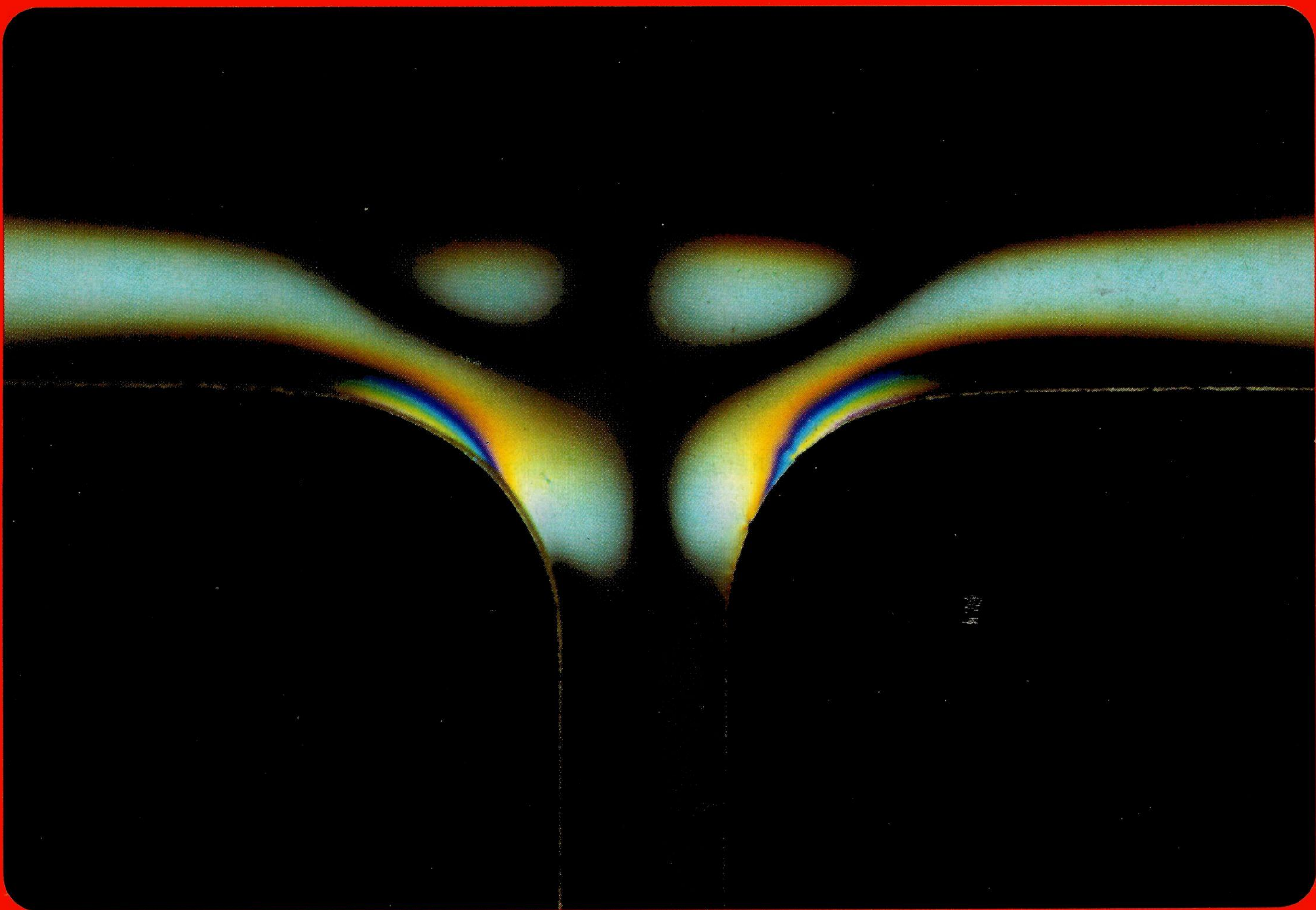
# CERN COURIER

International Journal of High Energy Physics



VOLUME 24 2 MARCH 1984

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CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 23 698
(CERN COURIER only Tel. (022) 83 41 03)
USA: Controlled Circulation
Postage paid at Batavia, Illinois

# CERN COURIER

International Journal of the High Energy Physics Community

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VOLUME 24 Nº 2 MARCH 1984



*Cover photograph: For moving material and personnel around the 27 km tunnel being built at CERN for the LEP ring, a monorail system is being planned. Seen here is the result of subjecting a model of the rail section to a photoelastic stress test using polarized light. The tests were carried out by the LEP Installation and Mechanical Engineering Group.*
*(Photo CERN 590.12.83)*

# Around the Laboratories

## KEK
## TRISTAN advances

The Accumulation Ring of the TRISTAN accelerator at the Japanese KEK Laboratory accelerated electrons to 4.2 GeV on 18 November 1983, just two years after the groundbreaking ceremony on 19 November 1981. The electron energy was boosted to 4.8 GeV on 13 December and is expected to reach the design level of 6 GeV before this article appears.

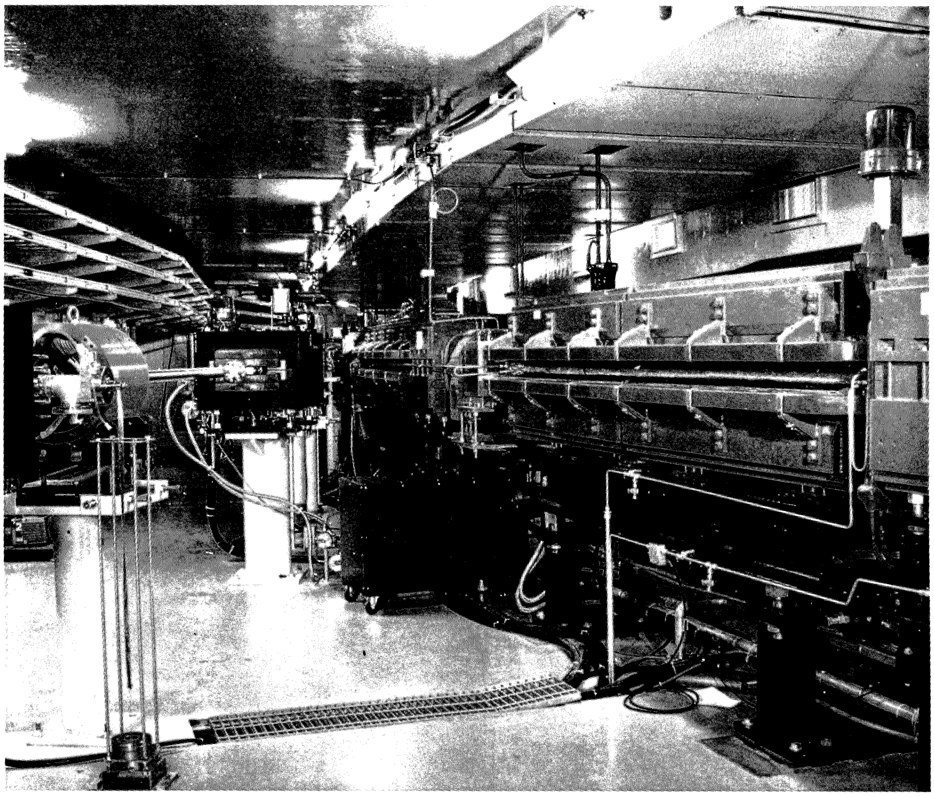
For TRISTAN, the 2.5 GeV electron linac (built for the Photon Factory — the KEK synchrotron radiation research facility) supplies electrons to the Accumulation Ring. This 120 m diameter ring accelerates two bunches of electrons (or positrons) to at least 6 GeV, for injection into the 970 m diameter 30 GeV Main Ring.

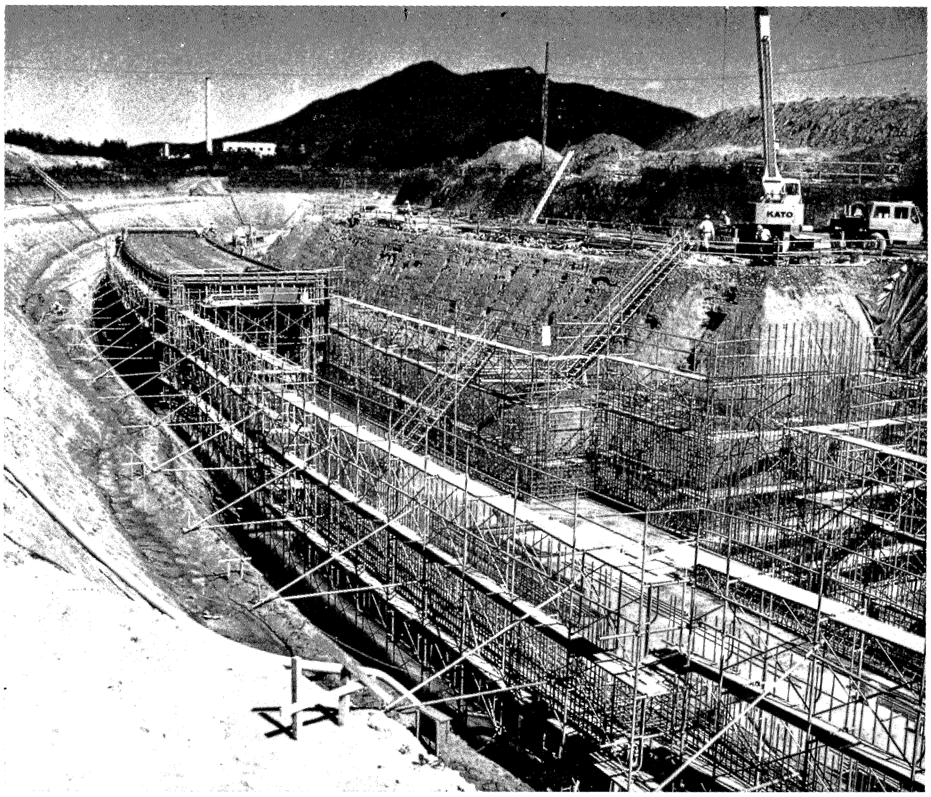
The Accumulation Ring tunnel is on the same level as the linac (about 4 m below ground), while the Main Ring tunnel is 7 m lower as it goes under the present 12 GeV proton synchrotron.

Civil engineering for the Main Ring is on schedule. In the current fiscal year, two experimental halls — Fuji (South-West) and Tsukuba (North-East) — and about half the tunnel will be completed. The two general-purpose detectors VENUS and TOPAZ will be installed in the Fuji and Tsukuba areas respectively (see January/February 1983 issue, page 4).

For the third TRISTAN experiment, the AMY project has been approved recently. This compact detector will be built by a joint US/Japanese team for installation in the Oho (South-East) hall. (A proposal to move the HRS detector from SLAC to KEK has

*The TRISTAN Accumulation Ring at the Japanese KEK Laboratory which accelerated electrons for the first time in November. On the left is the electron injection line.*

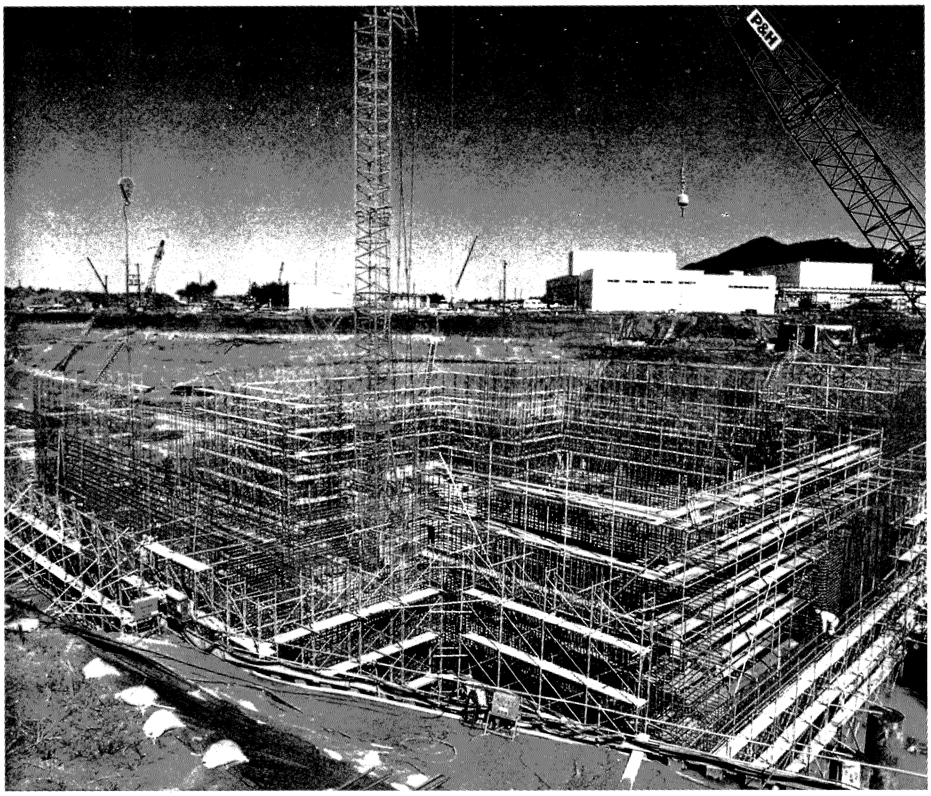





*Construction of the TRISTAN Main Ring tunnel. In the background is Mount Tsukuba.*

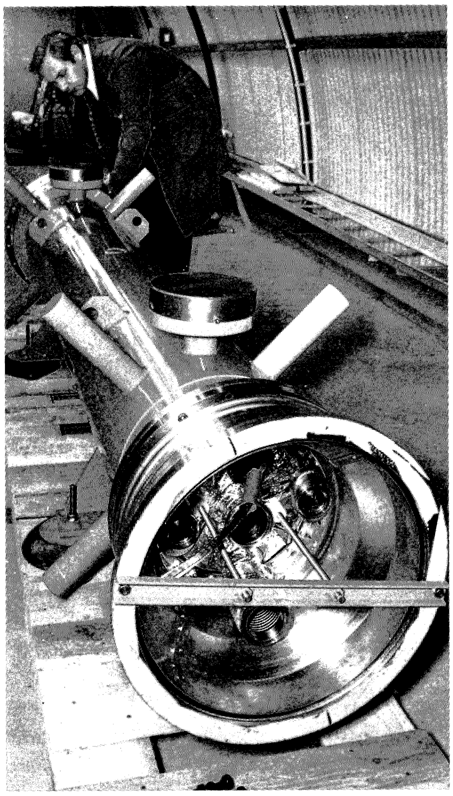
*More TRISTAN construction work, this time for the 'Fuji' experimental hall, so called because this hall is located in the direction of Mount Fuji when viewed from the centre of the ring. It will house the VENUS detector.*

*(Photos KEK)*



*Superconducting quadrupoles for HERA, such as this one ready for testing at DESY, are being made at Saclay.*

*(Photos DESY)*



been deferred.) Construction of the Oho and Nikko (North-West) halls and the remainder of the tunnel will shortly get under way and are scheduled for completion at the end of 1985. First beam in the Main Ring is expected by the end of 1986.

