine

The Department of Physics and Astronomy of the University of California, Irvine, invites applications for a tenure track, Assistant Professor appointment in Experimental Particle Physics. The appointment could begin as early as July 1, 2000. We are seeking an outstanding scientist who will establish a vigorous research effort that will enhance and complement our existing experimental program and who will participate effectively in teaching at the undergraduate and graduate levels. UCI has eight faculty in experimental particle physics. Our current program includes BABAR at SLAC; D0 and charmonium and antihydrogen studies at FNAL; rare K decay and lepton number violation experiments at BNL; ATLAS at CERN; Super-Kamiokande and K2K in Japan; MILAGRO at LANL; AMANDA at the South Pole; and studies of Newtonian Gravity. UCI has four faculty in particle theory. Currently, the theory group does research in model building, quantum field theory, quantum gravity, string theory, statistical mechanics, and the phenomenology of strong and weak interactions. The successful candidate must possess a Ph.D. (or equivalent). Applicants should send a curriculum vitae, bibliography, and statement of research interests and arrange to have at least three letters of recommendation submitted on their behalf to:

Professor Andrew J. Lankford
Chair of the Experimental Particle Search Committee
Department of Physics and Astronomy
University of California, Irvine, CA 92697-4575.

For full consideration, completed applications should be received before **May 15, 2000.** Please visit our website at **http://www.ps.uci.edu/physics.**

UCI is an equal opportunity employer committed to excellence through diversity.

Cornell University

EXPERIMENTAL ELEMENTARY PARTICLE PHYSICS RESEARCH ASSOCIATE

The high energy physics group at Cornell University has an opening for a Research Associate to work on the CLEO experiment at the Cornell Electron Storage Ring (CESR). Our research concentrates on the physics of the B meson, with strong programs in charm, tau, and two-photon physics as well. We have just completed a major detector upgrade, and anticipate that the person filling this position will contribute to the commissioning of the detector and its associated software. This is normally a three-year appointment with the possibility of renewal beyond that, subject to mutual satisfaction and the availability of funds under our NSF contract. A PhD in experimental elementary particle physics is required.

Please send an application including curriculum vitae and publications list and arrange for at least two letters of recomendation to be sent to: **Prof. Persis Drell, Newman Laboratory, Cornell University, Ithaca, NY 14853 (SEARCH@LNS.CORNELL.EDU).**

Cornell is an equal opportunity/affirmative action employer.

KENT STATE UNIVERSITY AND JEFFERSON LAB

JOINT POSTDOCTORAL POSITION IN EXPERIMENTAL NUCLEAR PHYSICS

Applications are invited for a postdoctoral position in experimental high-energy nuclear physics. The position is for one year initially, with the possibility of renewal up to three years upon mutual agreement and availability of funds.

The successful candidate is expected to work on electron scattering experiments that investigate the structure of the nucleon and of few-body nuclear systems at the Hall A Facility of Jefferson Lab in Newport News, Virginia. The successful candidate will also have the opportunity to participate in an experiment that will measure the parity nonconserving Moller cross section asymmetry at SLAC in Stanford, California. The successful candidate will reside in Newport News, Virginia, but travel to Kent and Stanford will be necessary.

Applicants must have a Ph.D. in nuclear or particle physics and a strong background in both hardware and software. Preference will be given to candidates with demonstrated experience in electron scattering at an accelerator facility. Initiation of new research projects by the successful candidate will be strongly encouraged and supported.

Applications by interested individuals, including a curriculum vitae, list of publications and three letters of reference should be sent to: **Prof. Makis Petratos Department of Physics Kent State University Kent, Ohio 44242 FAX: (330) 672-2959 gpetrato@kent.edu** Review of applications will begin on Feb. 10, 2000, and will continue until the position is filled.

Kent State University and Jefferson Lab are Equal Opportunity, Affirmative Action Employers.

BROOKHAVEN NATIONAL LABORATORY

POSTDOCTORAL RESEARCH ASSOCIATE

The Physics Department of Brookhaven National Laboratory has an opportunity for a research associate to work in the Omega Group for the ATLAS Experiment. The Laboratory is taking a leading role in the ATLAS Experiment at CERN with major responsibilities for the Liquid Argon Calorimeter with additional major responsibilities in the cryostat/cryogenics for the Barrel Calorimeter, readout electronics, system integration, and physics analysis and simulation. A PhD in experimental particle physics and the ability to contribute significantly to one or more of the above activities are required.

