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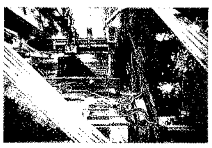

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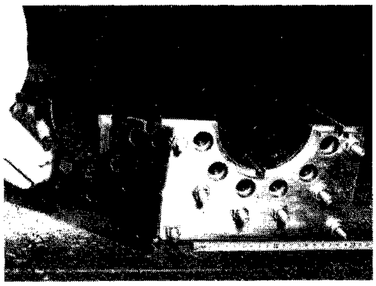

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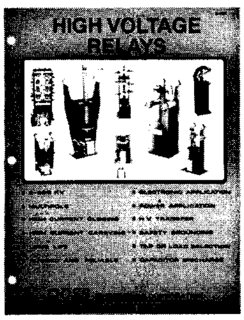

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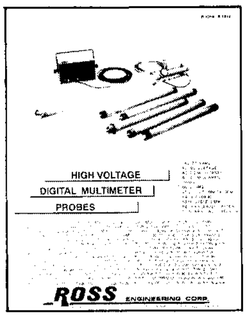

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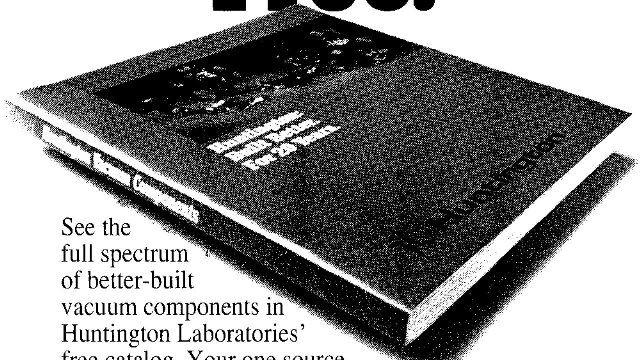

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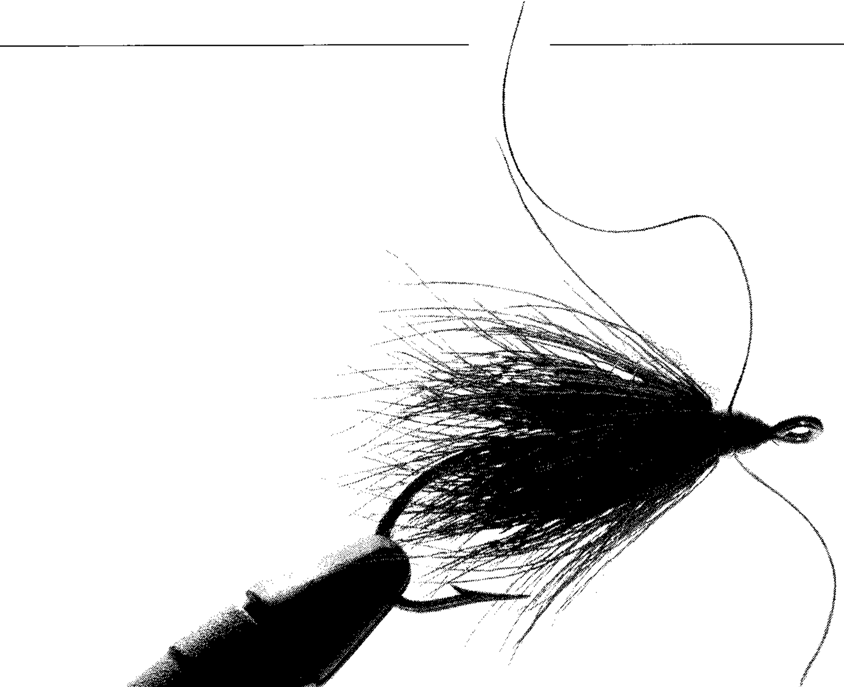

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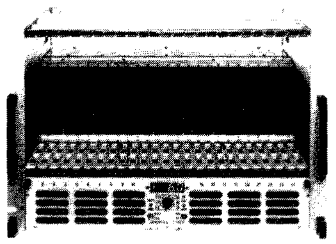

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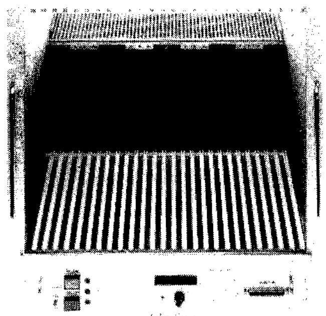

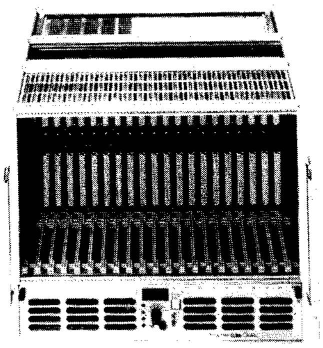

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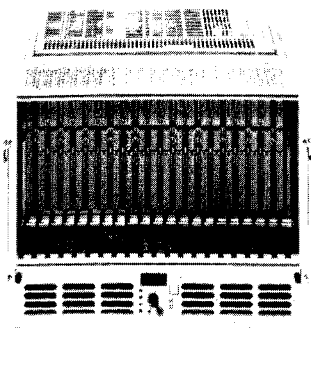

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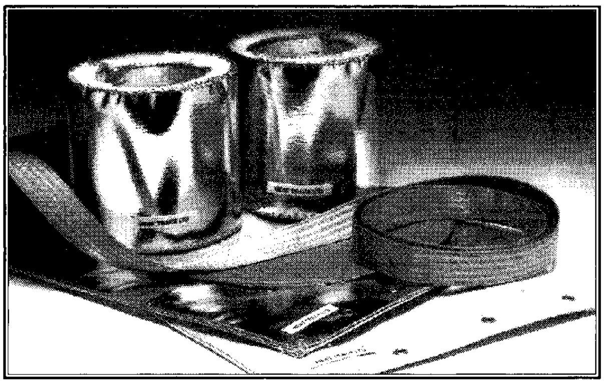

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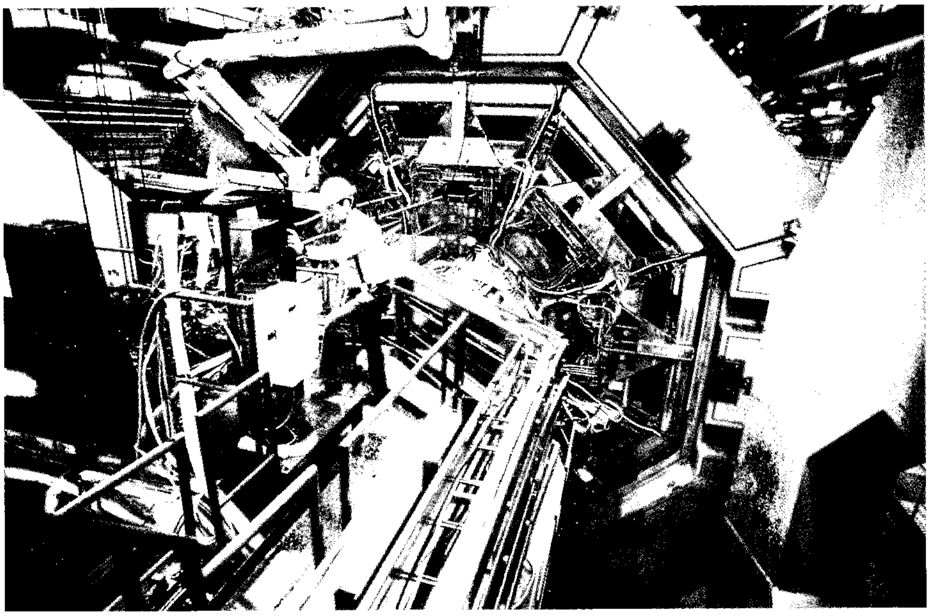
L3 detector



The L3 detector at CERN's LEP electron-positron ring – blazing a trail in worldwide physics collaboration.

(Photo P. Dhinaut)

This is the final article in the CERN Courier series marking a decade of the four big experiments – Aleph, Delphi, L3 and Opal – at CERN's LEP electron-positron collider. Data-taking started soon after LEP became operational in July 1989, followed by substantial runs in 1990 and 1991. Because of the long lead times involved in today's major physics undertakings, preparations for these four experiments got underway in the early 1980s. For Aleph, see January/February 1991, page 1; Delphi, November 1990, page 1. Opal's decade was covered in the June 1991 issue, page 4.

Eleven years ago, with design work for CERN's proposed 27-kilometre LEP ring well advanced, physicists started to think seriously about the big experiments to monitor LEP's electron-positron collisions. In June 1981, the alpine resort of Villars was the setting for the traditional ECFA (European Committee for Future Accelerators) major user community meeting to put the case for the new machine and study the physics possibilities.

That year Sam Ting's Mark-J experiment at the PETRA electron-positron ring at DESY, Hamburg, was well into its research programme, and the 1976 co-Nobel prizewinner was looking to the future. The electron-positron route could be continued at CERN's LEP ring, but there was another route, for protons, elsewhere. The idea for L3 was born when Ting visited Hans Hofer and his colleagues at the Swiss Federal Technical Institute (ETH) in Zurich in April 1981.

The Mark-J collaboration included Aachen (III) in Germany, MIT in the US, NIKHEF from Amsterdam, JEN in Madrid and the Beijing Institute of High Energy Physics. (Mark-J was the first western scientific project in which Chinese physicists participated following the 1977 cultural revolution.) As well as ETH, Antonino Zichichi's group, with valuable experience in studying lepton pairs, was eager to join any new Ting venture.

