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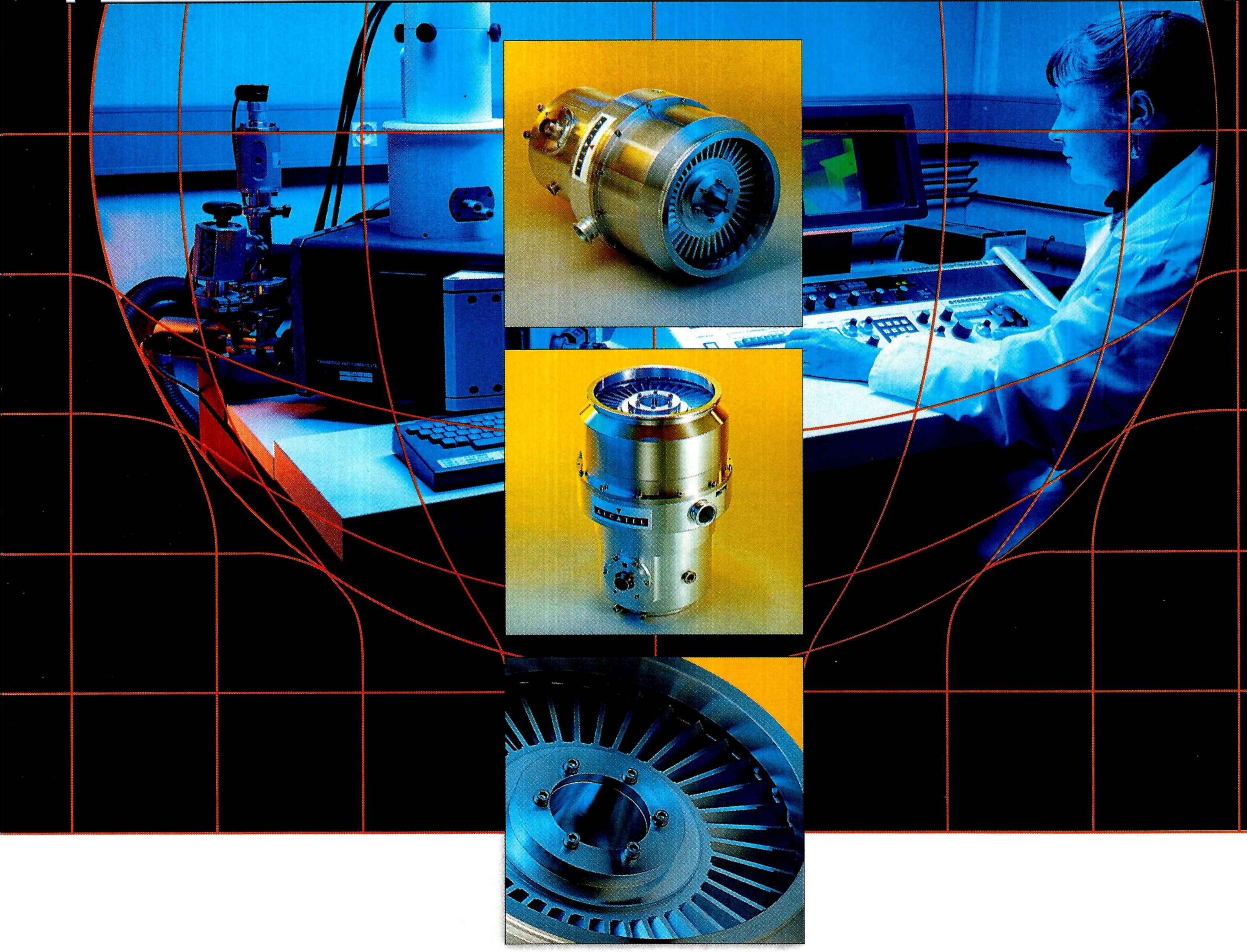

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Tel : (39) 2 33 00 80 13
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Alcatel ITS
Tel : (81) 3 5424 1411
Fax : (81) 3 5424 8580

Advertising enquiries

Europe

Micheline Falciola
Advertising Manager
CERN
CH-1211 Geneva 23, Switzerland
Tel.: +41 (22) 767 4103
Fax: +41 (22) 782 1906

Rest of the world

Laurie Shapiro
Advertising Manager, USA
Gordon and Breach Publishers
P.O. Box 200029
Riverfront Plaza Station
Newark, NJ 07102-0301
Tel.: 201-643-7500 (ext. 228)
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General distribution

Jacques Dallemagne
CERN, 1211 Geneva 23, Switzerland

In certain countries, copies are available on request from:

China

Dr. Qian Ke-Qin
Institute of High Energy Physics
P.O. Box 918, Beijing,
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Monika Stuckenberg or Kerstin Techritz
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USA/Canada

Cyndi Rathbun (B90904 @ FNALVM)
Fermilab, P.O. Box 500, Batavia
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CERN, 1211 Geneva 23, Switzerland
tel.: +41 (22) 767 61 11,
telex: 419 000 CERN CH,
telefax: +41 (22) 767 65 55

CERN COURIER only:
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telefax +41 (22) 782 19 06

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Editor: Gordon Fraser (COURIER @ CERNVM)*
Production and Advertisements:
Micheline Falciola (FAL @ CERNVM)*

**(Full electronic mail address... @ CERNVM.CERN.CH)*

Around the Laboratories

Physics monitor

Cover photograph: Excavation for the Japanese Super-Kamiokande 50,000-ton water Cherenkov imaging detector was completed at the end of June (see page 13). It took 31 months to excavate the 58 m high and 40 m diameter cavern and remove more than 75,000 cubic metres of rock. This summer some 200 people, including the President of the University of Tokyo and the Governor of Gifu Prefecture, were invited to a classical music concert and an exhibition of artwork in the completed cavern.

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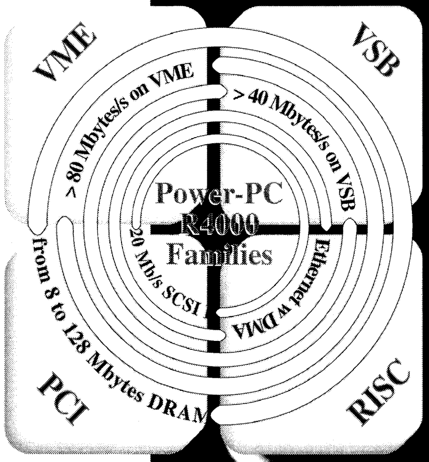

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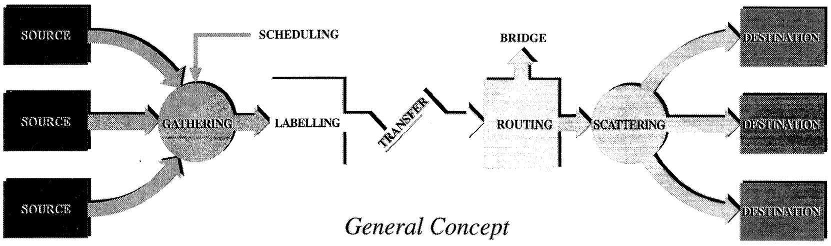

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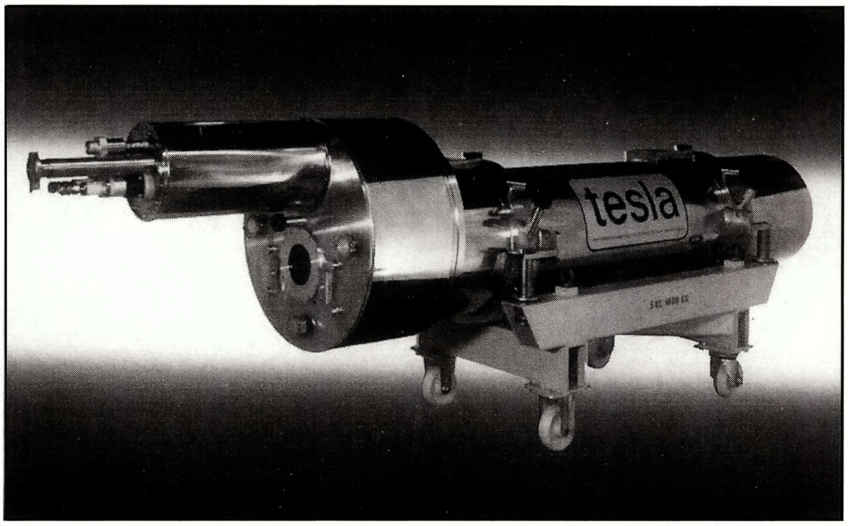
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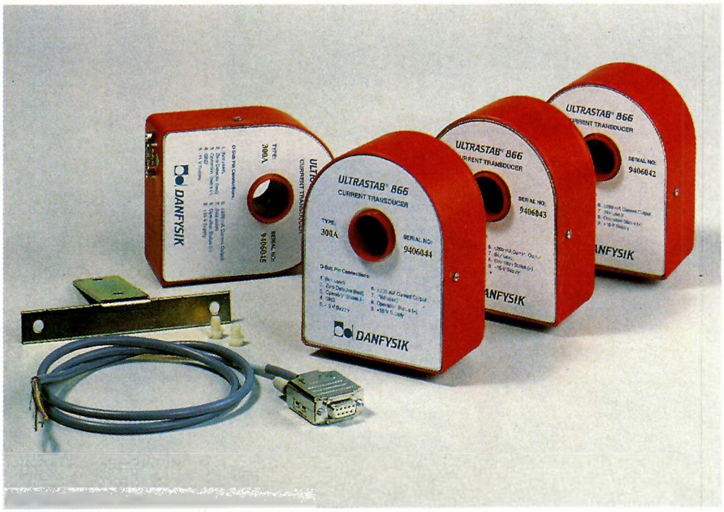
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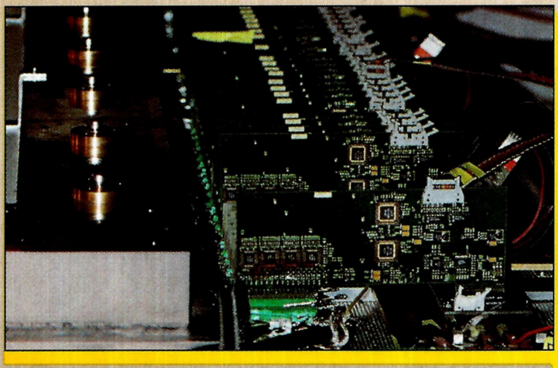
Four Reasons to Use PCOS 4

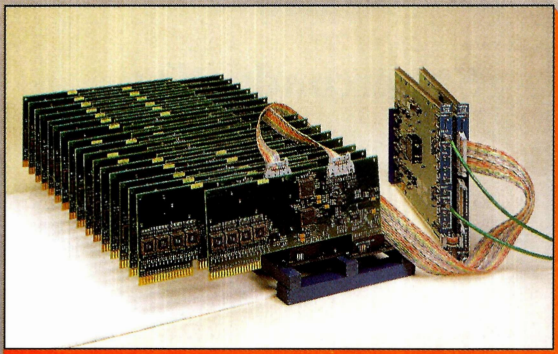


Introducing LeCroy's NEW Chamber System

Just as multi-wire proportional chambers have improved and evolved during the many years since their invention, so have the electronic readout systems.

LeCroy's NEW PCOS 4 chamber system is the latest in a series which started in 1972.

PCOS 4 is an integrated system incorporating the amplifier, shaper, discriminator, delay, coincidence latch and readout on a 16-channel, chamber-mounted circuit board. This new system offers many benefits over existing proportional chamber readout systems including:



LOW COST **-** PCOS 4 was designed from the ground up for on-chamber mounting. The highly integrated design and simple cable requirements means low total system cost and high system reliability.

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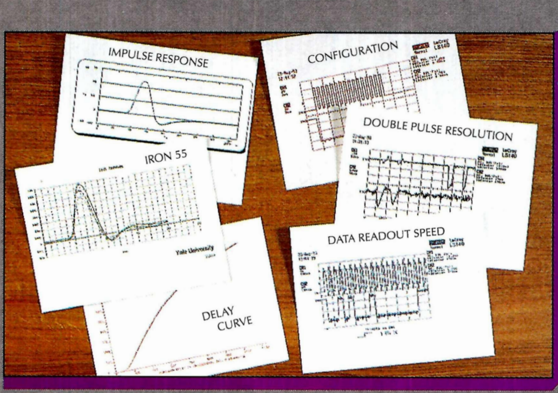

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Model 2741 16-Channel Amp./Discriminator/Delay/Latch
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* PCOS 4 was developed in cooperation with Yale University and Brookhaven National Lab. Photo courtesy of BNL.

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The long road to the top
by Christine Sutton

Earlier this year (June, page 1), initial evidence for the sixth ('top') quark from the CDF experiment at Fermilab's Tevatron proton-antiproton collider underlined the strength of the Standard Model. The top quark mass is exactly in line with predictions from Standard Model data, including the mass of precision data from LEP, CERN's electron-positron collider. In this specially-commissioned article, Christine Sutton, Oxford physicist and well-known science writer, reviews the story behind the top quark.

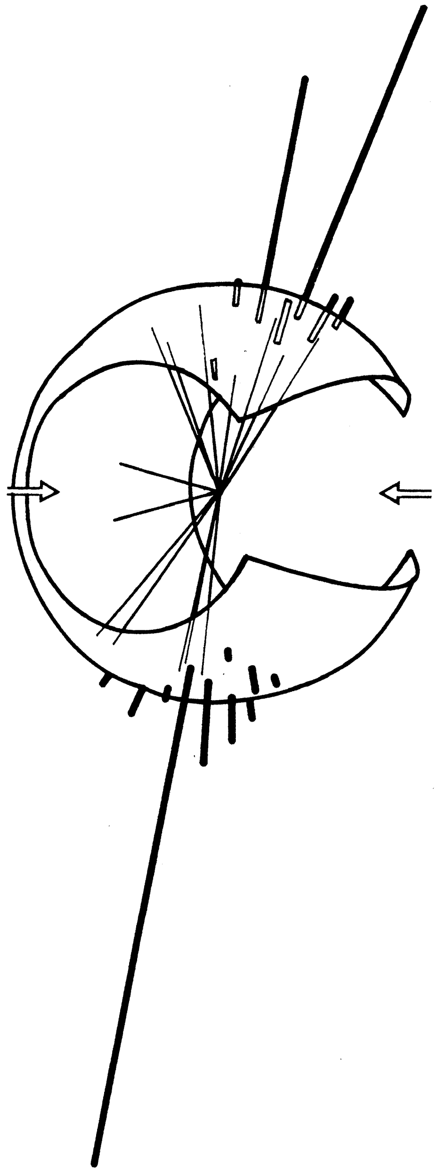
The top quark occupies a special place among the quarks. Not only is it the heaviest by far, it is also the only quark that particle physicists have actively hunted. The hunt has been long, but now at last the quarry is in sight and the net has tightened almost to a close.

It is 30 years since the idea of quarks first arose. By the early 1960s, experiments had revealed a host of short-lived particles created in nuclear collisions, both in cosmic rays and at accelerators. Many of these particles, such as the pion and the kaon, as well as the more familiar proton and neutron, interacted through a strong force, and became known collectively as hadrons, from the Greek for "strong". In 1963 Murray Gell-Mann and George Zweig came independently to the conclusion that they could explain the multitude of hadrons in terms of only three basic constituents. Zweig called these constituents "aces", while Gell-Mann dubbed them "quarks", the name by which we know them today.

To make the known hadrons the quarks had to have some bizarre properties. The hadrons fall naturally into two groups - the baryons (such as the proton and the neutron) with half-integer values of intrinsic spin, and the mesons (such as the pion and the kaon) with integer spins. To make a baryon requires three quarks, each with a spin of 1/2, while to make a meson requires a quark coupled with an antiquark. Then for the baryons to have the correct electric charge, the quarks must carry fractions of 1/3 and 2/3 the usual unit of charge, the charge of the electron.

For some time it was far from clear whether the quark model was basically a mathematical device or whether it did indeed reflect a new level of reality. As Zweig has since said, "The reaction of the theoretical physics community to the ace model was generally not benign ... The idea that hadrons ... were made of elementary particles with fractional quantum numbers did seem a bit rich." For experimenters, however, the hunt for quarks had begun. With a charge of 1/3, for example, a quark should produce only 1/9 the ionization due to a standard particle, such as a pion. So single quarks passing through a detector should leave faint tracks with only 1/9 the density of the usual high-energy tracks. But the search for quark tracks was destined to fail. We now know that quarks are always bound together as groups of three (baryons) or in quark-antiquark pairs (mesons), except perhaps at collision energies far higher than we can currently achieve.

