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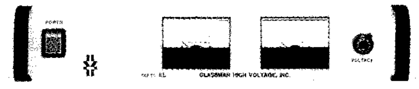
Cover photograph:
L3 over Lake Geneva. At a Norwegian-sponsored event for the Telecom international telecommunications exhibition in Geneva last year, specialist Janine Overney had the idea to project a laser image into screen of water fountains above Lake Geneva. One of the laser subjects was an electron-positron collision event recorded by the L3 detector at CERN's LEP ring.
(Photo Annelise Pachner)



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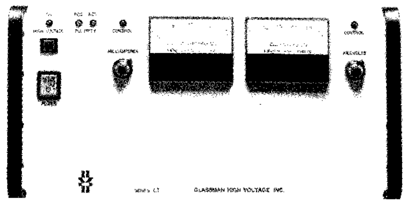

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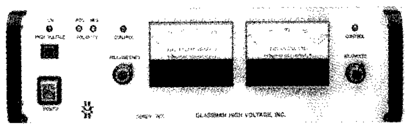

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Around the Laboratories

***Fermilab's Tevatron supplies the world's highest energy protons, at 900 GeV. The CERN Courier regrets the error in the June issue stop press.**

STANFORD
First SLC collisions with polarized electrons

Collisions between polarized (spin-oriented) electrons and unpolarized positrons began on 1 May at Stanford's SLC Linear Collider, less than three weeks after the new diode gun had been installed in early April. Polarization levels were typically 22 percent at the SLC interaction point, and about a thousand Zs were logged to tape by the SLD detector during the May engineering run.

Polarization levels of 25 percent have been routinely achieved with the new polarized gun, in which circularly polarized light from a Candela Dye laser strikes a cesiated gallium arsenide photocathode (May 1991, page 6). Substantially higher polarizations, close to 40 percent, are anticipated later this year when a tunable, longer-wavelength titanium-sapphire laser comes into operation. The photocathode has a typical lifetime of about 100 hours before its quantum efficiency falls to 1.5 percent. At this point the photocathode is cesiated again, which takes several hours and restores its quantum efficiency to 6-7 percent.

After a brief acceleration to 1 GeV, the electron spins are rotated by a superconducting solenoidal magnet into a direction perpendicular to the SLC damping ring. On exiting the ring, two more solenoids rotate the spins so that the electrons end up longitudinally polarized when they collide with positrons. Only minimal polarization losses are encountered during the entire process of spin rotation, acceleration in the linac, and transmission through the SLC arcs – resulting in 22-24% polarization at the interaction point, measured by a Compton polarimeter.

The SLC was operated in an engineering mode during the entire month of May. This run had the twin goals of raising the luminosity and learning to work with polarized electrons. At periodic intervals during this run, the SLD collaboration was able to log data; collection rates reached 10-12 Zs per hour. By month's end the SLD physicists had logged about a thousand Zs to tape, while running with polarized electrons. The current SLC schedule calls for collisions with polarized electrons to continue at least through September.

The SLD detector at Stanford's SLC Linear Collider is recording Z events from polarized (spin oriented) electrons. (Photo Harvey Lynch)

DESY
HERA protons at 820 GeV

On Friday 15 May at 7.25, a 85-microamp proton pulse was accelerated in the 6.3 kilometre superconducting ring of the DESY Laboratory's new HERA machine to the design energy of 820 GeV and stored.*

This follows initial commissioning last October when HERA protons were taken from the injection level of 40 GeV to 480 GeV (January/February, page 12).

HERA is the world's first electron-proton collider, and its (non-superconducting) electron ring was commissioned in 1988, when beams were taken to 27.5 GeV. When the proton ring came to life last October, the electron ring came into action

The Gallex (gallium-based) solar neutrino experiment in the Gran Sasso underground Laboratory in Italy has seen evidence for neutrinos from the proton-proton fusion reaction deep inside the sun. A detailed report will be published in our next edition.

again, with particles taken to 26.5 GeV and initial evidence for electron-proton collisions being seen.

Earlier this year, the big Zeus and H1 detectors were moved into position to intercept the first HERA collisions, and initial results from this new physics frontier are eagerly awaited.

HERA collisions

During the night of 31 May – 1 June, the HERA machine at the DESY Laboratory in Hamburg provided its first collisions between peak energy (820 GeV) protons and 26.7 GeV electrons. A 35 microamp proton pulse and a 140 microamp electron pulse were stored and collided in both experimental areas. Initial luminosity was measured at 1.5×10^{27} per sq cm per s and both the H1 and Zeus detectors were able to record and measure collisions. The HERA experimental programme has begun.

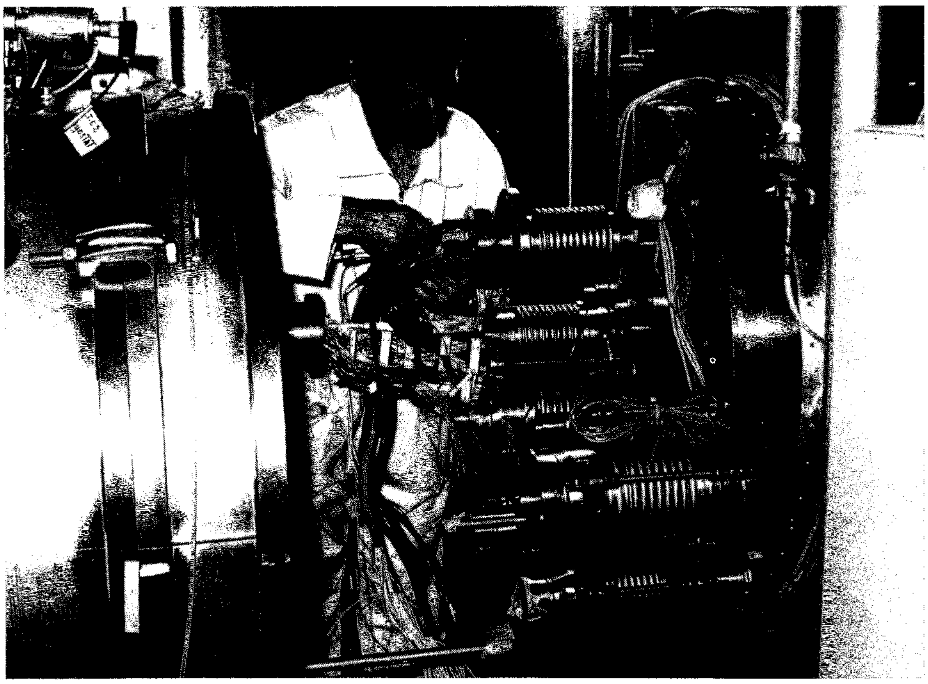
CERN LHC magnets

With test magnets for CERN's LHC proton-proton collider regularly attaining field strengths which show that 10 Tesla is not forbidden territory, attention turns to why and where quenches happen. If 'training' can be reduced, superconducting magnets become easier to commission. Tests have shown that quenches occur mainly at the ends of the LHC magnets. This should be rectifiable, and models incorporating improvements will soon be reassembled by the industrial suppliers.

New models are also being constructed to test different designs as well as alternative components and materials. A design with individual single collared coils is particularly promising, allowing the coils to be sorted according to multipole errors prior to installation. More single aperture models are also foreseen to test coil and collar assemblies and a new conductor distribution will further improve multipole components.

A number of other models and prototypes are being built elsewhere including a twin-aperture model at the Japanese KEK Laboratory and another in the Netherlands (FOM-UT-NIHKEF). The latter will use niobium-tin conductor, reaching for an even higher field of 11.5 T. At KEK, a single aperture configuration was successfully tested at 4.3 K, reaching the short sample limit of the cable (8 T) in three quenches. This magnet was then shipped to CERN for testing at the superfluid helium temperatures to be used at LHC.

A full length twin-aperture magnet (TAP) built in industry has been tested at the French Saclay Laboratory (May, page 5). This uses coils developed for the HERA superconducting proton ring at DESY, Hamburg, with a correspondingly lower central field. At 4.5 K the coils be-



At the French Saclay Laboratory, a high field twin aperture magnet of a type similar to that envisaged for CERN's LHC proton collider is prepared for tests.
(Photo CEA Saclay)

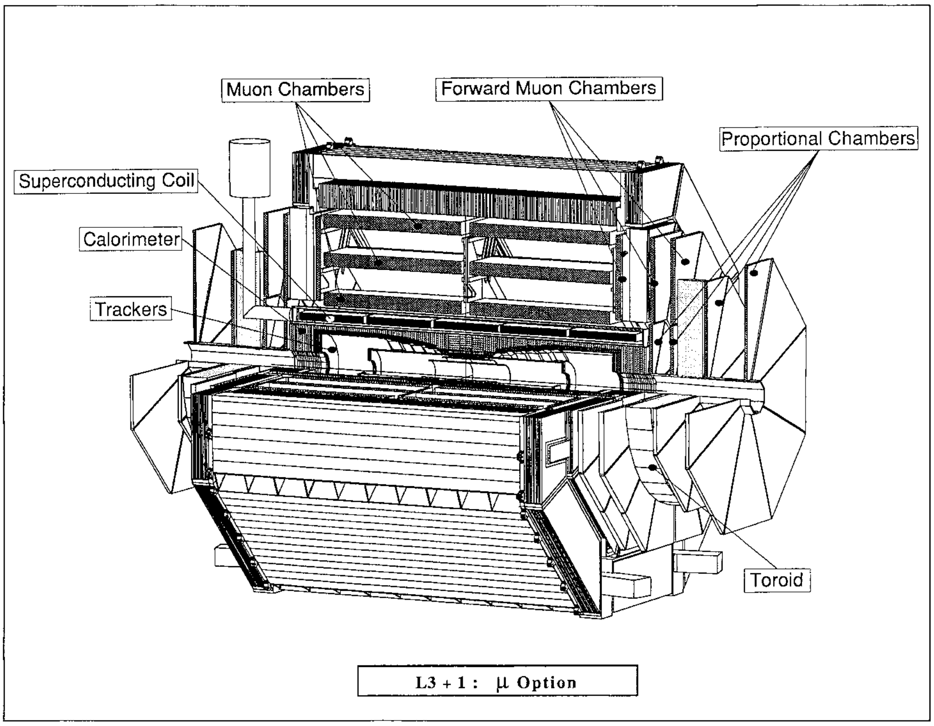
haved exactly as in the standard HERA magnets, going straight to 98% of their short sample field, while at 2 K the short sample field of 8.3 T was reached after only four quenches.

Manufacture of seven of the ten full-size prototypes being built in European industry is quite advanced, with three different variants of the mechanical structure, collars and yokes being used. The first magnet, in its cryostat, is scheduled for delivery early next year. Some of these will be used in the half-cell string tests next year, seen as an important milestone for LHC progress.

Meanwhile studies have shown how the LHC magnet lattice can be usefully optimized. The total length of LHC bending dipoles has been increased by five per cent, with each basic (half-cell) unit containing three magnets each 13.58 m long instead of four of 9.45 m as described in the original 'Pink Book' design. This reduces the magnetic field needed to hold the LHC beams in orbit while maintaining the maximum beam energy.