Due to the construction of the TRISTAN tunnel, the proton synchrotron will undergo a lengthy shutdown. Though a number of interesting experiments, such as studies of rare kaon decays, are scheduled at this machine, the emphasis of KEK high energy physics will naturally swing towards TRISTAN.

The proton synchrotron will concern itself more with intermediate energy nuclear physics. So far three series of such experiments have been proposed — spectroscopy of hypernuclei, experiments with a polarized proton beam, and studies with an ion beam. Technically, hypernuclear spectroscopy is the easiest to get under way as it requires only slight modifications of the existing beamlines.

A proposal by a Tokyo/Heidelberg group has been approved and a high intensity kaon beamline is being designed, bearing in mind the possibility of using some magnets from CERN beamlines. For hypernuclear spectroscopy, more intense kaon beams are required and it is planned to increase the injector linac energy from 20 to 40 MeV by adding a new tank.

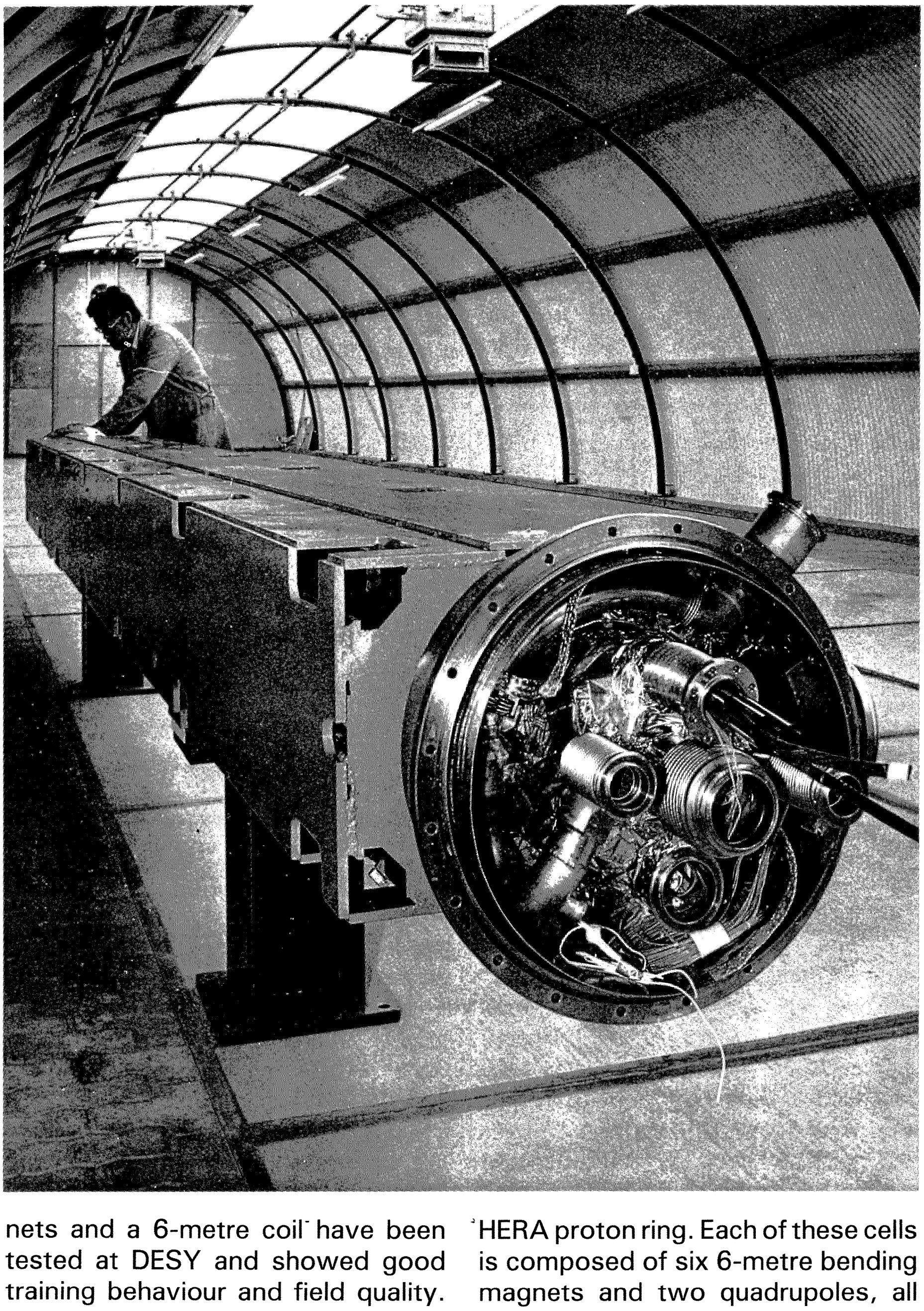
## DESY HERA progress

While formal steps towards the official approval of the HERA project continue, there have been several good reasons to celebrate at DESY. In January there was a call for tenders for the civil engineering work for the 6.3 km HERA tunnel and for the four experimental halls. Subject to the final decision of the Federal Ministry of Research (the city of Hamburg has already agreed to the HERA plans) construction is scheduled to start in May. The buildings should then be ready in 1987, the 30 GeV electron ring in 1988 and the 820 GeV proton ring the following year. An ambitious plan, which will keep busy DESY staff and several hundred visitors from about 20 participating Laboratories.

The first superconducting quadrupole for HERA, built at Saclay, has been installed in a new test tunnel hall, alongside the first two complete 6-metre superconducting bending magnets. The first two of the quadrupoles have been tested successfully at Saclay and have reached the design field gradient of 90 Tesla/m without quenching.

A series of one-metre dipole mag-

*Six-metre superconducting bending magnet for the proposed HERA electron-proton machine ready for tests at DESY.*



nets and a 6-metre coil have been tested at DESY and showed good training behaviour and field quality. They reached the so-called 'short sample design qualities' and the required field within only a few quenches. Magnet properties were well above the design values at the required field of 4.53 Tesla.

The new 70-metre tunnel-shaped test-hall has been designed to house two full-length magnet-cells for the HERA proton ring. Each of these cells is composed of six 6-metre bending magnets and two quadrupoles, all superconducting. It will also include correction coils, monitors, full refrigeration and remote controls, and everything needed to simulate the working conditions in the HERA tunnel.

At present two types of bending magnets are being prepared for these tests. The main difference between the two designs is that in one type the iron used to return the magnetic flux is independent of the coils and is placed outside the cryostat (warm iron — DESY design). In the other type the iron is inside the cryostat and is also used to help withstand the stress caused by the current-carrying coils (Brown-Boveri design). Four magnets of each type are being prepared for comparison tests and the final decision will be made next year.

In both HERA dipole projects the beam pipe is kept at low temperature. Superconducting correction coils are wound around the vacuum tube and cooled with liquid helium. These coils are being developed in collaboration with NIKHEF in Amsterdam. A one-metre correction coil prototype, built at NIKHEF, has already been successfully tested, and the first full size correction coil is being built by Dutch industry.

In the meantime, fruitful negotiations on contributions to the HERA project are under way with both physicists and authorities from Canada, France, Italy, Israel, the Netherlands and the United Kingdom.

## CERN
## Antiprotons in orbit

The LEAR Low Energy Antiproton Ring promised to supply beams of low energy antiprotons of intensities much greater than had ever been available before. And it has. In just a few hours of beam time last year, LEAR experiments were able to log data which would have taken months or even years with conventional antiproton beams.

Already the benefits are being reaped. Some initial LEAR results on the scattering of antiprotons from nuclei were described in a previous

Comparison of X-ray spectra from antiprotonic atoms of different isotopes of oxygen, measured by the Basle / Karlsruhe / Stockholm / Strasbourg / Thessaloniki group working at CERN's LEAR Low Energy Antiproton Ring. On the left, an unperturbed (8-4) atomic transition, and next to it, a strongly attenuated and broadened line (4-3). The attenuation of this line clearly increases with the number of neutrons.

issue (December 1983, page 416). Now a Basle / Karlsruhe / Stockholm / Strasbourg / Thessaloniki (BKSST) team has some interesting results from the X-ray spectra of antiprotonic atoms.

The study of such exotic atoms, in which an atomic electron is replaced by an orbital antiproton or other negatively charged particle, has long been a speciality at CERN.

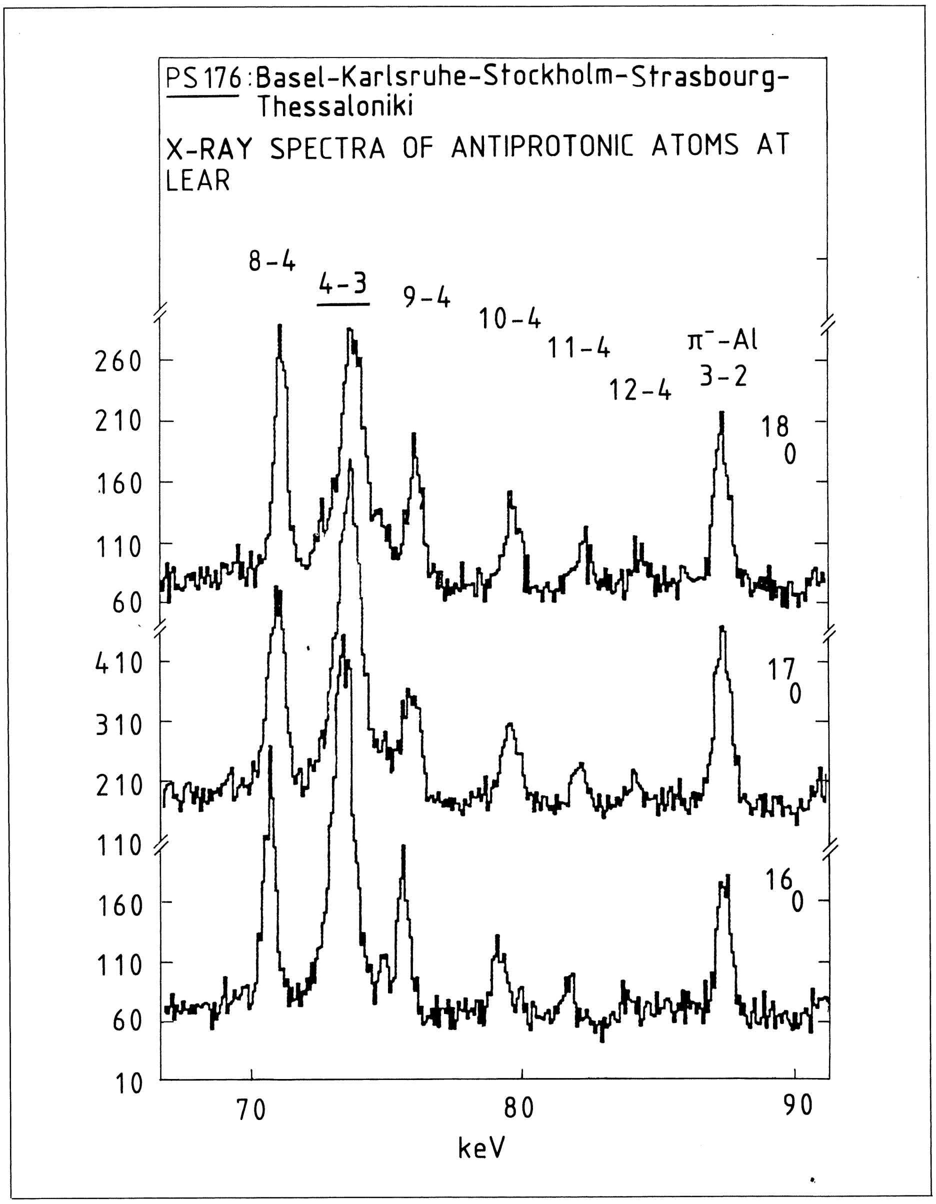
When antiprotons are brought to rest in a target, they are captured in an outer atomic energy level, but quickly fall down the rungs of the atomic energy level ladder. For each energy level transition, a quantum of radiation is emitted.