The first evidence that quarks really do exist within the proton and the neutron came instead from a different type of experiment. While we may not be able to track quarks directly, it turns out that we can in effect spy on them hiding with the proton and the neutron. This type of experiment goes back to the days of Ernest Rutherford, whose colleagues Hans Geiger and Ernest Marsden discovered that alpha-particles directed at a thin gold foil could be scattered through large angles, sometimes

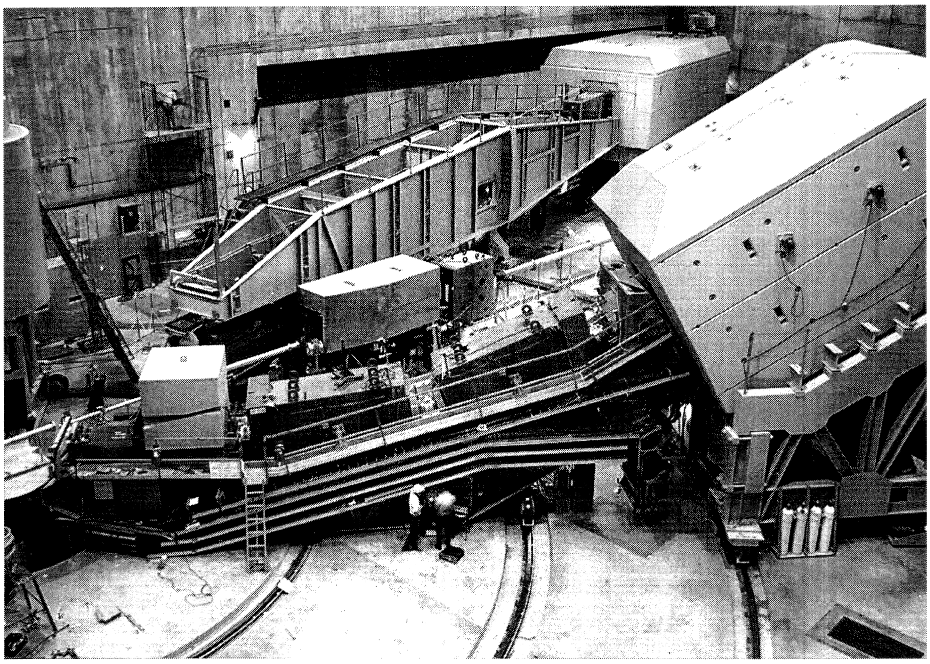


Spectacular 'jets' seen by the UA2 detector at CERN's proton-antiproton collider in 1982, with sprays of high energy particles at wide angles to the direction of the colliding beams (the lines are proportional to the energies of the emerging particles). The advent of such detectors surrounding the collision point and intercepting all emerging particles provided a major impetus to jet studies.

even knocked backwards. Rutherford realized that the positively-charged alphas were being deflected by the positive charge within the gold atoms. To explain the large angles, the positive charge within the atom had to be concentrated in a small region at the centre - Rutherford had found the nucleus.

In 1969, experiments at the Stanford Linear Accelerator Center (SLAC) began to see a similar phenomenon when high-energy electrons from the 3-km linac struck protons in a hydrogen target. This time it appeared that the electrons were scattering from tiny concentrations of charge within the protons. To show that these objects had the same fractional charges as the quarks required a comparison with similar experiments with uncharged projectiles - neutrinos. As Richard Feynman said at the time, "If you never did believe that "nonsense" that quarks have non-integral charges, we have a chance now, in comparing neutrino to electron scattering, to finally discover for the first time whether the idea ... is physically sensible ..."

At CERN, the team studying the interactions of neutrinos in the huge bubble chamber Gargamelle found the vital evidence. In a conference in Hawaii in 1973, Don Perkins reported to Feynman and others, "The evidence is rather compelling that electrons and neutrinos are seeing the same substructure inside the nucleon, with absolute rates standing in exactly the ratio predicted by the quark charge assignments." Later, the CDHS, CHARM and BEBC experiments at CERN followed in the footsteps of Gargamelle, using the high-energy neutrino beams at the SPS to probe in detail the complex world within the proton.



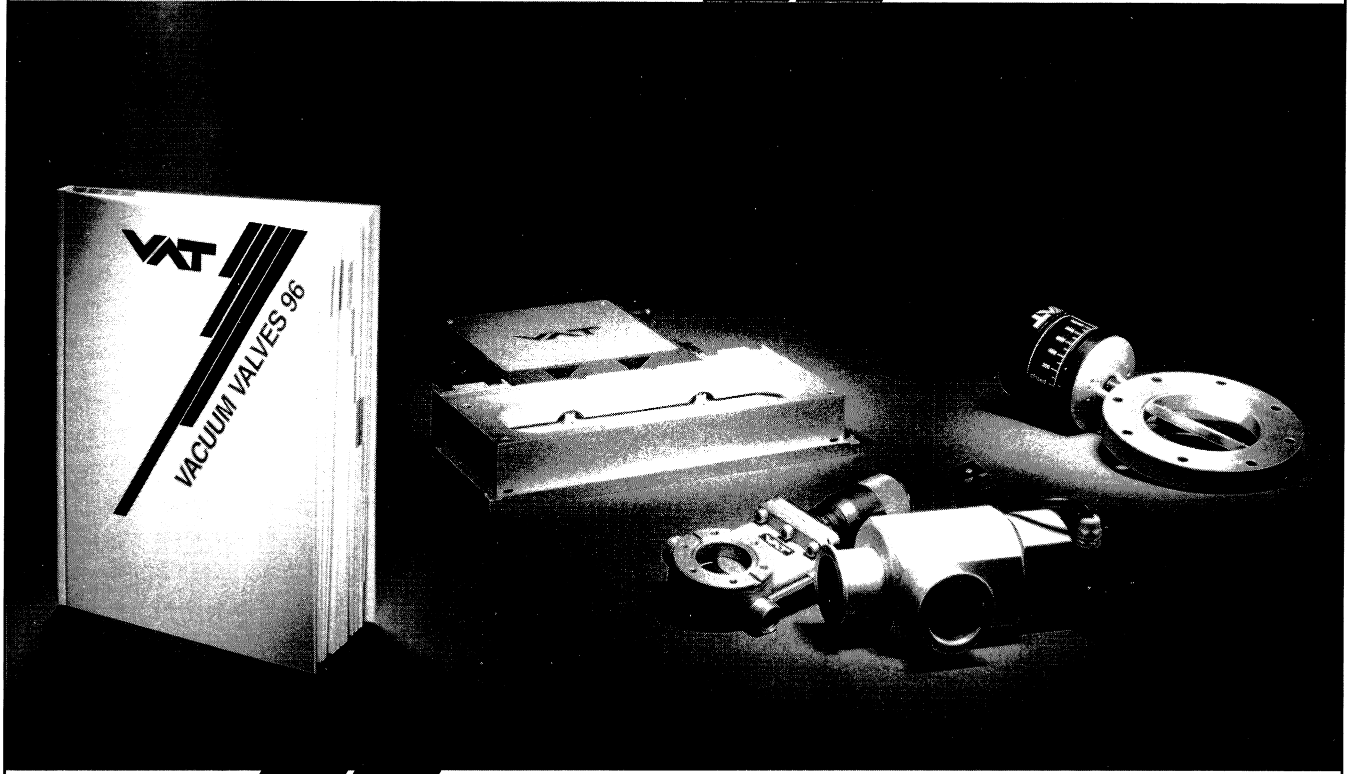
Rutherford revisited - end Station A at the Stanford Linear Accelerator Center (SLAC) first saw evidence for hard grains deep inside the proton.

Back in 1973, three types of quark - up, down and strange - were sufficient to build the wide variety of particles that had already been discovered. But since 1964 there had been hints that a fourth quark should exist. There were known to be four particles that did not consist of quarks. These were the weakly-interacting "leptons": the electron, the electron-neutrino, the muon and the muon-neutrino. Arguments based on symmetry suggested that as there were four leptons, which seemed to be fundamental, structure less particles, then why should there not be four quarks, as they likewise appear structureless and fundamental?

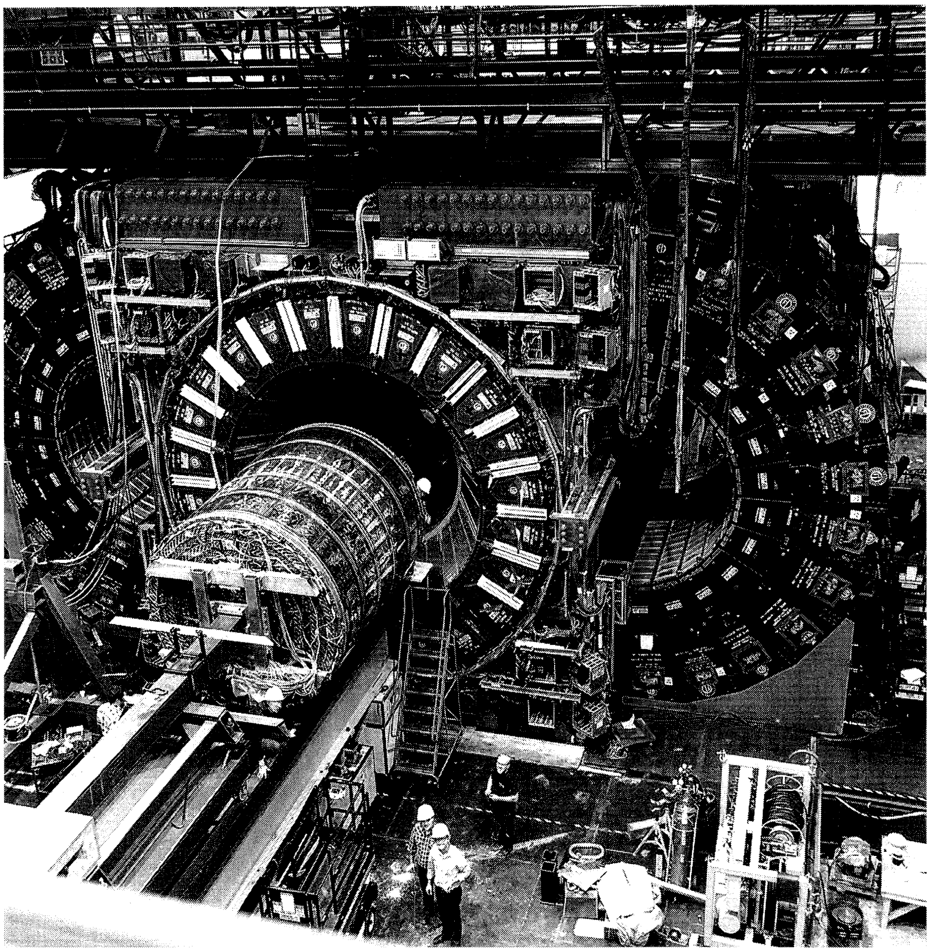
There was more to such arguments than simple aesthetics. The weak force, responsible for the decays of many particles, seemed to connect pairs of quarks and leptons. It could for example change a muon into a muon-neutrino, in muon decay; or a down quark into an up quark, in neutron decay. A fourth quark to partner the strange quark would complete the picture.

Later more compelling arguments for a fourth quark came from considering the lack of experimental evidence for interactions called "strangeness-changing neutral-currents". Neutral currents are interactions through the weak force in which no electric charge changes hands - they occur through the exchange of the now famous Z particle. At first sight there seems no reason why a strange quark (charge -1/3) should not change to a down quark (-1/3) in this way, with no change in charge but a change in "strangeness", a quantum number possessed only by the strange quark.

In 1970, Sheldon Glashow, John Iliopoulos and Luciano Maiani found that a fourth quark with a charge of +2/3 would provide an explanation as to why such interactions were not seen. The fourth quark could change to an up quark, also charge +2/3, through a second type of neutral interaction. The existence of this


VAT
VACUUM VALVES 96

Installation of the CDF experiment at Fermilab's Tevatron proton-antiproton collider, showing how the detector modules fit around each other like a giant high-tech jigsaw. The CDF detector has provided first evidence for the top quark.



second pathway for a neutral current would lead to a quantum mechanical cancellation between the two, so neither would be seen! The fourth quark would have a unique quantum number distinguishing it from the other quarks. Echoing earlier work by Glashow and James Bjorken this quantum number was called "charm".

It is probably fair to say that in the early 1970s, there was such a variety of competing theoretical ideas that no one tried seriously to search for the fourth quark. Instead, it gave itself up in a rather unexpected way. In the autumn of 1974 two experiments found evidence for a new surprisingly long-lived state, which at 3.1 GeV was more than three times heavier than the proton. This was the particle that became called the J/psi, discovered by Sam Ting's team at Brookhaven and Burt Richter's team at SLAC.

The new particle was at first a puzzle, but evidence gradually mounted to show that it must be a meson built from the fourth quark locked in a long but ultimately deadly embrace with its antiquark. A lepton-quark symmetry was therefore assured - but not for long. Even as the consensus on the nature of the J/psi was forming, Marty Perl and his colleagues at SLAC began to discover evidence for another new particle, this time a third charged lepton - the tau. Together with its likely (but still unproven!) neutrino partner, the tau brought the tally of leptons to six, with the quarks lagging behind again with only four members to the family. Now, however, the quark hunters were on guard. When Leon Lederman's team at Fermilab found evidence for a new particle rather like the J/psi but some three times heavier still, the idea that this should be a fifth quark bound with its antiquark did not seem at all absurd. By 1977, the bottom quark, with charge -1/3, had become an established member of the quark family, and the hunt was on for its partner, "top", with charge +2/3 to complete the picture.

The quest for the top quark proved longer and more arduous than anyone could probably have expected. It seemed always to be hiding just round the corner, to be caught by the next machine that would reach a little higher in energy. In 1977 no one would have predicted that it would eventually weigh in with a mass as great as that of a gold nucleus.

The very nature of quarks makes them difficult to snare. Like intrinsically shy creatures, they remain hidden within baryons or mesons. The experiments with electrons and neutrinos that probe within protons see the average effects of a mixture of three "valence" quarks entangled in a "sea" of ephemeral quark-antiquark pairs and gluons (which hold the mixture together). They can tell us how the constituents move around inside the proton, but not how to identify a specific quark. When we try to knock quarks out of particles, all that we succeed in doing is to create more quark-antiquark pairs, and hence more particles. In some circumstances we can use this effect to "see" a quark, through the tight cluster or "jet" of particles the quark spawns. But again it is difficult to determine the exact nature of the original quark (or gluon for that matter) that produces a given jet. In the 1970s initial evidence for such jets at CERN's Intersecting Storage Rings hinted that there was something within protons that could be knocked sideways in the head-on collisions - something which we can now identify as quarks.

Later, clear jet signals were seen in electron-positron annihilations and in experiments using lepton beams. A new phase of jet studies began in 1982 with the advent of big experiments at CERN's proton-antiproton collider with calorimeters wrapped round the beam collision point to pick up as much as possible of the emerging energy, an important feature of all today's major colliding-beam experiments.

The charmed and bottom quarks were found through the discovery of the mesons that contain the quark together with its antiquark. In principle, a similar meson formed from top and anti-top should also exist, and many hunts for the top quark have revolved around searches for such a particle. Electron-positron collisions provide a particularly clean way of producing mesons of this kind. In these interactions the electron and its antiparticle (the positron) simply annihilate into energy - a photon - which can then rematerialize as any quark or lepton together with its antiparticle, providing there is enough energy to create the mass of the new pair. This is the way the J/psi appeared at the SPEAR collider at SLAC, when the machine's colliding electrons and positron beams had just the right energy to produce a charm- anticharm pair.

Searches at electron-positron colliders for a similar state of "toponium" gradually pushed up the mass of the top quark as they failed to reveal their prey. From PETRA and PEP, through TRISTAN, and now to LEP, successive teams of physicists have been disappointed to discover that the top quark must lie beyond their machine's reach. With no sign of toponium at LEP's highest collision energy of 100 GeV, the top quark must weigh in at more than half this, or 50 GeV.

However, LEP had a far more subtle way of indicating what the top quark's mass might be. With some 8 million Z particles collected up to the end of 1993 (and many more coming this year, see page 6), the four experiments at LEP measure the parameters of the Z particle with unprecedented accuracy - the mass of the Z, for example, is fixed at 91.19 GeV to an accuracy of a few MeV. These and other LEP results can be compared with the predictions of the Standard Model and constrain as yet unknown quantities, such as the mass of the top quark. Other input comes from neutrino interactions; from Stanford's linear collider, SLC, using polarized beams; and from measuring the mass of the W particle, the electrically-charged companion of the Z, in proton-antiproton collision experiments - UA2 at CERN and CDF and D0 at Fermilab. (LEP will only be able to measure the W when its energy is upgraded - January, page 6).

For all these precision results to be consistent within the Standard Model, the top quark must exist, with a mass, to within about 10%, of 174 GeV.

Now, however, it may be that the top quark has at last appeared directly, in the CDF detector at Fermilab. Fermilab's proton-proton collisions at 1.8 TeV have just enough energy that on rare occasions a quark within the proton may annihilate with an antiquark within the antiproton to produce a top-antitop pair. The CDF collaboration have found 12 possible such events, which together yield a central mass for the top quark of 174 ±17 GeV - neatly within the range predicted by LEP and the Standard Model. If these events eventually do prove to be the first examples of the top quark, the consistency of all these numbers will be a great triumph, for the Standard Model, and our understanding of the fundamental nature of matter.

With the top quark mass accurately known, rather than just limited, the next step will be to probe the higgs symmetry breaking mechanism at the heart of the electroweak theory.

Around the Laboratories

CERN
More collisions for LEP

With CERN's LEP electron-positron collider now routinely operating in 'preztel' mode with eight interleaved bunches per beam (October 1992, page 17) and with operations crews mastering the delicate handling of the machine's beam orbits, luminosity has gone beyond 2 x 10^{31} cm^{-2} s^{-1}, substantially improving over the machine's design luminosity figure of 1.7 x 10^{31}. At the end of August, integrated luminosity at LEP (a measure of the total number of electron-positron collisions) had already surpassed the 1993 score (which amassed 3 million Zs), promising an excellent harvest for this year, with the total number of Zs seen since 1989 by all four experiments nearing 15 million.

In parallel, precision beam energy measurement using the resonance depolarization technique (September 1993, page 4) has been possible during physics runs, for both electron and positron beams. Previously this technique could only be used on single beams in machine development periods.

However while machine physicists pat themselves on the back for this year's improved performance, they face a tall order for the LEP 200 energy upgrade (January, page 6). Here, rarer event rates will call for more collisions, and luminosities will need to be boosted to around 7 x 10^{31} cm^{-2} s^{-1}.

For the LEP200 era, more particles have to be squeezed into the ring. With the beam currents under the pretzel scheme limited, the goal is to arrange each of the circulating beams in four 'trains'. While each train could in principle contain many bunches, LEP's magnetic configuration limits the number to at most four.

In this scheme, a major problem is to avoid unwanted collisions between circulating bunches. Additional electrostatic separators will be needed to keep the beams apart. While such separators have already been added for pretzel operation, the bunch train separator configuration will look very different. An initial set of bunch train separators is scheduled for installation in LEP before the end of the year so that collisions under these conditions can be studied.