Interested candidates should submit a CV, list of publications and three letters of recommendation, indicating position #MK8789, to:

Marsha Kipperman, Brookhaven National Laboratory, Bldg 185, P.O. Box 5000, Upton, NY 11973-5000.
Visit our website at www.bnl.gov

BNL is an equal opportunity employer committed to workforce diversity.

UNIVERSITY OF MICHIGAN

Postdoctoral Position(s) - High Energy Physics

The University of Michigan high energy physics group supported by the National Science Foundation would like to hire a postdoctoral research associate. The successful applicant will be based initially at CERN and will spend roughly half-time on analysis of L3 data and half-time on research and design studies (physics studies and detector design) for a high energy electron-positron linear collider.

Interested applicants should send a letter with curriculum vitae and the names and addresses of three references to the following address:

Prof. Keith Riles, Randall Lab, 500 E. University Ave., Ann Arbor, MI 48109-1120, U.S.A.

Inquiries concerning this position may be addressed to **Keith Riles (1-734-764-4652, kriles@umich.edu)** or to **Byron Roe (1-734-764-4441, byron.roe@umich.edu).**

We expect another postdoctoral position to be available soon for work on the mini-BooNE neutrino oscillation experiment scheduled to run at the end of 2001 at Fermilab (address inquiries to Roe).

CHIEF SCIENTIST TO LEAD RESEARCH IN NUCLEAR PHYSICS USING INTERMEDIATE - AND HIGH-ENERGY BEAMS.

The Institute of Physical and Chemical Research

RIKEN invites applications for the position of Chief Scientist to lead a laboratory working in nuclear physics using high-energy beams.

In RIKEN, Nuclear Physics has been promoted under the RIKEN Accelerator Research Facility. Heavy-ion from the Ring Cyclotron has been used for the reaction and structure studies of nuclei in particular of nuclei far from the stability line using RI beam facility. Also RHIC/SPIN project has been promoted extensively. In addition, the RI Beam Factory is under construction.

The successful candidate will be responsible for the laboratories over-all management and research strategy, directing research strategy, directing research projects and contribution to more general aspects of RIKENs management and research planning activities.

This laboratory is expected to promote nuclear physics using the facilities described above (RHIC and RI Beam Factory). The contribution to the high-energy part of the RI Beam Factory researches is strongly expected. The position is a permanent appointment, subject to RIKENs mandatory retirement age of 60. RIKEN expects that the successful applicant will be able to take up the position in October 2000 or as early as possible after that.

Applicants should send a full CV and photograph, 1 copy each of five-key publications, a statement explaining the former research experience and proposals for research in RIKEN, and the names and addresses of two referees. All applications should reach RIKEN by June 30, 2000.

Applicants should address all correspondence to:

Isao Tanihata, RI Beam Science Laboratory, RIKEN, 2-1 Hirosawa, Wako Saitama 251-01, Japan
Tel: 81-48-467-9471 Fax: 81-48-462-4689
Tanihata@rikaxp.riken.go.jp

BROOKHAVEN NATIONAL LABORATORY

POSTDOCTORAL RESEARCH ASSOCIATE

The Physics Department of Brookhaven National Laboratory has an opportunity available for a research associate to work on the development and construction of the ATLAS Cathode Strip ChamberSystem under the direction of V. Polychronakos. BNL's responsibilities for this system include the construction of the detectors, the front end electronics, and the overall system integration. Candidates should possess a Ph.D. in Particle Physics and experience in data acquisition systems, data analysis and simulations. Familiarity with gaseous detectors is desirable.