Because the antiproton is much heavier than the electron, it orbits much closer to the nucleus than the corresponding electron states. In fact when the antiproton approaches the lowest available atomic energy levels, it can be considered as orbiting inside the inner electrons. Such an atomic system can be viewed as a kind of superheavy hydrogen-like atom, with a heavy nucleus replacing the lone proton of hydrogen, and an antiproton replacing the valence electron.

But there is one big difference. As well as the electromagnetic interactions responsible for ordinary atomic structure, antiprotons also interact with nuclei through the strong force.

These strong interactions become more important as the antiproton approaches the nucleus, and should be measurable by comparing the observed behaviour with that expected from the pure electromagnetic interaction between the charged nucleus and the orbiting particle.

In highly excited states, the orbiting antiproton is still far from the nucleus, and the interaction is purely electromagnetic. However at or near the atomic ground state, the orbit is so small that the antiproton touches, or even penetrates, the nucleus.




These nuclear interactions affect the atomic spectra calculated on the basis of a hydrogen-type atom picture, and the deviations between the observed and 'expected' values should provide important information on the antiproton-nuclear interaction.

These deviations can occur in three ways. The closer the antiproton approaches the nucleus, the more the strong interaction shifts the energy level from its 'hydrogen' position. Increasing nuclear forces also mean that the inner antiproton levels have a greater chance of being annihilated in a nuclear proton or neutron. This has two consequences. When annihilation is still weak, a small fraction of the antiprotons disappear and the ensuing radiative transitions (when the antiproton falls to a lower level) are attenuated. In the lowest level, nuclear annihilation dominates over the atomic cascade. These states are very short-lived, and this shows up as a broadening of the corresponding spectral lines.

Careful measurements of all these effects should provide information on the interaction between the antiproton and the nucleons bound in the nucleus. In addition, comparison of measurements from neighbouring nuclei with the same proton number would show how the antiproton-nucleus interaction changes as one or more neutrons are added. In this way the antiproton-proton and antiproton-neutron interactions could be disentangled.

In classic antiproton experiments at CERN over the years, attempts were made to compare measurements from different nuclei, but statistics were so scanty that the resultant errors were large and conclusions were hard to draw.

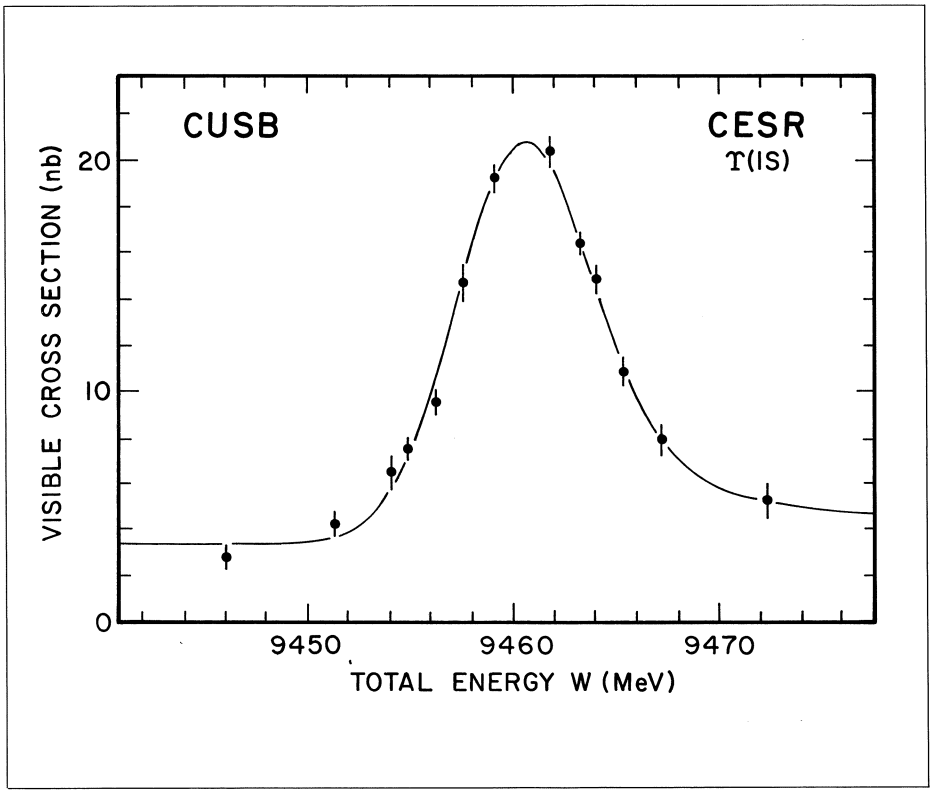
But LEAR soon changed that. With LEAR, the BKSST group was able to amass sufficient data in the brief 1983 run to provide a first look at the differences in atomic antiproton spectra from several neighbouring isotopes of oxygen.

Although final results have yet to be calculated, systematic effects are already clearly visible. These measurements will surely provide important new information on nuclear interactions, and will also complement the data coming from nuclear scattering using electron beams (see page 64).

But the termination of the atomic cascade does not necessarily spell the end for the antiproton. There is a slight chance that the antiproton picks up a nucleon from the nuclear surface and produces a state deeply bound by the strong force, emitting a high energy photon. Such evidence for 'baryonium' states has been found by the same group in previous (pre-LEAR) studies of antiprotons stopped in hydrogen and helium targets (see March 1983 issue, page 55). This time the detector was again searching for these energetic photons. As yet no evidence has been found, but the search (by a Basle / Stockholm / Thessaloniki sub-group) continues.

Other LEAR experiments are looking at antiprotonic hydrogen, and will provide the parameters of the basic antiproton-proton interaction. This will also be vital information for the heavier atomic studies.

In the months ahead, we can be sure of lots more interesting physics results from the experiments at LEAR.




*The upsilon production rate measured by the CUSB detector at the Cornell CESR ring, using the resonant depolarization method, giving a precise value (9459.97 ± 0.11 MeV) for the upsilon mass.*

# CORNELL
## Fixing the upsilon mass

The mass of a heavy vector (spin one) meson is one of the few quantities in high energy physics that can be measured with the precision that is routine in other areas of physics. These measurements, made in electron-positron storage rings, exploit the polarization of the beams resulting from the emission of synchrotron radiation, and the spin precession due to the anomalous magnetic moment of the electron.

This technique, called resonant depolarization, has been used at SPEAR (Stanford) to measure the psi mass, and at Novosibirsk to measure the phi, psi and upsilon masses. New measurements of the upsilon masses from Novosibirsk, DORIS

(DESY), and CESR (Cornell) were reported at conferences last year. The CESR measurement achieves a precision of 20 parts per million for the upsilon mass — within an order of magnitude of the current errors for the electron and proton masses.

The circulating electron beam in a storage ring emits synchrotron radiation due to the acceleration produced by the magnetic guide field. A small part of this radiation process flips the electron spin. Since the total energy of the electron state is lower when its magnetic moment is parallel rather than antiparallel to the magnetic field, the radiation rate is higher for transitions from an antiparallel to a parallel state, and the beam becomes polarized. The time for the beam to polarize is proportional to the average bending radius cubed divided by the beam energy raised to the fifth power. Consequently, the technique works best when the ring is operated at its maximum energy. At Cornell, CESR's relatively large dimensions (radius 120 m) result in a polarization time of about 5 hours near the upsilon energy. (At the same energies, polarization time at DESY's smaller DORIS-II ring is measured in minutes.)

A polarized electron precesses about the magnetic field direction with a definite precession frequency, but magnetic excitations at multiples of this frequency can destroy the polarization. Turning this statement around, resonant destruction of the electron polarization can be used to measure the beam energy in terms of the depolarizing frequency and other (known) quantities. Furthermore, typical perturbing fields require many thousands of revolutions to destroy the polarization, so the energy measured is averaged over many energy oscillations. This gives an accuracy much better than the natural energy width of the beam, which is typically of the order of 1 to 10 MeV.

In CESR, beam polarization was measured by the technique of scattering circularly polarized light, produced by a high power argon-ion laser, from the positrons in the ring. The spin dependence of Compton scattering leads to a slight vertical shift in the distribution of the backscattered laser photons. Although the shift is small, it can be measured by comparing the vertical distributions of photons backscattered from right and left circularly polarized light. The laser and photon detection systems were built and operated by the Harvard members of the CLEO group.

The upsilon cross-section (production rate) was measured by the CUSB group over a four-day period. Eleven measurements of the beam energy above and below the upsilon peak were interleaved with the cross-section measurements. (The CLEO detector was not used, since its magnetic field would have destroyed the beam polarization.)

After taking account of radiative corrections and other effects, the upsilon mass was determined to be 9459.97 ± 0.11 MeV. The 110 keV statistical error is larger than the systematic error, estimated to be 70 keV. The systematic error is dominated by the uncertainties in the fitting and chromatic corrections to the luminosity. If these contributions were zero, the systematic error would be dominated by an uncertainty of 26 keV due to the present error in the electron mass!

This measurement agrees with the value of 9460.6 ± 0.4 MeV obtained at the Novosibirsk VEPP-4 ring (see October 1982 issue, page 326). At the DESY DORIS-II ring, the technique has been used to measure the upsilon prime (see December 1983 issue, page 423, July/August 1983 issue, page 224).

# LOS ALAMOS
## Winds of change

The seventeenth annual Users' Group Meeting of the Los Alamos Meson Physics Facility (LAMPF) felt the winds of change. LAMPF Director Louis Rosen noted that recent progress at the 800 MeV proton linac should not hide the fact that these are difficult times. Extra funding for operations together with good luck in sustaining 800-900 μA beam for lengthy operating cycles have resulted in high utilization and effective running for difficult experiments such as neutrino scattering and the 'Crystal Box' measurement of rare muon decays. New impetus has been given to nuclear spectroscopy with the incorporation of a polarized target (partly from KEK) on the proton spectrometer, while the proton storage ring and beam areas will extend the LAMPF programme in 1985.

Nevertheless, sustaining scientific interest may be difficult without a major LAMPF upgrade. In Rosen's words, 'the 1990s look grim without LAMPF II'. Since the National Electron Accelerator Laboratory proposal has been funded, and the Nuclear Science Advisory Committee (NSAC) has endorsed the heavy ion collider concept, re-evaluation of LAMPF II is necessary. To involve the broadest community participation, Rosen initiated an American Physical Society session on the interface between high energy and medium energy physics for the next Washington meeting.

Closer to home, a panel discussion on LAMPF II concepts was arranged for the Users' Meeting, with NSAC representatives included. To set the stage, Arch Thiessen presented the options for LAMPF II as seen by his

At a recent users meeting at the Los Alamos Meson Physics Facility (LAMPF), a panel discussion was held on LAMPF II, the proposed major upgrade. From the left, the panelists from the Science Policy Advisory Committee: Dirk Walecka (Stanford), Peter Rosen (Los Alamos), Alan Krisch (Michigan), Leonard Kisslinger (Carnegie-Mellon), Akihiko Yokosawa (Argonne), Sidney Meshkov (NBS), Malcolm MacFarlane (Indiana), Lee Teng (Fermilab), panel moderator Erich Vogt (TRIUMF), then panelists from the Board of Directors: George Igo (UCLA), Arch Thiessen (Los Alamos), Charles Glashausser (Rutgers), Bob Redwine (MIT), Andy Bacher (Indiana), Jim Bradbury (Los Alamos), Hal Jackson (Argonne).

planning group. With each major step in beam energy, assuming that high intensity (100 μA) is maintained, new possibilities are opened. At 5 GeV, muon and muon-neutrino fluxes are enhanced, and an important energy range is opened for spin physics with polarized proton beams. A 12 GeV accelerator would make a kaon factory, and 32 GeV would make an antiproton factory. However by then the discussion is about an addition costing $200 million. The most ambitious option is a 50 GeV accelerator providing unique energy coverage with intense beams of nearly all possible species of particle.

Erich Vogt, panel chairman and director of TRIUMF, chose a nautical metaphor, the Americas' Cup race, to illustrate his interest in seeing the best kaon factory proposal developed. He also explained that at TRIUMF 'kaon' is really a pseudonym for K-meson, antinucleon, other hadron, or neutrino.