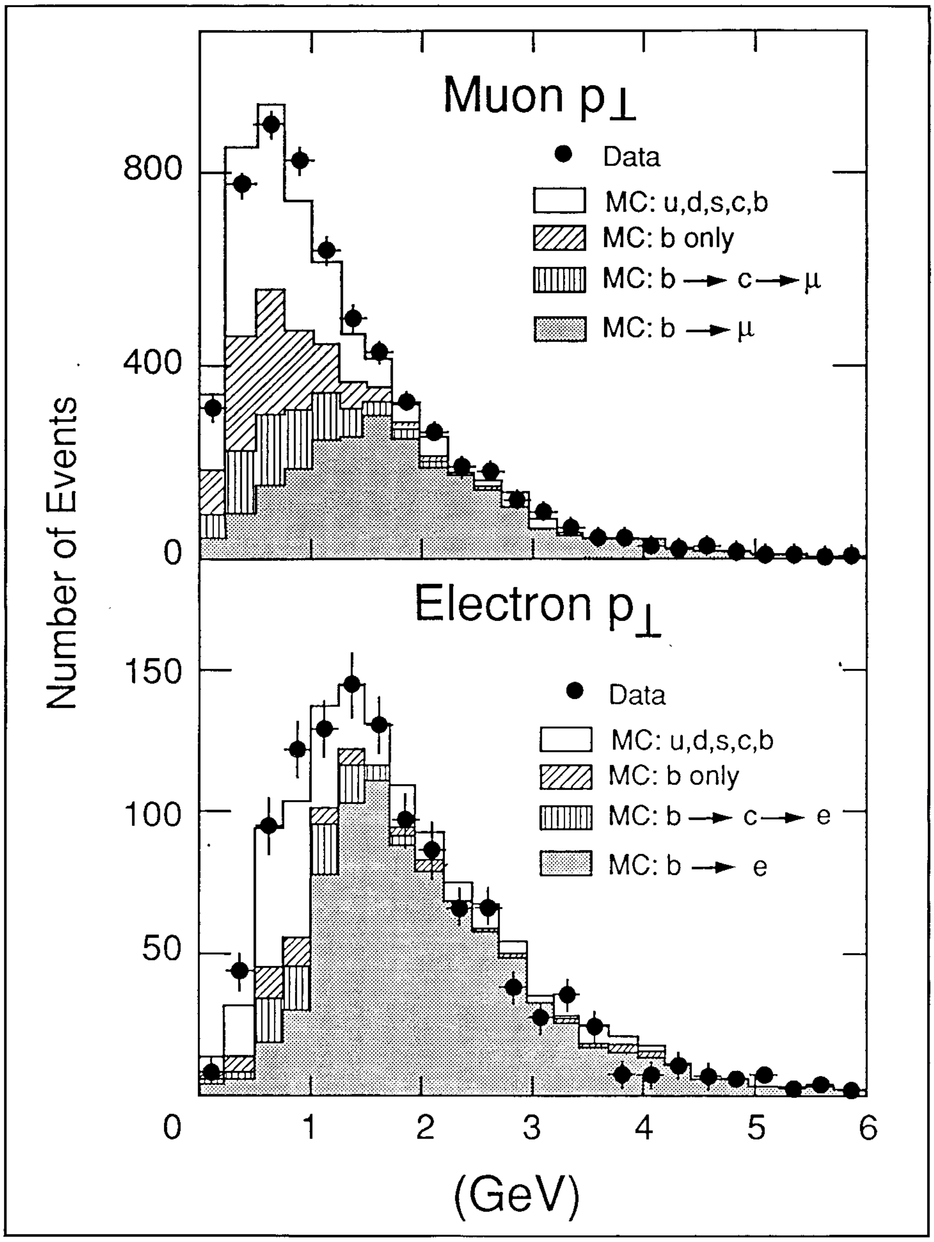
What came to be known as L3 (it was the third Letter of Intent to be submitted for approval in 1982) looked very different to the other LEP detector plans. While these concentrated primarily on the hadron (strongly interacting) and lepton (weakly interacting) products of the electron-positron collisions, Ting's plan was to construct a detector to emphasize the leptons and photons produced in electron-positron annihilation, looking deep inside the electroweak mechanism to see what makes it work.

As well as being large, L3 is also a truly world collaboration, the first major physics team to span Europe, the US, USSR, the People's Republic of China, and Asian countries.

Despite its $150 million pricetag, funding for the detector was never a major problem, with the USA, the Soviet Union and the Eurasian countries each contributing about a third of the total cost. However Ting says that setting up the worldwide team, for example with Soviet and Chinese scientists working alongside each other – a rarity in those days, took a lot of patient preparation.

Once outlined, the initial L3 design, with a large magnet enclosing a modular detector aimed at precision measurements of photon, electron and muon momenta, did not change very much. The need for an outer magnet to provide the required momentum measurement precision meant that the detector had to be big. Unlike the other LEP detectors, constructed on the push-pull principle with a 'garage' position away from the circulating beams, L3 had to be built in situ. As in effect it formed part

B particle physics is one of L3's emerging specialities. Cutting off muon and electron transverse momentum below 2 GeV gives a clean sample.



of LEP's infrastructure, L3 had to be ready and operational on LEP Day One. This was a powerful driving force in L3 installation.

Another novel L3 feature is the use of bismuth germanium oxide (BGO) for the electromagnetic calorimeter. Twelve tons of this material are used in the complete detector, which drove the material's market price down from $18 to $5 per cubic centimetre. The BGO raw material was supplied by the Soviet Union, but crystal production was in the capable hands of the Shanghai Institute of Ceramics.

Responsibility for the 8000-ton magnet, 15.6 metres high, 13.6 long and providing a central field of 0.5 T, and the large experimental area was shared by the big guns of the collaboration – CERN, ETH Zurich, ITEP Moscow and MIT.

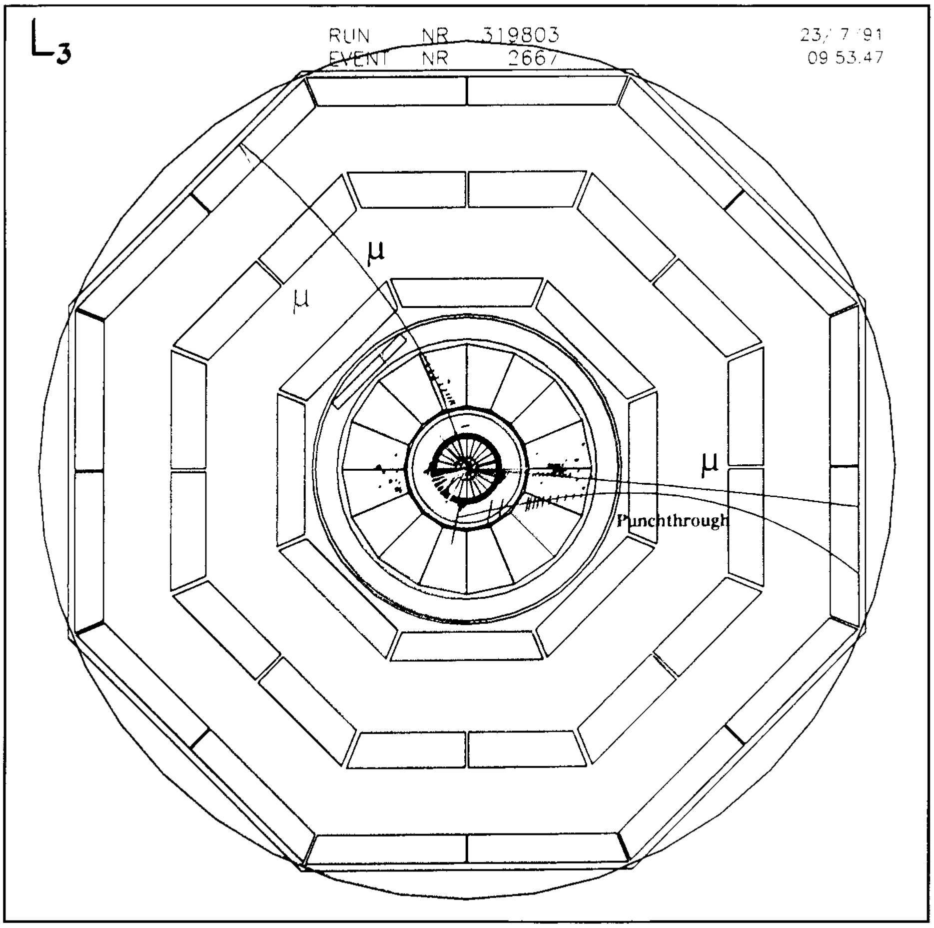
Inside the magnet are the muon large muon chambers (NIKHEF Amsterdam/Madrid/ETH Zurich/ Harvard/Naples/Leningrad/ MIT/ Northeastern) to give resolution of one per cent or better at the Z mass working point. Under Ulrich Becker of MIT, research and development work for this major detector component went through many iterations – it took two years to produce the first octant for the ultra-precise muon central barrel spectrometer – before an optimal design emerged and production could begin. Precision laser monitoring systems were specially developed to ensure accurate octant alignment.

Inside the muon chambers, the hadron calorimeter (Aachen/ Florence/ITEP Moscow/Michigan/Rome/ Bombay/ETH-EIR Zurich) with copper and Soviet uranium absorbers was assembled at the Swiss Federal Institute for Nuclear Research (EIR). Here too extensive initial R and D work paid dividends.

Inside the hadron calorimeter, the BGO electromagnetic calorimeter (including a luminosity monitor) is also delegated to a highly international team (Aachen/Annecy/ Beijing/ Budapest/Caltech/Carnegie-Mellon/ CERN/Geneva/Hofei/ Lausanne/ Lyon/Madrid/Munich/Moscow/ NIKHEF/Princeton/Rome). In place for the 1991 run are the endcaps, making the original L3 design finally complete.

The 'Time Expansion Chamber' vertex chamber currently at the heart of the detector was built by a European team (Aachen/Zeuthen-Berlin/ Zurich) after considerable prototype development at Aachen, Geneva and ETH Zurich.

L3's Governing Board – the Execu-



L3's Higgs candidate – explained as a Z decaying into a Higgs and a pair of muons (top left), the Higgs subsequently giving the particles, including a lone muon (right),corresponding to a beauty (b) quark-antiquark pair.