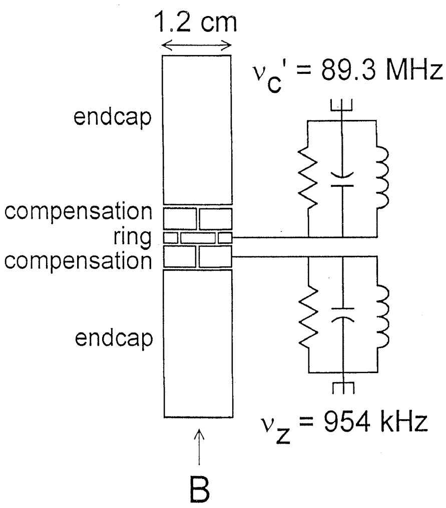
Meanwhile ongoing tests in LEP use magnetic 'bumps' to emulate the beam separation. Injection, ramping, background and instrumentation studies promise well, and bunch trains should make their appearance for LEP operations from next May.

Precision antiproton mass

A new result at CERN provides the most accurate comparison of the masses of the proton and its antimatter counterpart, the antiproton. The result, 40 times more accurate than previous measurements, also forms the most sensitive test ever of CPT invariance for a baryon system.

The CPT theorem says that if - mathematically - a particle is replaced by its antiparticle, its position in space reflected and the direction of time reversed, then the underlying equations are unchanged.

CPT invariance implies that the mass of a particle and its antiparticle are identical. By accurately measuring the mass of the proton and the antiproton, Gerald Gabrielse and his team - from Harvard, Mainz, and Seoul - conducted the most sensitive test ever of CPT invariance for a baryon system.

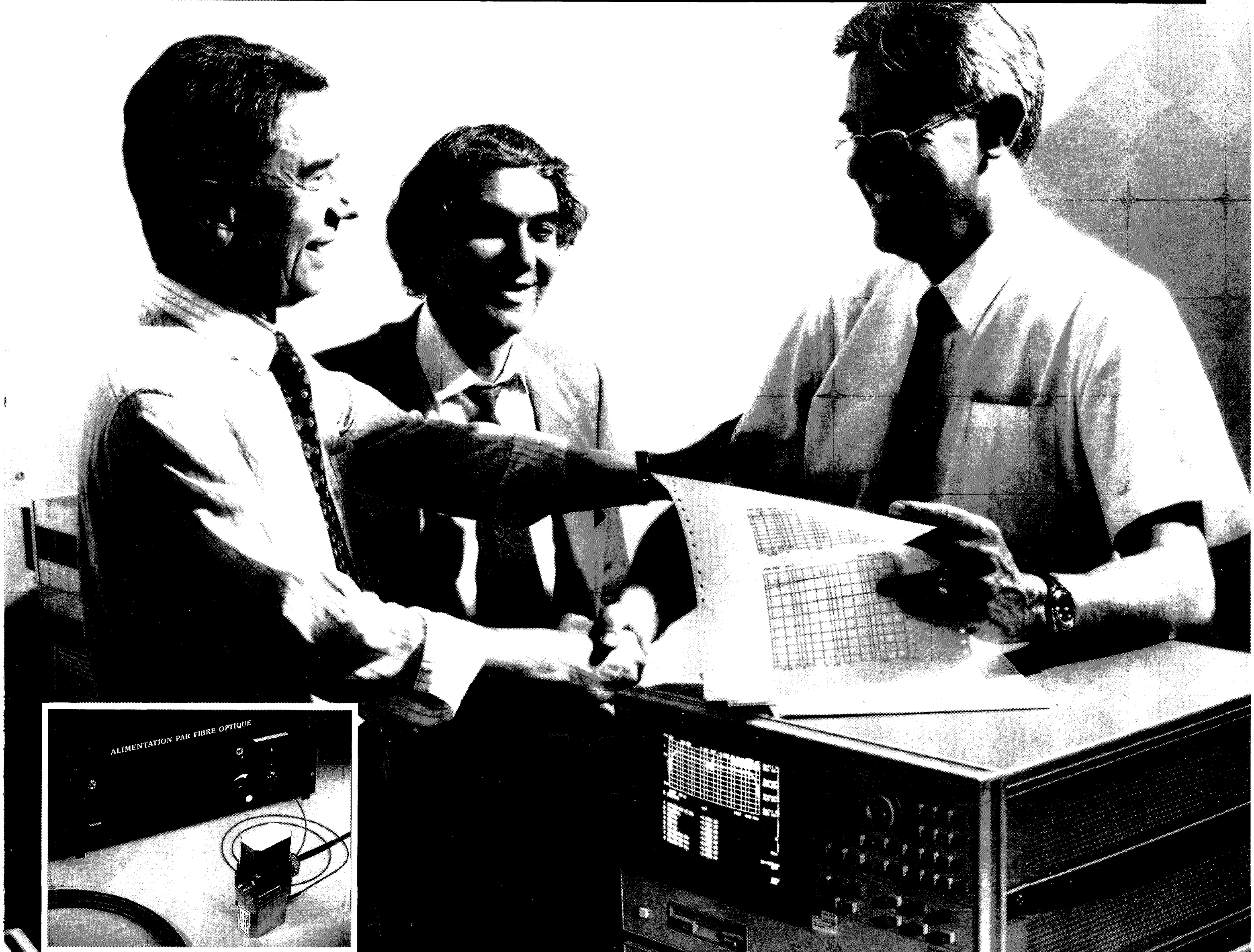


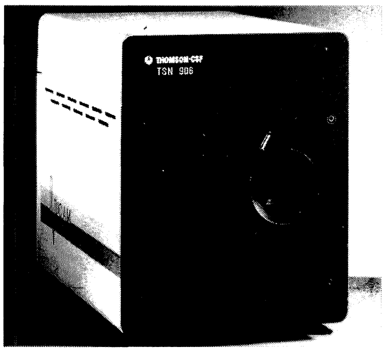
Catching antiprotons - the Penning trap. Antiprotons enter the trap but are turned back by the far endcap's negative charge. A fraction of a second later, the other endcap is switched negative, locking in the antiprotons.

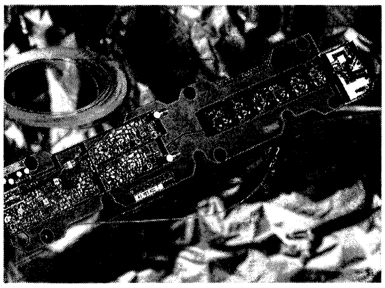
The result is the fruit of a new technique to slow and then trap antiprotons from LEAR, CERN's low energy antiproton ring. Antiprotons at 5.9 MeV were extracted from LEAR and slowed below 3 keV through collisions with electrons inside a thick beryllium degrader. At this energy they can be caught in a Penning trap - a stack of cylindrical superconducting magnets providing a uniform magnetic field with a superimposed electric quadrupole potential.

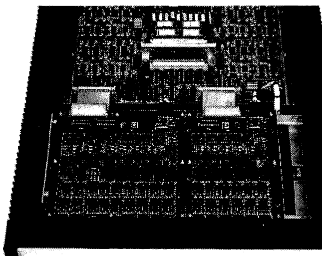
As the antiprotons entered the trap, the entrance ring and the central ring were grounded; the third electrode was held negative so that the antiprotons turned back towards the entrance of the trap. Approximately 300 ns later, the potential of the entrance electrode was suddenly lowered, capturing the antiprotons. The trap was kept under a vacuum of $5x10^{-17}$ Torr at 4.2 K, and the antiprotons were thus further slowed by collisions with surrounding cold electrons. At this stage, there were around 10^4 antiprotrons and 10^7 electrons in the trap.

OPTRONICS - CHRONOMETRY - RADIATION









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Pulsing the electric quadrupole potential at one end of the trap for 200 ns ejected the lighter electrons whilst retaining the antiprotrons; the antiprotons then rotated (cyclotron motion) in the magnetic field and the trapping well depth was reduced, spilling the excess. The cyclotron response was monitored, and when less than 15 antiprotons remained, their differing energies allowed them to be selectively ejected, until all but one were eliminated from the trap. The trapping well depth was then lowered to securely lock in the remaining antiproton.

The team tuned in to the characteristic radio signal emitted by the circulating antiproton and calculated its charge to mass ratio. By repeating the experiment with a proton in the same magnetic field gave a comparison between the two particles. The proton and antiproton masses are equal to a one part per billion.

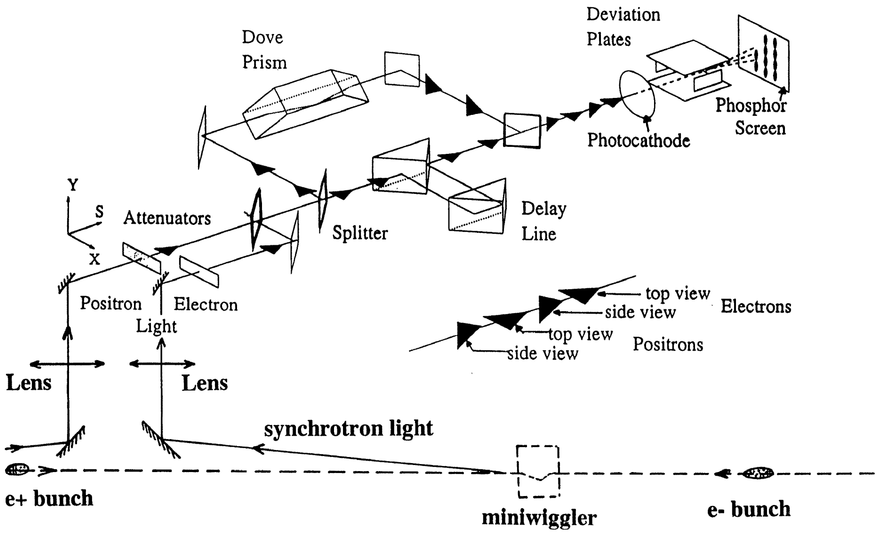
Looking at LEP light sideways

The Faraday Cup for innovative instrumentation, sponsored by Bergoz, goes to Edouard Rossa of CERN for his work in developing a system for viewing bunches of particles in three dimensions simultaneously. This diagnostic tool has been invaluable in LEP machine development, giving an otherwise unobtainable picture of particle behaviour in the ring.

When their trajectory is curved by a magnetic field, charged particles, such as the electrons and positrons emit light, called synchrotron radiation.

In CERN's LEP electron-positron collider, synchrotron radiation is produced virtually everywhere. Using a special dipole (miniwiggler) to provide a reference magnetic field, an optical channel collects this light, providing a window on the otherwise invisible circulating particles. The distribution of the photons is a measure of the density of the bunches.

A streak camera system developed at CERN enables photons to be seen sideways and from the top as well as just end-on. This has proved invaluable in viewing how electron and positron bunches behave inside CERN's LEP collider.
Before the photons (from synchrotron radiation) reach a streak camera a semitransparent mirror splits the light beam in two. One of the beams meets a Dove prism which rotates the image by 90°. In the other beam an optical delay carefully staggers photon bunches in time and avoids their subsequent superposition. A second semitransparent mirror recombines the two beams. So the streak camera displays both top and side view - the horizontal and vertical density projections of the beam.



However the problem which had to be solved was how to measure, in a single pass, the three dimensions of a photon bunch 1 millimetre wide, a few tenths of a millimetre high, and extending over 20 millimetres - a duration of 60 picoseconds or 60 millionths of a millionth of a second.

The answer was found by Rossa, who demonstrated in 1991 a new way to use a streak camera made by ARP of Strasbourg to CERN specifications. His set-up provides not only the front view of the photon bunches, as we see light on everyday life, but also the side and the top views, as would be seen by an observer travelling with the bunches. (Even when we think we are seeing natural light from the side, for example in a bolt of lightning, it is not the photons of the lightning which reach the eye, only the illumination produced in the intervening air.)

The streak camera is built with a specially developed vacuum tube made by Photek (UK) with two pairs of deflecting plates. Photons hit the photocathode of this tube where electrons are emitted, accelerated and the internal electrical focusing field gives the image (front view) of the input photocathode onto a phosphor screen, as in an ordinary TV camera.

After acceleration, the electrons from the photocathode are rapidly deflected by an electric field as they pass between two horizontal plates. This rotates the bunch of electrons, which finally strike the phosphor screen leaving an image of its length, as if it were observed from above.

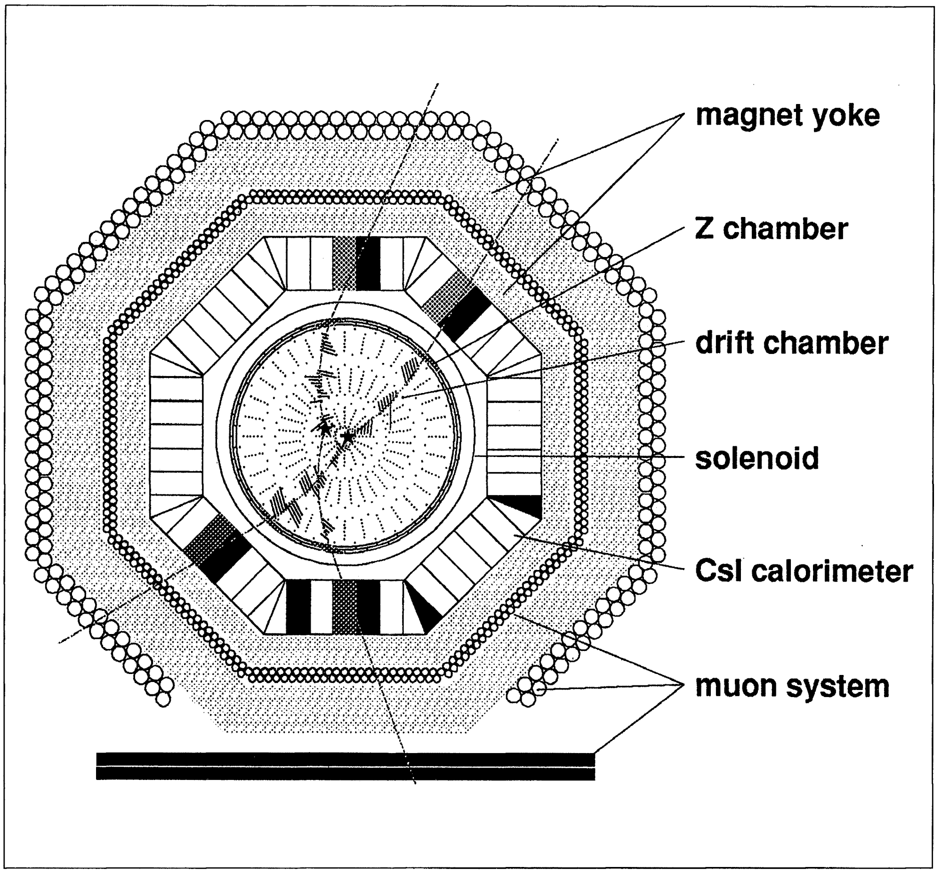
The incoming photon bunches are not collimated with a slit as in usual streak camera setup. Thus the image on the screen is the density projection in the horizontal plane of the total bunch and the two dimensions are preserved. The light produced by the positrons and electrons also arrives with a small geometrical delay (see figure), so that the side- and top-views of both beams can be shown simultaneously in one streak of the camera. Comparing the images from successive revolutions clearly shows the evolution of the beam behaviour.

A second pair of deviation plates inside the streak tube, perpendicular to the first, allows successive streaks to be staggered. The composite image on the phosphor screen is recorded by a CCD camera and digitized before being processed by a computer.

By 1991 the system had already revealed in LEP the tiny head-to-tail bunch oscillations which had been theoretically predicted but never seen, as well as dipolar and quadrupolar instabilities which were limiting machine performance. With this insight, LEP machine specialists were able to achieve dramatic performance improvements.

The prize was awarded to Rossa during the Beam Instrumentation Workshop in Vancouver early in October. Previous Faraday Cup winners include Alexander Feshchenko of Moscow's Institute for Nuclear Research in 1992 and Ralph B. Fiorito and Donald W. Rule of the US Naval Warfare Center, Silver Springs, in 1993.

The CMD-2 detector at the Budker Institute of Nuclear Physics in Novosibirsk - valuable physics.



NOVOSIBIRSK VEPP-2M

The VEPP-2M electron-positron collider at the Budker Institute of Nuclear Physics in Novosibirsk began a new life after completion of the booster BEP and construction of two new detectors - CMD-2 and SND. The collider covers a collision energy range from the threshold of pion pair production up to 1.4 GeV. Although this energy range is far below the summits needed to produce Z and W bosons or the top quark, it can nevertheless provide important information for a better understanding of the Standard Model and beyond.

The booster allows beam to be transferred at the energy of the experiment and currents of up to 500 mA to be stored in VEPP-2M. Maximum luminosity so far is 5×10^{30} cm^{-2} s^{-1} at the phi-meson and is expected to increase. This high luminosity allows studies of rare decays of rho, omega and phi-mesons and investigation of different processes relevant to future experiments at Novosibirsk's phi-factory as well as precise measurements of electron-positron annihilation into hadrons.

The total reaction rate for the production of hadrons in electron-positron annihilations is related by underlying theory to fundamental theoretical quantities used for precise interpretation of the Z and W-boson parameters obtained in higher energy electron-positron annihilations at CERN's LEP and Stanford's SLC colliders, as well as for calculating the anomalous magnetic moment of the muon (g-2).

In this case the main uncertainty comes from the energy range of VEPP-2M. The new Brookhaven experiment E821 on the measurement of muon magnetic moment (September 1991, page 23) will start taking data in 1996 and demands the hadronic production rate to be known with a systematic error less than 0.5 %.

Those measurements will be one of the most important goals of the CMD-2 general purpose detector built at Novosibirsk in collaboration with Brookhaven, Yale, Boston and Pittsburgh. The detector consists of a drift chamber and double layered multi-wire proportional chamber inside a superconducting solenoid with a magnetic field up to 1.5 tesla. Outside the solenoid is a barrel electromagnetic calorimeter made from cesium iodide crystals. The first double layer of limited streamer tubes comprising the initial stage of muon identification is placed between the barrel calorimeter and the iron yoke. The second layer of the muon system is outside the yoke. The detector is closed by endcap electromagnetic calorimeters of BGO crystals. The spatial resolution of the drift chamber is 200 microns, that of the MWPC 0.5 mm and the energy resolution of the calorimeter is about 9%.