The original design aimed at four magnets per half-cell because it was then thought important to have central correctors. These central correctors are now replaced by small magnets incorporated in the ends of each dipole.

The new design requires fewer magnets (1152 instead of 1600) with correspondingly fewer connections. If training problems are confined to the ends of the magnets, longer ones should not be any harder to make (the US Superconducting Supercollider – SSC – uses magnets over 15m long). Fewer, longer magnets should also reduce production, testing and installation costs.



The muon option for the L3+1 idea for an LHC proton-proton collision detector could be set up rapidly from the existing L3 LEP electron-positron collision detector.

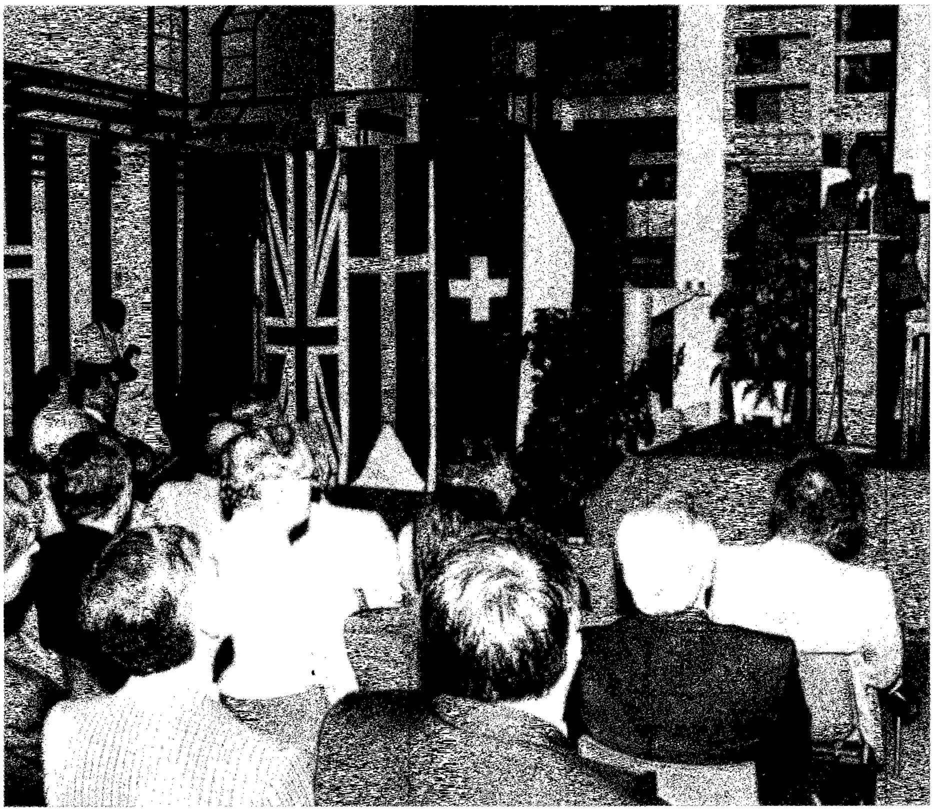
Lifted from L3

Among the major Expressions of Interest for studying proton-proton collisions at CERN's LHC collider (along with ASCOT, CMS and EAGLE – May, page 1) is the L3+1 scheme. This is based on the existing L3 experiment at the LEP electron-positron collider, where much effort went into taking a detector which would eventually be compatible with a high energy proton collider. The LEP tunnel was built with two colliders in mind.

For LHC operation, the L3 structure would have to be lifted from its present position in the LEP beam to the LHC beam level about a metre above. Thus L3+1 is an upgrade in more senses than one.

For L3+1, two options are being studied, both making use of the L3 magnet and existing muon chambers. A configuration studying muons and electrons could be set up rapidly, while a second alternative looking at electrons, muons and gammas uses the large magnetic volume, with electromagnetic detectors 3 metres from the interaction point.

Double celebration



A new setting for a CERN physics tradition. CERN Director General Carlo Rubbia inaugurates CERN's ISOLDE on-line isotope separator in its new home in a specially built experimental area at the 1 GeV Booster accelerator.
(Photo CERN 51.5.92)

26 May was a double celebration at CERN – the formal opening of the ISOLDE on-line isotope separator at its new home at the 1 GeV Booster accelerator, and the twentieth anniversary of the first acceleration of Booster beam to 800 MeV, the machine's nominal energy before its upgrade to 1 GeV in 1988.

Introducing the proceedings, held in the new ISOLDE experimental hall, CERN Director General Carlo Rubbia sketched the evolution of the ISOLDE idea at CERN from initial thinking in the early 1960s and the commencement of operations in 1967 at the 600 MeV synchrocyclotron (SC).

After its distinguished career at the SC, closed in December 1990, ISOLDE now reemerges in its new Booster environment. The old SC was a stand-alone machine, never integrated into the CERN beam network, so with ISOLDE resited at the Booster all CERN's experimental facilities become interconnected.

Rubbia pointed out how the Booster, after twenty years valiant work as a 'service' machine, now has its own experimental area, while the new ISOLDE benefits from the Booster's higher energies, pulsed beams and easier availability. The result demonstrates CERN's increased effectiveness, addressing wide scientific horizons and catering for a broad scientific community with an improved, and at the same time more economical, facility. Finally the Director General pressed the button to bring online the Booster beam for ISOLDE.

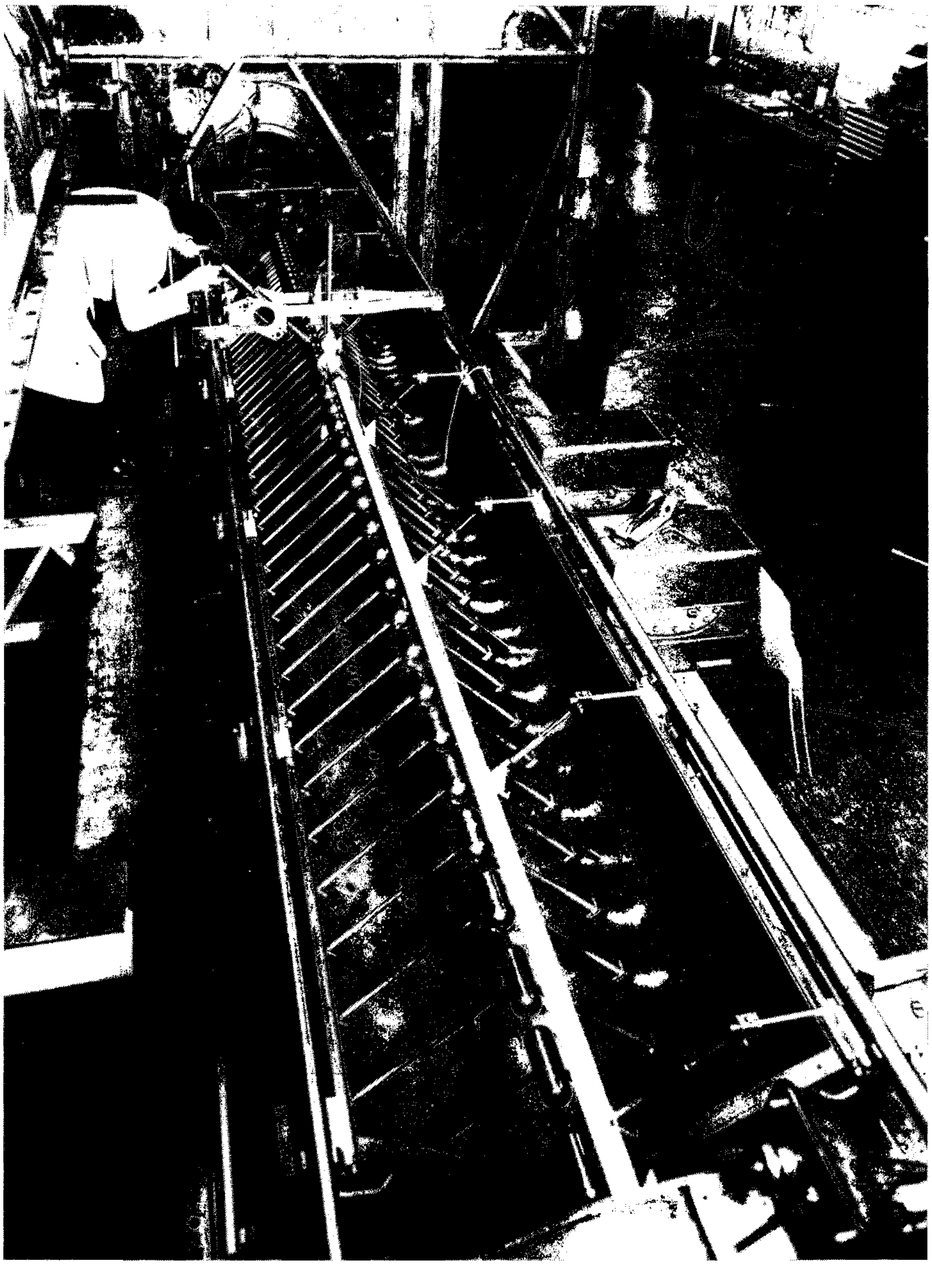
Bjorn Jonson of Göteborg, Chairman of the ISOLDE Experiments Committee, outlined the broad sweep of the new ISOLDE physics programme, where initial experiments approved last year (December 1991, page 3) have now been joined by four more. As well as exotic nuclear decays and nuclear properties, the ISOLDE programme covers particle physics topics such as searches for axions and heavy neutrinos, the very interesting new field of nuclear astrophysics to study how heavy elements could have been formed in supernovae, and specialist areas of nuclear solid state physics with implications for materials science, together with biophysics and nuclear medicine. In addition, the ISOLDE tradition of research and development work for new types of nuclear beams will continue.

Nuclear Physics European Collaboration Committee (NuPECC) Chairman Claude Detraz praised the achievements of international scientific collaboration and underlined the potential of new physics using radioactive ion beams, a topic highlighted in the recent NuPECC report (March, page 1). With the advent of new nuclear beams, 'astrophysics becomes a laboratory science,' remarked Detraz, who looked forward to ISOLDE's continued success.

End of the line for Linac1

In May, CERN's oldest functioning machine, the Linac1 linear accelerator, was finally switched off after a varied career lasting 33 years. After several weeks this year providing sulphur ions, a typical final act included supplying oxygen ions to the nearby LEAR low energy 'antiproton' ring in some tests exploring the heavy ion beam cooling procedures

Examining CERN's linear accelerator prior to commissioning in 1959. This machine, later known as Linac1, remained operational for 33 years, and was finally switched off in May.



which eventually will be needed to inject ions into the LHC ring to be installed in CERN's 27-km LEP tunnel.

Built using tried and tested techniques as the injector for CERN's 28 GeV proton synchrotron, Linac1 came into action at its 50 MeV design energy in 1959. Despite its conservative design, it surpassed all expectations, going on to supply proton currents well above 100 milliamps.

Despite these sterling performances, the machine began to show signs of wear and tear (or so people thought), and in 1973 construction began of a new linac, Linac2. This came into operation in 1978.