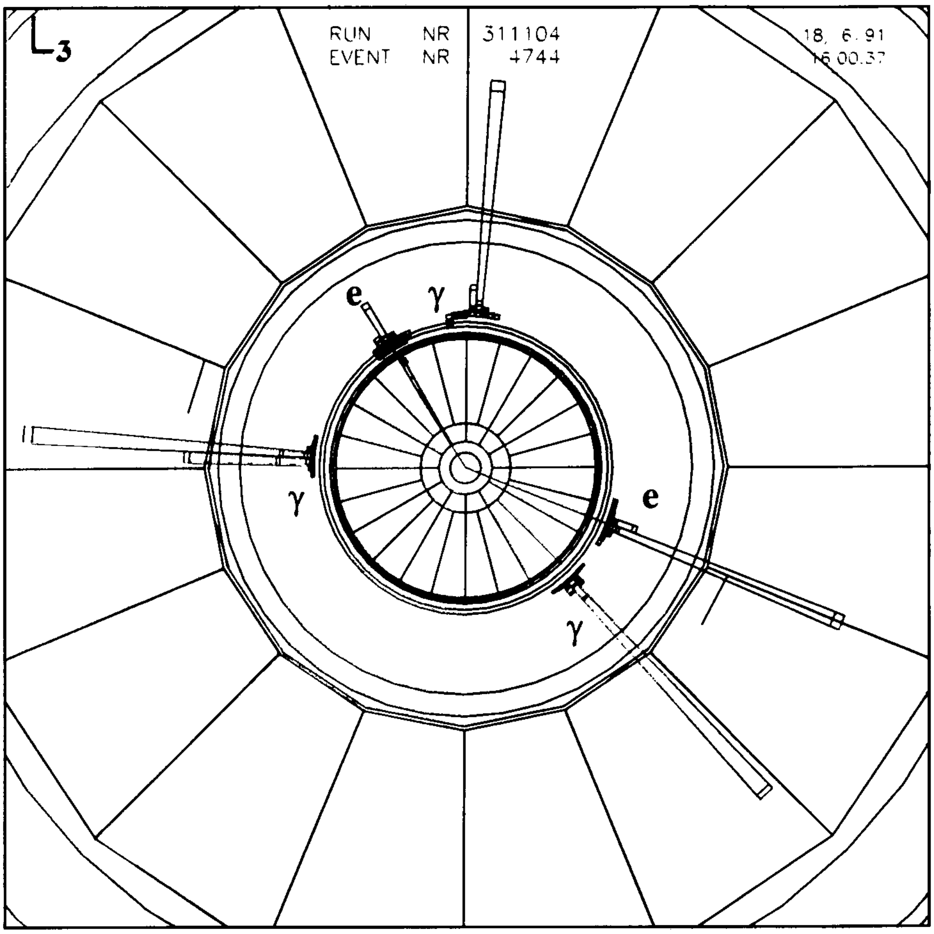
tive Committee – includes key delegates from the collaborating research centres with vital responsibility for subdetector units. Other groups represented on the Committee look after physics goals, detector improvements, assembly and parameters, the magnet and the experimental area, on- and off-line data analysis, triggering, and instrumentation R and D. The sessions are open to all L3 collaborators.

Special L3 roles are played by Hans Hofer of ETH Zurich with overall responsibility for coordination and finance (L3 has its own Finance Committee) and Frederic Eppling of MIT in administration and communications. At CERN, François Wittgenstein led the magnet team, while Alain Hervé and Mike Harris looked after engineering support.

The collaboration was boosted in the mid-80s with the advent of the World Laboratory. Under Antonino Zichichi, this project aims to capitalize on the science and technology base of the major industrialized nations to promote projects in developing countries. A World Laboratory contingent is now the largest single institute team in L3, sharing responsibility for much of the experiment's data analysis hardware and software.

In this way young scientists from developing countries get valuable experience in front-rank high technology, providing a strong springboard for future careers and a catalyst for technology sharing.

During L3 installation, cabling turned out to be a tough task, but monthly meetings under Lars Leistam sorted this out. Such a widespread collaboration also



An interesting Z decay from L3, giving an electron-positron pair and three high energy gamma rays.

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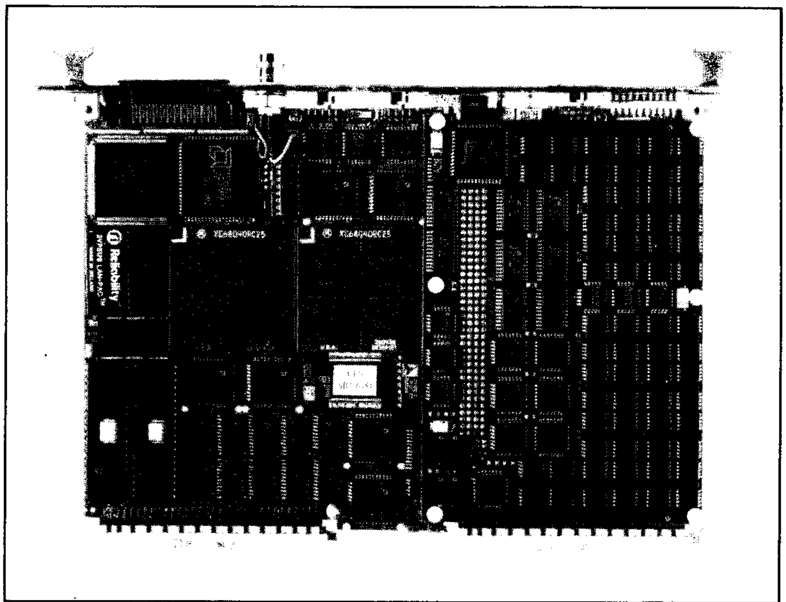

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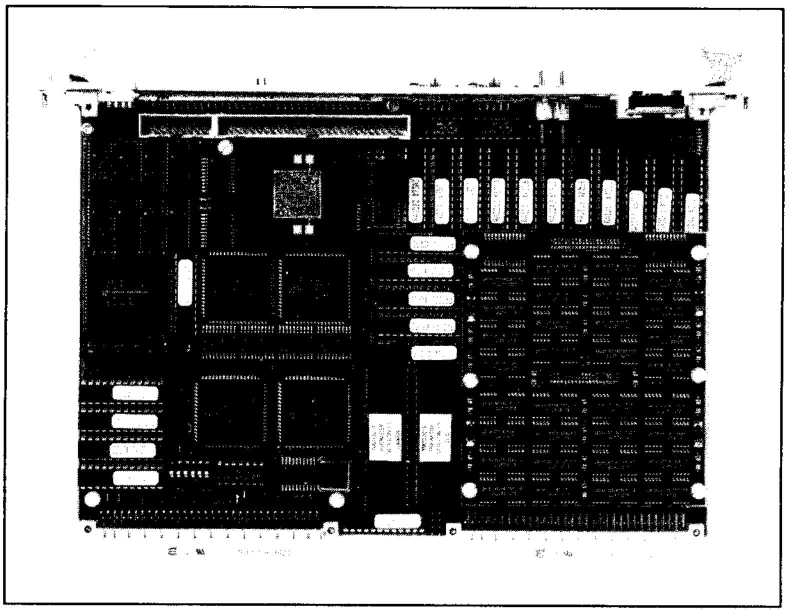

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Around the Laboratories

needed a special effort in data communications. Richard Mount of Caltech looked after the international computer network.

L3 has its own dedicated computer for data analysis. Provided by US Department of Energy funds, it currently uses an advanced IBM 3090-200J processor.

Despite its size and complexity, the detector worked very well when LEP provided its first beams in the summer of 1989. A few dead sectors in the vertex chamber were soon replaced.

Sam Ting sees the three data taking seasons so far as only the beginning of a long career for L3. With the current data samples there is little to choose between the four detectors, he explains. However specific design objectives should come into their own in the next few years, when the experiments have each a few million Z decays under their belts. He highlights the first L3 results on B physics (particles containing the fifth 'beauty', or 'b', quark) as a pointer to L3's future capabilities. These results include branching ratios for semi-leptonic b quark decays, the affinity of the Z particle for b quarks, the mixing parameter of the neutral B mesons, and the lifetime of B particles.

Also for the future, L3 is installing forward-backward muon chambers to extend muon coverage down to 22 degree angles. This will be particularly important for running at higher LEP energies to study the physics of W particle pairs. L3 will also be fitted with a microvertex detector inside the Time Expansion Chamber and immediately around a new narrow beam pipe, to improve tracking for very short-lived particles.

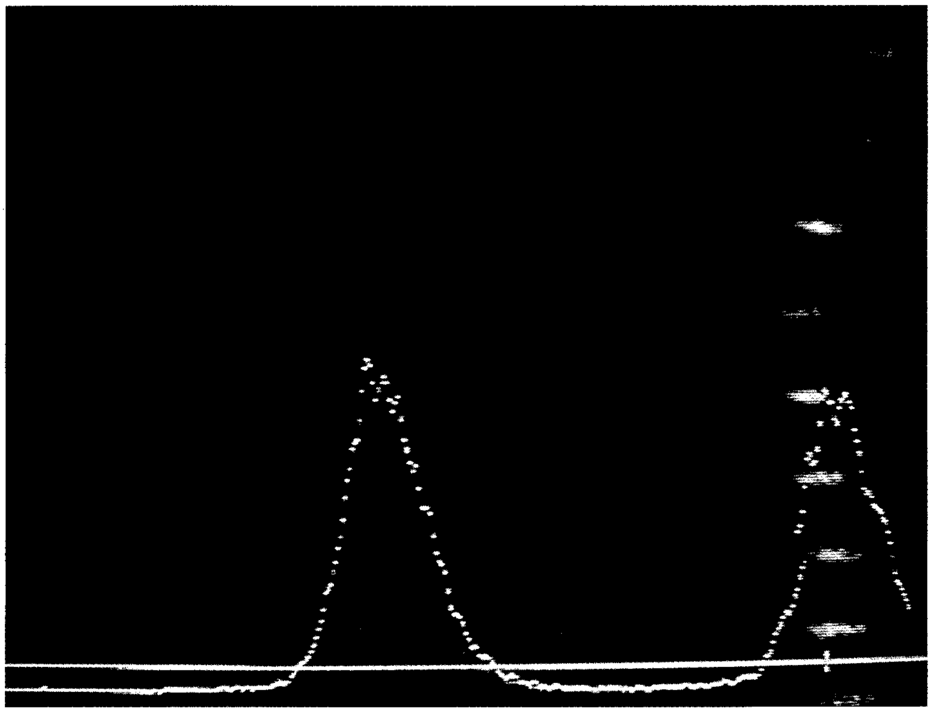
Despite the complexity of the detector and the size of the experimental collaboration, L3's results are presented publicly in a refreshingly clean and easy-to-assimilate form. 'Physics comes from transmission of simple ideas,' explains Ting. 'You don't have to go into too many details.'