Interested candidates should submit a CV and three letters of reference, indicating position #MK8366, to: **M. Kipperman, Brookhaven National Laboratory, Bldg. 185, PO Box 5000, Upton, NY 11973-5000.**

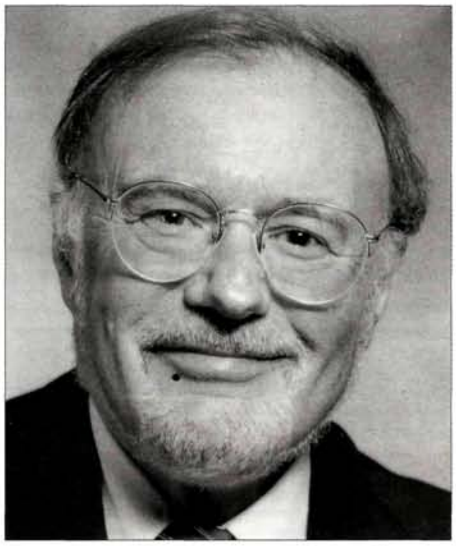
BNL is an equal opportunity employer committed to workforce diversity.

Pierre-Etienne Bisch (left), Préfet of the département de l'Ain, France, with CERN director-general **Luciano Maiani**. Much of CERN, and most of the footprint of its 27 km LEP/LHC tunnel, lies inside Ain. As a special contribution to CERN, the département has financed an assembly and storage area adjacent to the construction site for the new LHC collider.

New director at Cornell...

Maury Tigner, who two decades ago was the driving force behind the half-mile-circumference electron accelerator at Cornell, has been named next director of Cornell's Laboratory of Nuclear Studies (LNS). Tigner will succeed Karl Berkelman, who steps down on 30 June. LNS operates the Cornell Electron Storage Ring.

Tigner was professor of physics at Cornell from 1977 to 1994 and in his final year was named the first holder of the Hans A Bethe Chair in Physics, a post that a serious illness forced him to relinquish. In the intervening years, as professor emeritus, he has edited a handbook on accelerator physics and engineering (*CERN Courier* December 1999 p38), and with his wife has made long visits to Beijing as a visiting scientist at the Institute of High Energy Physics as well as a senior adviser to the Chinese Academy of Sciences.



Maury Tigner has been named next director of Cornell's Laboratory of Nuclear Studies.

MEETINGS

The 2nd workshop on Electronic Publishing – New Schemes for Electronic Publishing in Physics will be held at CERN on 31 March. Further information is available from Anita Olofsson at CERN, tel. +41 22 767 2431, e-mail "anita.olofsson@cern.ch". See also "http://documents.cern.ch/AGE/fullAgenda.php3?ida=a99231#s5".

An International Workshop on High Energy Photon Colliders will be held at DESY, Hamburg, on 14–17 June.The event will cover physics opportunities at high-energy gamma-gamma and gamma-electron collisions, and accelerator, interaction region (such as lasers and optical systems) and detector issues. The chairmen for the meeting are R Heuer (University of Hamburg/DESY) and V Telnov (Budker INP/DESY). For details, e-mail "gg2000@mail.desy.de". See also "http://www.desy.de/~gg2000".

A workshop entitled **CP Violation and Rare Processes: Standard Model and Beyond** will be held at DESY, Hamburg, on 26–29 September. It will cover topics on CP violation in K, B and lepton sectors; rare decays and scattering processes; mass matrices for quarks and leptons; standard model analyses; and effects from physics beyond the standard model. The event will be organized by A Buras (TU-Munich). See "http://www.desy.de/desy-th/workshop.00/index.html".

A Euro Summer School on Exotic Beams (within the framework of High-Level Scientific Conferences of the EU) will take place on 31 August – 8 September in Leuven, Belgium. For more details, contact Mark Huyse, IKS, Celestijnenlaan 200D, B-3001 Leuven, Belgium, tel. +32 16 327272, fax +32 16 327 985, e-mail "mark.huyse@fys.kuleuven.ac.be".

LETTERS

CERN Courier welcomes feedback but reserves the right to edit letters. Please e-mail "cern.courier@cern.ch".

Famous physicists

For several reasons I was very surprised to read the list of the "Top 10 physicists of all time" (January/February p11).

I was surprised, initially, by the almost total exclusion of experimentalists (except for Ernest Rutherford), but primarily for the exclusion of Micheal Faraday.

Faraday's experimental contributions in the areas of electromagnetic, optical and electrochemical phenomena were of the highest order, but even more important was his epoch-making concept of fields.

Much, if not most, of 19th- and 20th-century physics was based on this concept (as were the contributions of seven physicists in the list).

Thus I must take exception to *Physics World*'s rating.