Linac1 soon found a new role supplying beams of deuterons and alpha particles for subsequent acceleration, as well as test beams for the nearby LEAR ring. With the arrival of the compact r.f. quadrupole preinjector, the old Cockcroft-Walton apparatus could be taken away, liberating space in a linac area crowded by transfer lines. Linac1 was pushed back 12 metres and additional shielding installed, making for more comfortable conditions, and enabling installation work for the heavy ion project to proceed in parallel with normal PS working.

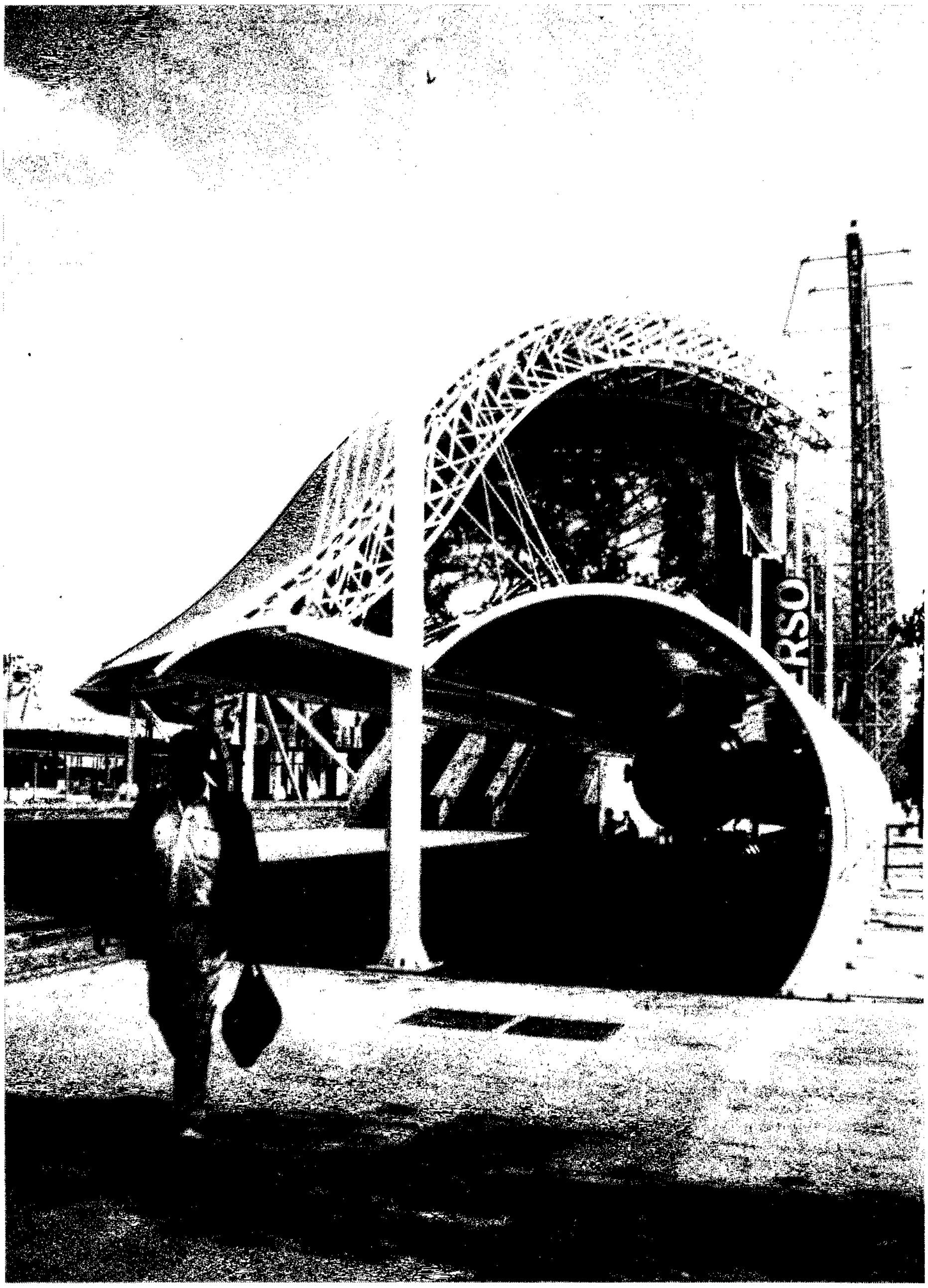
Soon after came a proposal to embark on a new CERN experimental programme using beams of oxygen ions. Despite a crowded schedule at CERN, the project got underway as a collaboration between CERN, the Darmstadt GSI Laboratory (beam transport) and Berkeley (radiofrequency quadrupole preinjector). Grenoble was GSI's contractor for the ion source. The elements gradually came together, and the refurbished Linac1, with 33% higher accelerating fields, came back online in June 1985.

A few years later, an upgraded ion source, again supplied by GSI Darmstadt and built by Grenoble, was installed to supply experiments with sulphur ions.

For the future, with experiments using still heavier ions, a new linac will be supplied by a collaboration of European and Indian laboratories, and with additional finance from Sweden and Switzerland (April, page 10).

See CERN at Seville

A six-month fiesta is underway in the unique Spanish city of Seville, where the EXPO '92 World Fair opened in April. It was in Seville five hundred years ago that Columbus planned his



CERN features prominently in and around the 'Pavilion of the Future' at the EXPO '92 World Fair in Seville.. A 25-metre mock-up of the tunnel for CERN's LEP electron-positron collider has been erected outside, and the entrance hall of the building is adorned with a huge painting of an event from the Delphi experiment at LEP. (Photo CERN EM36.5.92)

epic voyage of discovery. With discovery the theme of EXPO '92, science has much to contribute.

CERN's particle physics research is a prominent feature of the 'Universe' exhibition in the 'Pavilion of the Future'. The hall is easy to spot because a 25-metre mock-up of the tunnel for CERN's LEP electron-positron collider has been erected outside, and the entrance hall of the building is adorned with a huge painting of an event from the Delphi experiment at LEP.

Inside the hall, 16 square-metre banks of spark chambers reveal the cosmic ray particle messengers from outer space. Alongside is a Charpak-type detector showing the activity from gently radioactive elements.

The research tools of CERN are depicted with a huge aerial photograph on which LEP beams swirl and collide. LEP events from all four detectors – Aleph, Delphi, L3 and Opal – explode on large TV screens and even at a tenth of the scale, a model of the L3 detector communicates the size and complexity of modern physics apparatus.

Dominating the wall of the exit hall is a spectacular 8-metre diameter back-lit photograph of the Aleph 'rosette' with a laser beam, traversing the length of the hall, simulating the orbiting particle beams. Over seven thousand people a day are visiting.

For more formal contacts, CERN also has a stand in the Ambiente Pavilion, where the emphasis is on technology. In view of its special contributions both to the expo and to European science, CERN has been accorded a special day on 30 September – the anniversary of the signing of the CERN Convention in 1954 and always looked upon as CERN's birthday. The 'CERN Day of Science' will feature a parade, 'physics in the street' – a contact with the public, an award ceremony for young scientists, a televised debate on science and the future, and a ballet with the theme 'The birth of the Universe'.

Canada's pavilion features the Sudbury Neutrino Observatory

project (January/February 1990, page 23).

Join the fiesta!

The CERN Accelerator School "Magnet Class of '92" on the lakeside at in the mid-March sunshine enjoying a brief beak from a crowded programme.

Accelerator school

Anyone eavesdropping on a technical discussion among accelerator experts might be forgiven for thinking that their main business concerned the construction of huge electromagnets of both the warm and cold variety. It might therefore come as a surprise to find that the recent course on Magnet Measurement and Alignment organized by the CERN Accelerator School (CAS) was the first of its kind in the CAS series of specialist courses. (There has been a crowded menu of schools on other topics such as superconductivity and radiofrequency.)

But it was no surprise to find that the new topic turned out to be very popular. There were well over a hundred participants from almost a score of countries, eager to learn the arts of making and using search coils and using both Hall probes and NMR to make the numerous high precision measurements necessary to ensure that large accelerators perform as they should. The lectures also covered the basic classification of magnets and design theory as well as the state of the art in aligning them to their ideal geometry.

The next CAS events are the General Accelerator School (7-18 September) at Jyvaskyla in Finland and the Joint US-CERN School on electron-positron Factories (29 October-4 November) at Benalmadena in Spain. The deadlines for applications are 15 June to CASFIN@CERNVM.CERN.CH and 1 Aug to CASUS@CERNVM.CERN.CH respectively, or by fax to +41 22 782 4836.

ORSAY
CLIO free electron laser

CLIO – Collaboration for an Infrared Laser at Orsay – is in operation and will soon provide a high peak power source of coherent infrared radiation with adjustable wavelength.

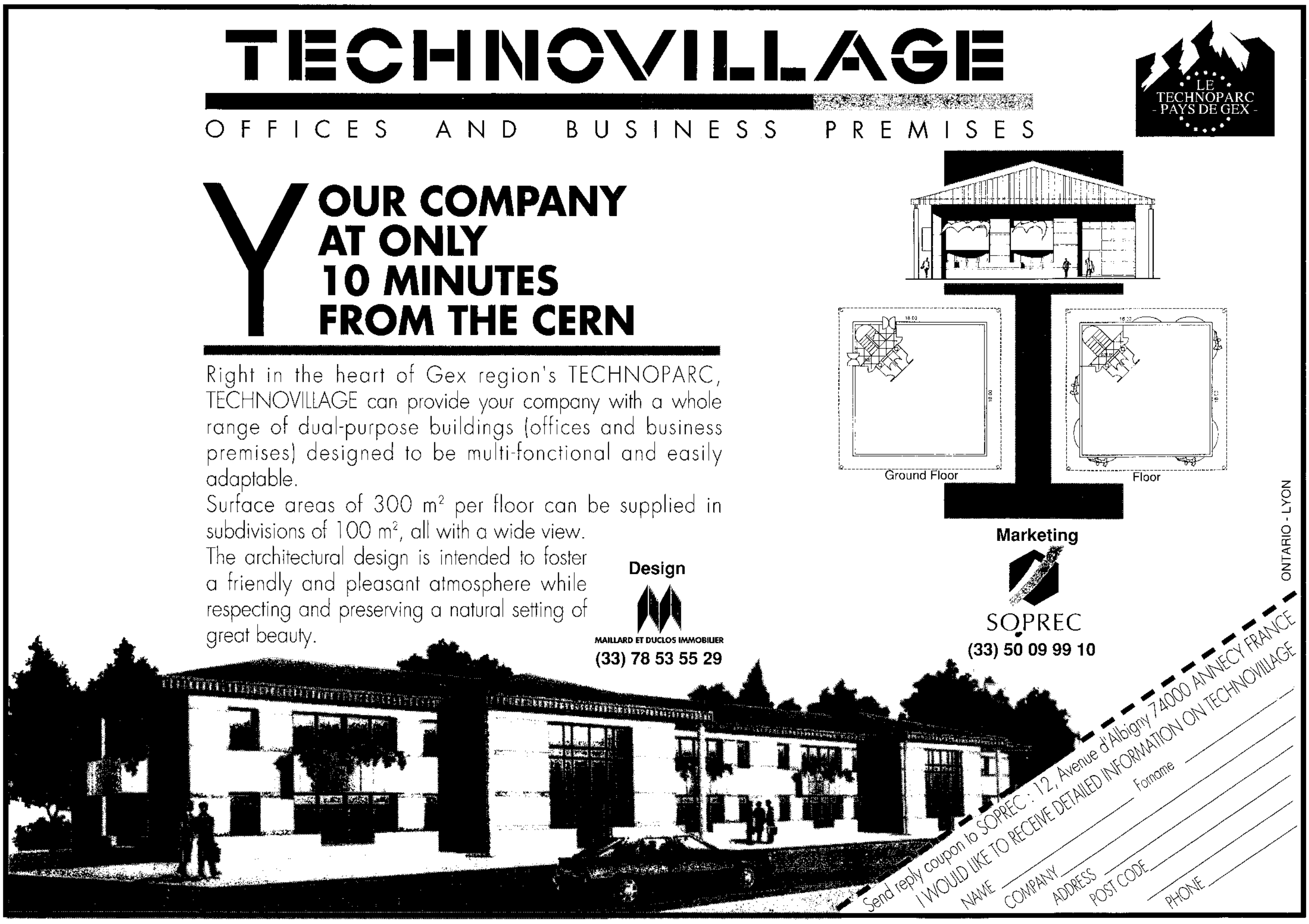
Conventional lasers amplify light by exciting bound electrons. They generate light with a well defined wavelength, but some applications ask for a broad range of wavelengths. This flexibility, together with massive intensities, is provided by free-electron lasers (FEL).