CMD-2 started experiments in 1992 and over two years collected an integrated luminosity of about 1.7 pb^{-1} around the phi-meson and 250 nb^{-1} in the 380-1000 MeV collision energy range. Measurements of both phi-meson parameters and hadronic production rates require precise knowledge of the beam energy, achieved using the famous resonance depolarization technique developed at Novosibirsk.

Data at the phi-meson were used for detector calibration and for a measurement of the leptonic affinity (width) of the phi-meson. It was the first time that all major modes of phi-meson decays had been measured in a single experiment. The data analysis is in progress and new results on rare decay modes as well as preliminary studies of correlated kaon decays are expected.

With detector subsystems well understood, the collision energy range between 360 and 1400 MeV was scanned in 10 MeV steps. Eventually about 1000 pion pairs will be collected in each of 100 energy points, providing a 3% statistical uncertainty in a point. So far the energy range from 1020 to 810 MeV has been covered. During 1994-1995 scanning will be continued, and more data will also be collected at the phi-meson as well as at higher energies.

The upgrade of VEPP-2M is planned for the end of 1995. The solenoidal focusing system will be installed to obtain so-called round beams and boost luminosity by a factor up to 20. Tests of the idea of round beams will also be crucial for the development of the Novosibirsk phi-factory now under construction (and which will be described in a forthcoming article).

BROOKHAVEN RHIC installation

This summer, the first superconducting magnet was installed in 3.8 kilometre tunnel for Brookhaven's RHIC heavy ion collider (October, page 31).

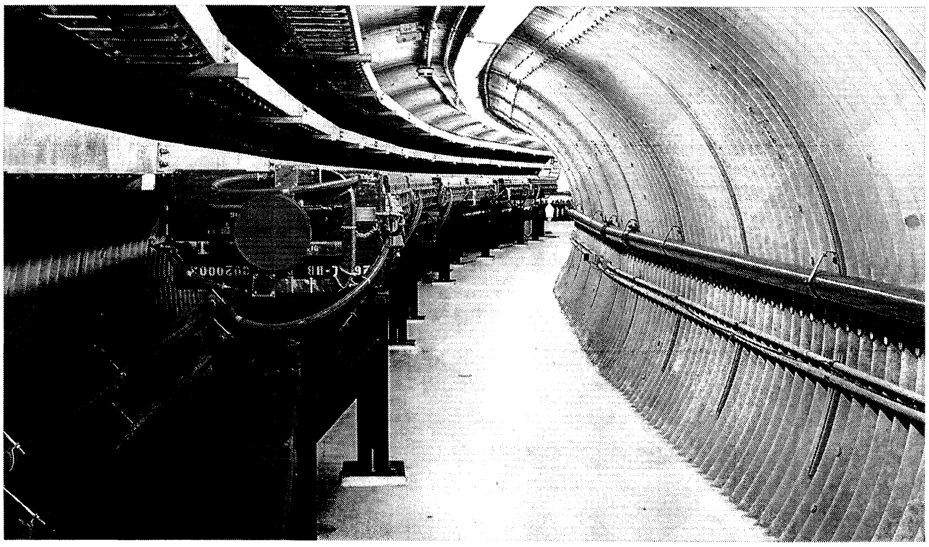
Manufactured by Northrop Grumman's Electronics and System Integration Division, the magnet is the first of RHIC's 373 dipoles. In addition to the dipoles, Northrop Grumman will also provide 432 RHIC quadrupoles. The first quadrupole was delivered on 8 April, a month before the first dipole arrived for on-site testing prior to installation.

RHIC will need 1,700 superconducting magnets - dipoles, quadrupoles, sextupoles and correcting magnets, 1,200 of which will be built by industry and the rest built at Brookhaven. The 300 sextupoles are being supplied by Everson Electric.

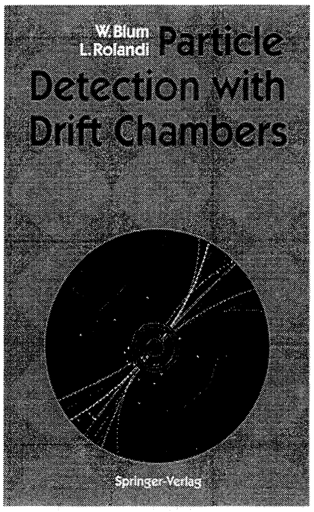
The first RHIC sextant, with 48 dipoles and 48 corrector-quad-sextupole focusing units should be complete early in 1996.

The injection line from the Alternat-

The transfer line from Brookhaven's AGS Alternating Gradient Synchrotron to the new RHIC heavy ion collider.



Your Guides to Particle Physics



W. Blum, L. Rolandi

Particle Detection with Drift Chambers

1st ed. 1993. 2nd printing 1994.
XV, 348 pp. 198 figs. (Accelerator Physics)
Softcover DM 96,- ISBN 3-540-58322-X

This study edition of Blum and Rolandi's successful book addresses those students who want to begin to understand particle detection and drift chambers. The book provides a solid foundation for judging the achievable accuracy for coordinate and ionization measurements.

It covers topics such as gas ionization by particles and by laser rays; the drift of electrons and ions in gases; electrostatics of wire grids and field cages; amplification of ionization; creation of the signal track parameters and their errors; ion gates; particle identification by measurement of ionization; existing chambers; and drift chamber gas. The topics are treated in a textbook style with many figures. Calculations are performed explicitly.

H. Wiedemann

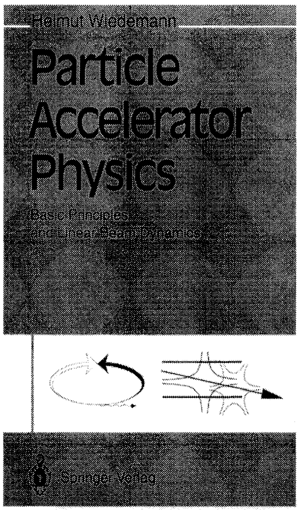
Particle Accelerator Physics II

Nonlinear and Higher-Order Beam Dynamics

1994. Approx. 430 pp. 140 figs.
Hardcover DM 98,- ISBN 3-540-57564-2

The discussion of particle accelerator physics beyond the introduction in Volume I is continued here. It is specially aimed at the graduate student and scientist planning to work or working in the field of accelerator physics. Basic principles of beam dynamics already discussed in Volume I are expanded into the nonlinear regime in order to tackle fundamental problems encountered in present day accelerator design and development.

Nonlinear dynamics are discussed both for the transverse phase space to determine chromatic and geometric aberrations which limit the dynamic aperture as well as for the longitude phase space in connection with phase focusing at very small values of the momentum compaction. Whenever possible, effects derived theoretically are compared with observations made at existing accelerators.



H. Wiedemann

Particle Accelerator Physics

Basic Principles and Linear Beam Dynamics

1993. XVI, 445 pp. 160 figs. Hardcover DM 98,-
ISBN 3-540-56550-7

Particle Accelerator Physics is designed to serve as an introduction to the field of high-energy particle accelerator physics and particle-beam dynamics. It covers most basic and advanced beam dynamics issues in connection with high-energetic particle beams and accelerators. In addition, the monograph serves as a reference book summarizing information scattered in numerous and difficult to obtain reports from particle laboratories.

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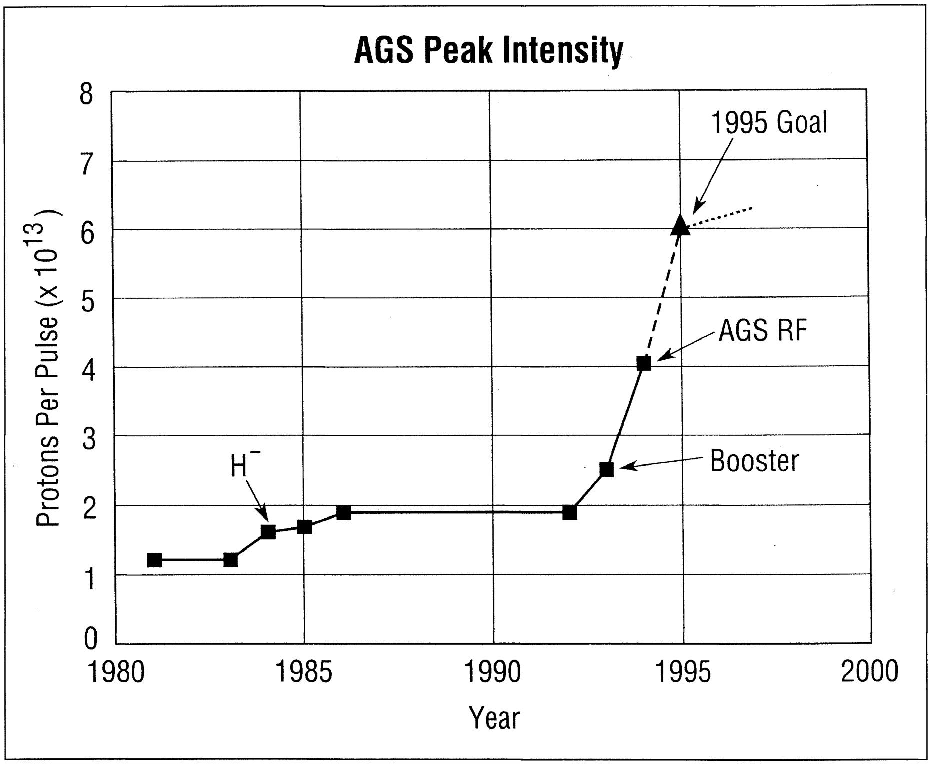
Springer-Verlag ☐ Heidelberger Platz 3, D-14197 Berlin, F.R. Germany ☐ 175 Fifth Ave., New York, NY 10010, USA ☐ Sweetapple House, Catteshall Road, Godalming, Surrey GU7 3DJ, England ☐ 26, rue des Carmes, F-75005 Paris, France ☐ 3-13, Hongo 3-chome, Bunkyo-ku, Tokyo 113, Japan ☐ Room 701, Mirror Tower, 61 Mody Road, Tsimshatsui, Kowloon, Hong Kong ☐ Avinguda Diagonal, 468-4° C, E-08006 Barcelona, Spain ☐ Wesselényi u. 28, H-1075 Budapest, Hungary ing Gradient Synchrotron (AGS) is now complete, and transfer tests will begin next year.



Peak beam intensity in Brookhaven's Alternating Gradient Synchrotron (AGS) for each year since 1981. Significant increases occurred in 1984 when negative hydrogen ion injection was introduced, in 1993 when the Booster started to contribute, and in 1994 when the AGS radiofrequency system was upgraded.

AGS intensity record

As flashed in the September issue, this summer the Brookhaven Alternating Gradient Synchrotron (AGS) reached a proton beam intensity of 4.05 x 10^{13} protons per pulse, claimed as the highest intensity ever achieved in a proton synchrotron. It is, however, only two-thirds of the way to its final goal of 6 x 10^{13}.

The achievement is the result of many years of effort. The Report of the AGS II Task Force, issued in February 1984, laid out a comprehensive programme largely based on a careful analysis of the PS experience at CERN. The AGS plan had two essential components: the construction of a new booster, and major upgrades to the AGS itself.

Construction of the Booster was completed in 1991. By 1993, it had reached an intensity of 1.2 x 10^{13} protons per pulse (each AGS pulse comprises four Booster pulses.) This spring, the Booster reached 1.7 x 10^{13}, comfortably exceeding the design goal of 1.5 x 10^{13}. This 40 percent gain in intensity was achieved by careful attention to detail. The important elements were a thorough correction of the stopbands, carried out in 1993, a realignment of the magnets, carried out before the 1994 run, careful tuning and setup in 1994, and sterling performance by the Linac, which routinely delivered 27 milliamps to the Booster.

Major system improvements also had to be made to increase the AGS intensity by a factor of four (six thousand times its original design intensity of 10^{10}!). The Task Force Report called for new vacuum and control systems, and major changes in the main power supply - all of which were in place by 1993. A new radiofrequency system and a system to jump the beam rapidly through transition were both scheduled for operation in 1994.

The new high power r.f. system has three key elements: new power amplifiers; fast feedback to control the power amplifiers; and reworked r.f. cavities to give better beam loading performance. Ten new power amplifiers installed in the ring next to the cavities increased the installed power per cavity from 40 to 200 kilowatts.

Operations had started well when a power line transformer for one of the new power amplifiers broke. In the next two weeks, two more transformers suffered the same fate and this shocking situation forced a decision to stop operations and examine the seven remaining transformers. In the midst of all this complex high technology, the manufacturer had failed to take full account of the stresses on the coil supports in the transformers, and many of those supports that had not yet failed were about to.

Rebuilding the transformers would take at least a year. Fortunately, the power supply from the old power amplifiers was still available. Lashed together as it was, the new r.f. system nevertheless accelerated the AGS beam to a new record. By the end of 1995, the AGS should be able to fully exploit the flexibility of the complete new system.

The new transition jump system pushed the beam through transition very quickly and with minimal losses. This set of fast quadrupoles was designed in 1987, but was mothballed until required.

The goals for 1994 had been 1.5 x 10^{13} in the Booster and 4 x 10^{13} in the AGS. Whoever sets these goals is remarkably clever, since so far they have been attained, just. For 1995, the goal is the AGS design goal of 6 x 10^{13} protons per pulse.

From Ed Bleser

JAPAN
Super-Kamiokande

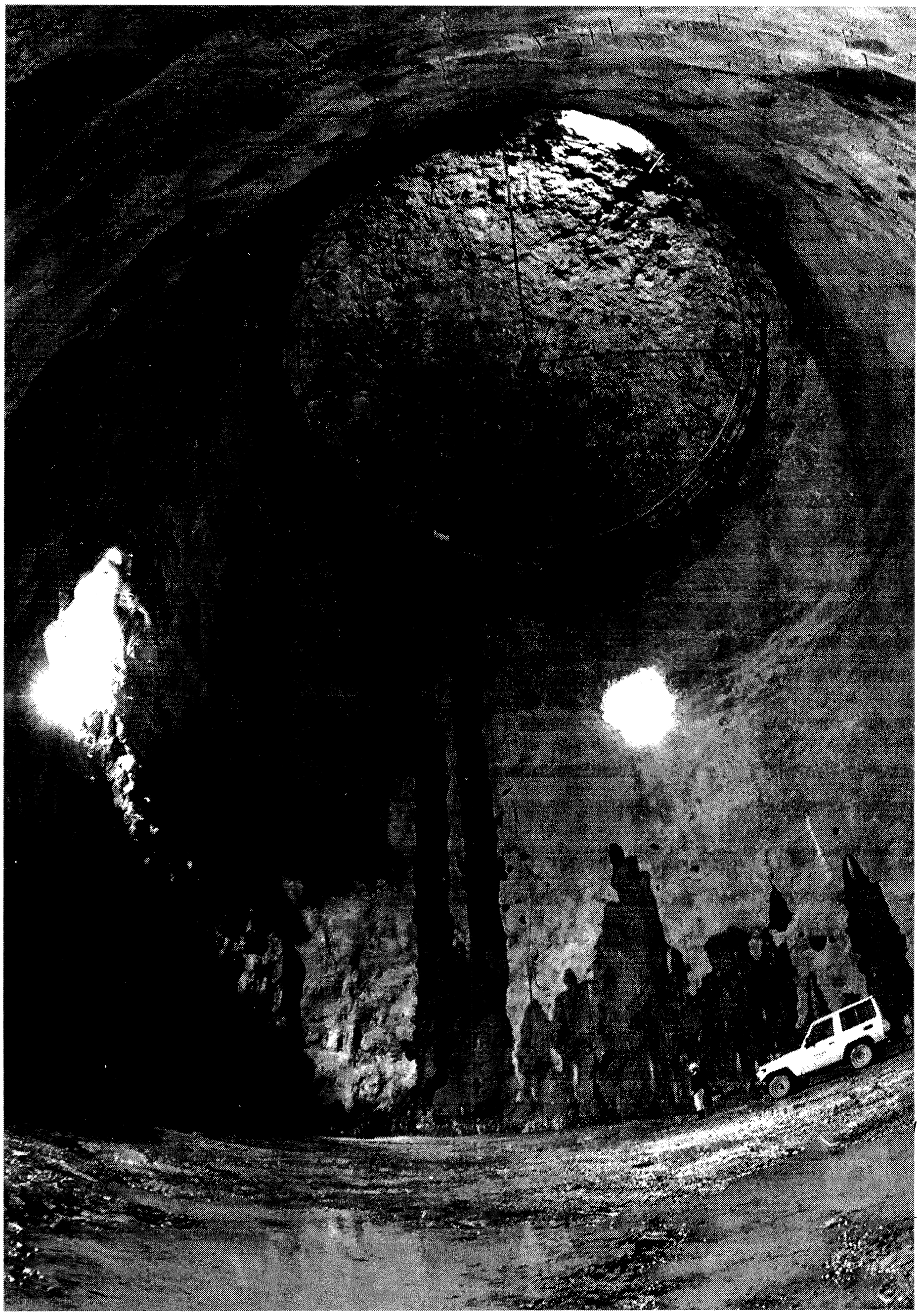
Excavation for the Japanese Super-KAMIOKANDE 50,000-ton water Cherenkov imaging detector was completed at the end of June. The goals include a search for nucleon decay up to a lifetime of 10^{33-34} years, high-statistics studies of solar and atmospheric neutrinos, and detection of any nearby supernova explosions.

The project was approved in 1991, with the official 'groundbreaking' in December of that year about 1,000 m underground in the Kamioka mine in Gifu Prefecture, about 250 km west of Tokyo.

The Institute for Cosmic-Ray Research of the University of Tokyo is construction overseer. It took 31 months to excavate the 58 m high and 40 m diameter cavern and remove more than 75,000 cubic metres of rock, including an approach tunnel.

On July 13 some 200 people, including the President of the University of Tokyo and the Governor of Gifu Prefecture, were invited to a classical music concert and an exhibition of artwork in the completed cavern.