Tom Ypsilantis, Bologna.

Physics World replies:

Michael Faraday just missed the Top 10, finishing in joint 11th place with Ludwig Boltzmann and Max Planck. Like Dr Ypsilantis I was surprised by the lack of experimenters in the Top 10. Indeed, I told the BBC Web site: "Einstein and Newton were always going to be one and two, but what was surprising about the Top 10 was that there were seven out-and-out theorists."

The *Physics World* article from which the Top 10 was taken (December 1999 pp7–13) also reveals that Einstein's top three physicists were Newton (2nd in the Physics World poll), Faraday and Maxwell (3rd).

Peter Rodgers, editor, Physics World.

Cosmic rays

Articles in the October 1999 issue of *CERN Courier* that discussed prospects for cosmic-ray studies using existing LEP detectors claimed to have seen "intriguing" events ▷

...and new directors for DESY

Robert Klanner – new DESY research director.

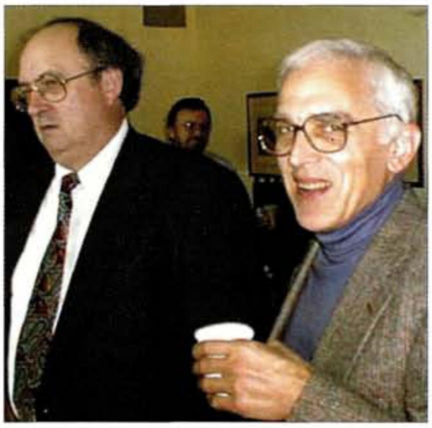
The Administrative Council of the German Electron Synchrotron DESY in Hamburg has extended the size of the DESY directorate. The board of directors now has six members instead of five.

The new director is in charge of research with synchrotron radiation, which in the past years has developed to become a second important research field along with elementary particle physics.

Jochen R Schneider was nominated the new director of this field, a position that he assumed on 1 January.

The administrative council also nominated Robert Klanner as DESY research director. He will be in charge of elementary particle physics, which was the initial major research field of DESY. He succeeds Albrecht Wagner, who becomes head of the DESY directorate (director-general).

Princeton's Institute for Advanced Study recently hosted a meeting entitled Symmetry Lost and Found to mark Stephen Adler's 60th birthday. Organized by Ed Witten and Frank Wilczek, the event focused on themes connected with Adler's pioneering work on chiral symmetry and field theory anomalies, which revived interest in field theory in the late 1960s and opened the door to what would become today's Standard Model and later developments. Stephen Adler is seen here (right) with William Bardeen, who spoke on "Anomalies in quantum field theory". (Kirk McDonald.)



"with the highest muon density ever seen" – five "spectacular" unexplained events with some 150 muons each.

Adding a few more drift chambers, the "muon pattern would give a window on the energy and composition of the primary cosmic-ray particles", "boosting studies...in the knee region (near 1015 eV)".

In high-energy cosmic-ray events, three key parameters are unknown: the primary energy, the primary composition and the height of the initial interaction in the atmosphere. Therefore, simultaneous measurements of several distinct physical quantities are needed to disentangle these parameters.

The cosmic-ray community has made remarkable progress in this direction, so that today's main obstacle is not the lack of high-quality data but the lack of reliable simulations of cosmic-ray interactions with the atmosphere.

LEP detectors would face the same problem and would be limited to the measurement of only the muon component of cosmic air showers.

An experiment in the Baksan Valley in the Russian Caucasus has been taking cosmic-ray muon data for some eight years under similar conditions. Seven events have more than 3500 muons each – and no anomalies are claimed!

Friedrich Dydak, CERN.

AWARDS

Wolf prize

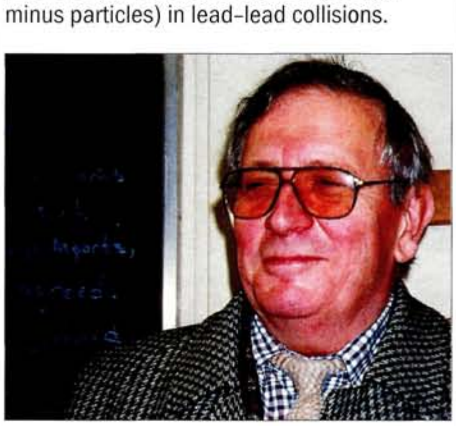
The prestigious Wolf prize for physics will be shared this year by Raymond Davis of Pennsylvania and Masatoshi Koshiba of Tokyo.