CLIO at Orsay is the latest in a line such lasers. John Madey at Stanford in the mid 1970s was the first to demonstrate the idea. Since then, numerous FEL projects have seen the light of day in different parts of the world. Some 15 devices have 'lased' so far.

Two or three machines of the CLIO type are operating in the United States, while in Europe, there are two such machines: FELIX (20-100 microns) in the Netherlands and CLIO (2-20 microns) in France. One is nearing completion at Darmstadt in Germany, and another, LISA, is under construction in Italy.

CLIO began in 1987 as an initiative of Orsay's Electromagnetic Radiation Utilization Laboratory (LURE), in collaboration with LAL, the Linear Accelerator Laboratory, which contributed in a major way to the project (15-20 people). A French Atomic Energy Commission team was also involved.

The electrons in CLIO's laser drive beam are arranged in very short (10 ps) microbunches grouped together in 'trains' of 10 microsecond bursts



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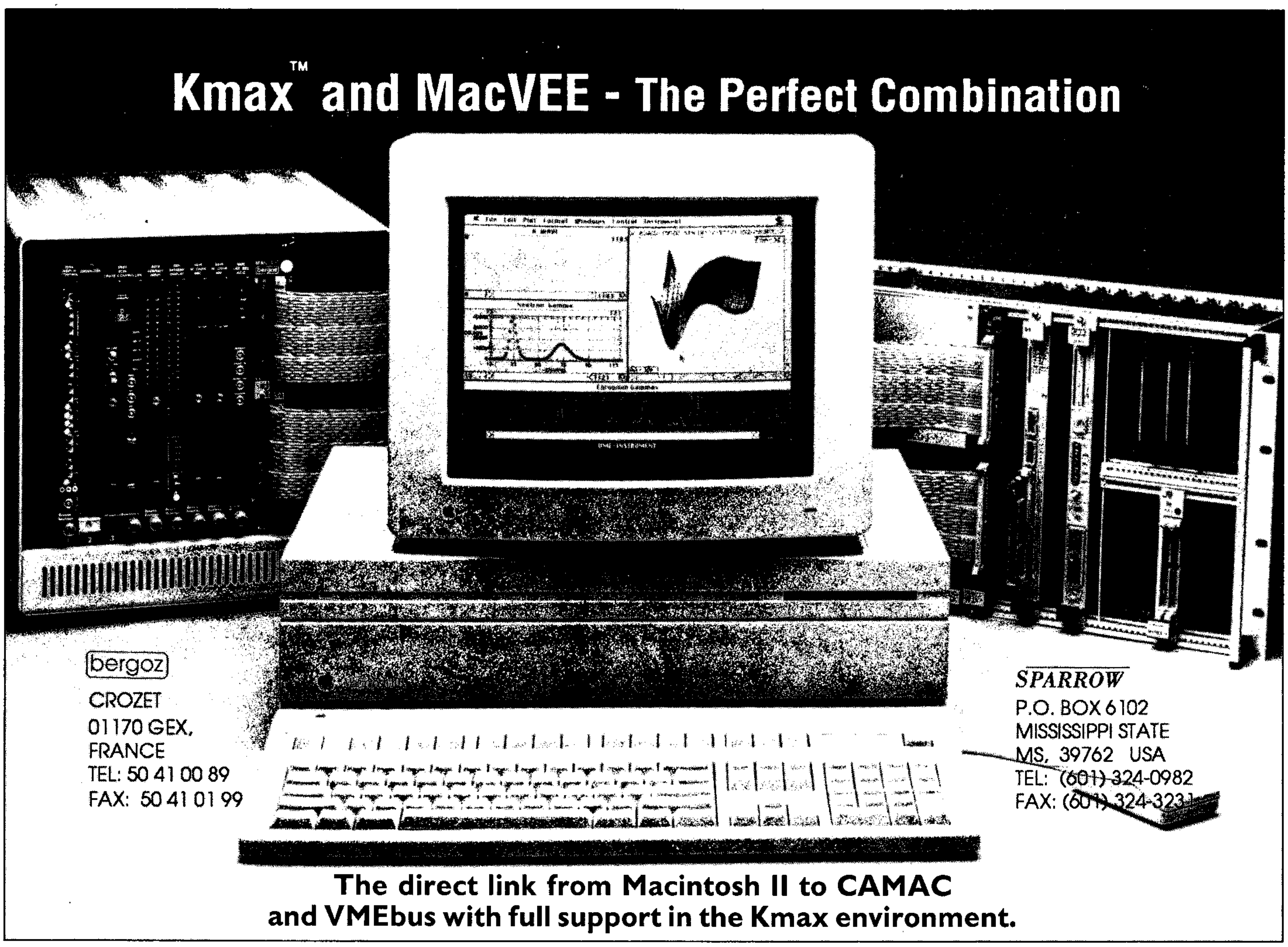

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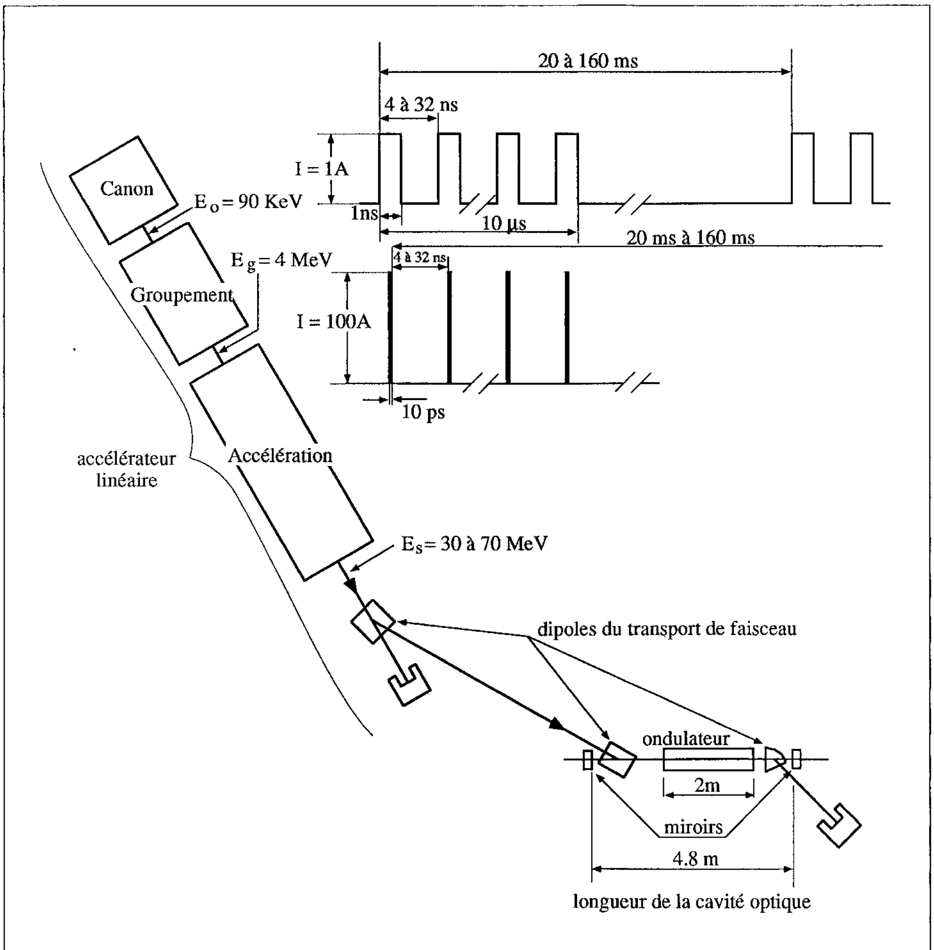
Schematic of the CLIO free electron laser at the French Orsay Laboratory. From the left, electron gun, buncher, acceleration system, beam transport dipoles, undulator. The electrons in CLIO's laser drive beam are arranged in very short (10 ps) microbunches grouped together in 'trains' of 10 microsecond bursts (macropulses). In each burst the very intense and low emittance microbunches are separated by a few ns.



(macropulses). In each burst the very intense and low emittance microbunches are separated by a few ns.

These electrons are routed towards an optical cavity (a space between two metallic mirrors) housing an undulator, a magnetic system consisting of a series of permanent magnets with alternating polarities which 'shakes' the electrons. These emit synchrotron radiation which, when coupled to the electron microbunches, trigger the resonant amplification process. This happens only if the electron microbunches and the light wave oscillating in the optical cavity are synchronized.

The wavelength of the laser beam is inversely proportional to the square of the electron energy and depends also on the square of the maximum transverse magnetic field (adjusted by varying the distance between the poles of the permanent magnets). With the energy of the linear accelerator and the undulator's magnetic field both adjustable, the wavelength range covered by CLIO will extend from 2 to 20 microns. The instantaneous laser power can reach up to 10 MW. CLIO will therefore be a coherent light source with potential use in different branches of research and industry such as molecular physics, photochemistry, surface and materials sciences, biology, etc.

Compared with a conventional accelerator, a linear accelerator used as an electron source for a FEL includes specific features: energy spread less than 0.25%, low emittance, strong peak current (30 - 100 A), short microbunch duration (10 – 20 ps), long macropulse duration (some 10 microseconds), and large variations in average power and energy.

The choice of technical parameters drew on experience gained by the LAL teams in the design and construction of the LEP pre-injector (LIL) for CERN, by the LURE team's work with storage rings and by the Los Alamos and Stanford teams in the United States that have already produced FELs in the same wavelength band. Beam dynamics simulation studies confirmed the choices.

Injection is the most complex part of the CLIO accelerator since the performance of the laser depends on injection parameters. An electron gun provides nanosecond electron pulses with a 1A peak current to a prebuncher (r.f cavity resonating at 500 MHz), followed by buncher (r.f. standing wave structure operating at 3 GHz). The two devices shorten the electron pulses to produce 10 ps microbunches with 100 A peak current.