CERN
LEP vintage 1991

When CERN's 27-kilometre LEP electron-positron collider finished its 1991 run in mid-November, the four big experiments – Aleph, Delphi, L3 and Opal – had each amassed about 300,000 Z particles over eight months. This was about twice the figure for the 1990 run, so that the total number of Zs seen by the four detectors since experiments got underway in August 1989 now exceeds two million.

1991 started on an optimistic note. Lessons had been learned, and a healthy crop of Zs was expected. In addition, LEP would continue to scan around the Z energy to see how behaviour changes across the resonance.

After the experience of the 1990



A specially developed streak camera at CERN's LEP electron-positron collider can give top (left) and lateral views of the circulating particle bunches. In this photograph, the development of the bunches (each a few centimetres long, about a millimetre high and a few millimetres across) in successive (bottom to top) turns around the 27-kilometre ring shows delicate oscillations. This camera has proved invaluable in understanding the complex behaviour of the LEP beams.

(Photo CERN CO 36.11.91/3)

run, simulation studies had suggested how troublesome beam-beam effects could be sidestepped using a new optimal working point (horizontal and vertical tuning). This worked, and together with some magnet realignment, gave luminosities of some 7×10^{30} per sq cm per s, compared with a best of 5×10^{30} in the previous year.

Among other things, beam-beam effects had meant that the experiments saw less than the predicted luminosity. In addition, the four experiments, spaced symmetrically around the ring, had each seen a different luminosity. In 1991, they enjoyed equal and predictable shares of electrons and positrons.

The next tentative advance came when new measurements showed that the (low-beta) focussing quadrupoles were not squeezing the colliding beams as tightly as was thought. The collision rate is very dependent on this final beam compression, and rectifying the error quickly took the luminosity to 10^{31}. With the Z score climbing fast, confidence was high.

However this fresh optimism was short-lived. The new conditions brought in their wake high backgrounds and radiation problems in the experiments. The new settings had to be abandoned, and the peak luminosity took a step back.

The experiments log their data while stable beams collide, a good beam coast lasting about eight or nine hours, sometimes more. Before the next one, the depleted beams have to be dumped and the ring refilled with fresh particles. Ramping the beams from the 20 GeV at which they are injected from the SPS towards 45 GeV takes the best part of an hour, and the final grooming of the beams before physics conditions are 'declared' normally takes another hour. However these figures are very variable, and coast turnround time has been as short as one hour.

Accumulated experience and know-how continually improve overall machine efficiency (the ratio of collision coast time to total time available for physics). One particular 1991 improvement (which also reduced residual beam-beam effects) was a combined ramp and squeeze procedure to simultaneously accelerate the LEP particles and focus them at the collision points. Over the year, the average efficiency was about 44 per cent, but attained 70 per cent at times.

Running during the height of the summer was dogged by a series of equipment failures. Also taking their toll were power supply instabilities due to thunderstorms, and skill shortages with key personnel enjoying well-earned vacations.

This down-time underlined the importance of comprehensive monitoring and diagnostics. The LEP control room can now follow a lot more behaviour on-line and anticipate trouble.

At the beginning of October a major vacuum leak was found in the beam tube inside the Delphi experiment, where the aluminium lining had become detached from the outer carbon fibre reinforcement. After heroic efforts, a sleeve was fitted to get physics underway again for the remainder of the run and minimize downtime.

After three operational seasons, the LEP team still acknowledge that their machine is tricky. Unforeseen wrinkles need careful investigation, but smoothing out one quickly reveals another somewhere else. The latest LEP obstacle to appear is unwanted sidebands of main resonances attacking the positron beam.

Interleaved with the physics, as always, was machine development time. As well as exploring new machine optics for improved running, the main 1991 goals were beam polarization (leading to an improved energy calibration – November, page 10), testing superconducting radiofrequency units which will take the LEP collision energy towards 200 GeV, and preparing the way for the 'pretzl' scheme – running with eight, rather than four – bunches per beam.

The 1992 LEP run begins in April.

SuperLEARative

With CERN's SPS ring now only occasionally serving as a proton-antiproton collider, the LEAR low energy antiproton ring at CERN is the main client for CERN's antiproton supply system.

LEAR has attacked a wide range of physics problems since its commissioning in 1983, and the experimental programme is continuing, notably with three major second generation studies – Crystal Barrel, Obelix and Jetset – while the CP-LEAR experiment is also poised to make important new contributions. However it is becoming increasingly clear that continued progress needs antiproton energies beyond the 2 GeV currently available.

With the Quantum Chromodynamics field theory of inter-quark forces in good shape, the gluons which carry this force should also show up as particles ('glueballs'), or combine with quarks to form hybrid particles. Initial evidence for glueballs has been seen (July/August 1989, page 21), but further study is needed to clinch the assignment.

Quarks could form complex 'molecular' states as well as just baryons

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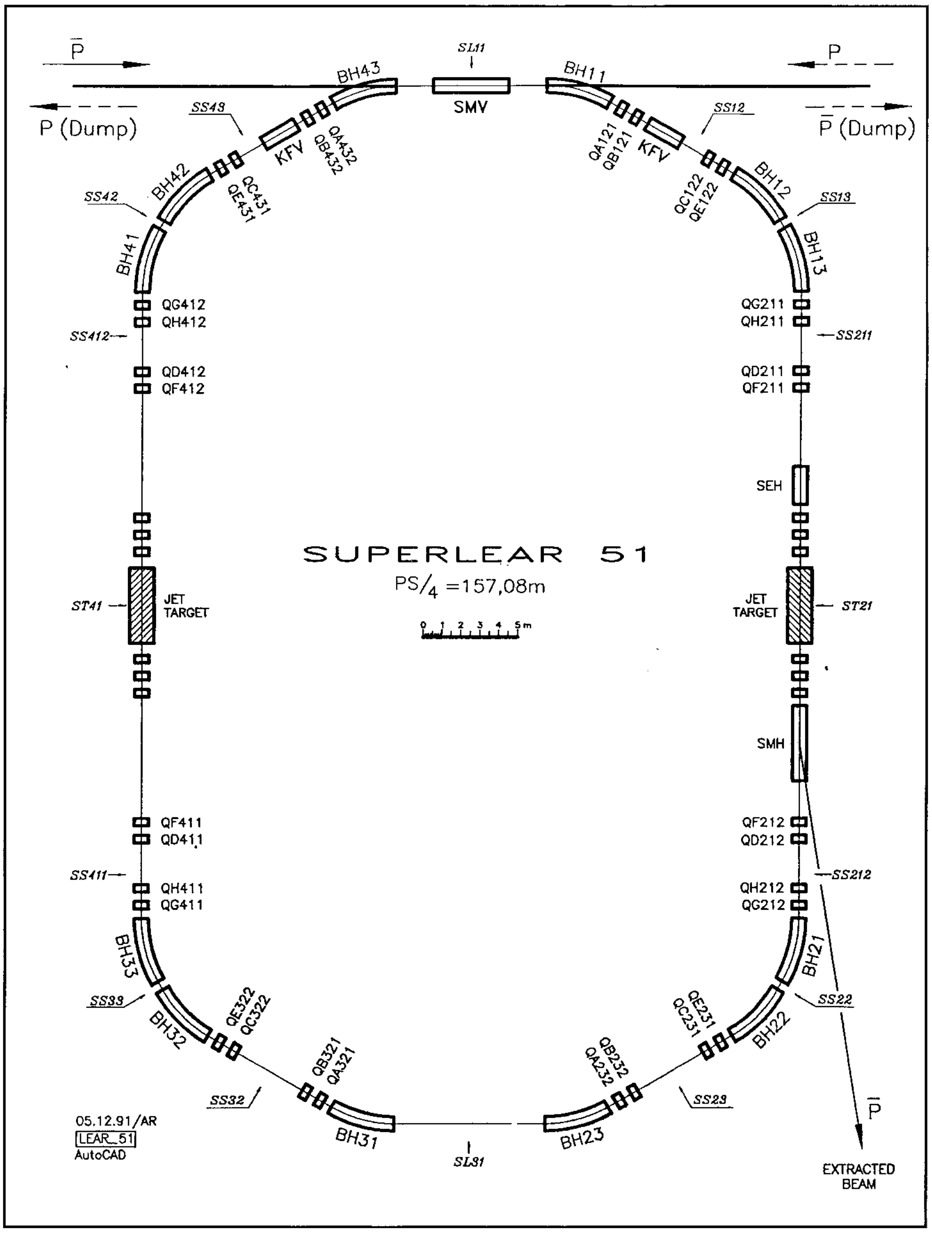
A 157-metre circumference ring of superconducting magnets envisaged for the SuperLEAR antiproton scheme at CERN.



(composed of three quarks) and mesons (quark-antiquark pairs). The particle spectrum invites further explanation, while evidence for gluon interactions (known at high energy) could be found at lower energies, and particularly in proton-antiproton annihilation.

To supply the higher energies needed to exploit this physics, plans have been prepared for a new SuperLEAR storage ring using superconducting magnets. Antiprotons would be injected into the PS synchrotron at 3.5 GeV (as at present), for acceleration or deceleration prior to injection into SuperLEAR. Operation of this modest 157 metre-circumference ring could be interleaved with major PS functions (LEP, heavy ions, LHC).