Construction of a water tank began in August. The tank, lined with stainless steel, will be separated into an inner counter and a 2 m thick outer counter (or anticounter) by black plastic sheets stretched over a support structure for photomultiplier tubes (PMTs). The inner counter, with a fiducial volume of 22,000 tons for solar neutrino observation will be viewed by 11,200 Hamamatsu 20-inch PMTs. The outer will have about 2,000 Hamamatsu 8-inch PMTs. Production of the larger PMTs started in 1992, and delivered units have been stored inside the mine. More than half of the Super-KAMIOKANDE electronics has also been delivered and extensive testing is underway. A building for a large computing facility has been constructed near the mine. Development of analysis and simulation software is also underway. Construction of Super-KAMIOKANDE is proceeding on schedule. Installation of the PMTs is expected to begin next June and the detector should be completed in early 1996.



Excavation for the Japanese Super-KAMIOKANDE 50,000-ton water Cherenkov imaging detector for a nucleon decay search and neutrino studies was completed at the end of June (see aldo cover photo).

BERKELEY
"Dry-hood" vacuum technique

During the five-week shutdown that began on May 2 (October, page 16), the Mechanical Technician Support Group at Lawrence Berkeley Laboratory's Advanced Light Source (ALS) successfully demonstrated a new "dry-hood" technique for making ultra-high vacuum (UHV) connections.

Use of this technique and pre-baked vacuum chambers makes unnecessary subsequent in situ baking of sections brought up to atmospheric pressure, thereby substantially shortening accelerator shutdowns and increasing operating time for the user community.

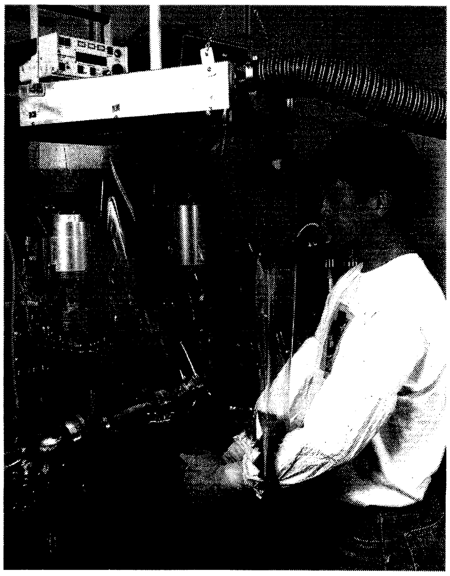
The idea is to keep water and other contaminants from entering the components when a new UHV chamber, which is pre-baked, is to be connected to one already existing. A dry hood or tent of clear vinyl plastic is erected over the connection point, with the bottom of the dry hood left open. After cleansing by a 5-micron molecular sieve, a stream of dry air flows inside the hood from above over a work area of 0.1 square metre. The flow is laminar to reduce turbulence at the joint.

Before end caps are removed from the UHV chambers to be joined, purified dry nitrogen is introduced into both components. When nitrogen flow is established, connections are made inside the dry hood through penetration ports by technicians wearing double surgical gloves. The connections are made using metal gaskets and are typically 4 to 8 inches in diameter. Finally, a dew point of -40C is established and maintained at all times.

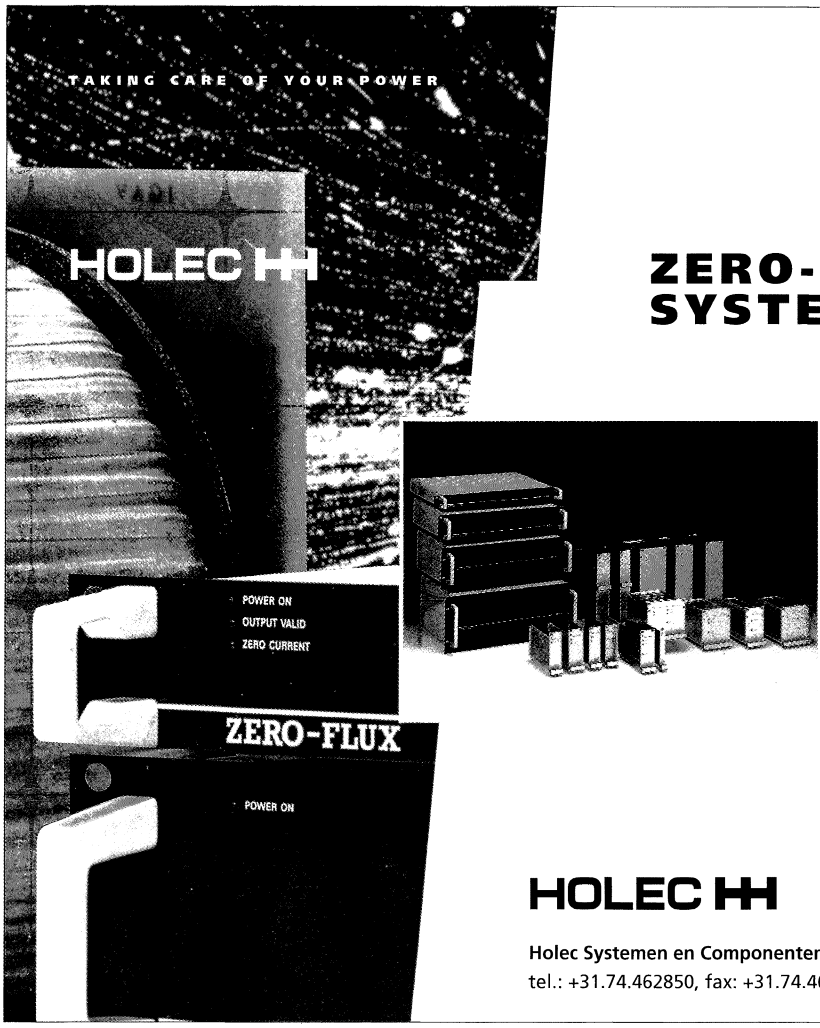
The technique was carried out successfully at ten different connection points during the May ALS shutdown. Immediately after the shutdown, operators brought the accelerator complex (linac, booster, and 1.5 GeV storage ring) back up without the customary vacuum-chamber bakeout procedure, although about three quarters of the storage ring had been exposed to atmospheric pressure during the shutdown. Remarkably, after running for just two days, the storage-ring beam lifetime was the same as it had been before the shutdown (14 hours at 200 mA).

Radiofrequency conditioning provides a second example of the usefulness of the technique. A pre-baked longitudinal kicker, to suppress multi-bunch instabilities that cause a small energy spread in the electron beam at high current and a consequent spectral broadening of the undulator third and fifth harmonics, was installed between the r.f. cavities in the storage ring. Rather than the expected several days, r.f. conditioning was carried out in just one hour because the dry-hood technique minimized the introduction of contaminants during kicker installation.

Overall, use of the dry hood technique shortened the shutdown from the anticipated eight weeks to five. Moreover, management can now confidently schedule shorter shutdowns, making more user shifts available and the facility more productive.



At Lawrence Berkeley Laboratory's Advanced Light Source mechanical technician Ed Wong uses the new dry-hood technique to make a bend-magnet beamline connection. The technique has given substantial reductions in machine downtime for routine maintenance.



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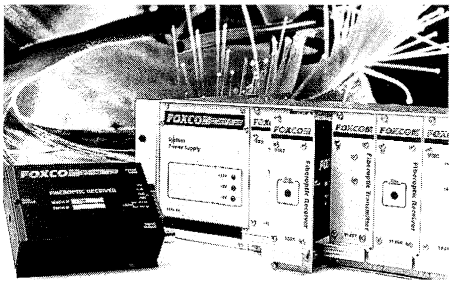

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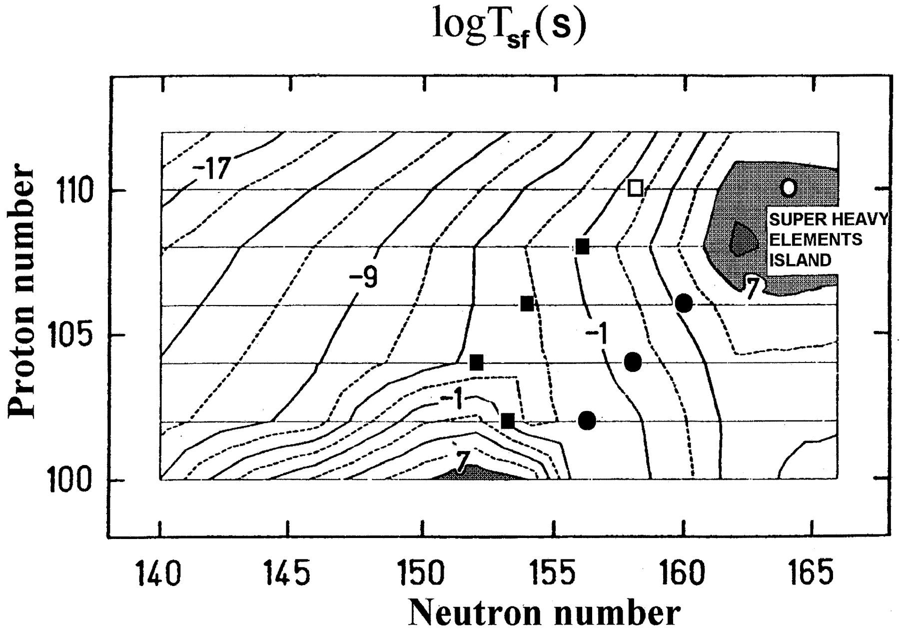
Physics monitor



Contour map of spontaneous fission half-life Tsf for superheavy nuclei. The squares denote isotopes produced in cold fusion reactions, the circles those produced in hot fusion reactions.

New isotopes of elements 104, 106 and 108 - highly stable superheavy nuclei

In April 1993, as part of a joint Dubna-Livermore experiment at the Flerov Laboratory of Nuclear Reactions, new heavy isotopes of elements 104 and 106 were synthesized - $^{262}104$, $^{265}106$ and $^{266}106$.

Compared with the known even-even isotopes of elements 104 and 106, the new nuclei are characterized by their extraordinary high resistance to spontaneous fission. This is a direct proof of the macro-microscopic theory predictions in its version calculated by A.Sobiczewski et al. regarding a substantial increase in the half-lives of heavy nuclei near deformed shells with atomic number (Z) 108 and neutron number (N) 162.

In previous years, the heaviest elements up Z=109 were synthesized in cold fusion reactions of the 'magic' nuclei lead-208 or bismuth-209 with ions of titanium-50, chromium-54, and iron-58. The resultant compound nuclei with excitation energies between 18 and 20 MeV decay through the emission of one or two neutrons and gamma rays.

In contrast, the synthesis of new nuclides used a "hot" fusion reaction of curium-248 and neon-22 nuclei, producing a compound nucleus $^{270}106$ with an excitation energy of 45-50 MeV. It decays to its ground state through the emission of 4 or 5 neutrons.

Isotopes of elements 104 and 106 in these reactions are produced with approximately equal rates, but the excess of neutrons in the combination of curium-248 and neon-22 penetrate the region of a sharp increase of spontaneous fission half-life close to the top of the island of stability of the superheavy elements.

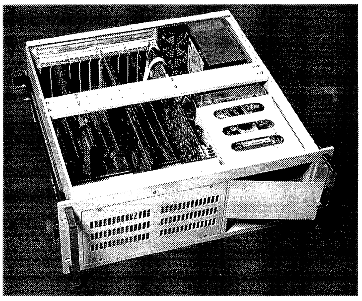
Following this approach, the same collaboration at Dubna recently looked at the synthesis of isotopes of element 108. The radioactive properties of these isotopes test the effect of the closed proton shell at this atomic number.

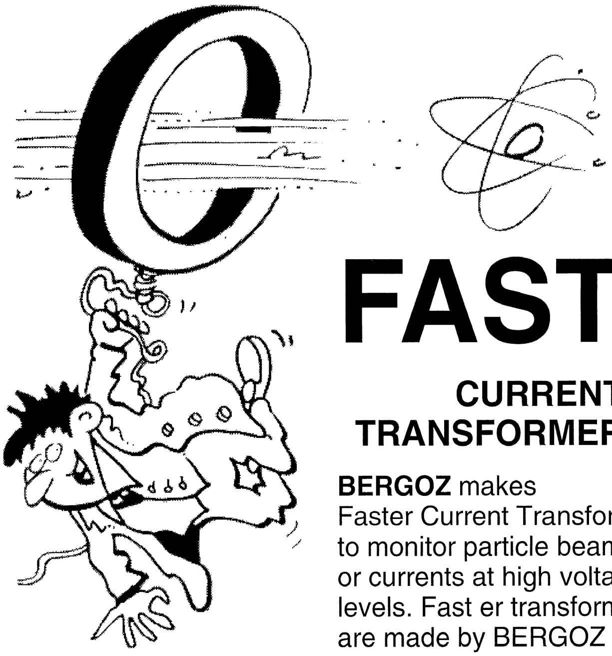
Of all possible target-ion combinations, the fusion of uranium-238 and sulphur-36, leading to the production of a compound nucleus $^{274}108$ seems to be the most promising. After the emission of four neutrons and gamma-rays the evaporation residue $^{270}108$ appears to be just on the peak of stability at Z=108 and N=162.

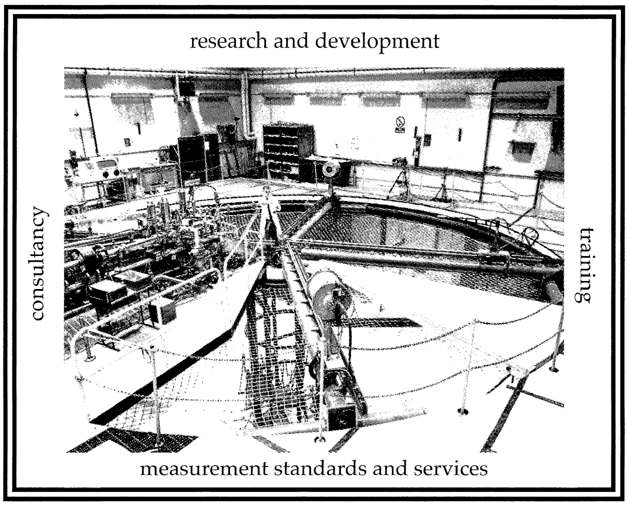
Unfortunately, because of a large consumption of the rare and expensive isotope sulphur-36 (0.015% of the natural content of sulphur) by the ion source, the experiments were using an ion beam of enriched isotope sulphur-34 which led to the production of a compound nucleus $^{272}108$. The experiments were completed by the synthesis of the isotope $^{267}108$ - the heaviest nuclide in the nuclear table.

A rotating target of uranium-238 with thickness 0.5 mg/cm^2 was irradiated with an ion beam of 185 MeV sulphur-34 at an intensity of about 10^{13}pps. The recoil nuclei moving in the beam direction were separated from beam particles and products of incomplete fusion reactions by Dubna's gas-filled kinematic separator. The time-of-flight from the target to the focal plane of the separator was one microsecond.

The detector block consisted of two parts: a time-of-flight counter directly preceding 12-strip position-sensitive silicon detectors with a total area of about 60 cm^2. Recoil nuclei, after passing through the gas counter, were implanted in the sensitive layer of a strip detector. As well as the signal energy, the spatial location of the implanted nucleus on the surface



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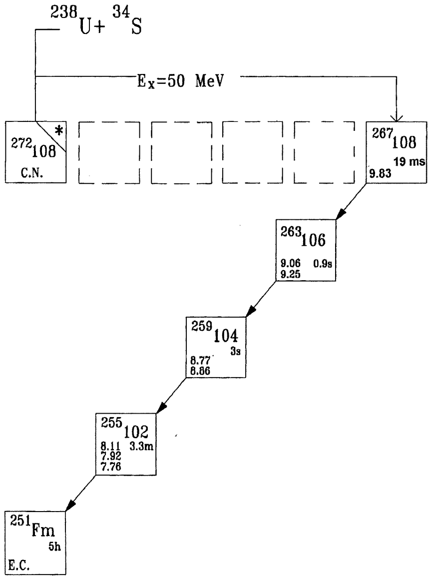
Decay properties of the isotope ^{267}108 - the heaviest nuclide in the nuclear table - produced by the fusion of sulphur-34 on uranium-238.



of the detectors (the strip number and the position versus length) was measured.

Then the decay properties of the nucleus were examined: the sequential emission of particles with the measurement of alpha-particle emission time and energy. This method, used for the first time at the GSI (Darmstadt) Laboratory, can retrace all genetic decays from the new unknown nuclides to their known daughter nuclei.

The beam dose of 1.7 x 10^{19} produced three alpha-alpha correlated events for which the energy and emission time of alpha-particles produced by the nucleus ^{267}108 were measured.

All isotopes of element 108 with N=156,157 and 159 undergo such alpha-decay. Their half-lives increase with the number of neutrons as expected from the calculated values of nuclear masses.

The reaction rate (cross-section) for the production of this nucleus by uranium-sulphur fusion is about 2 pb. This is approximately 5-10 times slower than the cold fusion of lead-208 and iron-58 producing the nucleus ^{265}108.

On the scale of these new elements, this is a noticeable but not too strong a difference. Of much greater interest is that the expected strong decrease in the survival probability of evaporation residues due to the required cascade emission of five neutrons (instead of one neutron in cold fusion) is compensated to a great extent by lifting strong dynamic limitations for the fusion of more symmetric combinations like lead-208 and iron-58.