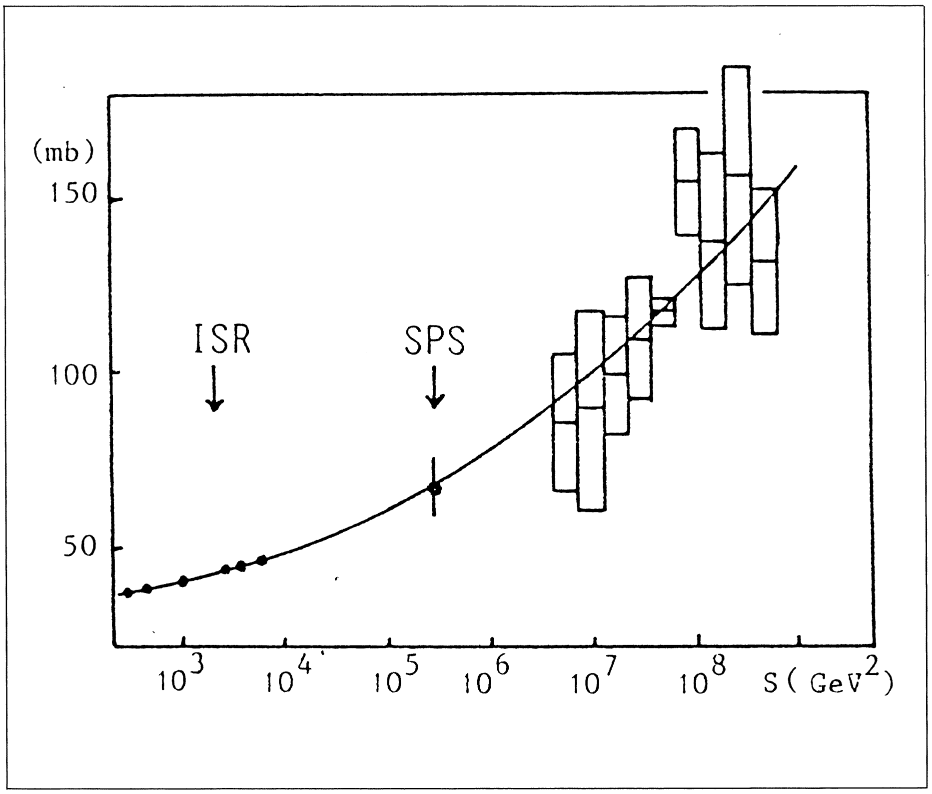
Leonard Kisslinger reported on a subpanel discussion with Sid Meshkov, Malcolm MacFarlane, Val Fitch and Fred Reines on the 'three-star' physics accessible through more intense intermediate energy beams. High on their list was the area of strong interaction physics which has recently experienced a theoretical revolution. Expected new phenomena are glueballs, dibaryons, and scattering phenomena involving high transverse momentum, especially with spin degrees of freedom. In nuclear physics, a three-star programme is to further understanding of mesonic states in nuclei by use of strange probes; this would encompass the topical interests of a large community of nuclear scientists. Again in particle physics, there are electroweak experiments with intense beams of muons, neutrinos, and kaons.

Alan Krisch, Akihiko Yokosawa and Lee Teng reported on subpanel meetings. Access to all this physics apparently would require a very powerful and expensive facility; an attempt to reach part of the programme sooner requires careful balancing of physics, cost, and effectiveness of each stage as a component of the next. The challenge is illustrated by choice of energy stages: a synchrotron destined eventually to be a booster from 800 MeV to a 30-50 GeV ring would be cost-optimized around 3 GeV, according to Lee Teng, but as a first stage, 3 GeV does not make a kaon factory as defined by the requirement for a hundred times the kaon flux of the Brookhaven AGS.

Dirk Walecka initiated the discussion on strategy. He emphasized the connection to the nuclear physics community: 'One of the strongest arguments for LAMPF II is the variety of probes you can bring to bear on important questions.' This was elaborated by Malcolm MacFarlane; 'What would be the use of an electron accelerator without hadron probes of as wide a variety as you can get', going on to draw attention to the complementarity of existing pion, proton, and electron spectrometers in medium energy nuclear physics. A debate followed on the likely course of large USA accelerator projects, and whether educational opportunity, preference for smaller collaborations, and better access might lead 10 to 40 per cent of the high energy experimentalists to projects like LAMPF II (or an upgraded AGS). Many comments underlined the artificial distinction between nuclear and high energy physics; Kisslinger said there is a large common area of interest in strong interactions.

The next day, Alvin Trivelpiece of the US Department of Energy pointed out that high energy physics has led to international research collaborations and a collective planning infrastructure. For the bigger facilities envisaged for the future (such as the Superconducting Super Collider, SSC), an even higher level of planning may be required. Towards this goal, a ministerial-level meeting was held recently in Williamsburg, Virginia.

# Cosmic rays at Bangalore




*The proton-proton total cross-section rise from CERN Intersecting Storage Rings (ISR) through CERN SPS Collider to cosmic ray energies (s represents collision energy squared).*

With collision energies in particle physics experiments beginning to probe the region hitherto accessible only through cosmic ray studies, there is a new impetus to the exchange of information and ideas between the two fields.

The 18th International Cosmic Ray Conference was held in Bangalore, India, from 22 August to 3 September 1983. About 425 delegates from all over the world presented over a thousand papers on various aspects of cosmic rays. A unique feature of this Conference series is that bound volumes of all contributed papers are given to the delegates at registration and the first two days are left free for digesting the papers and private discussions.

Contributed papers on the origin, acceleration, propagation, energy spectra, composition and anisotropy of primary cosmic rays, extremely energetic hadronic interactions, etc. were presented in four parallel sessions. In the plenary sessions, eight invited talks were given by experts on topics ranging from the radiation backgrounds and their cosmological implications to recent results from the CERN proton-antiproton collider and developments in particle detectors. The conference ended with 20 rapporteur talks. Apart from the main programme, several informal sessions were held in the evenings on specialized topics such as antiproton fluxes in the primary cosmic radiation, neutrino astronomy, hadronic interactions at ultra high energies, simulations of air shower cascades, history of cosmic ray research etc.

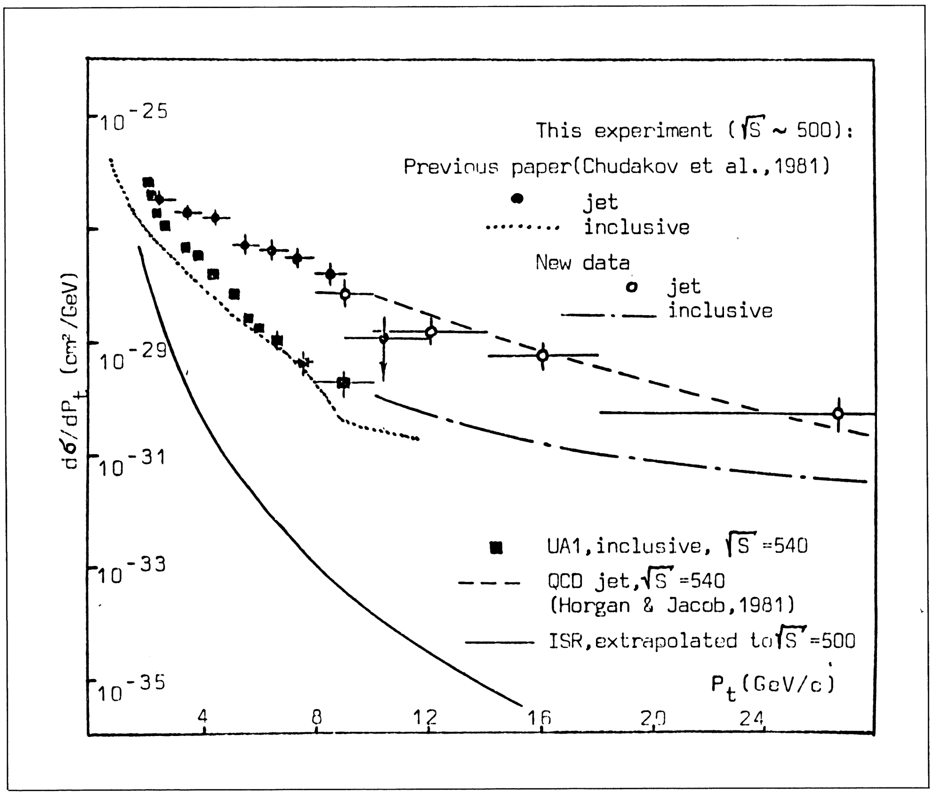
The centenary of the birth of Victor Hess of Austria, who discovered cosmic rays in 1912, was celebrated by a special symposium.

Considerable attention was devoted to questions of origin, composition and energy spectra of the primary cosmic ray particles. In spite of more than half a century of activity in this areas, the main problem of the origin of cosmic rays still eludes solution essentially because cosmic rays, being charged particles, lose their directions due to interactions with the irregular magnetic fields in the galaxy. As Kenneth Greisen of Cornell commented long ago, it is like trying to do visible astronomy through an atmospheric haze that scatters the starlight equally in all directions.

At Bangalore, the Kiel group from West Germany reported sighting of a cosmic ray source, Cygnus X-3, beaming particles (photons?) of energy near $10^{15}$ eV, with typical periodicity of 4.8 hours at lower energies, which was also confirmed by the Haverah Park group (UK). A puzzling result on multiple muon events was reported from the Soudan (US) proton decay experiment. Pairs of multiple muon events (muon threshold energy about 600 GeV) separated in time by less than 5000 seconds (the average time separation in their experiment) appear to be preferentially arriving from a direction with galactic latitude 20° and galactic longitude 95°. Their primaries are unlikely to be charged particles as they would lose their directions in the interstellar magnetic fields at energies below $10^{15}$ eV. They are not likely to be gamma rays either unless photonuclear reaction rates are unexpectedly large.

Direct measurements with balloon-borne detectors up to energies of some $10^{14}$ eV and inferences from air shower studies beyond suggest that the cosmic ray composition is a mixture of protons and nuclei, mostly protons up to around $10^{14}$–$10^{15}$ eV, and few nuclei above $10^{16}$ eV. The flattening of the cosmic ray energy spectrum at energies

*Production rate of high transverse momentum jets from cosmic ray studies compared with results from colliding beam machines and theoretical calculations.*




above $10^{19}$ eV, previously seen only in experiments in the northern hemisphere, is now seen from the southern hemisphere also. No significant anisotropy is seen in this hemisphere, unlike in the northern hemisphere. This poses a puzzle since the universal 3K microwave radiation is expected to deplete the flux at these energies if it is of extragalactic origin.

A proof of the existence of antimatter in the Universe would be its detection in cosmic rays. At the previous Conference in Paris, an American group reported a finite flux of antiprotons at energies of a few hundred MeV, which is too high to be accounted for by interstellar production because of the high energy threshold for nucleon-antinucleon pair production. At Bangalore, an Indian group reported a few antiproton events in agreement with the high flux. Further investigations are necessary to establish the flux and understand its origin.

Cosmic rays are still the only source of particles with extremely high energies (up to $10^{20}$ eV) particularly for the study of hadron-nucleus and nucleus-nucleus interactions, though the energies available at colliding beam machines are rapidly increasing (the CERN Collider being equivalent to a $10^{14}$ eV beam hitting a fixed target). Several notable discoveries in particle physics have been made with cosmic rays, including many new particles. Any massive particles existing in Nature could be produced in cosmic ray interactions. If their production rate is large enough and if they are reasonably long-lived, they could be detected in cosmic ray experiments.

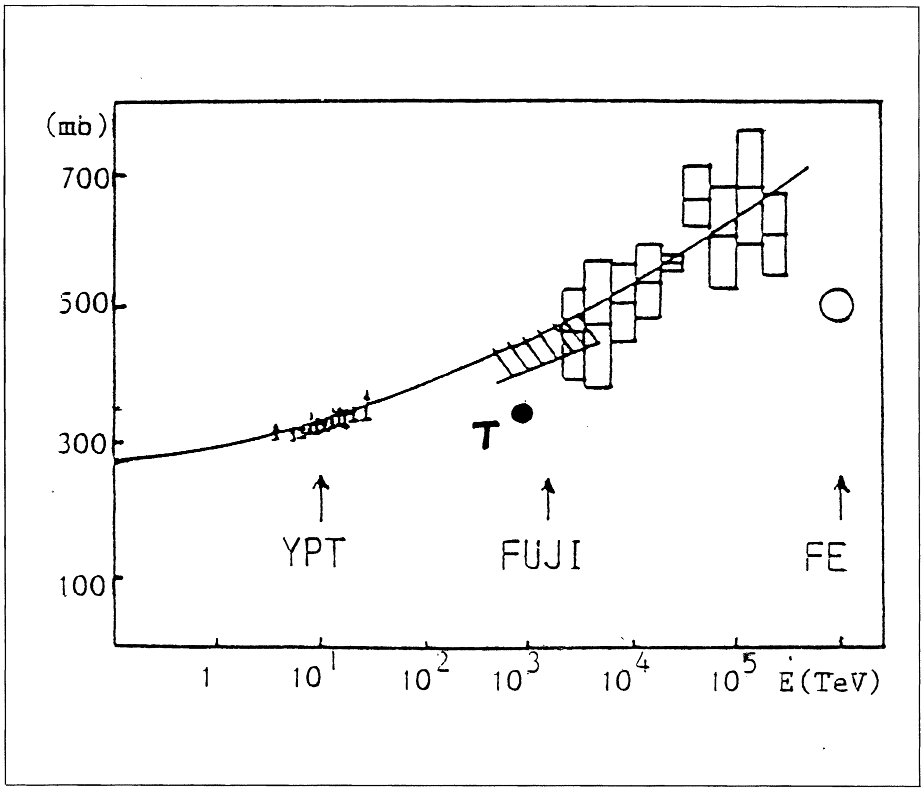
Searches for various types of particles were reported at the Conference, many with negative results, including the slow-moving $10^{16}$ GeV monopoles predicted by Grand Unification Theories. However there are many astrophysical constraints on the possible flux of such monopoles and these predict even a few orders of magnitudes less than the current cosmic ray experiment limit. There has been speculation on monopole-antimonopole bound states, relics from the early Universe with lifetimes of $10^{11}$ years whose annihilations in the space near earth would generate extensive air showers (EAS) in the atmosphere.

No new results on free quark searches were reported. However McCusker proposed a limit for the free quark flux based on fluxes of 'Centauro' events, 'long flying component', EAS cores and horizontal EAS. A Japanese group reported evidence for a flux of fractional charges (2.5 $m^{-2}$ $sr^{-1}$ $d^{-1}$).

Because of low fluxes, cosmic ray data is scarce, but sometimes suggests strange phenomena, some of them persistent and lacking a convincing explanation. An example is the so-called 'long flying component' in the hadronic cascades developing in lead calorimeters at energies above 200 TeV, observed by the Tien Shan group and interpreted as due to the effect of charm mesons and baryons. An explanation for these exotic phenomena is offered by the formation and explosion of 'quark globs'. Muon pair production in the cores of EAS has been interpreted as due to a long-lived (more than $10^{-8}$ s) particle of mass near 20 GeV.