As well as examining the physics aims in detail, a workshop with 120 participants in Zurich from 9-12 October also looked at the machine possibilities. Several options have been prepared, with different arrangements of gas jet targets and extracted beams.

Three high priority SuperLEAR physics objectives were identified at Zurich – spectroscopy of particles containing the fourth ('charm') quark, light quark spectroscopy in the 2-3 GeV mass range, and the production of hyperon pairs.

'Charmonium' states (composed of a bound charmed quark and antiquark) are a good laboratory for studying the details quark forces. A wider range of these states is accessible through proton-antiproton annihilation than through the electron-positron route (for example at a tau-charm factory).

In contrast to light quarks, where states cluster and overlap, the charmonium spectrum is well spaced out. With the potential of the inter-quark force well known, the spectrum is also predictable, so that 'exotic' additional particles would soon show up.

In the light quark sector, the basic quark-antiquark states are well charted. However many additional levels are expected carrying radial and angular momentum (just as in atomic spectroscopy). To explore this potentially rich spectrum, where the component quarks are wider apart than usual, needs higher proton-antiproton energies.

If a decision is taken next year, SuperLEAR could be running for physics in 1996. The configuration of jet targets and extracted beams would have to be carefully matched with the physics objectives, and the Zurich meeting helped the selection

of likely scenarios.

Two working groups on the conceptual design of possible detectors have been set up, one for extracted beams and external targets, headed by Lucien Montanet (e-mail montanet at cernvm.cern.ch) and the other, on internal target possibilities, headed by Claude Amsler (e-mail amsler at cernvm.cern.ch).

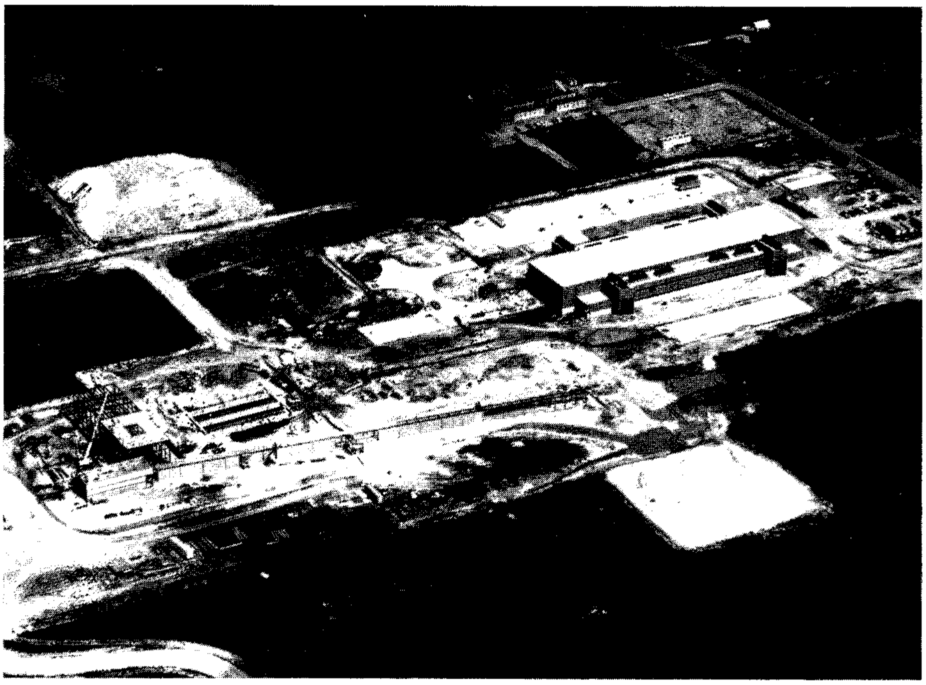
SUPERCOLLIDER Texas meeting

With preparations pushing forward for the Superconducting Supercollider (SSC) to be built in Ellis County, Texas, there was a full agenda at the third SSC fall conference, held in Corpus Christi, Texas, from 14-17 October.

Participants heard that civil construction is progressing at the N15 area, with staff and equipment already moving into the Magnet Development Laboratory. The Accelerator System String Test (ASST) building was completed in October, and installation of refrigeration equipment has now begun. The ASST will be used for system testing of a string of full-length 50-mm collider dipole magnets, now being assembled by industry using facilities at Fermilab and Brookhaven.

On the machine side, the design of the accelerator complex continues to be refined, with the low-, medium- and high energy boosters better optimized. Soviet accelerator physicists working at the SSC Laboratory have contributed to this work.

An SSC site development plan, drawn up by the architectural and engineering contractor, covers technical facilities and lays out buildings, roads, utilities and other services for the east and west complexes. A zoning plan for Ellis County is being prepared by an independent contractor. The first campus building contracts are expected to be awarded by the end of the year, and 'pioneers' should start moving onto the campus during 1994.



Construction at the Ellis County, Texas, site of the Superconducting Supercollider (SSC). Right is the football-pitch size Magnet Development Laboratory (MDL), and at lower left the Accelerator String Test System (ASST, some 200 metres long, and now complete). Under construction alongside are the refrigeration buildings. Nearby, work for the first magnet delivery shaft has now also begun.

On the experimental side, the first major proposal – the Solenoidal Detector Collaboration (SDC) – has selected scintillating tiles with wavelength-shifting fibre readout for its central calorimeter. The tracking radius has been fixed at 1.7m, while the number of layers of silicon and other trackers has been reduced to lower costs and reduce thickness of material near the interaction point.

The second major detector candidate – the Gammas, Electrons and Muons (GEM) collaboration – involved 300 physicists from nine countries as of October, and was growing rapidly. Detector technology options were being selected – for the electromagnetic calorimeter, barium fluoride and an accordion geometry liquid argon or krypton were being studied. The magnet is planned as a large (17m diameter × 30m long) unshielded superconducting solenoid.

A full day of the Corpus Christi meeting was devoted to detector research and development, with talks on calorimetry, tracking, electronics, muon systems, and computing.

Meanwhile magnets are being built at the SSC Laboratory, and the first SSCL-built magnet has been assembled and successfully tested. This short 50-mm-aperture dipole went to 'short sample' (the superconductor current limit, about 7500 amperes at 4.35 K) on the first quench when testing began at Fermilab in October, and has continued to perform consistently.

The first prototype 'spool piece' has been sent to Fermilab as part of the 40-mm magnet test programme (December 1991, page 6). Each half-cell of the collider lattice will include a spool piece to provide the interface between the magnets and the outside world of electrical power, liquid helium, and control systems. A spool piece contains superconductors and hence must operate at liquid helium temperatures like the dipoles and quadrupoles.

The first magnet delivery shaft is under construction. T.L. James and Co, of Kenner, Louisiana, have begun excavation of a 60 by 30 foot elliptical shaft, 250 feet deep. Two 75-foot-long horizontal tunnels leading from the base of the shaft will be provided to serve as 'starter' tunnels for excavating the main tunnel. Using the shaft and stub tunnels, a subsequent subcontractor will lower and assemble a tunnel boring machine and drive the first section of tunnel northward for 2.7 miles. The shaft, to be completed by mid-1992, will later be used for delivering magnets to the tunnel; its 60-foot dimension will allow them to be lowered in a horizontal position.

Meanwhile the first two full length 50 mm collider dipoles have been tested successfully at Fermilab and Brookhaven. Both went well above the design current of 6500 amperes and performed well. These are the first of a series of dipoles being built at the two Laboratories to transfer the magnet technology to industry. General Dynamics will now build seven dipoles at Fermilab, and Westinghouse will build five at Brookhaven. Of these first dozen industrially assembled magnets, five will be used in the string test next fall at the SSC Laboratory.

DESY HERA commissioning

The commissioning of the world's first electron-proton collider – the 6.3 kilometre HERA ring at the DESY Laboratory in Hamburg – last year was the result of more than a decade of careful planning, design and construction.

Although 1991 will be remembered as HERA commissioning year, trials began back in August 1988 when 7 GeV electrons were injected into the electron ring. Just three days later, electrons were being held for 20 minutes.

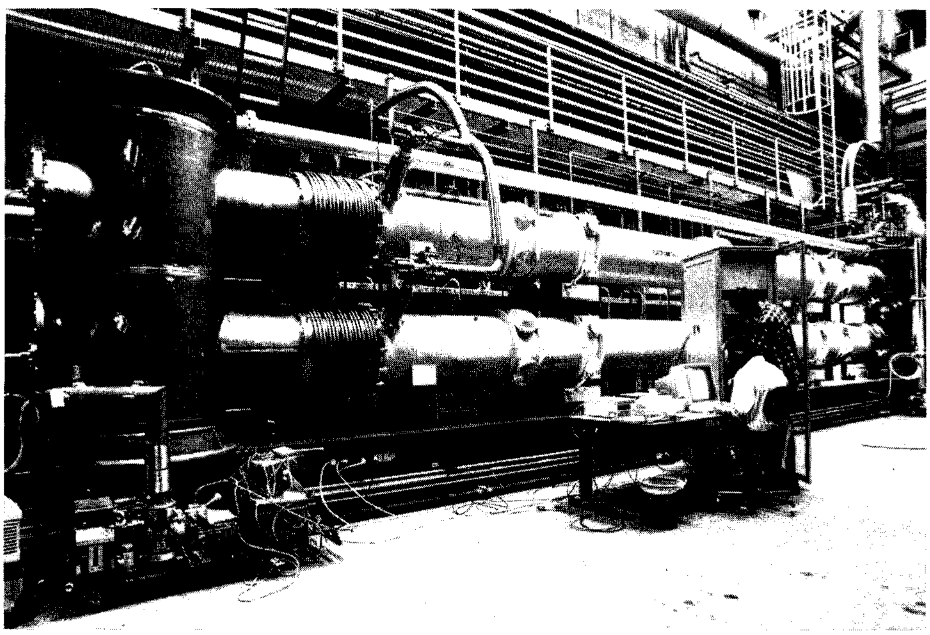
This initial success was followed by a six-week study which confirmed that the electron machine behaved as expected. Commissioning continued eleven months later, and by the end of September the following year, the electron energy had climbed to 27.5 GeV, limited at the time by the radiofrequency power available from the 84 conventional accelerating cavities. Beam optics and multiturn injection were well understood and completely under control. The maximum single bunch electron current of 2.5mA achieved so far is almost a factor of ten above the design value.