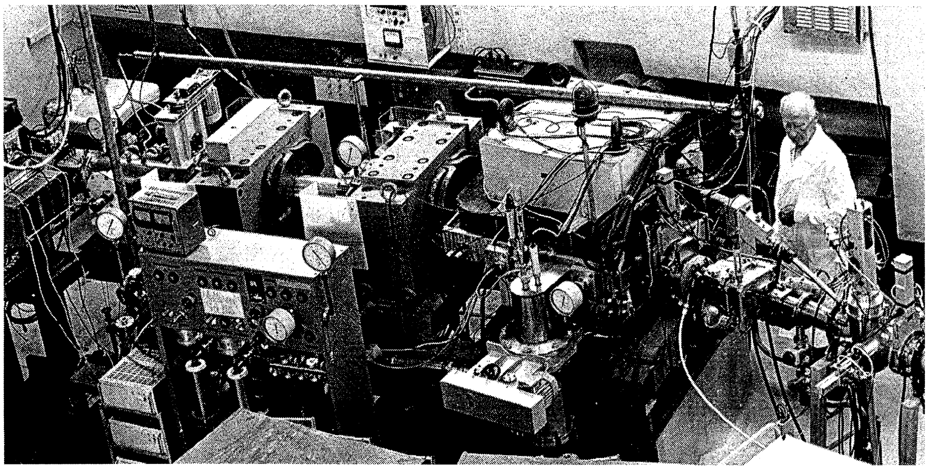
Hot fusion reactions open the way to the synthesis of heavier elements. The Dubna-Livermore collaboration is attempting an experiment on the synthesis of a heavy isotope of element 110 from sulphur-34 and plutonium-244. Daughter nuclei from the alpha-decay of evaporation residues of $^{273-274}$110 will be isotopes of element 108, at the top of the already known island of stability of superheavy deformed nuclei.

The experimental investigation of properties of nuclei near closed deformed shells not only tests the main thesis of the macro-microscopic theory, but also increases its predictive power with respect to the properties of still heavier nuclides in the region of spherical shells with Z near 114 and N around 184.

Element 108 has been given the name hassium (Hs) by its discoverers (November 1992, page 27).

Yuri Oganessian
Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna

The gas-filled separator used at the Joint Institute for Nuclear Research, Dubna, for work on superheavy nuclei.



Standard Model masses

The initial evidence for the sixth ('top') quark from the CDF experiment at Fermilab's Tevatron proton-antiproton collider (June, page 1, and this issue, page 1) is focusing interest on the unusual mass patterns of the Standard Model particles.

The Standard Model (June, page 4) contains three pairs of quarks and three electrically-charged leptons (the electron, muon and tau) accompanied by their associated neutrinos.

The quarks interact through a 'field' of gluons, while all the particles also interact through an entirely separate electroweak field, carried by the photon of everyday electromagnetism and the W and Z particles of the weak nuclear force.

Physicists speak of these as the 'gauge' interactions of the Standard Model. The equations of the theory are the same for all physics systems - there is no 'seam' between one realm of applicability and another, and the theory is said to be 'gauge invariant'. For this to happen, the formalism must incorporate messenger ('gauge') particles which transmit the field information. The coexistence of two apparently unrelated gluon and electroweak gauge fields inside the Standard Model needs to be explained.

As well as these gauge interactions, the Standard Model also contains other interactions involving the symmetry-breaking 'higgs' particles which give the quarks and leptons their mass. The masses of the Standard Model's quarks and leptons are fixed by these higgs couplings. Physicists call these the 'Yukawa' interactions of the Standard Model, after Hideki Yukawa's 1935 idea that the nuclear force is the result of exchanging intermediate mass particles (although both the Standard Model and higgs particles were unheard of in Yukawa's time).

As well as masses, the Standard Model also governs the chain of quark decays under the weak nuclear force, with the heavier ones successively decaying into lighter ones. With three pairs of quarks, these decays are described by a three-dimensional array of numbers, the well-known Cabibbo-Kobayashi-Maskawa (CKM) matrix. Despite the growing predictive power of the Standard Model, these quark mixings can only be measured in experiments. Apart from the top sector, the general features of these quark decays are now known.

With the Standard Model never having been able to say anything about its higgs particles, the mass sector was for a long time left alone. However with the top quark mass now confidently assigned to the region around 175 GeV, interest is shifting.

Why is the top so much heavier than all the other quarks (the next heaviest, the beauty - 'b' - carrying at most about 5.3 GeV)? What governs the lepton mass pattern - the electron at 0.5 MeV, the muon at 106 MeV and the tau at 1777 MeV? Are the three types of neutrino massless?

Do these patterns hint at some deeper symmetry beyond the Standard Model? In the same way that the electroweak picture unifies electromagnetism and the weak nuclear force, at extremely high energies (10^{16} GeV, the so-called Grand Unified Theory, GUT, level), the strong and electroweak sectors of the Standard Model could unify into a single force.

Even with three pairs of quarks and leptons, there are many higgs couplings. These contain much more information than just masses, determining also the CKM - quark mixing - information. The hope is that the higgs patterns will be simpler at the 10^{16} GeV GUT energy. Some of quantities could become zero, others would be simply related, or even equal. Extrapolating this picture down to lower energies would give the observed masses and quark mixings.

This can be done using the supersymmetric picture, where the price of unification is a doubling of the number of basic particles - the ordinary particles of the Standard Model are augmented by additional supersymmetric 'sparticle' partners. The quark and lepton ingredients of the Standard Model are paired with by spinless 'squarks' and 'sleptons', and the photon, W and Z force carriers by quarklike 'photinos', 'charginos' and 'neutralinos'.

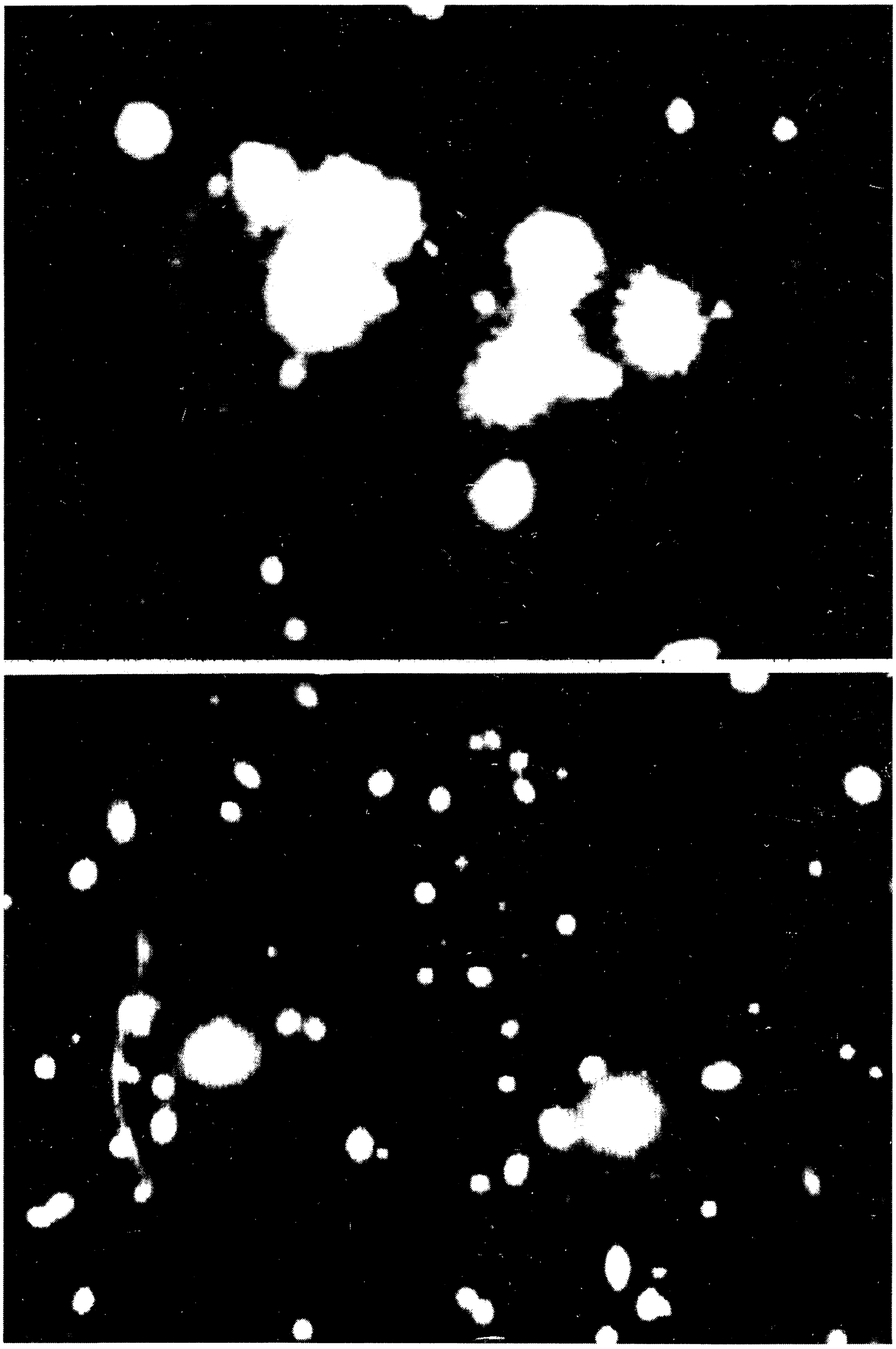
Theorists expect new symmetries to emerge at the unification energies to explain the simpler mass patterns there. Improved measurements of quark masses and inter-quark decay rates will provide further insights.

DARK MATTER
Optical shears

Evidence for dark matter continues to build up. Last year (December 1993, page 4) excitement rose when the French EROS (Expérience de Recherche d'Objets Sombres) and the US/Australia MACHO collaborations reported hints that small inert 'brown dwarf' stars could provide some of the Universe's missing matter.

In the 1930s, astronomers first began to suspect that there is a lot more to the Universe than meets the eye. To explain galactic motion needs more gravitational pull than can be accounted for simply by counting visible stars. Still more gravity is needed if the explosive power of the Big Bang is one day to be halted and prevent the Universe from expanding for ever.

MACHO and EROS have been carefully surveying millions of stars astronomically close to the Earth, finding several cases where the distant image was temporarily ampli-



The faint curves (left) are due to the gravitational lensing of light from distant galaxies by intervening matter. This gives a valuable insight into the distribution of otherwise invisible interstellar material.

fied as grains of invisible intervening material in our galaxy crossed the line of sight. This gravitational microlensing effect was pointed out by Bohdan Paczynski of Princeton in 1986, who now has his own search team, acronymed OGLE, which has recently reported some lensing events.

The initial MACHO survey, using the Australian Mount Stromlo Observatory, looked at eight million stars in the Large Magellanic Cloud (LMC), the nearest galaxy to our own. A parallel survey using the bulge of the Milky Way has revealed a further four events from 'only' 450,000 stars - an embarrassing surfeit, compared to the LMC counting.

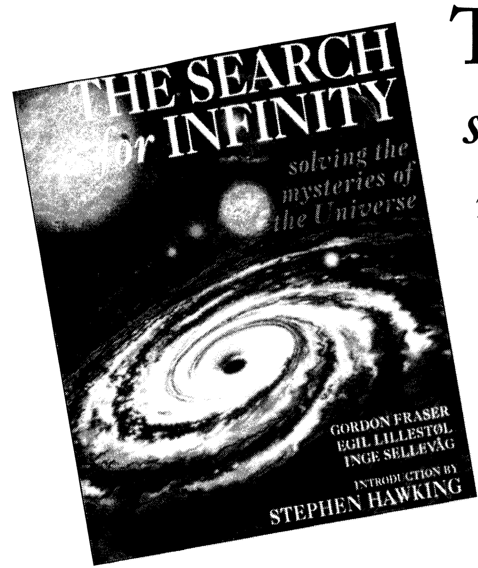
The EROS survey, using the European Southern Observatory 1m telescope, reported two candidate brown dwarf sightings last year, from about half of the photographic plate data. From the duration of these signals (26 and 30 days rise time), the intervening objects are rather large (smaller than the Sun, but not that small). The remaining data did not reveal any new candidates. Together, the results suggest an absence of smaller dark matter objects.

In parallel, EROS do a CCD (electronic) scan using a smaller telescope, shooting every 12 minutes or so. Here the idea is to look for small dark objects, less than one ten-thousandth the size of the Sun (a tenth of Jupiter), which would produce fluctuations varying from one hour to a few days. The CCD-recorded data reveals no such short-scale candidates, excluding a wide range of dark matter possibilities in our galaxy.

A new window on dark matter comes from the optical shear tomography technique used by Anthony Tyson of AT&T. The images of pairs of faint and very distant blue galaxies can be used as a backdrop to search for otherwise invisible foreground mass patterns. Using all possible pairs of thousands of galaxies, no matter what their angular separation in the sky, gives correlations analogous to gravitational microlensing. Scanning the sky in this way provides a different way of seeing how the optical image of the distant galaxy is distorted by otherwise invisible clumps of intervening mass.

The resulting dark matter distribution matches what was predicted by the kinematical analysis of galactic motion which first showed the need for additional invisible material. Not only is dark matter there, but it is there in the right places.

Direct evidence for gravitational lensing by intervening dark matter has been studied by several groups, notably at Toulouse.

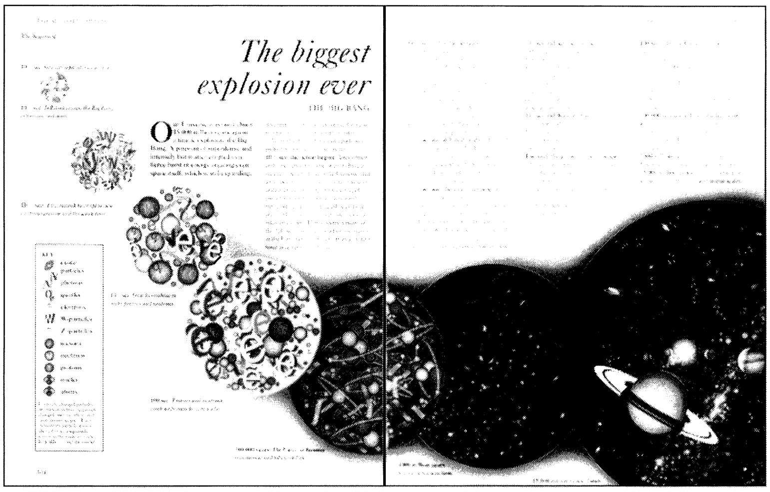


THE SEARCH *for* INFINITY

solving the mysteries of the Universe

The Search for Infinity explains what particle physicists do in a way that their non-scientific friends and relatives can actually understand. A bold claim, but one which may easily be verified! This has been achieved by teaming up the scientific expertise of CERN's Professor Egil Lillestøl with the journalistic talents of Inge Sellevåg of the *Bergens Tidende* and Dr Gordon Fraser, the editor of *CERN Courier*. Their explanations of the mysteries of the Universe have in turn been enhanced using creative computer graphics to give the best visual interpretation within the limits of imagination. And Stephen Hawking has kindly endorsed the enterprise by providing a lively introduction.

The book tells the story of the search for the ultimately small, from the early days of atomic physics to modern particle accelerators, and how the conditions necessary to reveal quarks replicate those of the first moments of the Universe – elegantly linking particle physics and cosmology, while at the same time providing straightforward explanations of the basics of modern physics.



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People and things

Herwig Schopper (left), CERN's Director General from 1981-88, at his 70th birthday symposium at CERN, with parity violation pioneer C.S. Wu.

Herwig Schopper 70

Herwig Schopper, CERN Director General from 1981-1988, celebrated his 70th birthday in style with a star-studded symposium at CERN on 15 September. In his introduction, Director General Chris Llewellyn Smith underlined Schopper's watershed role in overseeing the approval and construction of CERN's LEP electron-positron collider and the development of the plans for its experimental programme.

Opening the programme, Sam Ting recalled Schopper's pre-CERN role at DESY, where according to Ting, he showed great leadership skills in being the only Director of DESY who, in addition to his many other accomplishments, managed to improve the canteen.

His other achievements include the establishment of international collaborations; He Sheng Chen highlighted Schopper's part in the development of relations with China, which Schopper visited in 1977 and where he helped set up the first international collaboration in physics after the cultural revolution. Quoting a Chinese proverb, he said, "remember the people who dug the well when you drink the water".

C.S. Wu spoke on how her pioneer 1957 results on parity violation in beta-decay were supported by two experiments, one of which involved Schopper, and Chris Fabjan described Schopper's part in the development of hadron energy measurement, a technique which he believes "has blossomed into one of the most ubiquitous and versatile experimental methods".

US accelerator pioneer Robert Wilson described the evolution of machine physics responsibilities in major projects.

Former LEP project director Emilio Picasso underlined Schopper's role in pushing LEP construction, and described his own worry that the 27-kilometre tunnel would never meet its other end, instead spiralling in ever-decreasing circles.

Concluding, Herwig Schopper looked back with satisfaction at 50 years in physics and said, "Being a physicist is a privilege, especially in the second half of this century; it is a great privilege to live through such exciting developments – I moved up an order of magnitude every ten years or so."

On people

At Brookhaven, Tom Kirk became Associate Director for High Energy and Nuclear Physics on 3 October. He succeeds Mel Schwartz, who has returned to academia as the I. I. Rabi Professor of Physics at Columbia University, and Larry Trueman, who has been acting in an interim capacity.

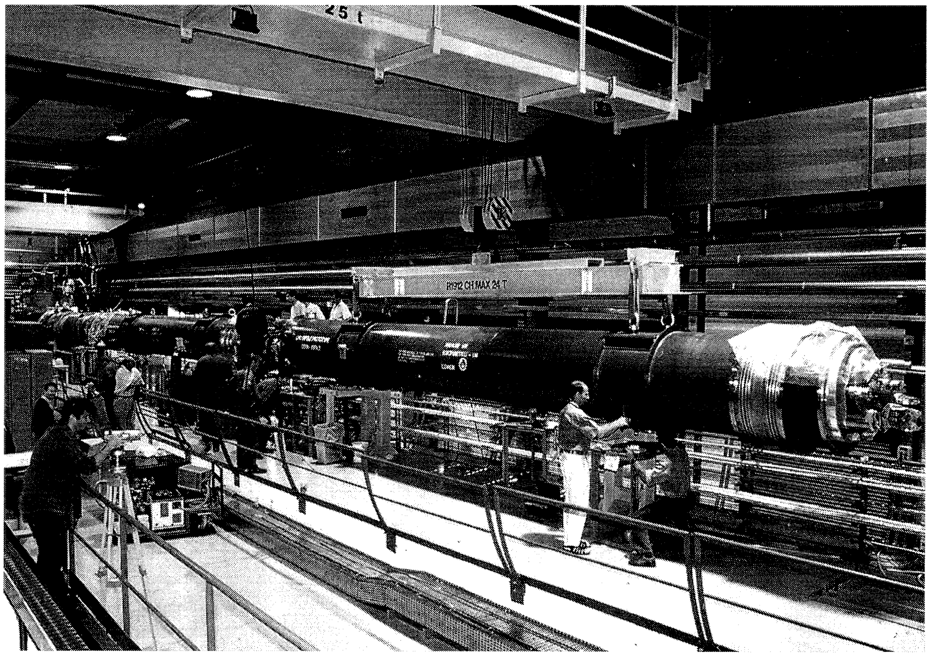
Bernard Frois of Saclay receives the prestigious Silver Medal of the French Centre national de la recherche scientifique (CNRS).