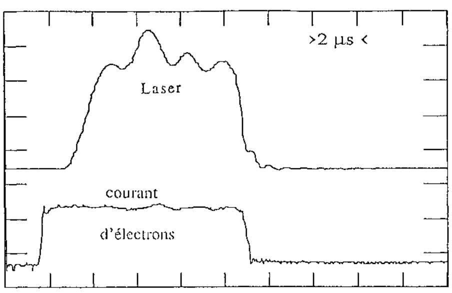
A microwave travelling wave structure operating at 3 GHz accelerates the microbunches to energies between 30 and 70 MeV without altering their characteristics. The necessary pulsed r.f. power is supplied by a 20 MW klystron produced by the Thomson company.

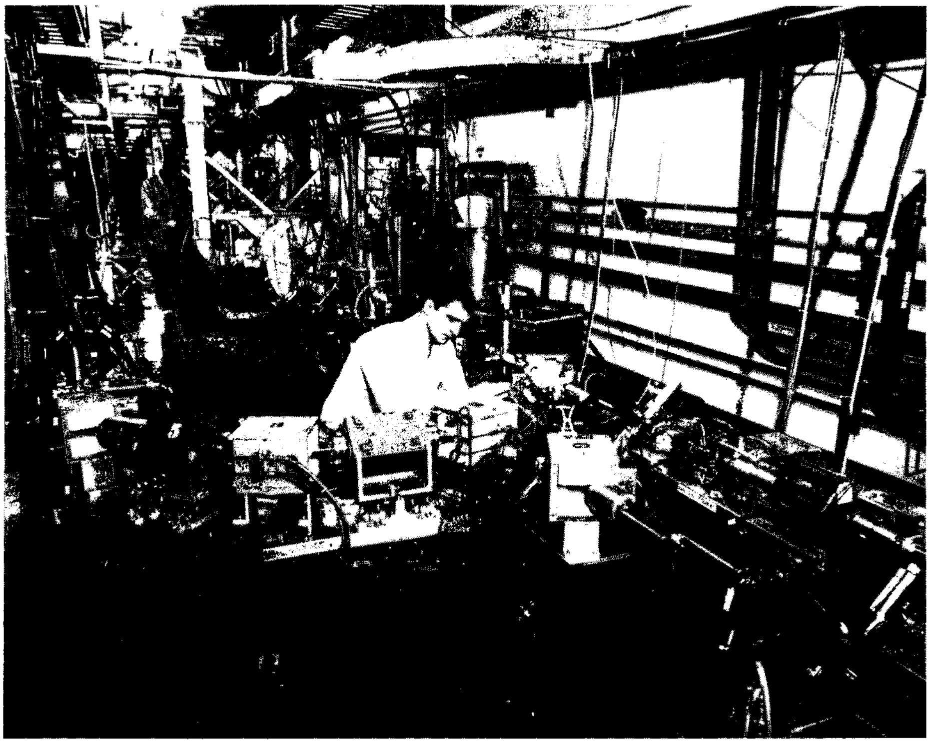
The magnetic elements transporting the microbunches to the undulator minimize the transverse size of the microbunches and allows their trajectory in the undulator to be adjusted to optimize the interaction between the electron and light beams. It also helps send the beams into the optical cavity without the electrons striking or destroying the mirrors.

Construction and development of the accelerator and the optical parts took five years. After injector beam tests in late 1990, 1991 measurements of the electron beam passing through the undulator showed that the required standards had been reached. Lasering was observed on 17 January this year at 4.8 microns; laser saturation at 8 microns was obtained on 18 February and a peak power of several megawatts on the microbunches was obtained a few days later.

The results are very reproducible in the 5-10 micron band in the ground mode with a 60-70% gain at 8 microns, a saturation time of 2-3 microseconds and a laser macro-pulse duration of some 8 microseconds. The yield obtained for the power transfer from beam to laser is some 0.35% against a theoretical value of 0.5%. CLIO can now be considered operational. Wavelengths lower than 5 microns and higher than 10 will be obtained by regulating the machine's energy at 50 and 30 MeV respectively (in place of the present 40 MeV).

CLIO laser saturation at a wavelength of 8 microns.





Extensive 45 MeV injector testing has validated the basic superconducting design of the 4 GeV accelerator at CEBAF, the Continuous Electron Beam Accelerator Facility under construction in Newport News, Virginia. In an encouraging test of the CEBAF design, a temporary beamline (foreground) has recycled beam through the linac to reach 85 MeV.

CEBAF Injector in operation

Extensive 45 MeV injector testing has validated the basic superconducting design of the 4 GeV accelerator at CEBAF, the Continuous Electron Beam Accelerator Facility under construction in Newport News, Virginia. The injector has met all beam performance objectives, using production hardware and software similar to that being installed in the recirculating accelerator, including 18 superconducting cavities in two and one-quarter cryomodules.

The injector first reached 45 MeV in June 1991. More recently, continuous beam operation at 200 microamperes and 45 MeV has been achieved, with specifications met for transverse and longitudinal emittance and momentum spread. Over 1500 hours of 45 MeV operations have now been completed, mostly at 16 shifts per week. Radiofrequency phase is controlled to within 0.03 degrees, and amplitude to 3×10^{-5}. Bunch lengths under 0.5 degrees are routinely obtained. Components have been thermally cycled between room temperature and 2 K several times, without performance degradation. Test results show excellent agreement with simulations.

The CEBAF design uses an injector to fire into a racetrack of two antiparallel recirculating linacs linked by recirculation arcs. (The scheme can be seen in the photograph on page 18.)

Testing has included using a temporary beamline to recirculate beam through the injector's two 20 MeV cryomodules to reach 85 MeV. Currents up to 55 microamperes have been recirculated, and energy recovery has been demonstrated at full accelerating gradient.

Injector operation and the recirculation experiment continues through June. By mid-May, 7 of 20 cryomodules had been installed in the first of the main accelerator's two antiparallel linacs, and preparations were beginning for initial linac tests. In tests prior to cryomodule assembly, cavity pairs continued to perform in excess of specifications, with mean usable gradient of 8.5 MV/m (the specification says 5 MV/m) and average resonance Q factor of 5.3×10^9 (specification 2.4×10^9). CEBAF's first nuclear physics experiments are scheduled for 1994.

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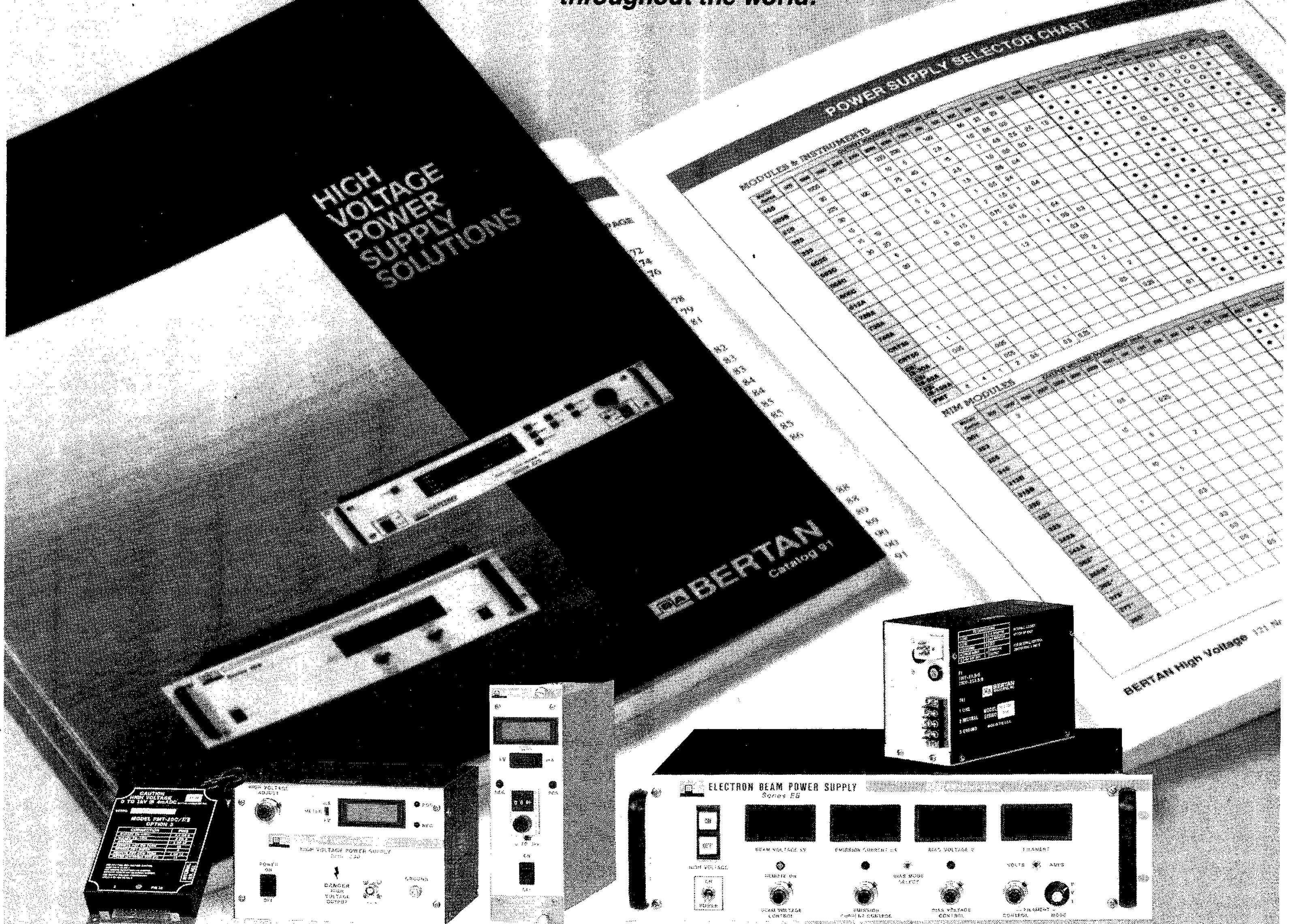

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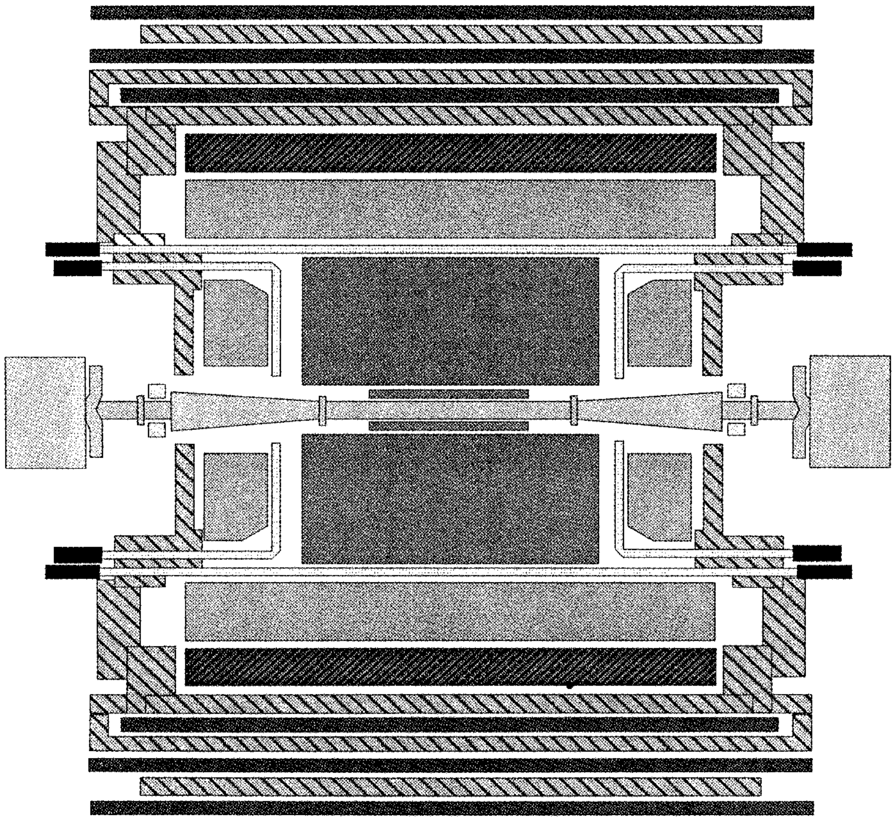
New data from the Beijing Spectrometer (BES) operating at the Beijing Electron-Positron Collider (BEPC) at the Beijing Institute for High Energy Physics gives an improved mass for the tau lepton.