A powerful bunch-to-bunch damper system is needed to control the instabilities which develop if the design intensity is stored in 200 bunches. Such a damper system implemented in the downstream PETRA ring enabled design intensity to be reached in this machine. The same system was then built for HERA where its damping capability has been successfully demonstrated.

With the installation of 12 superconducting four-cell cavities the ring is now fully equipped with r.f. power, and last July HERA-e reached its design energy of 30 GeV.

A laser polarimeter to measure transverse spin polarization was tested last summer, and on 20 November, an 8 per cent transverse spin polarization was picked up.

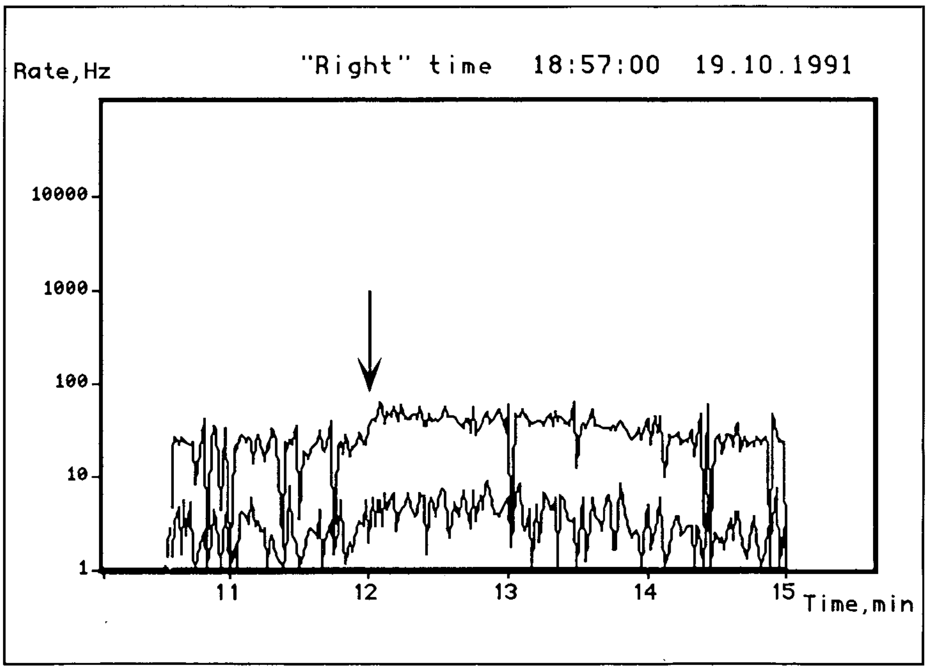
For the proton ring, equipped with superconducting magnets and completed in September 1990 for



Potentially troublesome persistent currents in the superconducting magnets of the proton ring for the HERA electron-proton collider at DESY, Hamburg, are constantly monitored by these two superconducting reference magnets switched into the main magnet circuit. Although the effects are quite strong, they are sufficiently reproducible that field errors can be corrected.

Photo P. Waloschek

A blip on the H1 experiment's luminosity monitor on 19 October showed that electrons and protons had begun colliding in HERA.



initial cooldown, prior measurements of field quality and extensive performance tests on each major component promised a smooth commissioning. After hardware trials in early spring 1991, commissioning with 40 GeV protons started last April.

A major concern at proton injection is the strong field errors due to 'persistent' eddy currents in the superconductors. Despite their name, these currents decay, producing further complications.

For the April run no acceleration was planned, and persistent current problems could therefore be avoided by a special magnet excitation cycle. Despite a low injection rate, stored beam was achieved in a few days. After a few technical problems, proton beam lifetimes of about 30 minutes were being obtained by the end of April.

HERA-p commissioning continued in August with the superconducting magnets powered up to 1000 A and persistent current field errors at full strength. After careful adjustment of the correction circuits and optimization of beam parameters, proton lifetimes of more than three hours were achieved at 40 GeV.

The persistent currents are constantly monitored in HERA by two superconducting reference magnets switched into the main magnet circuit. Although the effects are quite strong compared to the tolerances, they turned out to be sufficiently reproducible, and field errors can be corrected so that injection is possible without significant degradation of the proton beam behaviour (emittances).

This reproducibility and transparency of the persistent currents opened the door to energy ramping in the proton ring, and on 8 October, the beam reached 480 GeV with good intensity. The preaccelerators deliver about 2.5×10^{10} protons per bunch which can be accelerated without losses up to the maximum intensity. The beam emittances are close to the design values. So far, ten proton bunches at a time have been accelerated.

With each ring delivering, the next step was to run them in parallel. On 19 October, a proton bunch of 10^{10} protons was accelerated to 480 GeV. 12 GeV electrons were then injected into the electron ring, and the beams adjusted at the North interaction point using beam position monitors. Luminosity (collisions) was immediately picked up by detection of bremsstrahlung photons.

Progress continued in November with electrons taken to 26.5 GeV prior to collisions. To ensure good collision conditions over about ten hours, electron and proton beam sizes at the collision points are matched. The maximum luminosity for single bunch collisions is 0.7×10^{28} per sq cm per s. No problems have been detected when the number of colliding electron and proton bunches is each increased to ten.

These achievements promise a successful start to the HERA operations on 9 March. Soon after, the big ZEUS and H1 detectors will be ready to log their first data.

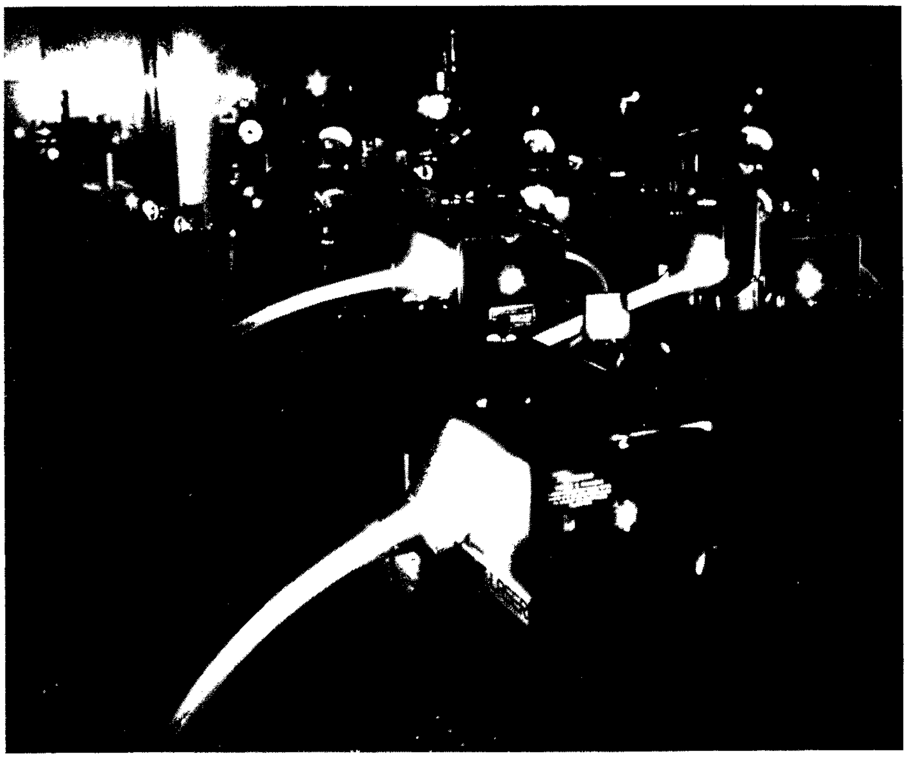
SPIN PHYSICS
Lasers at work

Lasers are now an everyday tool in particle physics, particularly for the spin polarization of beams, targets, and even short-lived particles.

Development has been boosted in recent years by the availability of reliable multiwatt tunable lasers to select spin in an experimentally useful sample.

One watt of laser light contains about the same number of photons as there are electrons in one ampere of current. If the photon polarization were transferred efficiently, a 1 watt

The dye laser system used for development of an optically-pumped polarized ion source at the Canadian TRIUMF Laboratory, Vancouver. The straight beams on the right are from argon lasers, powering four dye lasers. The curved paths are tubes carrying the dye solution. This source produces five microamps of 75 per cent polarized 500 MeV protons (December 1991, page 10).



polarized laser beam could in principle provide a nearly infinite angular momentum source to orient electron or nuclear spins. Although the process in practice is relatively inefficient, new standards of polarization have been set.

A major initial project was the laser-driven polarized electron source at the Stanford linear accelerator (SLAC), in operation in the late 70s. In this application, laser light interacts with the surface electrons of a semiconductor (gallium arsenide) photocathode where atomic levels are spread out into bands and spectroscopically pure light is not necessary. Circularly-polarized photons pump electrons from the semiconductor valence band into a spin state in the conduction band from which they can be emitted to form a polarized electron beam.

This technique is now being applied and perfected at many other electron accelerator laboratories, including Kharkov, Nagoya, MAMI-B at Mainz, MIT-Bates, ELSA at Bonn, and the CEBAF machine under construction at Newport News, Virginia. Emphasis is on increasing electron polarization above 50% by means of solid-state effects to remove the degeneracy in the electron spin levels (May 1991, pages 4 and 6).

With narrowband lasers now available, polarized electron beams can also be made from helium, optically pumped in the metastable state formed in a radiofrequency discharge. This method is under development at Orsay and promises high polarization.