Dirac medal

On 4 October, Frank Wilczek of Princeton's Institute of Advanced Study was awarded the 1994 Dirac Medal of the Institute for Advanced Study, Trieste, for his theoretical contributions, particularly his role in the discovery of the phenomenon of 'asymptotic freedom' in non-Abelian gauge theories - when the interaction between two quarks becomes weak at short distances.

Harry Bingham 1931-94

Berkeley experimentalist Harry Bingham died on 24 August, age 63.



Ready for testing is a magnet string of two superconducting dipoles and one quadrupole for CERN's LHC proton collider.

A special symposium at CERN on 28 September marked the 65th birthday of distinguished CERN theorist André Martin.

Born in Chicago, he was a colourful personality, keen sportsman and inveterate poker player who enlivened many physics meetings. His initial research career at CalTech, the Ecole Polytechnique in Paris and CERN revolved around the development and exploitation of heavy liquid bubble chambers. He joined the Berkeley faculty in 1964 and participated in experiments at several major research centres as well as being an enthusiastic teacher.

For several summers he was Acting Chairman of Physics at Berkeley, and received national attention in 1989 by offering a Berkeley position to the prominent Chinese physicist and suspended university administrator Fang Lizhi.

His last visit to CERN was in 1993 for the meeting organized to mark 40 years of world bubble chamber achievement, where he gave a typically candid talk - 'Old and new, big and small, European and American; contrasts in styles'. It was typical of his courage and fortitude that he hosted his final physics collaboration meeting with a telephone link from his bedside.

LeCroy grant

US instrumentation specialists LeCroy Corp. of Chestnut Ridge, New York, in collaboration with Jorway Corp and Yale University, have been awarded a Small Business Technology Transfer Grant by the US Department of Energy to develop a compatible extension of the CAMAC standard electronics interface to increase data acquisition speeds eventually to 60 Mbytes/ second.

Physics in Vietnam

This summer, a school on particle physics at Dalat, on the highlands about 300 km from Saigon, attracted 30 vietnamese physicists and seven European physicists (lecturers). Next year, twin conferences (one on Particle Physics and one on Astrophysics : from the Sun to the Universe, Fundamental issues in Astrophysics) will be held in Saigon - Ho Chi Minh City from 22 to 28 October 1995. These dates are chosen as there will be a full eclipse in South Vietnam on Wednesday October 24. It is hoped that this exceptional event will underline efforts being made to attract young students to fundamental science. In former socialist countries making the transition to a free market economy, many good students are tempted towards initially more lucrative careers.

Meetings

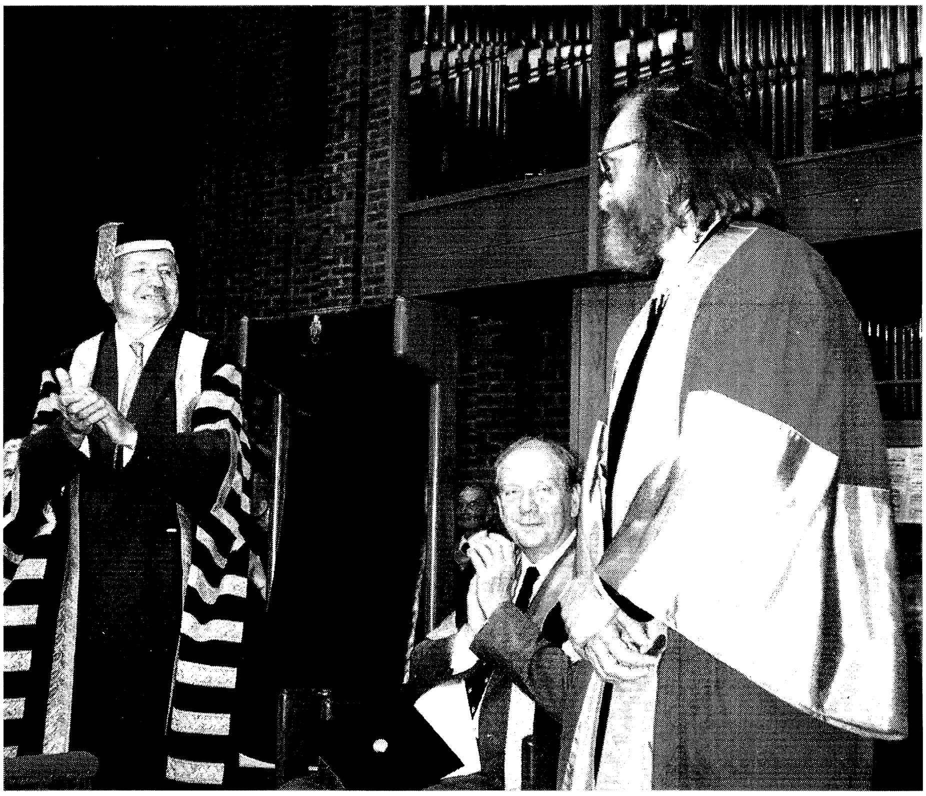
The SERC School on Coherence and Correlations in Modern Optics and Quantum Physics will be held from 23 January to 10 February 1995 at the Institute of Mathematical Science,

Japanese Minister for Science and Technology Makiko Tanaka with Director General Chris Llewellyn Smith at CERN on 22 September.

Madras, India. Further information from Khan S A Khan, Publicity Secretary SERC School, E-Mail: optics@imsc.ernet.in

The Third International Winter School "QCD: Perturbative and Non-Perturbative Topics" will be held at St.Petersburg Nuclear Physics Institute, Russia, from February 26 - March 11, 1995. Lectures will be at the postgraduate and young postdoc level and include such topics as low x physics, colour coherence phenomena, confinement, effective chiral theories, two-body systems, coherent multi-particle production, instantons, etc. Among the lecturers are Profs. Anselm, Bailin, Diakonov, Dokshitzer, Eides, Lipatov, Migdal, Mueller, Polyakov and others. Further information and applications from maxpol@lnpi.spb.su

At the European Particle Accelerator Conference in London earlier this year (September, page 11) Roger Cashmore of Oxford admires a 'virtual reality' computer simulation. (Photo DRAL)



After receiving an honorary doctor of science at Southampton University, UK, distinguished CERN theorist John Ellis (right) is applauded by University Chancellor Lord Jellicoe.

Books received

Superconductivity, by V.L. Ginzburg and E.A Andryushin;

Physics of New Methods of Charged Particle Acceleration - Collective Effects in Dense Charged Particle Ensembles, by A.G. Bonch-Osmolovsky;

Selected Papers, with Commentary, of T.H.R. Skyrme - World Scientific Series in 20th Century Physics, Volume 3, Edited by Gerald E. Brown.

All three published by World Scientific, Singapore, 1994.

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Royal Holloway
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EU Fellowship (HCM Programme)

Particle Physics

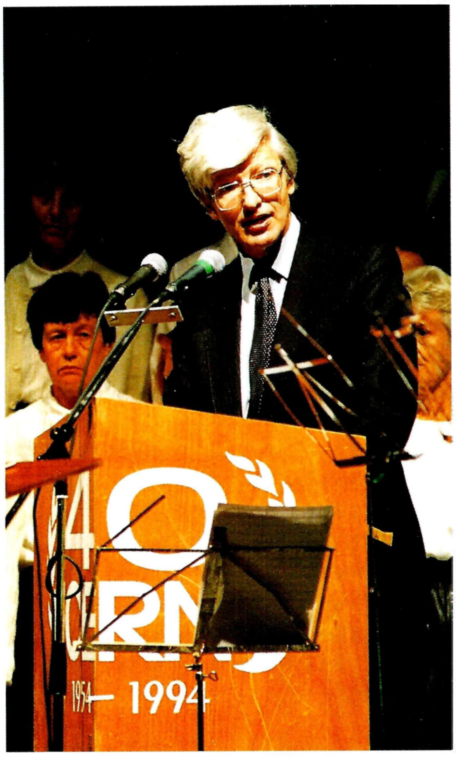
Applications are invited for 2 one-year postdoctoral fellowships in experimental particle physics. Applicants must be nationals of an EU member state (excluding the UK), or an associated state, must be aged under 35 and should hold a PhD or equivalent qualification.

The particle physics group at Royal Holloway is a member of the ALEPH collaboration at LEP and the ATLAS experiment planned for the LHC, and has recently joined the BaBar collaboration at PEP-II. At ALEPH we took part in the construction of the electromagnetic calorimeter and were responsible for the design and building for the Level 2 trigger. We are currently working on the analysis of the LEP I data from ALEPH and plan that one of the fellows will join this programme. We are members of the CERN R&D project RD11 (EAST) developing second level trigger systems for LHC. This work is continuing for the ATLAS experiment where we are also involved in physical studies. The second fellow will become part of this programme. The group is well-supported by the UK Particle Physics and Astronomy Research Council and the College and has good facilities for both computing and electronics development.

Royal Holloway is part of the University of London and is situated on a pleasant campus about 30 km west of the centre of London near to Heathrow airport and the town of Windsor. It is about 40 minutes from London by train. There are about 5000 students on campus in faculties of arts and science.

Further details about the Royal Holloway group and its current programme can be found on World Wide Web (http://www.ph.rhbnc.ac.uk/research/hep/hep_home.html). More about the fellowships and the general conditions can be obtained from Dr M G Green, Physics Department, Royal Holloway University of London, Egham, Surrey TW20 0EX (phone +44 1784 443454, fax +44 1784 472794, email GREEN@V1.PH.RHBNC.AC.UK).

Fellows will be employed under the EU's general conditions governing research training fellowships and will receive c.2700 ECUs per month to cover subsistence and mobility expenses, tax and social security contributions and cost of attending conferences etc. It is intended to submit the names of one or two candidates to the next round of EU selection which has a closing date of 15 December 1994. A letter of application and a CV should be sent to Mike Green at the above address to arrive by **Friday 25 November 1994**. Applicants should also arrange for two references to be provided by the same date.



Director General Chris Llewellyn Smith opens the day's proceedings at CERN's 40th birthday party.

CERN at 40

CERN celebrated its 40th anniversary with a special family day on 17 September where the accent was on fun, games and entertainment for staff and their families. After a brief opening ceremony, pomp gave way to play, formality to frivolity.

The following extracts from the DG's speech of welcome were freely translated from the French original:

'Forty is the traditional age for taking stock of the past and assessing future prospects. CERN is no exception to this rule and it is particularly appropriate at what is clearly a major turning point in its existence. Before looking to the future, allow me to say a few words about our past.

Europe was the trail-blazer in particle physics with the study of cosmic rays. However, after the Second World War it lagged far behind the United States in accelerator physics which dominated particle physics research from the beginning of the 'fifties.

CERN was founded to enable Europe to make up the ground it had lost, which it rapidly did. The discovery of neutral currents in 1973, which should have earned André Lagarrigue a Nobel Prize had not his untimely death intervened, put CERN firmly amongst the leading physics laboratories.

In 1983 the development of our proton-antiproton collider led to the discovery of the W and Z bosons, which brought Carlo Rubbia and Simon Van der Meer Nobel Prizes the following year. Our Laboratory had thus become firmly established as a world leader in particle physics research, a position LEP has been instrumental in maintaining.

I have received a nice message from Viki Weisskopf, who was Director-General of CERN from 1961-1965. It begins: "CERN meant a lot to me", and concludes: "Isn't it a great idea that our CERN today is in many ways the leading particle physics laboratory in the world!". It is typical of Viki to use the expression "our CERN" and it is important that political decision-makers realise how much all CERN users regard it, quite rightly, as their laboratory.

Of course our scientific successes have been made possible by groundbreaking technical achievements that are too numerous to mention. One important landmark was the construction of the first proton-proton collider, the ISR, and another was undoubtedly the development of multiwire chambers. This invention, for which Georges Charpak received the Nobel prize in 1992, revolutionised detection techniques.

In addition to purely scientific aims, our founding fathers were pursuing another objective, namely that CERN should provide an opportunity through science for countries to contribute to the joint reconstruction of Europe after years of war. There can be no doubt that this objective has been attained.

CERN's pioneering work has not stopped there. Throughout the "cold war" CERN maintained fruitful scientific relations with Eastern Europe and was one of the first Western European institutions to welcome former communist Central European countries as members.

The Organization has also served as the blueprint for a new type of cooperation which has been emulated in other research fields. In particular, CERN acted as a midwife at the births of the European Molecular Biology Laboratory and the European Southern Observatory.

Looking towards the future, we are on the threshold of the approval of a great project, the LHC, which will help mankind to take a decisive step forward in our understanding of the fundamental nature of matter. The LHC will be the flagship of particle physics research at the beginning of the next century and will assure CERN's future for many long years to

Three times 40 years' service - left to right Giorgio Brianti, Wolfgang Schnell and Bas De Raad, with the Director General.

Fired by the Director General. The start of a relay race round the Intersecting Storage Ring (ISR) road. A distinguished runner, Chris Llewellyn Smith is familiar with this situation.

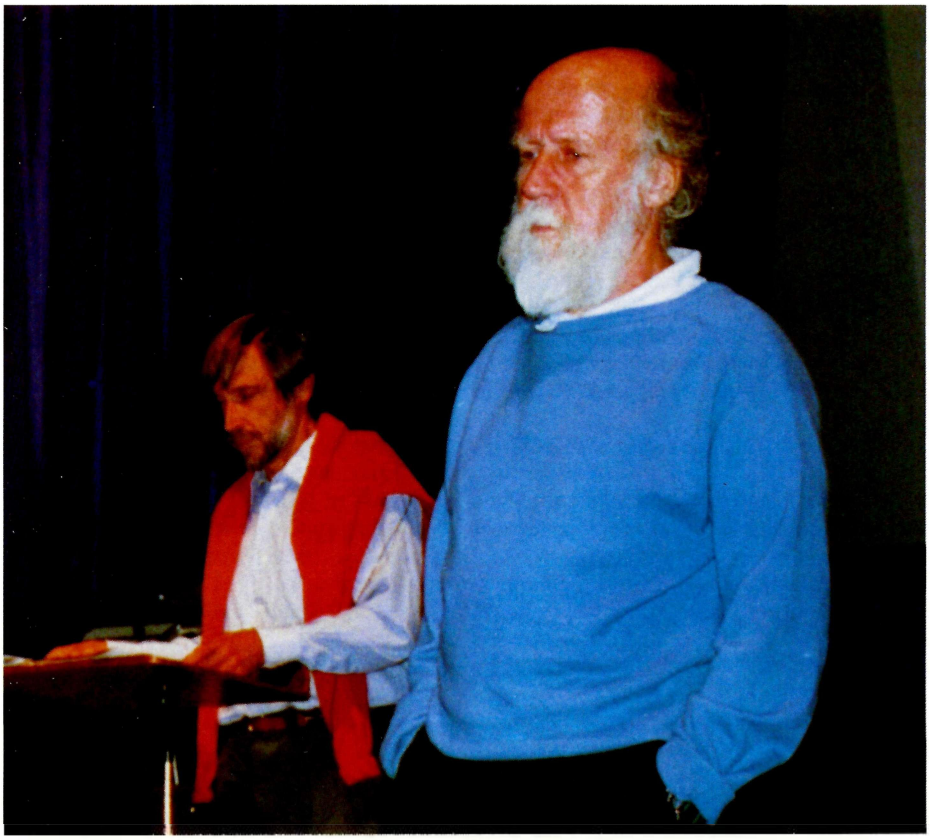
come.

Looking to its world role, CERN is also facing new trends which are the logical consequence of its past successes. Our facilities are already host to over half the world's experimental particle physicists, nearly 30% of whom are from non-Member States. The fivefold increase in the total number of users over the last twenty years, during which period non-Member State users increased tenfold, is an objective testament to CERN's excellence.