BEIJING
Tau data

New data from the Beijing Spectrometer (BES) operating at the Beijing Electron-Positron Collider (BEPC) at the Beijing Institute for High Energy Physics (IHEP) suggests a more confident value for the tau lepton mass.

BEPC provides 3-6 GeV electron-positron collisions at 4-5 times the peak luminosity provided by the SPEAR electron-positron collider at SLAC (Stanford) which produced important physics discoveries in the 1970s.

Construction of the BES tau-charm detector was completed by Chinese physicists at IHEP and data taking began at the J/psi for detector shakedown and physics analysis in 1989. A Chinese-US collaboration was formed in January 1991 with physicists from IHEP and US groups to focus on data taking and analysis. (The US members are Boston, Caltech, Colorado State, MIT, SSC Lab, SLAC, UC Irvine, Texas/Dallas and Washington/Seattle.) The group recently completed an electron-positron scan to measure the tau mass and is currently scanning for D (charm meson) pair production near threshold.

In the Standard Model, the tau is a simple sequential lepton, the heaviest of a trio including also the muon and the electron. However there has been a pattern of experimental inconsistencies which have led to some speculation that the tau might be more exotic. In particular there have been discrepancies between inclusive and exclusive branching ratios (the 'one prong problem') which now seem to be partially resolved in the light of new electron-positron results from Cello at DESY and from the Aleph and Opal experiments at CERN's LEP collider.

There has also been a disparity between the tau mass, its lifetime and its branching ratio into electrons. These three quantities are intimately related – the product of the tau lifetime and electronic branching ratio are proportional to the fifth power of the tau mass. The latter quantity is therefore vital to a good understanding of tau physics. Previously the accepted value for the tau mass was dominated by a measurement of 1784+3-4 MeV made some time ago by the DELCO experiment at SLAC's PEP collider.

The BES group therefore set out to make a fresh measurement of the tau mass, and preliminary results were presented by Nading Qi of IHEP at the April meeting of the American Physical Society in Washington (which also heard the new cosmic background radiation 'ripple' results from the COBE satellite – June, page 1).

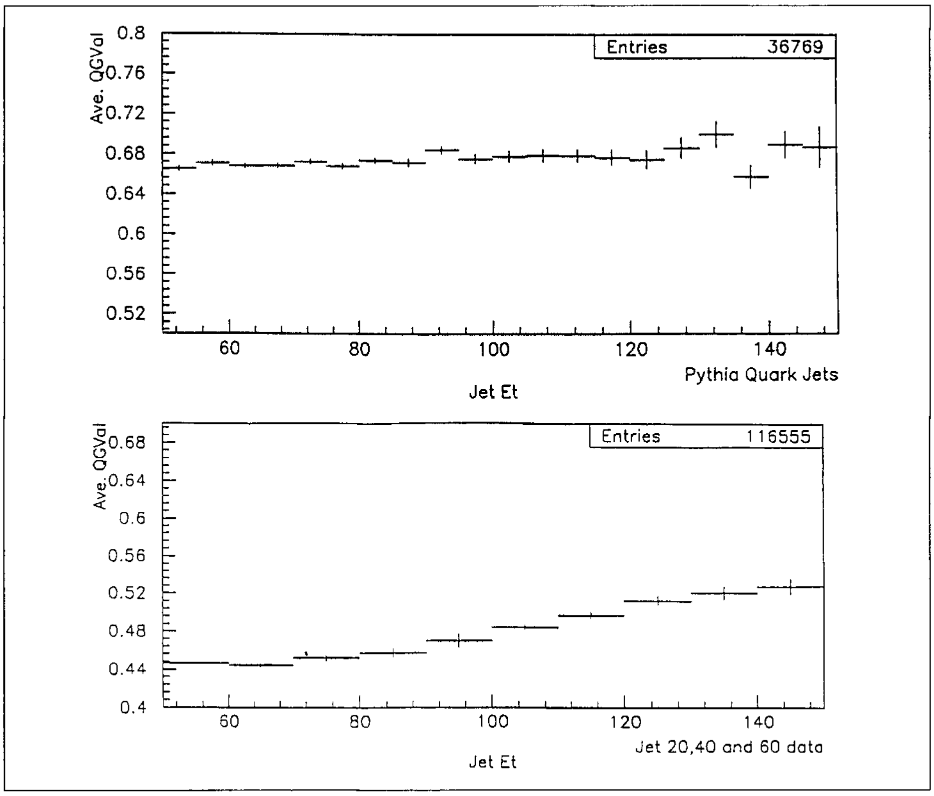
The tau pair production rate near threshold was measured by detecting muon-electron events, giving a preliminary tau mass of $1776.9 \pm 0.4 \pm 0.3$ MeV, with approximately ten times the precision of the previous measurement. While this result reduces the discrepancy, it does not solve it and the precision of the BES measurement suggests the problem is not due to the uncertainty in the tau mass.

BES data is being analysed on both IHEP and SLAC computers, and these efforts will be boosted by an Intelsat satellite-based communications network between the two Laboratories, which will also improve contact between IHEP physicists and their collaborators at the SSC Lab, CERN and Fermilab.

Future physics from the BES group will cover studies of D decays and charmonium as well as the tau.

From Walter Toki

Neural networks can tell the difference. Top – a simulation-trained neural network, tested on simulated (Pythia) quark and gluon jets, detects no variation with jet transverse energy. However when the network is tested on real jets (from the CDF experiment at Fermilab's tevatron proton-antiproton collider), the result slowly rises with transverse energy, consistent with the quark/gluon mixture becoming richer in quarks, as expected from the underlying theory.



Neural networks

The 1980s saw a tremendous renewal of interest in 'neural' information processing systems, or 'artificial neural networks', among computer scientists and computational biologists studying cognition. Always on the lookout for new techniques, high energy physicists were not long to follow suit, and the first papers on applying neural networks to pattern recognition in particle tracking appeared in 1987 and 1988.

Since then, the growth of interest in neural networks in high energy physics, fueled by the need for new information processing technologies for the next generation of high energy proton colliders, can only be described as explosive.

In January, at the Second International Workshop on Software Engineering, Artificial Intelligence and Expert Systems in High Energy and Nuclear Physics at La Londe-les Maures, Côte d'Azur, France (May, page 12) there were some 25 individual contributions on applications of neural networks in high energy physics in the Artificial Intelligence sessions. For comparison, at the first workshop in this series, in Lyon, France, in March, 1990, there were just two such presentations.

Last year, CERN's first Neural Net Workshop, commissioned by Walter Hoogland and organized by Jacques Altaber and J.-P. Porte, included 33 contributions on neural network applications in high energy physics.

Artificial neural networks are data processing architectures with many simple processors, or neurons, operating in parallel. Usually arranged in layered structures, these architectures are modeled on current understanding of pattern recognition in animal nervous systems. Neural networks are used in high energy physics as an algorithm for data analysis, and are also beginning to be used as hardware for triggering systems.

In data analysis applications, the neural network algorithm is valuable for classification since it provides a good approximation to an optimal classifier (the Bayes classifier) with a minimum of computational overhead. In addition, the neural network can be 'trained' to recognize certain classes simply by presenting it with correctly classified examples, without specifying a precise algorithm.

An example comes from the Delphi experiment at CERN's LEP electron-positron collider. Electrons and muons are easily identified, so the relative decay rate of LEP's Z particles into pairs of electrons and pairs of muons is well known. However measuring the relative decay rate of the Z into the five known quark species, (up, down, strange, charm, beauty) is considerably more difficult. The quark species must be inferred from the event topology and from the properties of the resultant particle jets.

Neural networks use all the available event information to construct feature variables which reliably identify the quark. The network, trained in simulations, is able to capture correlations in the input variables which would be difficult to find using a more traditional analysis. With the neural network technique, the Z branching ratios into the five known quark species have now been determined with errors of the order of only a few percent.

A similar analysis of Aleph data at LEP compared neural network and conventional discriminant analysis for extracting b-quark events in Z de-

At Fermilab, Bruce Denby (right) and Clark Lindsey fit a special chip to the neural network board attached to the readout motherboard of their drift chamber. In this pioneer neural network hardware experiment, muon track angles and intercepts are calculated on-line from the chamber's analog sense wire signals. The agreement between network and offline track fitting is excellent (below).

cays, with encouraging results. People in L3 have looked at neural network possibilities for interpreting the output from the BGO crystals of their electromagnetic calorimeter.

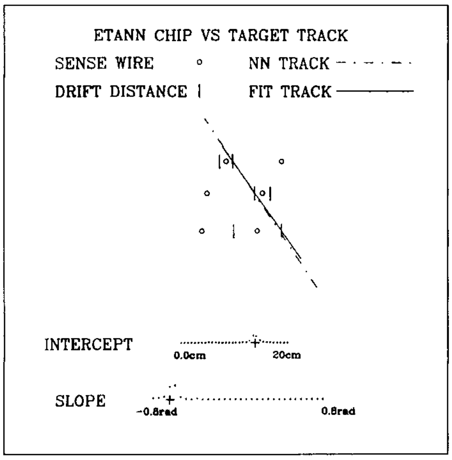
Another exciting result using a neural network in data analysis comes from the CDF experiment at Fermilab's Tevatron collider. A number of simulation studies have used neural networks to distinguish between jets resulting from quarks and jets resulting from gluons, but the Fermilab result hints at a reliable separation of these two classes of jets in real proton-antiproton collider data.