"Their observations of the elusive neutrinos of astrophysical origin have opened a new window of opportunity for the study of astronomical objects, such as the Sun and exploding stars, and the study of fundamental properties of matter," the jury stated.

Davis pioneered solar neutrino measurements by the radiochemical method, while Koshiba led the design and construction of the versatile Kamiokande neutrino detectors in Japan. The $100 000 prizes will be presented at the Israeli Knesset on 21 May.

Dennis Skopik, former director of the Saskatchewan Accelerator Laboratory, Saskatoon, becomes deputy associate director of physics at the Jefferson Laboratory, Newport News, Virginia, where Larry Cardman is associate director for physics.

CERN physicist **Emanuele Quercigh** has been awarded the Gold Medal of the Faculty of Mathematics and Physics of Comenius University, Bratislava, and the Slovak Academy of Sciences' Diorys Ilkovic Gold Honour Medal for Achievements in Physics. Quercigh plays a leading role in heavy-ion experiments at CERN, in which Slovak physicists have themselves made important contributions. In the search for new forms of nuclear matter, these studies have provided evidence for the substantially increased production of strange particles (up to 15 times as many omega-minus particles) in lead–lead collisions.



Emanuele Quercigh – Slovak awards.

Louis Michel 1923–99

Eminent French theorist Louis Michel died in December. Born in Roanne, France, he studied at the Ecole Polytechnique before carrying out research at Manchester, in the fledgling CERN Theory Group at Copenhagen and at Princeton's Institute for Advanced Study, before returning to France, where he held posts at Lille, Paris, the Ecole Polytechnique, and finally the Institut des Hautes Etudes Scientifiques at Bures-sur-Yvette.

His name will always be linked with his first major research success: the description of the decay spectrum of a muon into an electron and two neutrinos using a single "Michel parameter". Corollary work on lepton polarization and isotopic parity (later known as G-parity) was soon brought to the fore with the discovery of parity violation in lepton decays. Extensions of his muon work subsequently bore additional fruit with the discovery of the tau lepton in 1975.

Other landmarks of Michel's work include his framework for handling the analysis of polarized particles and the 1959 Bargmann-Michel-Telegdi equation describing relativistic spin precession in an electromagnetic field.

In the 1960s his counsel in the underlying theory of relativistic symmetries was much sought after. Later, his mastery of modern mathematics allowed him to make valuable contributions to studies of internal symmetries and spontaneous symmetry breaking, both in elementary particles and condensed matter physics. Most recently, he developed mathematical tools to describe crystals and quasi-crystals.

He played a major role in the rebuilding of postwar French theoretical physics, with the creation of the Ecole Polytechnique theory centre, and he served on many committees, including a term as president of the French Physical Society and almost 20 years with various CNRS boards, including the scientific council.

Michel was a member of key international scientific collaborations, and his numerous students in turn went on to fulfil major roles. His understanding of physics and his mastery of mathematics were much in demand for keynote talks at international meetings.

A member of the French Academy of Sciences, Officer of the Legion of Honour and Commander of the Order of Merit, abroad he was a member of the Academy of Catalonia (Spain), was awarded the Wigner Medal, and delivered the Leigh Page Prize lectures at Yale. Louis Michel was a French physicist who played on an international stage.

Raymond Stora.

Andrej Amatuni 1928 –99

On 10 October, Andrej Amatuni, full member of the Armenian National Academy of Sciences, professor and principal researcher of the Yerevan Physics Institute, died of a heart attack on a plane en route to a conference in Japan.