Searches for the exotic events like Centauro, Chiron and Geminion events discovered earlier by the Brazil-Japan group at high mountain altitudes were also covered. The Centauro events, thought of as 'pizeroless' showers, a majority of which were first suggested by an Indian group to be due to fluctuations in the

*Inelastic proton-air cross-sections at cosmic ray energies (YPT — Yodh, Pal and Trefil analysis, T — Tien Shan Mountain observations, FUJI — Japanese emulsion chamber results and FE — Fly's Eye detector, Utah). The rectangles are from the Akeno (Japan) Air Shower Group's deductions.*




development of atmospheric showers, have not been observed in the Pamir and Fuji collaboration experiments, nor in the UA5 experiment at CERN's collider looking for pizeroless high multiplicity events. Chiron and Geminion events, which are interpreted by the Brazil-Japan group as multiparticle production events and pair production events respectively with large transverse momentum and without pion production, have been observed by other groups. Simulation of atmospheric cascades show that the Geminion events could be understood as coming from fluctuations in the usual pion production process if half the inelastic interaction leads to the production of high transverse momentum jets at energies near $10^4$ TeV. Similar calculations are necessary for understanding the Chiron events. Estimates of production rates of high transverse momentum jets at collision energies of around 500 GeV from multicore studies of EAS by the Baksan group show excellent agreement with theoretical predictions and with results from laboratory experiments.

Estimates of the inelastic interaction level of protons on air nuclei upto $10^{18}$ eV, from measurements on extensive air showers, were reported. The Akeno air shower group in Japan found the proton-air cross-section to be 290 $E^{0.066 \pm .005}$ mb in the energy range $10^3$-$10^6$ TeV from the frequency attenuation of showers with fixed number of muons and electrons, after making allowance for the possible presence of nuclei in primary cosmic rays. This is an upper limit considering the uncertainties in the details of particle production at these energies. With certain assumptions, they estimate the proton-proton cross-section to be 38.5 + 0.46 $\ln^2$ (S/100) mb with S (squared collision energy) in $GeV^2$. From the fluctuations in the depth of shower maximum, the Fly's Eye group (US) estimated the proton-air cross-section to be 500 mb at $10^{18}$ eV. Both these measurements are consistent with the extrapolation of the dependence given by Yodh, Pal and Trefil, about a decade ago, in the few TeV energy region from unaccompanied hadron fluxes at mountain altitudes.

There is speculation that at extremely high energies, particularly in nucleus-nucleus collisions, where matter can be compressed beyond the nuclear densities, phase transition from hadronic to quark matter can occur and quark-gluon plasma may be produced. This would be characterized by very high multiplicities, direct production of gamma rays and enhanced production of strange particles and baryons. Because of the possible presence of energetic nuclei in the primary beam, this phenomenon can be looked for in cosmic ray experiments. At the Conference, a few isolated events of unusually high multiplicity (1500!) were reported from balloon-borne emulsion chamber experiments. A Japanese contribution showed that most of these and other similar events can be understood in terms of a multi-chain model of nucleus-nucleus interactions without invoking the idea of a quark-gluon plasma. Nevertheless this remains a very exciting area in which contributions can come only from cosmic ray experiments in the near future.

With indications for many new phenomena at superhigh energies, cosmic ray investigations with ambitious detector set-ups are planned and the field is still very active. The large experimental set-ups will be massive underground (or underwater) detectors, giant air shower arrays at the surface with detectors spread

# Physics monitor

over areas of several tens to a hundred square kilometres, some of them with hadron calorimeters of areas above $10^3 m^2$. Emulsion chamber exposures at mountain altitudes hope to reach $10^4 m^2$ year in the near future.

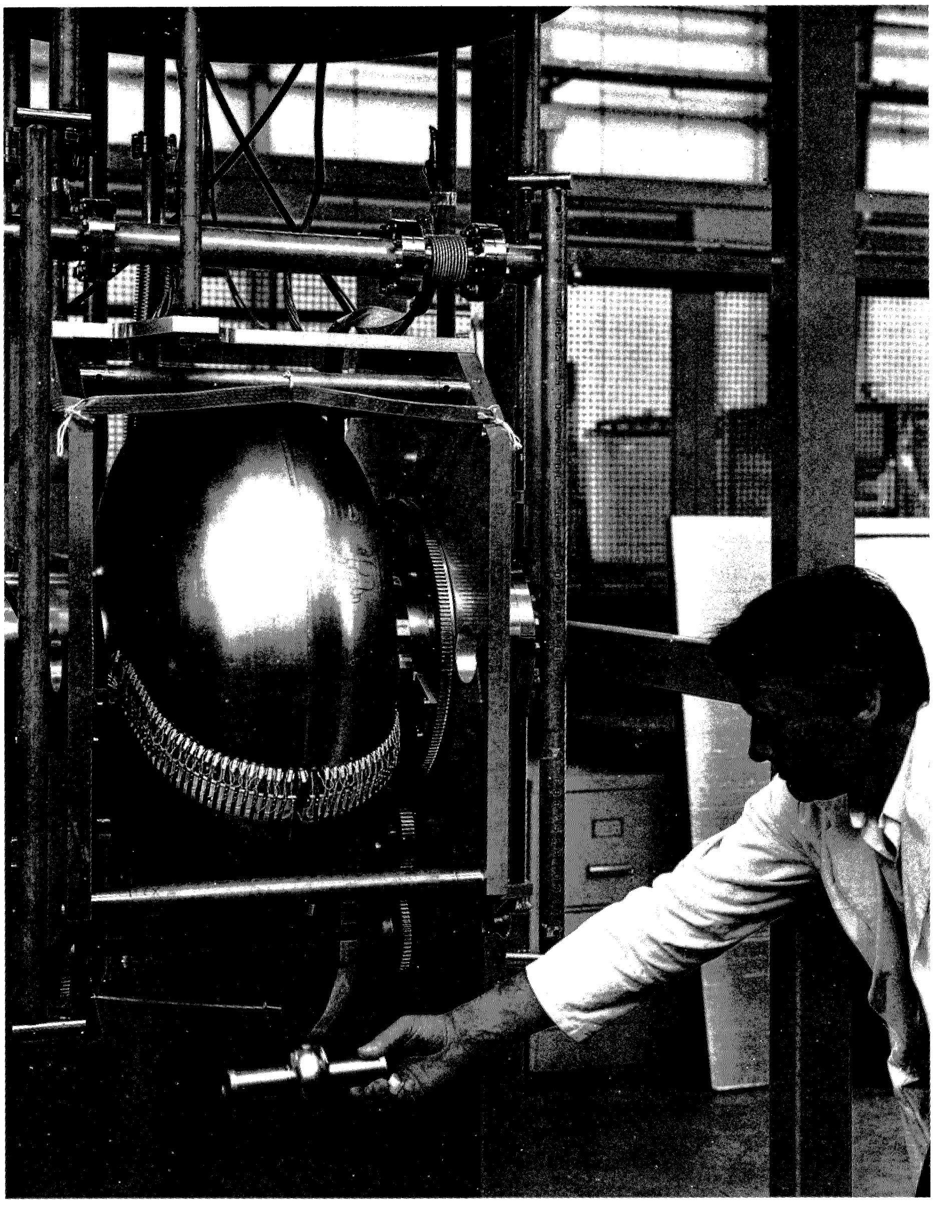
*(From M. V. S. Rao and A. Subramanian)*

## Conference Papers

The Conference Papers of the 18th International Cosmic Ray Conference, held in Bangalore, India, from 22 August-4 September 1983, are now available. The Contributed, Invited and Rapporteur papers are brought out in 13 Volumes totalling to nearly 5000 pages. Topics covered in these volumes are X-rays, gamma rays, origin, composition and energy spectrum of primary cosmic rays, modulation of primary cosmic rays, solar particle production, high energy interactions, extensive air showers, muons and neutrinos and techniques. They may be obtained by mailing a cheque for US $ 180 (Air Mail) or US $ 120 (Surface Mail) to Prof. P.V. Ramana Murthy, Tata Institute of Fundamental Research, Colaba, Bombay-5, India. The cheque should be drawn in favour of 'Tata Institute of Fundamental Research'.

*Big and little brother! Above, a 350 MHz superconducting niobium cavity of the type envisaged for LEP at CERN. Below, a small 3 GHz cavity, used for investigating the surface problems of superconducting niobium.*

*(Photo CERN 218.7.83)*



## Superconducting cavities looking good

The push for superconducting accelerating cavities to supply higher energies for large electron storage rings continues apace in Europe as well as the US and Japan.

(As electron beam energies climb beyond the 50 GeV level envisaged for CERN's LEP Phase I, the accelerating cavities would have to compensate for the extremely high synchrotron radiation. This would incur very high r.f. losses, and in turn, immense power bills. At other machines, such as PETRA at DESY, the energy has been taken as high as conventional r.f. accelerating cavities allows — there is simply no more room to install more r.f. equipment!)

In Europe, development efforts are mainly concentrated at CERN and DESY. At DESY, a 9-cell 1 GHz niobium cavity has reached an accelerating field of 5.7 MV/m with a quality factor Q of $8 \times 10^8$. (The quality factor is inversely proportional to the r.f. losses in the cavity.) This cavity was produced by industry and surface treated — partly by new polishing methods — at the University of Wuppertal and at DESY. This year, the DESY group intends to install it in the PETRA ring for a long-term test. Another DESY line of approach uses cavities made from niobium sheet, with the outer surface coated with a good thermal conductor (e.g. silver) to reduce the likelihood of thermal breakdowns.

At CERN, a single cell cavity working at 350 MHz (the frequency chosen for the LEP copper cavities) has attained an accelerating field of 6 MV/m, and the excellent Q value of $4 \times 10^9$ at 4.2 K. Powerful new computer programs for r.f. cavities have carried out cavity layout calculations for LEP, taking into account not only the fundamental r.f. mode but also the most dangerous higher order modes and the requirements of r.f. coupling.

Also at CERN, a 500 MHz single cell copper cavity, sputter-covered with a few microns of niobium, reached an accelerating field of over 8 MV/m and gave a Q value at low field of $10^9$. Its most encouraging feature is the absence of thermal breakdown. The high thermal conductivity of the copper wall avoided breakdowns with r.f. power dissipated inside the cavity well above 150 W. It may be possible to cool this type of cavity by tubes, instead of the usual liquid helium bath which requires both large amounts of helium and large containment vessels.

This year at CERN, the plan is to push this promising new approach, along with a 350 MHz 3-cell niobium cavity including all ancillary equipment — r.f. power couplers, higher order mode couplers, frequency tuners and cryostats matched to LEP requirements.

In the US, the Cornell group concentrates on 1.5 GHz cavities. A 5-cell cavity has reached an accelerating field of 5.4 MV/m and a Q value of $5 \times 10^9$ at 1.8 K. This year, it is planned to test two such cavities in the CESR storage ring.

There is also good news from the group at the Japanese KEK Laboratory. A 3-cell 500 MHz cavity, equipped with coupling ports, attained an accelerating field of 5.8 MV/m and a Q value of $1.3 \times 10^9$ at 4.2 K. This will soon be tested in the new TRISTAN Accumulator Ring (see page 51).

All this valiant effort seems to be paying off. It is encouraging that in many cases accelerating fields now exceed 5 MV/m, and hopes are high that this year's planned tests will greatly increase our knowledge of superconducting cavities. Optimism grows that LEP can be pushed beyond the 50 GeV envisaged for initial operation.

*(From H. Lengeler)*

## Looking for oscillating neutrinos

The 'charged current' of the weak nuclear interaction (the part which permutes electric charges) sees definite mixtures of quarks, described by the classic Cabibbo theory (see December 1983 issue, page 418). Less clear is whether it also sees definite mixtures of the three known types of charged lepton (electron, muon and tauon) with neutrinos of different masses.

Conventional neutrino dogma used to say that neutrinos are massless, and hence travel with the speed of light, but this has never been proved. On the contrary, evidence is building up for non-zero neutrino masses. Recent experiments at IHEP, Moscow, underline earlier suggestions that the electron neutrino has a mass (at least 20 eV). Many cosmologists would like to have neutrino masses too.