In research and development work for the electron-positron linear colliders of tomorrow, laser irradiated photocathode techniques are being used to generate intense electron pulses (November 1990, page 5).

If polarized particles other than electrons are needed, an optically-pumped polarized alkali vapour can be used for spin exchange. In vapour or gas, the atomic absorption lines are narrow, and intense spectrally-pure laser light must be used to obtain adequate efficiency and vapour density. The polarized laser light pumps the alkali valence electrons out of one spin state and the vapour is left with nearly perfect electron spin alignment.

Depending upon the end-product required, one or more additional spin transfers are possible through atomic interactions. For example to make a beam of nuclear-aligned sodium atoms, the ordinary hyperfine magnetic interaction between valence electrons and nuclei will exchange spin.

Exchange of the valence electron spin orientation from the alkali (or in some cases transfer of the electron itself) to a different atom or ion makes possible the formation of other spin-polarized species. For example, TRIUMF (Canada), LAMPF (Los Alamos) and KEK (Japan) have optically-pumped polarized negative hydrogen ion beam sources in operation (December 1991, page 10) and the Moscow Institute for Nuclear Research has this source on the test bench. These sources produce negative hydrogen ions with proton polarizations around 65-70% and peak currents from 30-400 microamperes.

A group at Argonne (USA) is building a spin-exchange polarized deuterium target for the VEPP-3 electron storage ring at Novosibirsk.

TRIUMF uses a spin-exchange polarized helium-3 target. In this technique, first developed at Princeton, the helium nuclei exchange spins directly with polarized electrons in the alkali; the paired helium electrons play no role. Be-

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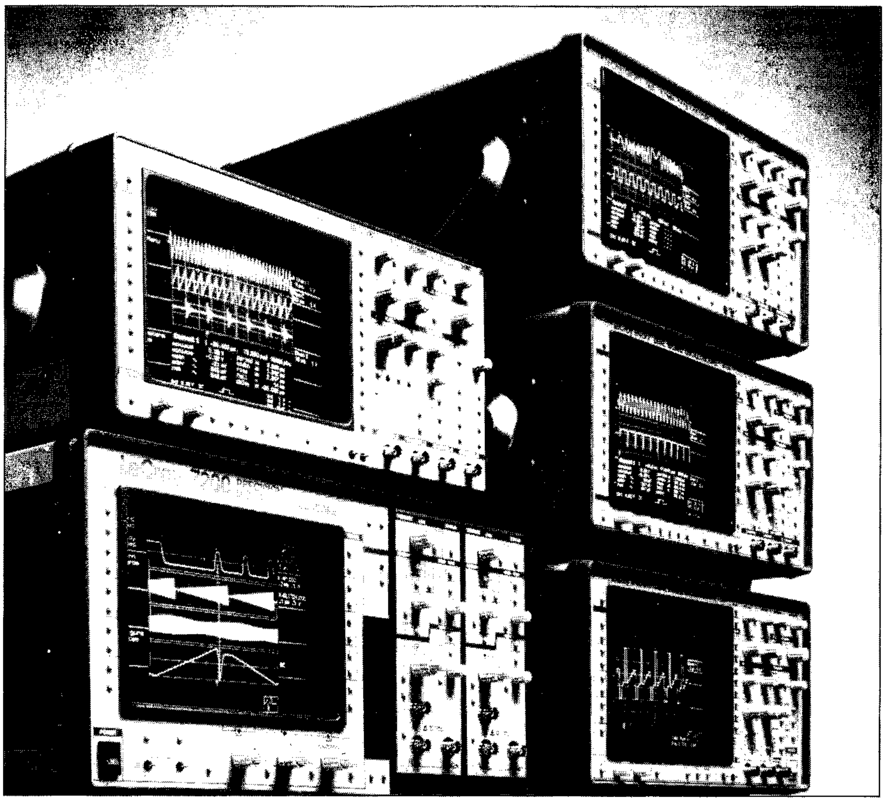

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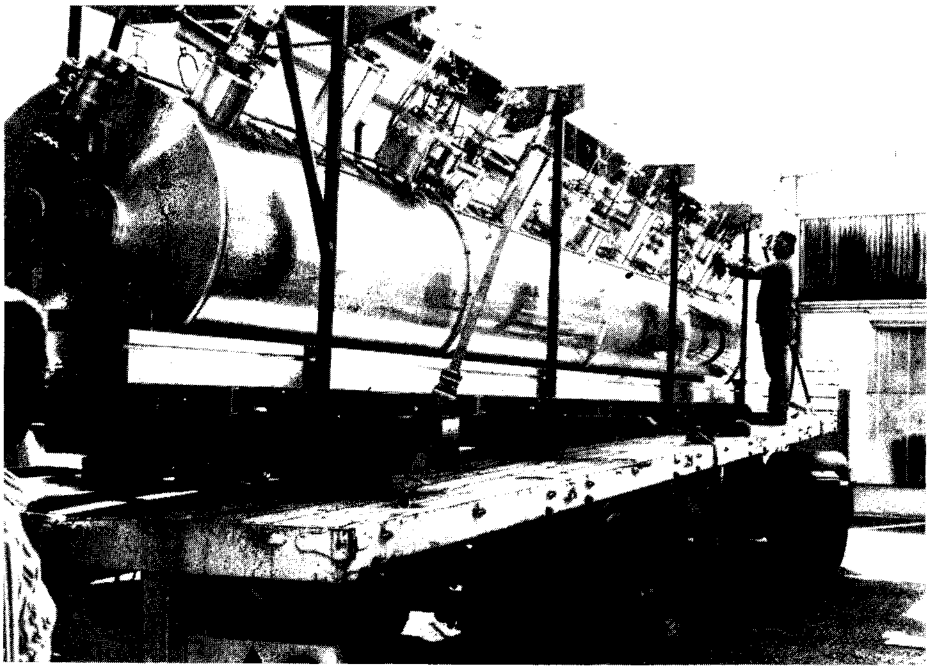
The Digital Scope Specialists

One of the superconducting cavities arriving at CERN's LEP electron-positron collider, where it will help push collision energies towards 200 GeV.



cause the overlap of the nucleus with extra-orbital electrons is small, the spin exchange time is slow, of the order of a few hours. Once the alkali vapour is removed, the inert helium can retain its nuclear polarization for 100 hours.

Helium nuclear spin is so isolated from all perturbations except magnetic that the gas can be compressed above 1 bar in a mechanical pump while retaining most of its polarization, as shown by a group at Mainz.

With spin exchange and helium, a Princeton-Syracuse team at LAMPF has manufactured highly-polarized muonic atoms. In the process of capture, a negative muon will eject both electrons from a helium atom. Polarization transfer to the muonic atom from a nearby polarized alkali electron occurs by spin exchange through the magnetic moments or by capture of the electron by the helium ion. With adequate density of optically-pumped polarized rubidium, the muonic atom polarizing time is less than the 2 microsecond muon lifetime and high polarizations are achieved. Results in the last few months show muonic atom polarizations more than ten times that resulting from retention of polarization in the muon beam, opening the door to new spin-sensitive experiments in the fundamental interactions.

From Olin van Dyck

WORKSHOPS
Radiofrequency superconductivity

In the continual push towards higher energy particle beams, superconducting radiofrequency techniques now play a vital role, highlighted in the fifth workshop on r.f. superconductivity, held at DESY from 19 – 24 August 1991.

Since the previous workshop at KEK, Japan, in 1989, there has been increased operational experience of superconducting electron and heavy ion accelerators. At KEK a total of 32 superconducting cavities are now routinely operated in the TRISTAN electron-positron collider.

At CERN three modules with four superconducting cavities each (two of solid niobium and one of niobium-sputtered copper cavities) have been installed in the LEP electron-positron collider as the first step towards higher energy running. In addition two more niobium-copper cavities are routinely operated in the SPS synchrotron. At DESY twelve four-cell cavities have been installed in the HERA electron ring.

In the domain of electron accelerators for nuclear physics, the first recirculating beam has been achieved at the Darmstadt S-DALINAC (May 1991, page 10), and an electron energy of 103 MeV attained. At the CEBAF machine under construction at Newport News, Virginia, the 45 MeV injection energy has been reached in cryomodules with eight superconducting cavities (September 1991, page 28), and the production of a total of 360 cavities at industry is steadily advancing. At Saclay in France the MACSE test facility with 5 superconducting cavities at 1.5 GHz has been started.

Higher acceleration fields are vital for new projects, and a large coordinated effort is going on, particularly at Cornell, Saclay and Wuppertal. Field emission of electrons by surface defects is the most limiting factor. New and refined diagnostics like field emission microscopes have been developed and it is hoped that this will lead to a better understanding of the defects causing field limitations.

It has been shown that small surface areas can withstand electric surface r.f fields up to 140 MV/m (corresponding to accelerating fields of some 70 MV/m). For large accelerating cavities (low frequency or multicell) these values are considerably reduced by surface defects which still escape control.

Nevertheless continuous accelerating fields of 25 MV/m have been repeatedly reached in single-cell cavities at 1.5 and 3 GHz, while multicell cavities in this frequency range have attained 15-20 MV/m.

At present the highest fields are achieved by high temperature annealing under ultrahigh vacuum at 1500 C. It is hoped that this treatment, combined with the use of very pure niobium, can push field limits even higher.