This will be very important in searches for the sixth ('top') quark. Top quark-antiquark states will most often decay into quark jets, while background processes will predominantly contain gluon jets. In the Fermilab analysis, a neural network was simulation-trained to tell quark jets from gluon jets using jet shape variables. The trained network was then applied to samples of jets from real proton-antiproton collisions. With neural networks, the probability of recognizing a quark jet among simulated gluon and quark jets does not vary sharply with the transverse energy of the jet. However using networks with real CDF jets, the quark jet probability increases steadily with jet transverse energy. This is consistent with the increasing fraction of quark jets at higher transverse energies expected from quantum chromodynamics. The measurements are continuing.

Because of the parallel nature of neural computing, neural networks can be implemented as very fast electronic systems. With processing times less than a microsecond, it should be possible to implement sophisticated pattern recognition algorithms within the trigger hardware of a high energy physics experiment.

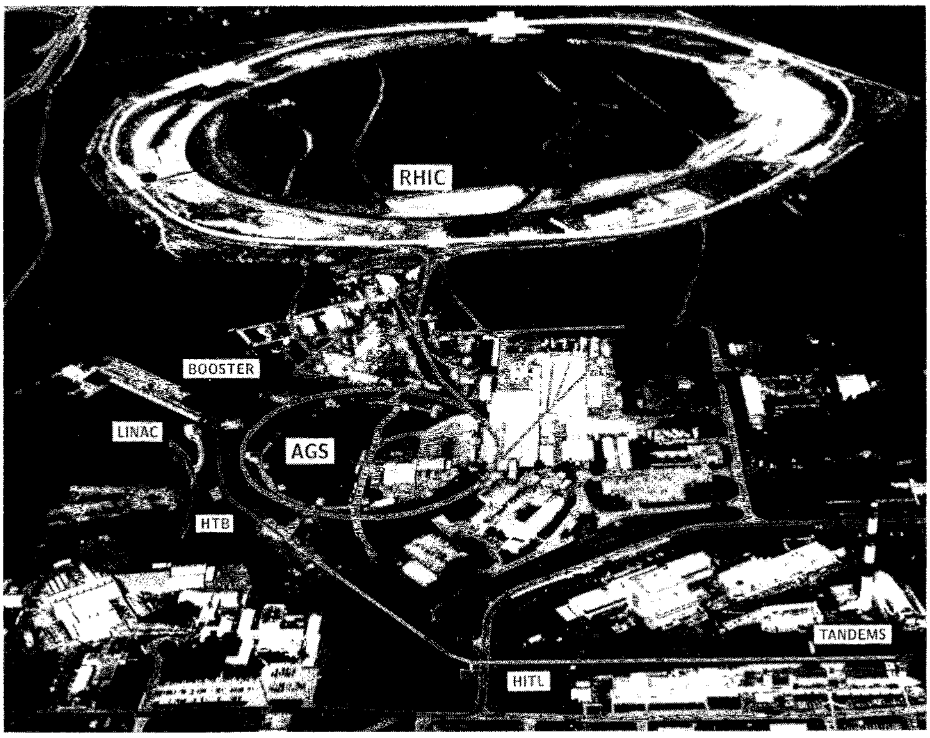
The first such application comes from a recent Fermilab test beam experiment, where a VLSI neural network chip was interfaced to the data acquisition system of a prototype drift chamber. Drift time information from the sense wires, encoded as voltages, was passed to the neural network, which calculated the slope and intercept of the track traversing the chamber and sent this information back to the mother readout board to be read out with the rest of the event, without any dead time.

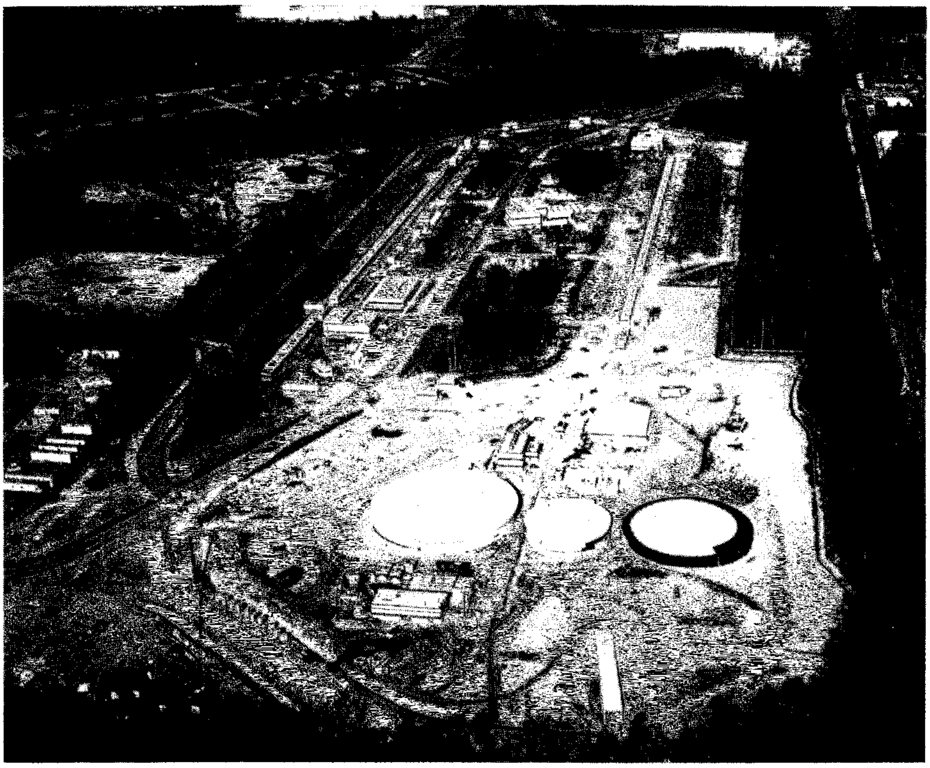
Neural network hardware is also finding its way into other trigger systems. The CDF experiment has



three neural network triggers in place for its 1992 run: an isolated endplug electron trigger, an isolated central photon trigger, and a semileptonic B

Preparing major new US nuclear physics facilities. Top, a view of the RHIC heavy ion collider being constructed at Brookhaven. Below, the CEBAF electron machine site at Newport News, Virginia. These facilities figure prominently in a recent US Nuclear Science Advisory Committee report which examines the evolution of US nuclear science over the next five years.





particle trigger.

Also at Fermilab's Tevatron collider, a group in the D0 experiment is studying the use of neural networks in the muon trigger for the D0 Muon Upgrade. A neural network trigger for H1 at DESY has been under development for some time and will be tested in the current run. Several R&D projects at CERN are looking at the feasibility of neural networks for LHC experiment trigger systems.

Another application of neural networks under study is in adaptive control systems for accelerators. A group at SLAC recently simulated how a neural network control system could be trained both to emulate and control a section of beamline.

These new artificial intelligence techniques could go on to play an important role in the acquisition and analysis of experimental data for the coming generation of proton colliders.

From Bruce Denby and Clark Lindsey (Fermilab) and Louis Lyons (Oxford)

US nuclear physics funding

Because of restrictions in the federal budget, US science spending is coming under close scrutiny, with strong implications for the evolution of the nation's physics research. Recently the Witherell subpanel of the Department of Energy's High Energy Physics Advisory Panel (HEPAP) submitted recommendations on how the US research scene could evolve pending commissioning of the SSC Superconducting Supercollider (June, page 3).

While high energy US thinking is dominated by plans for the SSC, for lower energy studies the goals are less clear-cut, and the funding agencies involved – the Department of Energy (DOE) and the National Science Foundation (NSF) – requested the Nuclear Science Advisory Committee (NSAC) to advise them on the implementation of a long range plan (through to 1997) for nuclear science.

This called for the traditional three budget scenarios – a low one, with constant real dollars; a middle one, with constant inflation-corrected dollars; and an upper one with a real 2-3% annual growth above inflation. NSAC appointed a subcommittee under John Schiffer of Argonne to come up with the recommendations.

On the DOE side, presentations covered the RHIC heavy ion collider being built at Brookhaven, the CEBAF electron source under construction at Newport News, Virginia, the KAON beam factory plan at the Canadian TRIUMF Laboratory in Vancouver, and the LAMPF meson physics facility which came into operation at Los Alamos in 1972. On the NSF side, presentations were heard from university labs.

The report was accepted by NSAC in April and sent on to the DOE and NSF. The Schiffer subcommittee endorsed the scientific priorities of the previous (1989) plan and laid out a modest base budget scenario through to 1997 which would permit essential scientific goals to be achieved.

For DOE, this base budget scenario corresponded approximately to a 2% increase in funding, although some interim years overshot this modest increase. For NSF, the base budget foresaw 2% growth.

The DOE section of report recommends that the construction of the new major facilities, CEBAF and RHIC, be completed without further delay to start their important research in a timely fashion. It also supports the Canadian KAON project, however construction funds could only be liberated towards the end of RHIC construction.

A phaseout of the Los Alamos Meson Physics Facility, LAMPF, threatened in the Congressional Budget for the next financial year, would affect what has been the major US nuclear facility for two decades. During this time its research has been scientifically productive, exploiting its beams of protons, mesons and leptons and providing fresh nuclear physics insights.

At present, some first-rate and intellectually challenging experiments utilizing unique LAMPF features are almost ready to start and are likely to produce significant results in the next few years. Experiments like MEGA and LSND will have fundamental impact, while other research using LANSCE intense neutron beams have opened up new horizons in nuclear parity violation.

For the intellectual integrity of the field and for reaping the benefits of major investments in money and manpower, the Subcommittee strongly recommends that means be found to keep the LAMPF facility operational until 1995. After that, its future would depend on the support from the numerous areas outside nuclear physics where LAMPF has made an impact, and on possible new nuclear physics initiatives.

(For nuclear physics, the Congressional Budget Submission for Financial Year 1993 includes increased construction spending for RHIC, while that at CEBAF naturally decreases as the end of construction nears. The document also suggests terminating the Holifield Heavy Ion Research Facility at Oak Ridge and the Fast Neutron Generator at Argonne, together with completion of experiments leading to an orderly shutdown of the Bevalac at Berkeley as well as LAMPF at Los Alamos.)

Even a modest budget growth of 3% would allow one of several attractive new initiatives to be started in the next five years. However if there is no real growth, and if the continuing CEBAF and RHIC construction pace is maintained, the LAMPF programme would have to be terminated abruptly, with no chance of an 'orderly phaseout', and with a serious loss of science and of a recent investment in new experimental capabilities, the report contends.

With a declining real budget, existing goals would be seriously compromised, the report continues, seriously damaging the research vitality of the field. LAMPF phaseout would be have to be accelerated and KAON participation abandoned, with the base budget reduced by roughly $150 million over five years. In addition, research funds would be cut by $40 million, operating budgets would be limited, and RHIC construction stretched until 1998. Such a scenario would not provide the nation with the appropriate scientific return on the major investments in facilities and skilled manpower already in place, says the subcommittee.

The NSF summary broadly mirrors the DOE findings.

Whatever happens, the nuclear physics scene in the US will look very different by the year 2000, but the way this change comes about will not please everybody.

People and things

SPACE
More high energy gamma sources

Ultra high energy (TeV) gamma rays have been observed by an international team working at the Whipple observatory in Arizona. These also correlate with some of the signals seen by NASA's big Gamma Ray Observatory (GRO) satellite launched by the Space Shuttle Atlantis last year.