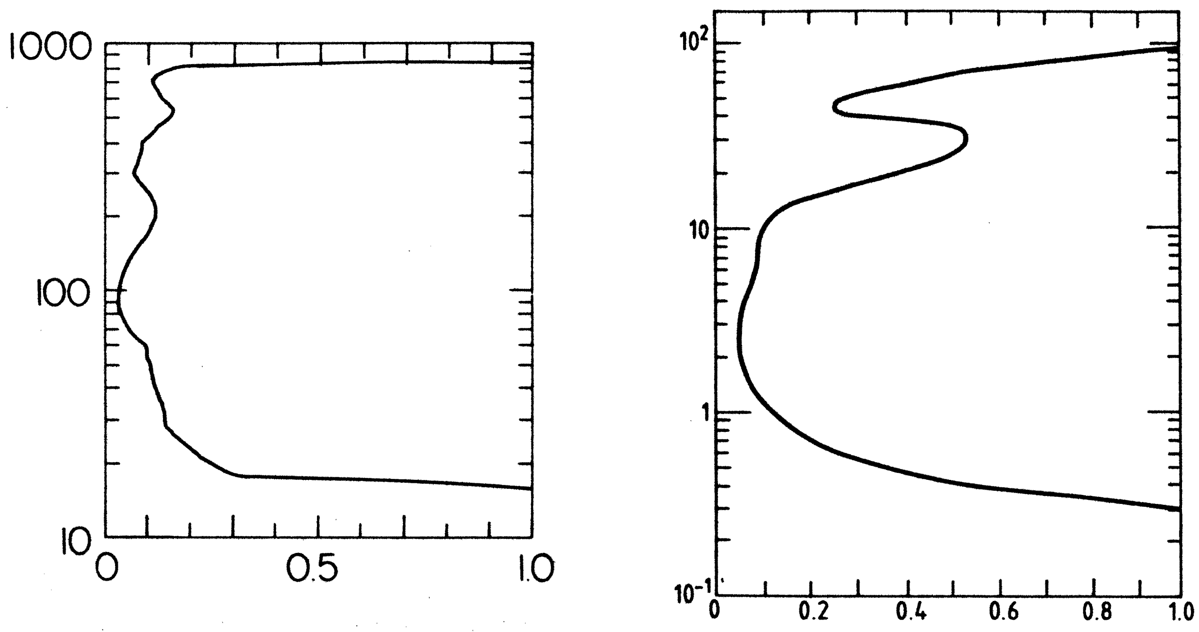
If neutrinos carry characteristic masses, and if the weak interaction does see mixtures of leptons, then a neutrino beam formed by a specific particle decay contains a mixture of neutrino types. Each of these types has its own mass and therefore travels with a different speed. Such a neutrino beam should 'oscillate' — its composition depending on where it was measured.

This possibility was first pointed out by Bruno Pontecorvo about twenty-five years ago, and ever since, controversy has oscillated. In the past few years, a major investment has been made in the search for such oscillations. Claims have been made, but the vast majority of the studies have proved negative, and these limits are gradually becoming more restrictive.

Neutrino oscillation searches can be divided into two main types: those comparing the measured flux of neutrinos at a particular place with the expected (computed) flux, and those comparing the neutrino fluxes measured by two detectors at different distances from the neutrino source. The two-detector method has the great advantage of not requiring an absolute value for the neutrino flux.

In addition, a search (of either type) can be characterized as an 'appearance' or a 'disappearance' experiment. Disappearance experiments look for anomalous variations in the

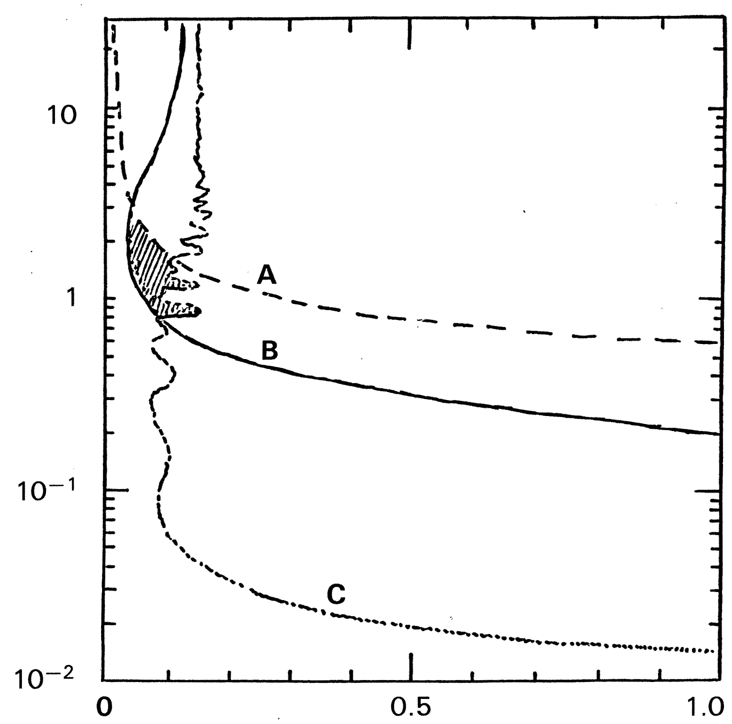
*Neutrino oscillation limits from (left) the Chicago / Columbia / Fermilab / Rochester experiment and (right) the CERN / Dortmund / Heidelberg / Saclay study. The vertical axis gives the possible squared neutrino mass (eV²), and the horizontal axis gives the neutrino mixing parameter. Both these experiments were looking for the disappearance of muon neutrinos. The region where oscillations are not ruled out is to the left of the curve in each case.*




flux of neutrinos of a particular type with distance, while appearance experiments look for neutrinos of a type not present in the initial beam.

Results are now available from three counter experiments (two at CERN and one at Fermilab) which simultaneously exposed two detectors at different locations.

The two CERN experiments were based on neutrino detectors which usually use beams from the 450 GeV SPS Super Proton Synchrotron. However for the oscillation search, they used instead a special 'low' energy neutrino beam using 19 GeV




*Neutrino oscillation limits from two 'appearance' experiments looking for definite neutrino transitions. Curve A is from the BEBC bubble chamber at CERN, curve B is preliminary data from the CERN / Hamburg / Amsterdam / Rome / Moscow ('CHARM') group at CERN. Curve C is from a 'disappearance' experiment by the Caltech / Munich / SIN group working at the Goesgen reactor. The units are the same as the diagrams above.*

protons extracted from the Proton Synchrotron.

Modules from the big CERN / Dortmund / Heidelberg / Saclay (CDHS) and CERN / Hamburg / Amsterdam / Rome / Moscow (CHARM) experiments in the West Experimental Area of the SPS were installed upstream, just 150 m from the source of the PS neutrino beam. Data recorded in these modules and in the main detectors, several hundred metres downstream, was then compared (see December 1982 issue, page 413).

Both experiments looked for the disappearance of muon neutrinos, and their results are in broad agreement. The CDHS study benefitted from having a lot of iron and gives more stringent limits. In addition, the CHARM studies also looked for the appearance of electron neutrinos, giving useful new limits.

At Fermilab, the Chicago / Columbia / Fermilab / Rochester experiment used a high energy 'narrow band' neutrino beam. The existing 1000-ton neutrino detector, about a kilometre downstream from the neutrino source, was supplemented by a smaller detector in the 'Wonder Building', where some of the early Fermilab neutrino experiments were carried out. Because of the high energy of the beam, this study was sensitive to higher neutrino mass differences than the CERN experiments.

The CERN low energy neutrino beam has also been used in a neutrino oscillation search using the BEBC bubble chamber, however for this study only one detector position is available. Other results using artificial neutrino beams come from experiments at Brookhaven and Los Alamos.

These laboratory neutrino studies are supplemented by searches at nuclear reactors in Switzerland (Caltech / Munich / SIN group), in France (Annecy / Grenoble) and in the US (Irvine). These experiments look for the disappearance of electron neutrinos, and are sensitive to very small neutrino mass differences, down to 0.01 $eV^2$. The detectors are placed at varying distances from the reactor so that signals can be compared.

More limits come from passive experiments (such as those searching for proton decay) which compare neutrino signals coming in from space with those traversing the Earth.

Measured in terms of the possible neutrino mass difference and the lepton mixing parameter (not given by any theory), the area where neutrino oscillations can confidently be ruled out is now very large. However there are plenty of unexplored corners still left, and neutrinos could still turn out to oscillate, albeit gently.

## Opening up nuclei with electrons

The US decision to build NEAL — Nuclear Science Electron Accelerator Laboratory — illustrates the increasing attention being paid to the use of high energy electron beams to probe nuclear structure.

Such electron probes have already produced interesting results. The energies available mean that fine details of nuclear structure can be examined, and new effects have been discovered which challenge conventional ideas of nuclear theory.

While these effects are small, this does not mean to say that they are not significant. The history of modern physics is littered with examples of precision measurements of subtle effects providing the first clues to new behaviour (Lambshift, 3K extragalactic background radiation, etc.).

Electron beams of some 700 MeV from machines at MIT and Saclay can probe below 1 fermi, while the 20 GeV SLAC beams can probe down to 0.1 fermi.

The elastic scattering of electrons on nuclei (where the electrons 'bounce' off their nuclear targets) reflect the general properties of nuclei and their collective excitations. Recent studies have revealed interesting new information on low energy nuclear structure and excitations.

Complementary information comes from deep inelastic scattering, where the incident electrons penetrate deep inside the nuclei and interact with individual nucleons, or even with the constituents of these nucleons. This provides information on the properties of nucleons in nuclear matter.

In the simplest possible picture, a single nucleon inside nuclear matter is assumed to behave like a 'Fermi gas'. This picture accounts for many of the observed general characteristics. However precision experiments soon reveal additional effects, and the picture quickly becomes more complicated. Additional mechanisms (nucleon excitations, meson exchanges, etc.) have to be introduced into the model in the hope of obtaining a more realistic description.

New observations also show that ground state charge densities of heavy nuclei such as lead (conventionally considered as a closed shell nucleus) show a smooth behaviour, without the oscillations predicted by conventional theory.

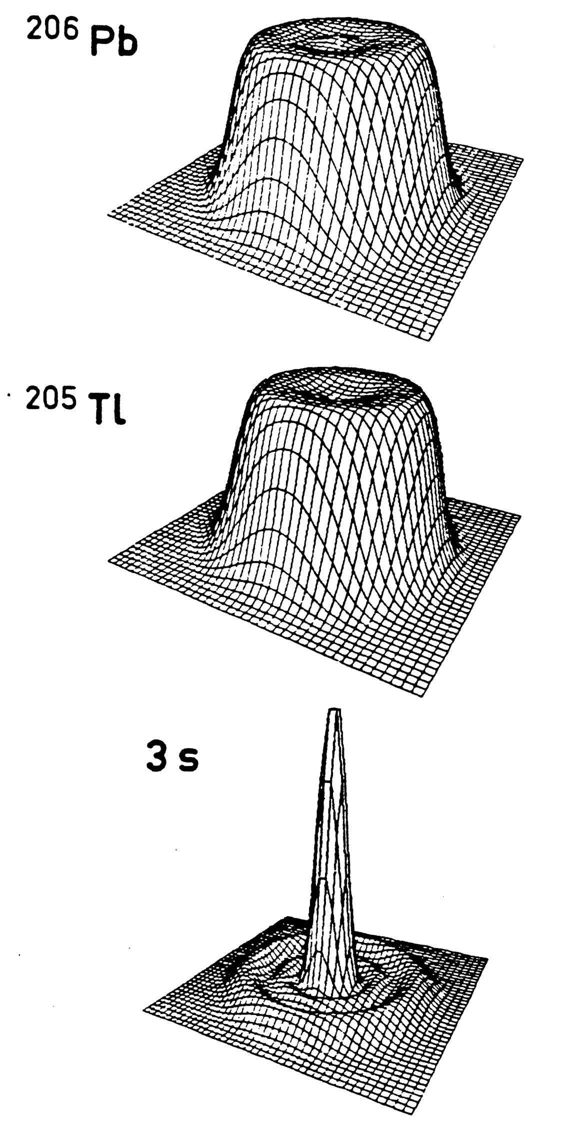
In an attempt to pin down these new effects, electron scattering experiments at Saclay looked at the adjacent nuclei of lead 206 and thallium 205. The difference between the behaviour of these two nuclei should be due to just one extra proton. Despite the high density of these nuclei, the contribution of this single proton is clearly seen, and is in itself surprising.

In addition, the nuclear charge densities, while following the shape of the theoretical prediction, are systematically suppressed by some 35 per cent.

Precision electron studies of nuclear magnetic densities enable measurements to be made of the properties of neutrons as well as protons, and provide valuable additional information to extend our knowledge of nuclear mechanisms. In some cases, it looks as though conventional ideas again have to be modified or extended.

Light nuclei provide an especially valuable means of studying few nucleon systems. New effects have been found in the observed form factors, and three-body forces and quark clusters are among the candidate mechanisms which have received attention.

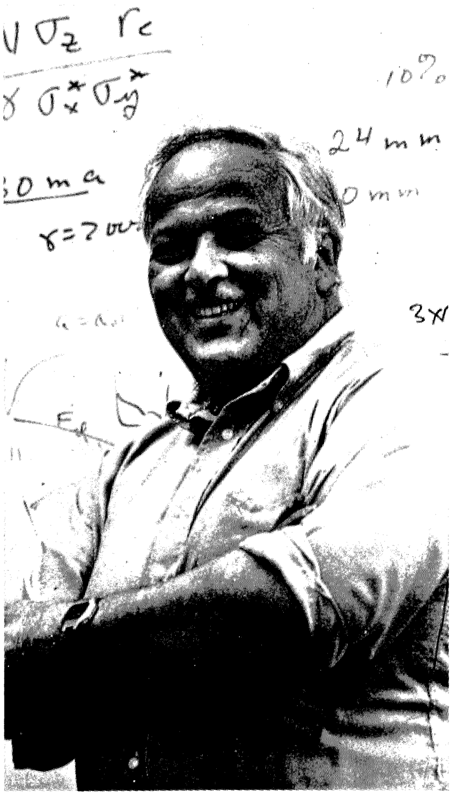
The increasing theoretical attention being paid to collective quark effects could pay off in light nuclei. Evidence for anomalous quark structure in nuclei has now been seen in a wide range of experiments (see January/February issue, page 19).