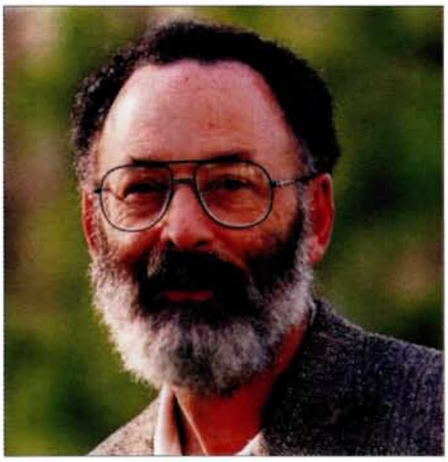
Amatuni was born in Leningrad and received his higher education from Yerevan State University. He continued his studies at Moscow Lomonosov State University. Working at the Yerevan Physics Institute from 1956, in 1958 he joined a group headed by academician Artem Alikhanian, working on the Yerevan 6 GeV electron synchrotron, brought into operation in 1967, and at the time one of the world largest machines of its kind. In 1965 he was a visiting scientist at CERN.

Amatuni's interests went on to span a variety of elementary particle physics, but finally he returned to the problems of charged particle acceleration and to the development of non-conventional acceleration schemes. In his last years he headed a group that solved some important problems of charged particle interactions with plasma.

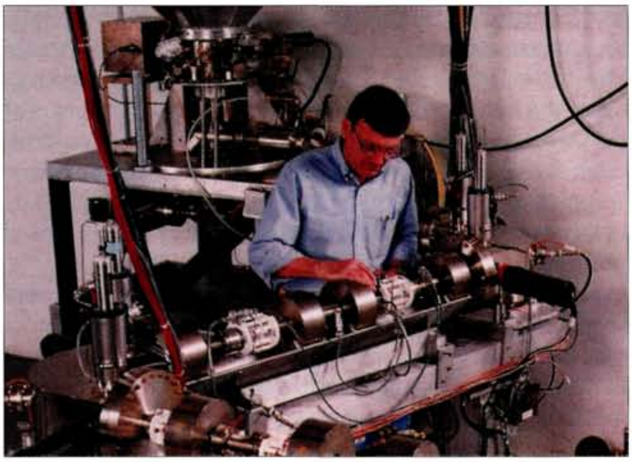
Besides being a brilliant physicist, Amatuni was an outstanding research organizer. from 1965 to 1977 he served as a first deputy to the director of Yerevan Physics Institute and from 1973 to 1991 he was the director of this, the largest scientific centre in Armenia.

His contributions to science were recognized by scientific communities worldwide. He was awarded the title of Honoured Scientist of Armenia and received many decorations from the USSR, Armenia and Russia.

Andrej Amatuni was a highly intellectual, cultured, sympathetic, accessible and vital personality. His absence will be strongly felt, not only by those at his home institute, but also by his numerous friends and colleagues over the world.



A special event at the Jefferson Laboratory, Newport News, Virginia, celebrated the special contributions to physics in general, and the success of the laboratory in particular, of eminent theorist and Chief Jefferson Scientist Nathan Isgur (left) and Injector Group Head Charles Sinclair (right).



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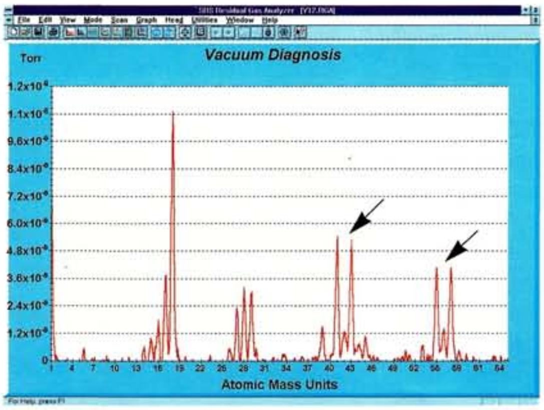

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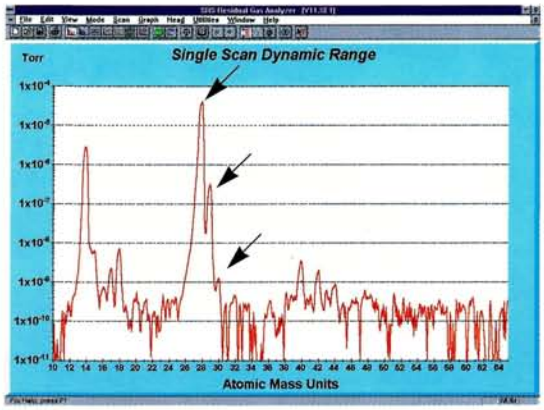

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