High energy gamma rays could help pinpoint sources of cosmic rays. However gammas are readily absorbed by the upper layers of the atmosphere, and it was not until 1971 that the first point gamma source was identified, in the Crab pulsar. Continuing studies in the 1970s revealed more gamma sources, notably the puzzling 'Geminga' object in the Gemini constellation.

To explore the gamma ray sky as never before, the GRO project began in 1978, and was finally launched on 5 April 1991. GRO, at about 16 tons, is the heaviest scientific satellite launched to date (The Hubble Space telescope is 'only' 10.8 tons).

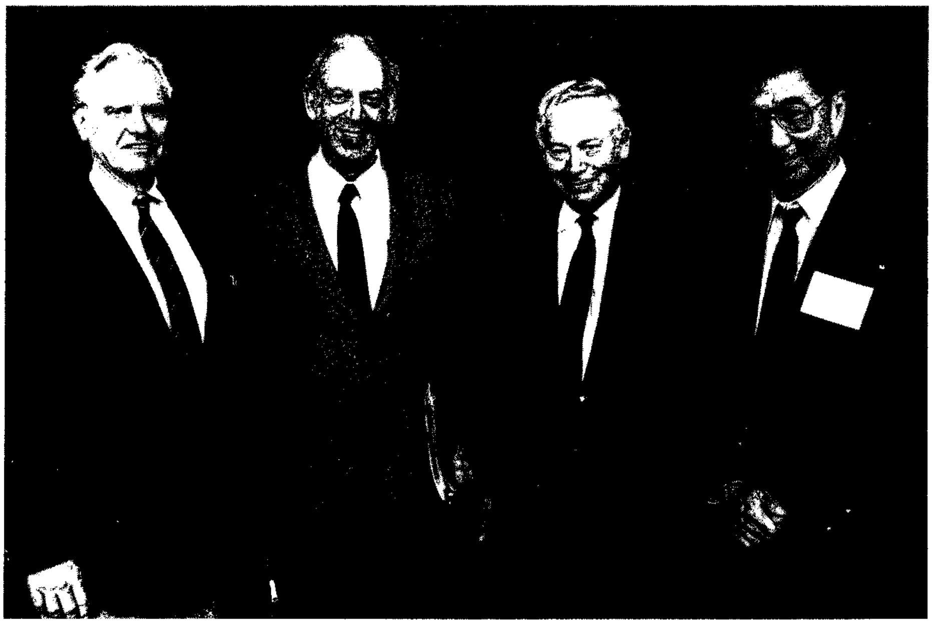
GRO carries four instruments – EGRET (Energetic Gamma Ray Telescope), COMPTEL (Compton Imaging Telescope), OSSE (Oriented Scintillation Spectrometer Experiment), and BATSE (Burst and Transient Source Experiment), between them covering a wide range of energies.

Soon after being switched on last year, COMPTEL registered a series of gamma ray bursts. Subsequently, in a series of International Astronomical Union (IUA) telegrams, the EGRET and Comptel teams have have also reported a series of high energy gamma ray sources. (COMPTEL covers energies up to 30 MeV, while EGRET continues into the TeV range.)

In several hours of observation with a high resolution imaging camera at the Whipple 10-metre optical reflector, a significant flux of extremely high energy gammas (above 0.5 TeV) was picked up by a US/Ireland/UK team. They were looking at Markarian 421, a compact object embedded in a giant elliptical galaxy 120 Megaparsecs away.

Physics Nobels at MIT for the 46th anniversary of MIT's Laboratory for Nuclear Science, 13-16 May. Left to right, Henry W. Kendall (1990), Jerome I. Friedman (1990), Steven Weinberg (1979) and Samuel C.C. Ting (1976).

(Photo Donna Coveney, MIT News Office)



Meetings

This year's DESY Theory Workshop, from 28-30 September, will cover 'Flavour physics'. Information from E.A. Paschos at Dortmund, e-mail UPHX01 @DDOHRZ11.

Among the physics topics in the comprehensive programme of European Research Conferences organized by the European Science Foundation jointly with the Commission of the European Communities and the European Physical Society is Advanced Quantum Field Theory: Low Dimensional Field Theories, coordinated by R. Stora and to be held in Como from 23-27 September. Further information from Josip Hendekovic at the European Science Foundation, 1 quai Lezay-Marnesia, 67080 Strasbourg Cedex, France, phone +33 88 76 71 35, fax +33 88 36 69 87.

C.N. Yang (centre) with his wife (right) and physicist Sau-Lan Wu at a dinner in Washington to celebrate his 70th birthday. Gauge theories and such things seem to be good for you.

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M. Riordan

Superconducting Super Collider, (USA)
N. V. Baggett

TRIUMF Laboratory, (Canada)
M. K. Craddock

Above, neutrino specialists Fred Reines (left) and Ray Davis (right) received this year's Panofsky Prize of the American Physical Society (APS). They are seen here with APS President Ernest Henley.

(Photos Maurice Jacob)

Below, American Physical Society President Ernest Henley congratulates Kurt Gottfried of Cornell on winning the APS Leo Szilard Award.

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Group Leader

Fast Electronics

The Continuous Electron Beam Accelerator Facility (CEBAF) is a 4 GeV high intensity (200 microamp) high duty factor electron accelerator located in Newport News, VA, that will begin operations for physics research in 1994. We have commenced a search for an engineer or physicist to establish and guide an Electronics Group devoted to developing state-of-the-art fast analog electronics for the various particle detectors used by the three large experimental halls. Extensive past experience with the development and use of such electronics is required as well as familiarity with small scale industrial production. The Electronics Group will be expected to work closely with the CEBAF Detector and Data Acquisitions Groups and the physics collaborations. This position offers a challenging opportunity to become a critical member of the Physics Division team developing exciting physics capabilities for the 90's. The qualified candidate must have an advanced degree in electrical engineering or physics and at least ten years experience with the design of state-of-the-art experimental electronics equipment. CEBAF offers a very competitive total compensation package. Applicants should send resume with salary history to: Employment Manager (PR3102), CEBAF, 12000 Jefferson Ave., Newport News, VA 23606. Please specify position #PR3102 and job title when applying. CEBAF is an equal opportunity, affirmative action employer.

CEBAF
The Continuous Electron Beam Accelerator Facility

DIRECTOR
HIGH ENERGY PHYSICS DIVISION

Argonne National Laboratory invites inquiries and nominations for the position of Director of High Energy Physics Division. The Director has overall responsibility for the scientific leadership and management of the high energy physics program. This includes experiments with detectors such as CDF and ZEUS, theoretical research, SDC detector development, and advanced accelerator research.

Candidates should possess extensive experience in elementary particle physics including demonstrated success in initiating and leading research projects. Administrative experience and managerial skills are also important.

All responses will be reviewed by a Search Committee chaired by Dr. T. Fields and should be mailed to: Rosalie L. Bottino, Appointments Officer, Box HEP-99137-88, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439. Argonne is an Equal Opportunity/Affirmative Action Employer.

ARGONNE NATIONAL LABORATORY • UNIVERSITY OF CHICAGO

Im Rahmen eines Kooperationsvertrages zwischen der Universität Hamburg und dem Deutschen Elektronen-Synchrotron DESY in Hamburg zur Durchführung eines internationalen Forschungsvorhabens "Elektron-Proton-Reaktion mit ZEUS an HERA" suchen wir eine(n)

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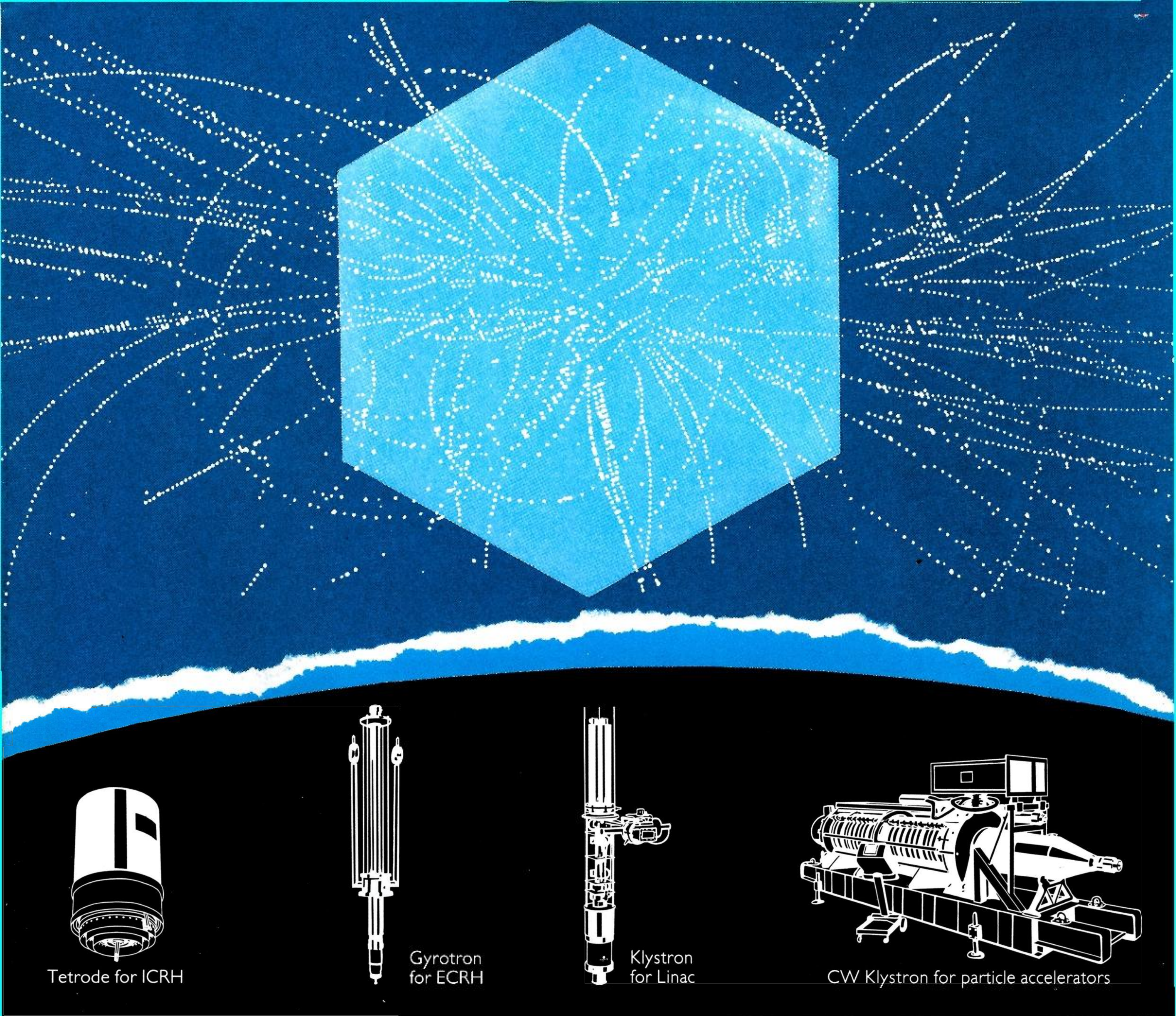

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