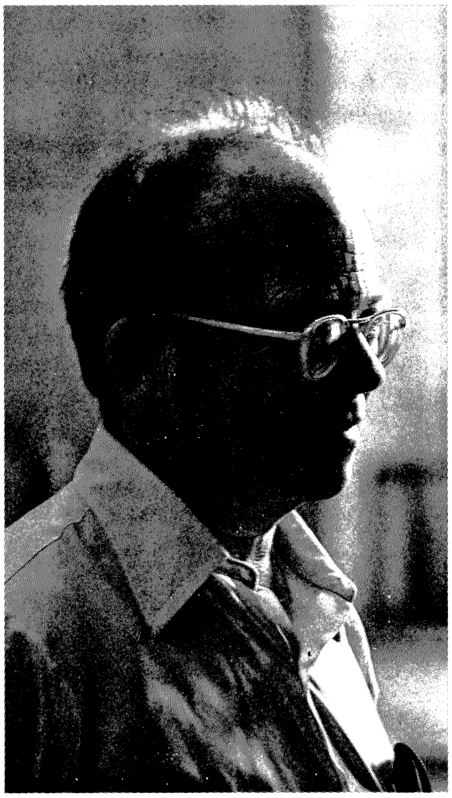



*Top, nuclear charge distributions of lead 206 and thallium 205, measured in electron scattering experiments at Saclay. The difference between the two distributions clearly shows the contribution of the single additional proton (3s orbit), surprising in view of the high density of these nuclei.*

# People and things

*SLAC Directors old and new. On 1 September Burt Richter (left) takes over from 'Pief' Panofsky (right).*





## Richter to head SLAC

*Some time ago, Wolfgang ('Pief') Panofsky, Director of SLAC since 1961 and one of the prime movers behind both the famous two-mile electron linac and the Laboratory itself, announced his intention to step down in 1984. Immediately a search began for a worthy successor.*

*It is no surprise that the SLAC Director from 1 September will be Burton Richter, SLAC's Technical Director since 1982. With Sam Ting, Richter shared the Nobel Physics Prize in 1976 for their discovery of charmed particles. As well as a physicist, Richter is also a machine heavyweight. He was one of the pioneers of electron-positron storage rings, and more recently, was the main architect of the current SLAC Linear Collider (SLC) project, which opens up a new era in accelerator design.*

*Underlining his preoccupation with future facilities, Richter says: 'High energy Labs have to do not only first-rate research now, but also have to look forward to the development of new research tools and accelerators so that we can continue to do research in the future. The real challenge is not so much to maintain what is going on, but to keep things moving and make sure that SLAC continues to be a first-rate institution five and ten years from now.'*

## On people

*Carlo Rubbia, leader of the UA1 experiment at CERN which last year discovered the W and Z particles, was named by the US science magazine 'Discover' as its 1983 'Scientist of the Year'.*

*Simon van der Meer, with Rubbia one of the major architects of the CERN antiproton project which made the W and Z discoveries possible, has been awarded an honorary doctorate by the University of Amsterdam.*

*Taiji Yamanouchi, Fermilab Assistant Director and Head of the Program Planning Office, received the 1983 Nishina Memorial Prize at a ceremony in Tokyo on 6 December. This prize is given to Japanese physicists who have performed distinguished work in the field of atomic and nuclear physics. Dr. Yamanouchi was awarded the prize for his accomplishments in high energy physics research, including his contribution to the discovery of the upsilon particle at Fermilab.*

*Taiji Yamanouchi*

*A special meeting was held at Bologna to mark the 70th birthday of Bruno Ferretti, who from 1956-58 was head of CERN's Theory Division.*

*A meeting 'Frontiers of Physics' was held recently at Bologna to mark the 70th birthday of Bruno Ferretti. After work at Bologna, Milan and Rome, he came to Geneva to head the CERN Theory Division in 1956. From 1958 to his retirement, he held Bologna's chair of Theoretical Physics. He has made important contributions to nuclear and particle physics, to quantum field theory, and to crystal physics. He proposed the first methods for determining the parity of the charged pions, and his ideas on baryon number conservation are particularly relevant to today's research. He is a member of the Accademia dei Lincei and of the Academies of Sciences of Bologna, Modena and Turin.*

*Georges Charpak of CERN has been awarded the 'Prix du Commissariat à l'énergie atomique' of the French Academy of Sciences for his work in developing high energy particle detectors.*

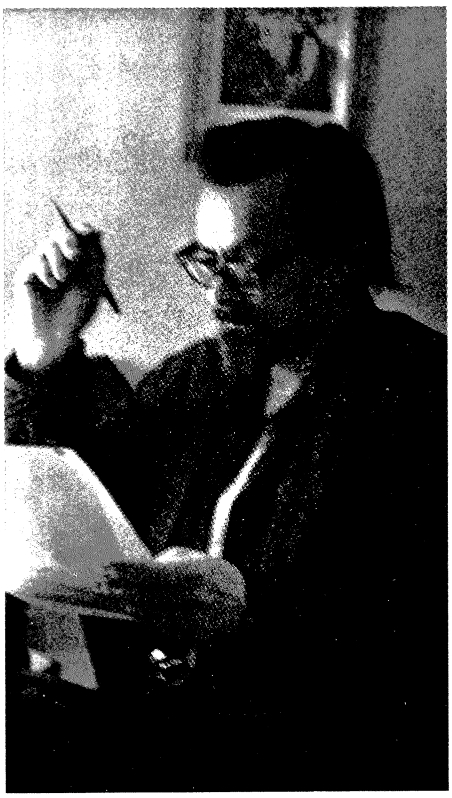
## Vladimir Jurko Glaser

*Vladimir Jurko Glaser died on 22 January, in his sixtieth year, after a serious illness. Born in Gorizia, Italy, on 21 April 1924, he studied at Zagreb, submitting a thesis in 1953 on work carried out in Göttingen under Heisenberg. In 1955 he became Head of Theory Division at Zagreb's Ruder Boskovic Institute, and in 1957 he came to CERN, where he was until his death one of the key figures in the Theory Division.*

*As a physicist he was deep, cultured and highly mathematical. His work in rigorous theory maintained a contact with reality, establishing a bridge between the abstraction of axiomatic field theory and the description of elementary particle collisions. In several basic papers, he set up the analyticity properties required for the use of dispersion relations in proton-proton and proton-antiproton collisions, the point of departure for the use of asymptotic theorems on maximum growth of cross-sections and comparison of particle-particle and particle-antiparticle collisions. He extended these results to production reactions. The recent use of antiprotons in the ISR and the SPS provides spectacular experimental proof of these results. Other work made important contributions to perturbative renormalization theory.*

*Jurko Glaser was interested in many fields: in quantum electrodynamics, on which he wrote one of the first modern texts; on field theory models, particularly that of Thirring; and a deep study of the Schrödinger equation, on which some of his work remains unpublished. His last work, on a 'spin glass' model, displays once more his remarkable mathematical prowess.*

*An exceptional teacher, some of his students became close longtime collaborators. A cultured man with widespread interests, warmhearted and full of ideas, he had many friends. He leaves a memory not only of a great physicist, but of a man of great spirit and generosity.*



*Vladimir Jurko Glaser, 1924-84.*

## Hadron collider workshop

*A CERN-ECFA Workshop to study the feasibility of hadron colliders which it might at some time in the future be possible to install in the LEP tunnel, is to be held at the University of Lausanne from 21-24*

March. This will be followed by summary talks in the CERN Auditorium on 26 and 27 March, which are open to all. The studies are in preparation for an international seminar on long-range prospects for high energy physics, organized by ICFA, to take place in Tokyo in May. Further information on the CERN-ECFA Workshop can be obtained from the Secretary of the Organizing Committee, Christine Petit-Jean-Genaz, at CERN, telephone Geneva 833275.

## 1984 US Accelerator School

Fermilab will host the 1984 US Summer School on High Energy Particle Accelerators from 13-24 August — the fourth in this series of summer schools.

The basic objective of the School is to boost US accelerator science in order to advance the frontiers of high energy physics. The School is intended for scientists and engineers interested in pursuing accelerator physics. A mixture of basic accelerator concepts and advanced topics will be presented. Plans for this year include extensive courses on the design principles of very high energy hadron (circular) and electron (linear) colliders.

Further information and application forms are available from M. Paul, School Secretary, Fermilab, Batavia, Illinois 60510, USA.

## 1984 CERN School of Computing

The 1984 CERN School of Computing, the eighth in the biennial series, is being organized in collaboration with the Instituto Estudios Energeticos (Junta de Energia Nuclear, Madrid) and the Facultad de Informatica, Barcelona, and will be held from 9-22 September at Aiguablava, Spain.

The theme of the School is 'Computing in the LEP era and beyond', reflecting the rapid evolution of technology in this area. This will be comprehensively covered in the programme, with courses covering microprocessors, data networks, underlying semiconductor technology, etc., as well as the requirements of LEP experiments.

The School is aimed at postgraduate students and research workers with a few years' experience in particle physics, computing, or related fields. Further information from Ingrid Barnett, Scientific Conference Secretariat, CERN, 1211 Geneva 23, Switzerland. Deadline for applications, 30 April.

## Physics for AGS II

The 1984 Users' Meeting of the High Energy Discussion Group (HEDG) at Brookhaven on 29-31 March will include a Workshop on the possible physics from an improved Alternating Gradient Synchrotron. The aim is for higher quality and more intense beams, using several machine, beamline and equipment improvements, including a beam stretcher and booster. Participation from physicists and machine experts outside the US is welcomed. Those interested should contact Mrs. L. Kouchinsky, Building 510F, Brookhaven Laboratory, Upton, New York 11973, USA.

Earthmoving for the Stanford Linear Collider (SLC) project. The aim is to finish construction by the end of 1986 so that physics can begin early in 1987. Behind the site can be seen the buildings of Stanford campus, and beyond, the San Francisco Bay and the coastal mountains. (Photo Stanford)

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# BEAMLINE PHYSICIST

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Candidates should have a Ph.D. degree in physics or engineering, or equivalent, and at least three years experience in design and construction of accelerator components. Salary will depend upon qualifications and experience.

Please reply in writing as soon as possible, outlining qualifications and experience to:

**TRIUMF Personnel (competition No. 431)**
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**4004 Wesbrook Mall**
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The On-Line Computing Support Group in the CERN Data Handling Division has a vacancy for a young

# PROGRAMMER

to develop and maintain general purpose support software and firmware for mini and micro computers, mainly in the domain of FASTBUS, a data collection and processing system for intelligent front-end electronics in future high energy physics experiments.

Candidates, who must be nationals of the Member States of CERN *, should have a university degree in physics, computer science or engineering, with a knowledge of programming scientific computers in both high level languages and machine code. Post-graduate experience in the latest techniques used in at least one of the following areas is desirable: real-time applications, computer interfacing, multi-processing, networking, computer simulation, scientific data management.

The ability to collaborate well with physicists and hardware designers is essential. A good knowledge of English or French and some knowledge of the other language is required.

For application forms, please write to:

**Head of Personnel,**
**CERN, 1211 GENÈVE 23, Switzerland**
**quoting the reference: DD-OC-249.**

* *CERN Member States are: Austria, Belgium, Denmark, Fed. Republic of Germany, France, Greece, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and United Kingdom.*

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# STANFORD LINEAR ACCELERATOR CENTER OF STANFORD UNIVERSITY

**announces an opening for the position of**

# ASSOCIATE DIRECTOR, TECHNICAL DIVISION

The Stanford Linear Accelerator Center (SLAC) is a major high energy physics research laboratory operated by Stanford University under contract with the U.S. Department of Energy. SLAC's Technical Division consists of groups that are responsible for operating and maintaining the large electron accelerator and colliders; for advanced research and development in the fields of accelerator physics and engineering; and for the general provision of technical services to the rest of the laboratory. The Associate Director, Technical Division, has primary responsibility for the leadership and management of this program under the general direction of the Laboratory Director.

Candidates for the position of Associate Director, Technical Division, must have had extensive and widely recognized experience as practicing scientists in the field of accelerator physics. The laboratory is seeking a person who is willing to play a strong leadership role in the years ahead.

The intended starting date for this position is 1 October 1984; the actual date can be a matter of negotiation. Applicants should submit a curriculum vitae, together with the names of at least three references, to Professor W.K.H. Panofsky, Chairman, Associate Director Search Committee, Bin 80, SLAC, Stanford University, P.O. Box 4349, Stanford, California 94305. SLAC is an equal employment opportunity employer.