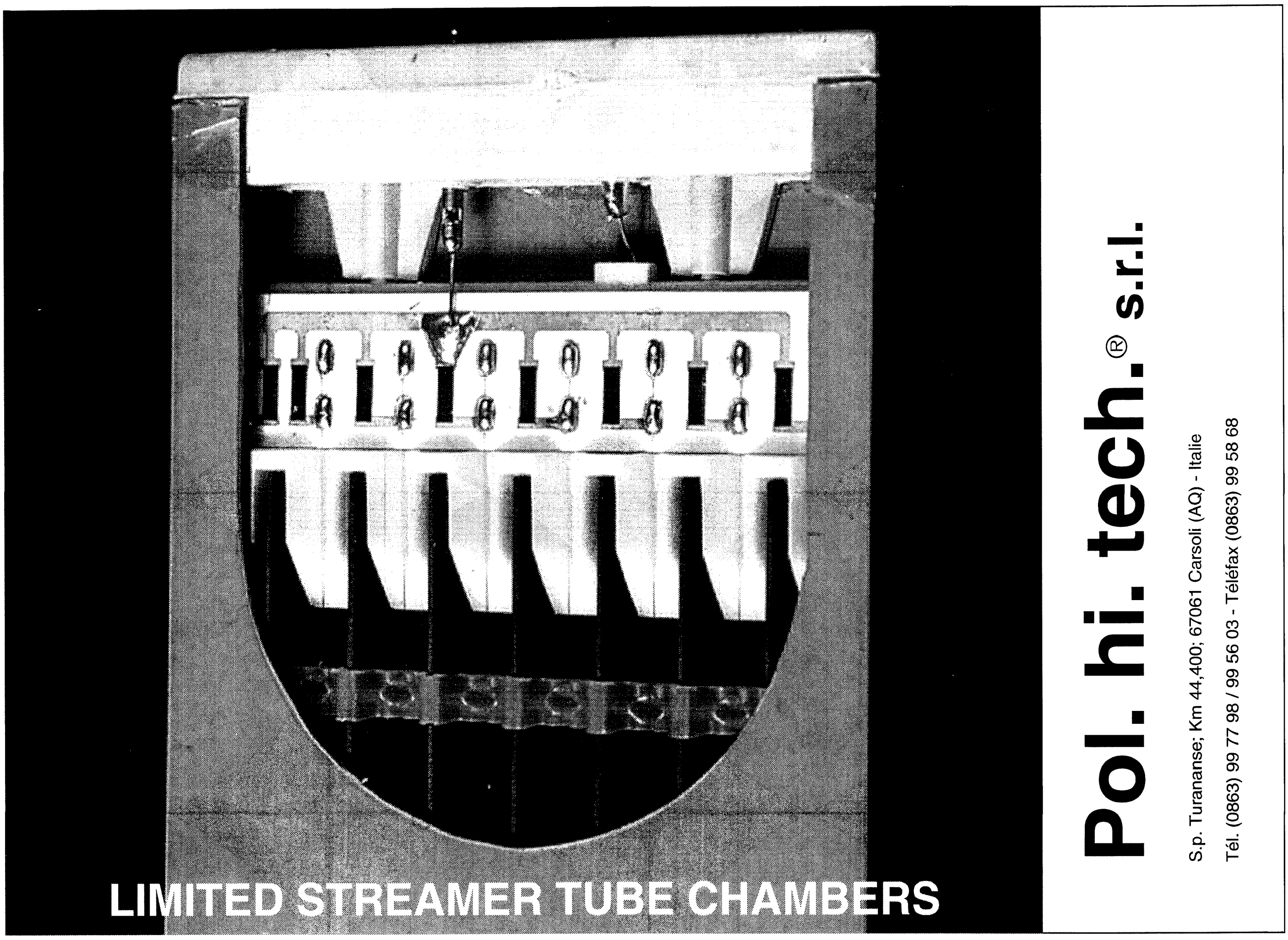
Since there is no challenger to the LHC as the next-generation research tool for exploring the still unrevealed secrets of matter and its innermost structure, the proportion of users from non-Member States looks set to increase further during the LHC era.

CERN greatly appreciates the input from research physicists from other continents and willingly welcomes them, faithful to its tradition of openness. The Organization benefits from the new ideas generated by European and world-scale cooperation. Here, too, CERN can play an important political and cultural role as a catalyst and a meeting point for people from all over the world.

Besides being inherently attractive goals in themselves, such cultural diversity, and the pooling of the energies and talents of physicists and engineers from very different cultures and with very different intellectual approaches, are important contributory factors to the suc-



Science personalities Hubert Reeves (right) and Alvaro de Rujula held capacity crowds for hours with talks on the first moments of the Universe.



INSTITUTE OF PHYSICS
UNIVERSITY OF LUND, SWEDEN

Professor in Experimental Nuclear Physics

Applications are invited for a permanent position as full professor in experimental nuclear physics at the Institute of Physics, University of Lund. The Institute has besides undergraduate programmes five research divisions belonging to the Faculty of Mathematics and Natural Sciences and four research divisions belonging to Lund Institute of Technology, covering nuclear and particle physics, atomic physics and solid state physics.

The position, on the Faculty of Mathematics and Natural Sciences, is vacant from January 1, 1996.

Experimental nuclear physics at the Division is at present conducted in laboratories in Scandinavia (Uppsala and Risö, Denmark) as well as on the Continent (CERN, GSI and GANIL) and in the USA (Brookhaven National Laboratory). One group studies high spin physics and is involved in the development of the NORDBALL and EUROBALL systems, a second group is leading an intermediate energy heavy ion physics collaboration, working mainly at The Svedberg Laboratory (CELSIUS) in Uppsala, while a third group is taking a leading role in a relativistic energy heavy ion physics programme at SPS and LHC at CERN and at RHIC (Brookhaven). There is an exceptionally good collaboration with researchers at the Institutes of Theoretical Physics at the University of Lund, including Theoretical Nuclear Structure Physics and Theoretical Elementary Particle Physics and Field Theory. A long established network of collaboration also exists with physicists at NORDITA and the Niels Bohr Institute in Copenhagen.

The Institute is seeking an internationally recognized physicist to lead and conduct research in and teaching of experimental nuclear physics. It is required that the candidate has made important contributions to his or her own field of research and has documented experience in building up complex experiments. The successful candidate is expected to conduct teaching at pre- and post-graduate level.

Applications should include a *curriculum vitae* giving evidence on which the evaluation of the applicant's scientific and teaching qualifications can be based. Further, a complete list of publications, and one copy of each publication referred to therein, as well as four copies of each of the ten publications which the applicant selects as the most relevant for the application, are required.

Applications should be addressed to the **Rector of Lund University, Box 117, S-221 00 LUND, Sweden** and marked '13160'. The deadline for the receipt of all application material is January 11, 1995.

For further information on salary, research and teaching duties, staff, laboratory and other facilities, please contact:

The Chairman of the Institute of Physics,
Docent Bengt Lörstad,
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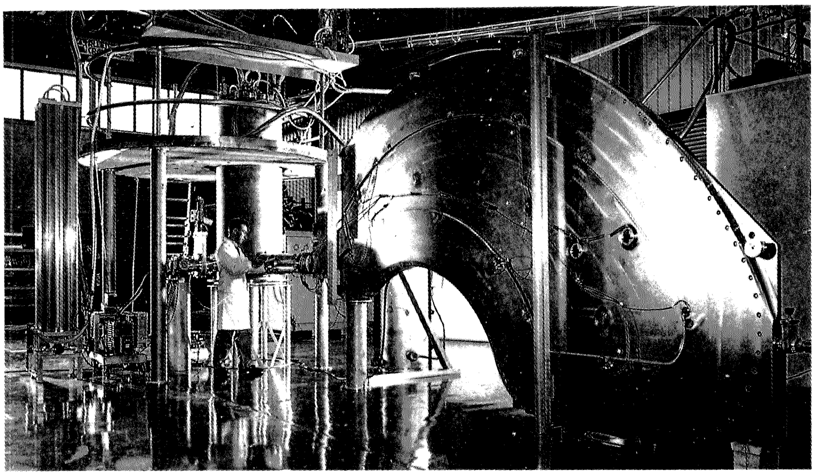

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Applications and suggestions of candidates should be sent before **December 15, 1994** to **Prof. Dr. B.H. Wijk c/o DESY,** Notkestr. 85, 22607 Hamburg.

Further information about the position can be obtained from **Prof. Dr. B.H. Wijk.**

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE

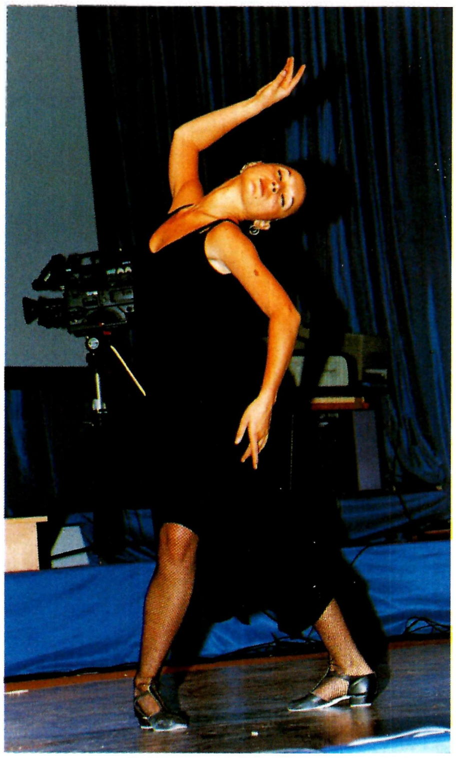
IN2P3/CNRS - UNIVERSITE AIX-MARSEILLE II

In the course of an expansion plan the Particle Physics Center of Marseille is expecting to recruit a young physicist on a permanent appointment as "Chargé de Recherche de 1ère classe" (corresponding to an age ≈ 30 years). The successful candidate will be expected to join one of the existing experiments of the laboratory. At the present time we are involved in the Aleph (LEP), CP Lear, H1 experiments and in the ATLAS project.
The laboratory plans to expand its manpower during the next four years. Physicists and technical staff number around 100, and the institute has just moved into a new building offering very attractive working conditions.

Further information can be obtained from :

- JJ Aubert -
Centre de Physique des Particules de Marseille
case 907 - 163 avenue de Luminy
13288 Marseille cedex 09 - Tél : 91 82 72 00

Below, Marzio Nessi makes off with Event Coordinator Paola Catapano in his tombola prize.



Above, contemporary dance by Celine Ployer at the closing ceremony.

cess of our projects, and often give rise to highly innovative developments.

However, the increase in the number of users from non-Member States raises fundamental questions concerning CERN's very nature as an institution. I certainly do not expect CERN to accept countries from other continents as full Member States, at least not in the near future. That would be too radical a step for both them and CERN. I can nevertheless envisage the possibility of the LHC being built in partnership with certain countries in other continents. Such countries could, for example, be granted an associate status. At any rate, it seems to me desirable that all the research communities that will one day use this machine are involved in LHC construction from the very beginning and have the opportunity to take part in the major project decisions.

The idea of building the LHC in a world partnership headed by Europe offers many scientific, political, human and even financial advantages. It would be the first major planet-wide scientific project and could well set the pattern for large-scale projects in other research fields.

The approval of the LHC will do more than assure CERN of a tremendous scientific future: it will also give it a new pioneering role in shaping a new type of organization.

I have great hopes that these plans will bear fruit and that our successors will be able to look back over the next forty years as proudly as we, today, look back over the first forty.'

LHC style - Les Horribles Cernettes do their stuff

ION SOURCE PHYSICIST
NATIONAL SUPERCONDUCTING
CYCLOTRON LABORATORY
MICHIGAN STATE UNIVERSITY

The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) is seeking to fill the position of Group Leader for Ion Sources. The NSCL has a staff of approximately 130 people and is funded by the National Science Foundation for research in nuclear physics, accelerator physics, and related instrumentation R&D. The successful candidate will lead the ion source group at the NSCL which is responsible for developing beams of highly charged positive ions for cyclotron injection, maintenance and operation of the present complement of electron cyclotron resonance (ECR) ion sources, design and construction of advanced ion sources, and research directed towards furthering the fundamental understanding of ECR ion sources. Requirements include a Ph.D. in physics or related area or equivalent experience. Knowledge in the areas of space charge limited beam transport, low energy beam injection, and plasma physics are highly desirable

Positions in the NSCL Continuing Appointment system parallel tenure system ranks at MSU. The position will be filled within the Continuing Appointment system at the level commensurate with the successful applicant's experience. Applicants should send a resume and have three letters of reference to **Ms. Chris Townsend, Laboratory Administrator, National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824-1321.** Michigan State University is an affirmative action/equal opportunity institution. Women and minorities are especially encouraged to apply.

2nd European Workshop on Beam Diagnostics and Instrumentation for Particle Accelerators
Travemünde, Hotel Maritim
Federal Republic of Germany
28 - 31 May 1995
The workshop will be organized by
Deutsches Elektronen-Synchrotron DESY

The workshop will give specialists, active in the development and operation of beam instrumentation, the opportunity to exchange ideas and share their experiences. We anticipate a mixture of experienced staff, and junior scientists and engineers who could benefit especially from contact with others in the field.

Contributions on new and interesting developments in beam instrumentation may be accommodated as short oral presentations, posters, or during afternoon discussion groups. An area of special emphasis will be the front end signal processing associated with beam instrumentation. Abstracts must be received by **31 December 1994**. Participation will be limited to about 100 people and will be by invitation only.

Contact: Mrs. I. Nikodem, DESY / FDET
Notkestr. 85, D - 22603 Hamburg
Phone: (49) 40 8998 3441
Fax: (49) 40 8998 3094
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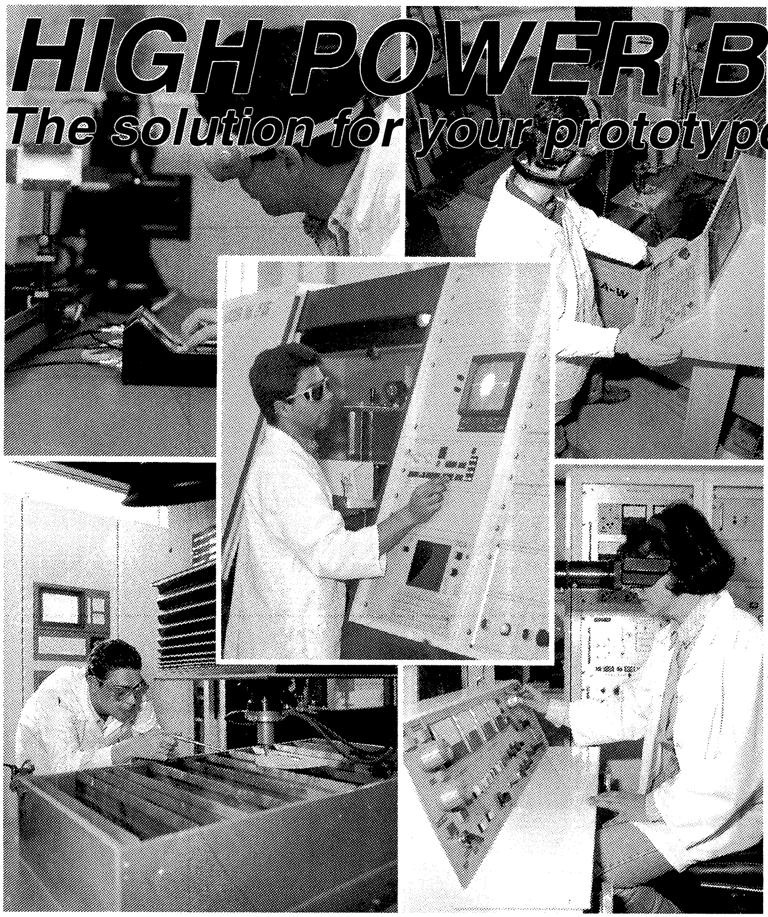

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Plain text (ASCII) is preferred. Illustrations should follow by mail (CERN Courier, 1211 Geneva 23, Switzerland).
Contributors, particularly conference organizers, contemplating lengthy efforts (more than about 500 words) should contact the Editor (by e-mail, or fax +41 22 782 1906) beforehand.

External correspondents

Argonne National Laboratory, (USA)
D. Ayres

Brookhaven, National Laboratory, (USA)
P. Yamin

CEBAF Laboratory, (USA)
S. Corneliussen

Cornell University, (USA)
D. G. Cassel

DESY Laboratory, (Germany)
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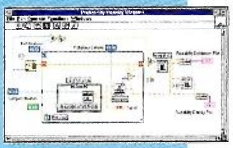

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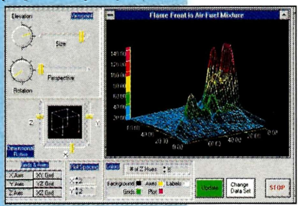

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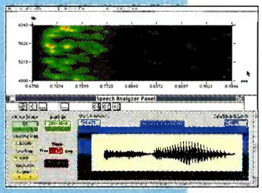

Data courtesy of NIH.

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TENURE-TRACK FACULTY POSITION
THEORETICAL HIGH ENERGY PHYSICS
THE OHIO STATE UNIVERSITY

The Department of Physics invites applications for a tenure-track assistant professor (or possibly tenured associate professor) position in theoretical high energy physics to begin in Autumn Quarter 1995. Candidates should have a strong background in high energy physics with significant field-theoretic foundations and demonstrated experience and keen interests in particle and/or particle/astrophysics phenomena. A commitment to teaching is also required. The theoretical high energy physics group includes: G. Kilcup, W. Palmer, S. Pinsky, S. Raby, J. Shigemitsu, K. Tanaka, and K. Wilson. There are also close ties with the theoretical astrophysics and cosmology group, including R. Boyd, R. Scherrer, G. Steigman, and T. Walker, in the Physics Department, and others in Astronomy as well as the theoretical nuclear physics group, including B. Clark, R. Furnstahl and R. Perry. In addition, the department has a strong experimental high energy group, whose members are actively involved in CLEO II at Cornell and in Zeus at HERA. The extensive computer facilities available on campus include a Cray Y/MP and T3D supercomputers. For fullest consideration, applications, including a resume and at least three letters of recommendation, should be sent no later than February 15, 1995 to: Professor S. Raby, Department of Physics, The Ohio State University, 174 W. 18th Ave., Columbus, OH 43210-1106. Further inquiries can be made by phone at (614) 292-3910 or via email to RABY@EMPS.OHIO-STATE.EDU. The Ohio State University is an Equal Opportunity/Affirmative Action Employer. Qualified women, minorities, Vietnam-era Veterans, disabled veterans and individuals with disabilities are encouraged to apply.

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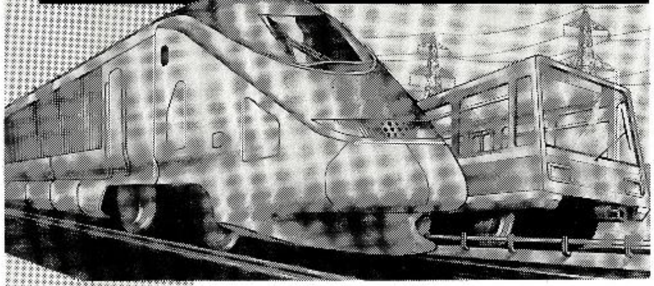

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