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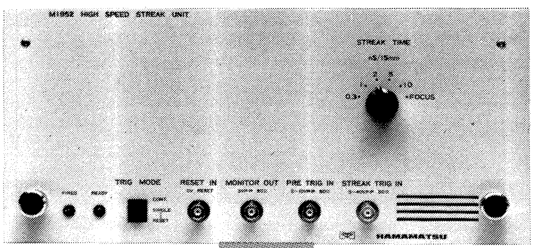

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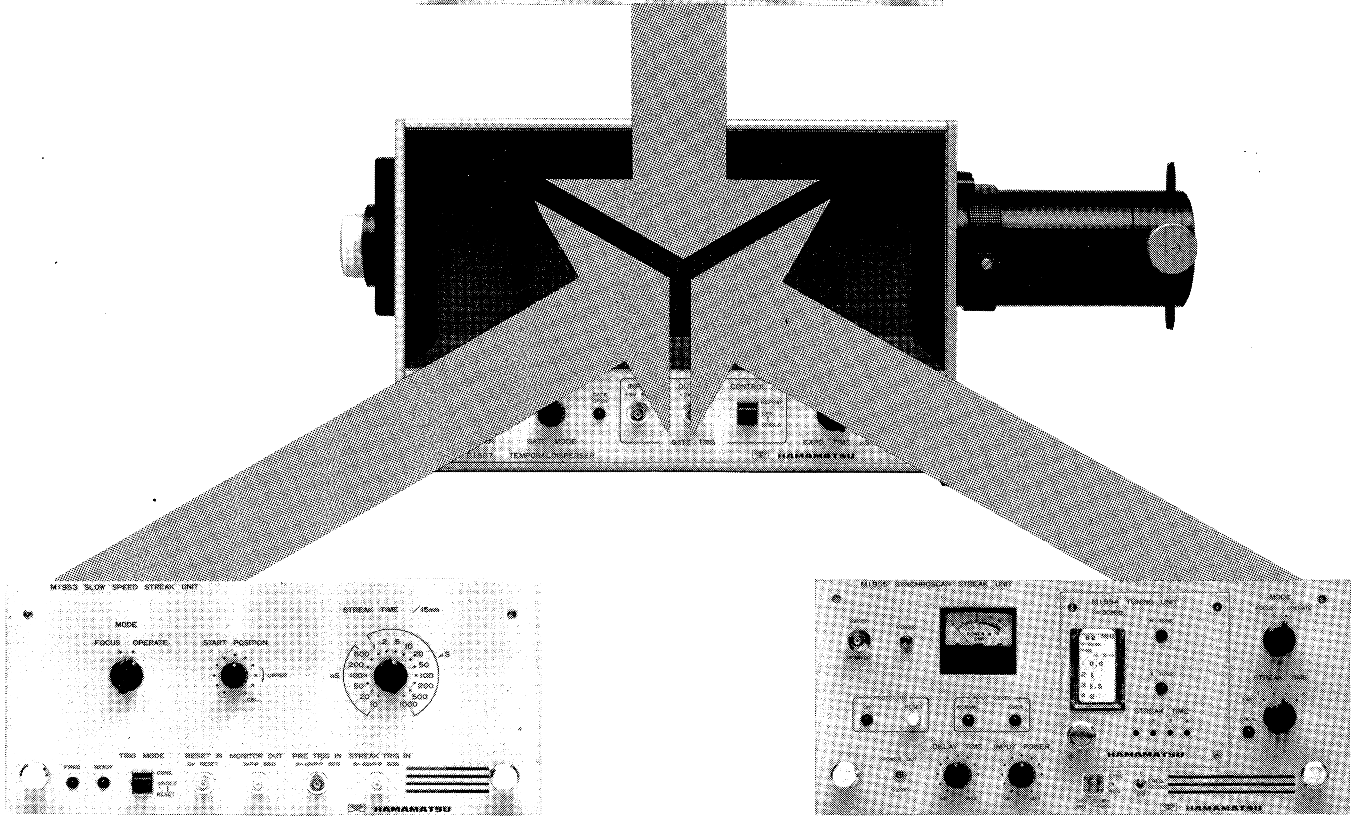

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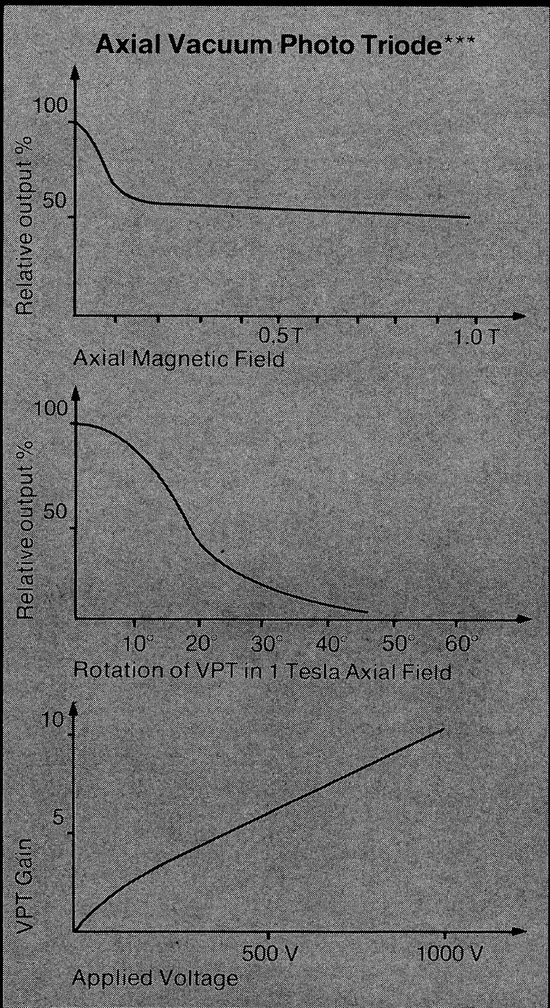
Axial Vacuum Photo Triode***
Relative output %
100
50
0.5T
1.0 T
Axial Magnetic Field
Relative output %
100
50
10°
20°
30°
40°
50°
60°
Rotation of VPT in 1 Tesla Axial Field
VPT Gain
10
5
500 V
1000 V
Applied Voltage


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**Format A4** **Monthly publication**

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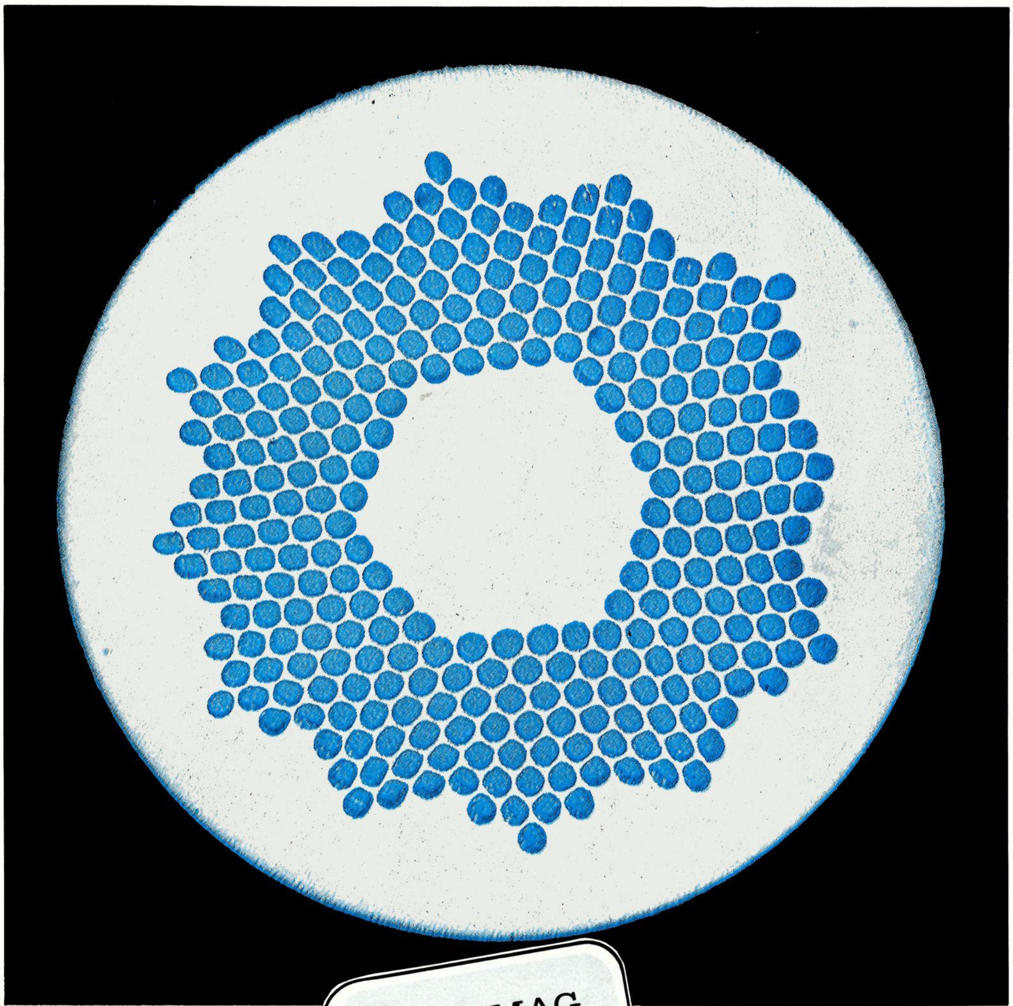
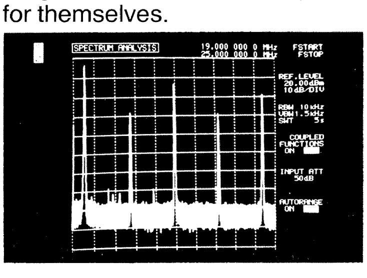



# Spectrum and Network Analysis Simpler and greater accuracy, at last!

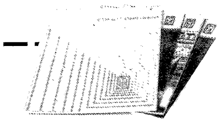
Precision, even with simpler operation? The SNA-1 Spectrum and Network Analyzer, 100 Hz to 180 MHz, offers both at the optimum.

**Simple operation:**
For overview measurements, the "analog" settings with three knobs for center frequency, sweep width, and level range are obviously useful. On the other hand, known parameters are best entered exactly and easily via the keypad. Thanks to the "softkeys", the rest is easy. Complete standard setups can be stored, or else setting and evaluation are taken care of by computer via the IEC 625/IEEE 488 Interface.

**Accurate measurements:**
The SNA-1 offers the stability of a synthesizer and the high accuracy of our classical level measuring setups, with which we have achieved such worldwide success. Indeed, bandwidths starting at 3 Hz and a level measuring range down to −130 dBm speak for themselves.




The evaluation? Very easy: calibrated electronic graticule, parallax-free readings, two digital measurement curve stores (measurement, reference/difference), superimposed measuring traces and tolerance limits as well as alphanumeric display of all important parameters.
For easy documentation, the complete formatted measurement results are shown on the video screen and are available as hardcopies from a graphics/video plotter or by photographic recording. Are you looking for such an instrument? Then just request detailed information about the SNA-1 and its interesting price.



Please send me:
☐ Information about the SNA-1
☐ An applications engineer to advise me

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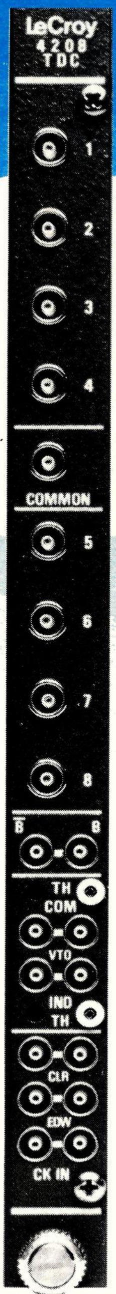
# "TIMING TWINS"

## NEW

## MULTICHANNEL WIDE RANGE

# Time Digitizer




### For Time-of-Flight Detectors and Mass Spectrometers

**CAMAC Model 4208**
**Time-to-Digital Converter**

- **8 Time Digitizers**
- **1 nsec resolution**
- **24-bit dynamic range**
- **Real-time technique minimizes dead time**
- **Common start or stop**
- **Flexible operation**

Designed for applications requiring wide dynamic range with high resolution and minimum dead time, the Model 4208 offers several configurations: eight independent channels, single channel multi-stop (8), dual channel multi-stop (4), and more. The design provides for a common start or stop mode to be used. Logic circuits and an external clock expand the time range beyond 16.6 msec. A fast clear is used to clear the unit in less than 50 nsec.

Whether your application is time-of-flight, mass spectroscopy, astronomy, laser ranging, synchrotron radiation, fusion or high energy physics, LeCroy provides the answer to your experimental problems.

For details call or write your nearest LeCroy sales office.

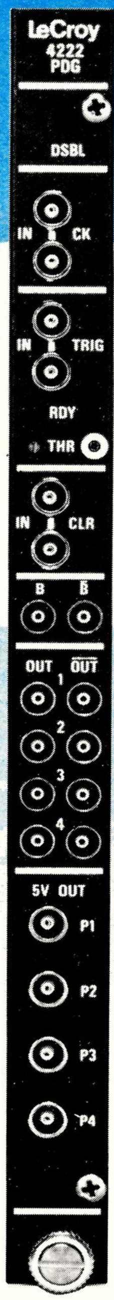
**LeCroy**

Rue Cardinal-Journet 27, 1217 Meyrin 1-Geneva, Switzerland, 82 33 55. Offices: USA, (914) 425-2000; Heidelberg, W. Germany, (06221) 28192; Les Ulis, France, (6) 907.38.97; Botley, Oxford, England, (0865) 72 72 75. Representatives throughout the world.

## NEW

## 4 CHANNEL, WIDE RANGE PROGRAMMABLE

# Gate and Delay Generator




*For:* **Process Control**
**Time-of-Flight Experiments**
**Drift Chamber Simulation**
**Precision Pulse Sampling**
**Test and Measurement**
**Calibration**

**CAMAC Model 4222**
**Wide Range, Gate and Delay Generator**

- **170 nsec to 16.7 msec (24 bits) dynamic range**
- **Programmable in 1 nsec steps**
- **4 channels of delay or 2 channels of gate**
- **Minimum dead time with real-time technique**
- **Single width CAMAC Module**

Designed for applications requiring long, accurate, time delays or precise time windows, the LeCroy Model 4222 replaces rack size units with a compact, easy to use, remotely programmable modular instrument.

The Gate and Delay Generator provides four delayed positive and negative outputs triggered by a common start or trigger. Delays may be programmed in 1 nsec steps over a 170 nsec to 16.7 msec range.

The unit may also be set to produce two precision time gates synchronized to a common trigger. Leading edge and trailing edge times may be independently programmed.

Whether your application is simulation, test and measurement, real-time industrial control, or physical and chemical research, LeCroy can provide the answers to your time generation problems.

For details call or write your nearest LeCroy Sales Office.

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