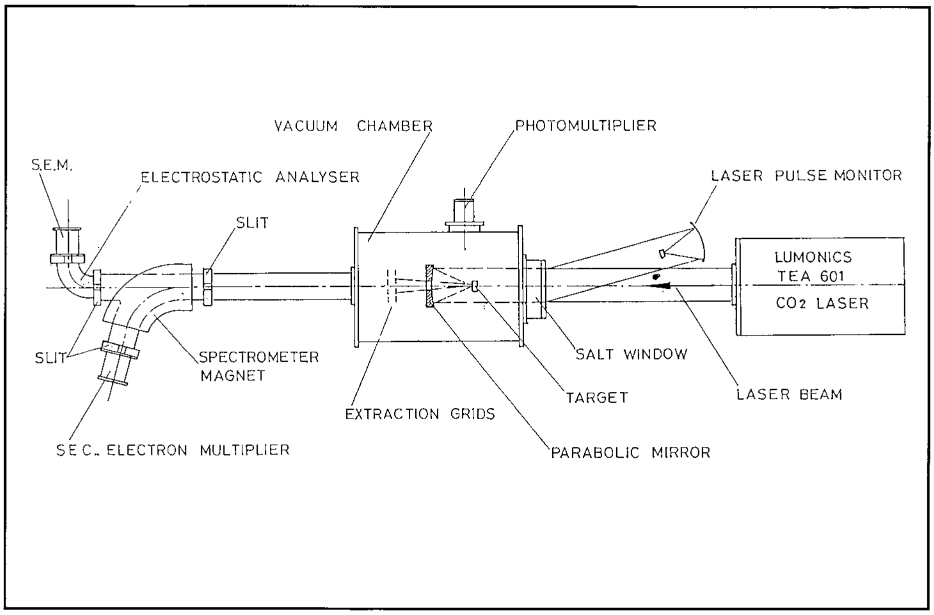
Recent promising results at Cornell used pulsed high power processing at many 100 kW, a method already used extensively at the kW level. Rinsing with clean dust-free water at high pressure has been applied successfully at CERN.

The sputtered niobium on copper cavities pioneered at CERN for 350 MHz are now applied elsewhere at higher frequency and to more complex structures (at INFN Legnaro).

The natural extension of this method to reactive sputtering for superconductivity at higher temperatures is being pursued in a number of laboratories. The increased use of high purity niobium for better thermal stabilization of defects has sometimes unexpectedly degraded cavity resonance. In a remarkable common effort, this has been traced to hydrogen introduced into the niobium by chemical treatments. Remedies like annealing at 700 C have been developed.

One review talk was devoted to high temperature superconductivity and its r.f. properties. Although a large number of sophisticated production processes are now at hand, performance is severely limited by high defect density. Small-scale applications for passive microwave devices are already under development at Wuppertal.

At CERN, recent work using this 50J carbon dioxide laser setup has given lead ions up to charge 28.



Superconducting cavities are now considered for new applications such as particle factories and linear colliders. For the former, new geometries have been designed, combining low impedances with extremely strong damping of higher order modes against multibunch instabilities (Cornell).

The biggest challenge is in the field of linear colliders, and a special series of talks concentrated on the TeV Energy Superconducting Linear Accelerator (TESLA) idea, with the two last days of the Workshop devoted to a TESLA collider in the 500 GeV range.

The basic advantage of superconducting cavities is the very efficient storage of r.f. energy, so a low frequency (around 1 GHz) and a rather long pulse (1 ms) can be used. The former gives a large aperture (low wakes, long bunches, low alignment tolerances, ...) while the latter allows multibunch operation (with long bunch separation, modest peak power, r.f. feedback, ...). Niobium cavities at 1.3 GHz with an accelerating field up to 25 MV/m are anticipated.

In a final talk Maury Tigner from Cornell underlined the considerable progress achieved since 1960. Superconductivity is at the heart of new and fascinating challenges in modern accelerators and hopefully the remarkable progress so far will continue.

The Workshop was attended by 150 participants from 35 institutions and from industry, and was splendidly organized by local chairman D. Proch and his team.

Ion sources

Against a background of increasing use of radiofrequency- or microwave-driven ion source plasmas, the recent International Conference on Ion Sources – ICIS 92, held at the GSI Darmstadt Laboratory, included some interesting new developments.

I.A. Bykovsky and V.N. Nevolin from Moscow surveyed 20 years of work on laser-induced ion source plasmas, including commercially available machines built in the Ukraine for ion beam analysis with 100 nanometre resolution, or for ion implantation for surface modification.

Ray Sherwood of CERN showed recent results using a 50 J carbon dioxide laser, giving lead ions up to charge 28. A collaboration with ITEP Moscow has also investigated five-microsecond pulses and a repetition rate of 1Hz, well suited for synchrotron injection.

A good source of metallic ions is the MEVVA – Metal Vapour Vacuum Arc – technique. These sources are usually pulsed, but now there are results with DC operation with ion currents up to 1A (I. Brown, Berkeley). For metallic ion production, negative ion sources also show remarkable results, with 10 mA DC or more than 100 mA pulsed (Y. Mori, KEK Japan).

Special applications like microprobes for ion beam analysis or for direct writing or etching of micromechanics or microelectronics are the domain of liquid metal sources (R. Muehle, Jena). For ion etching, broad low energy ion beams are used (H.C. Scheer, Berlin). Large area intense ion beams of some 10 keV are needed for ion beam assisted deposition techniques (W. Ensinger, Heidelberg).

C. Jaquot of the French Cadarache centre reported on the joint European programme for neutral beam injection into Tokamaks. Large cusp ion sources generate 4 A of negative deuterium ions which will be accelerated to 1.2 MV.

Ion beams are also used as thrusters in satellites and space probes. Although producing low thrust, they can be maintained from solar panels for a very long period and are well suited for long-term stabilization (H.W. Loeb, Giessen).

On-line mass separators need efficient ion sources. Besides classical discharge and microwave (electron cyclotron resonance – ECR) sources, surface ionization is also effective, while laser ion sources provide a fresh approach.

ECR sources are widely used to generate high currents of multiple charged ions. By injecting electrons or by coating the source chamber, high charge yields can be improved. Special source optimization to an afterglow mode of 100 microamps of lead 28+ during a 0.4 ms pulse and at a repetition rate of 1-4 Hz have been detected (P. Sortais, GANIL, France).

Even higher charge states with moderate intensities can be produced in electron beam ion sources (EBIS) and are mainly used for atomic physics experiments.

In an electron beam ion trap (EBIT), extremely high charges (thallium 80+ and uranium 70+) have been created, stored and used for spectroscopy (D. Schneider, Livermore). Until now such highly charged ions could only be generated by stripping high energy beams of heavy ions.

The next meeting in the series – ICIS 93 – will be held end-August 1993 in Beijing. Contact Zhao Weijian, Institute of Heavy Ion Physics, Beijing University, Beijing 100871, China, fax +86-1-2564095.

From B. Wolf

Theory flexes its muscles

With the Standard Model of interactions between the fundamental quark and lepton constituents of matter so

A highlight of the 1991 DESY Theory Workshop was the interest in possible baryon and lepton number violation at high temperatures. Among the speakers looking at the implications were V. Rubakov (right) and L. McLerran.

successful at describing laboratory experiments, theorists have looked at the possibility of new phenomena occurring under extreme conditions – high temperatures, high densities or high energies.

Thus the 1991 event of the annual DESY Theory Workshop looked at 'The Standard Model at High Temperature and Density'. Three main topics were covered – baryon and lepton number violation at high temperatures and energies; high temperature transitions between ordinary hadronic matter and the quark-gluon plasma; and cosmological and astrophysical implications.

The mathematical structure of the Standard Model allows for baryon (B) and lepton (L) numbers – the numbers of strongly and weakly interacting particles respectively – to be not strictly conserved. However under usual conditions the effects are tiny, and can only happen via highly damped quantum tunneling. For example, the deuteron is in principle unstable, decaying into an antinucleon and three antileptons. Its lifetime, however, is of the order of 10^{200} years!

At the Workshop, V. Rubakov (INR Moscow) reviewed (B+L) violation at high temperatures. At temperatures of order 10 TeV and above (B+L) violation is no longer a quantum effect. Quantitative studies and real-time computer simulations support this expectation.

M. Shaposhnikov (INR Moscow and CERN) reported on the cosmological implications of unsuppressed high-temperature (B+L) violation. The explanation of matter/antimatter asymmetry in the Big Bang model of the Universe is a challenge for theoretical physicists. However the weak interactions in the hot plasma of the early Universe fulfilled all necessary conditions for such an asymmetry – B is violated strongly at high temperatures; weak interactions violate charge and charge/space reflection (CP) parity; and there are large effects in the electroweak phase transition between the high-temperature phase of massless particles, and the low-temperature phase, where the W and Z particles become heavy.

As a result, the matter asymmetry of the Universe may originate from the electroweak phase transition at temperatures around 100 GeV, without resorting to 'Grand Unified Theories' incorporating strong interactions as well, and needing energies of 10^{16} GeV.

Electroweak generation of matter asymmetry requires a relative light Higgs boson, preliminary estimates giving an upper limit of 64 GeV in the minimal Standard Model. No stringent bounds come from extended versions of the Standard Model with multiple Higgs particles.

While electroweak (B+L) violation comes into its own at very high temperatures, it is not yet clear whether it would show up in high energy collisions above 10 TeV. L. McLerran (Minneapolis) thought that while at first sight it might look difficult to provide the conditions for (B+L) violation in high energy scattering, the heavily damped tunneling factor may go away.

A. Ringwald (CERN) looked at ways of estimating effects at energies around 10 TeV. Extrapolating existing calculations shows that the exponential suppression of (B+L) violation disappears at collision energies around 30 TeV, so that these processes might be seen at future supercolliders.

G. 't Hooft (Utrecht), the 'father' of low-energy electroweak (B+L) violation, concluded the first day by presenting an alternative method for investigating high energy (B+L) violation and looking at the implications.

The workshop also looked at quark systems at high temperature – the thermodynamics of hot and dense strongly interacting matter. The theoretical basis is provided by quark field theory of a lattice, explored by computer simulation.

F. Karsch (Juelich) reviewed these studies, which concentrate on the predicted deconfinement of quarks in dense matter and on the properties of the resulting new state of matter, the quark-gluon plasma. The deconfinement temperature is found to depend on the number of quark 'flavours', and the best present estimate for the 'physical' case of two light quark species lies around 150 MeV.

This means quark deconfinement sets in when matter reaches twice the density of a single nucleon. The transition itself has been the centre of much attention; three light quark species behave one way (first order transition), two such species another (continuous changeover). Which of these two alternatives is correct in the real world of two light and one heavy (strange) quark appears to require more extensive studies on still larger lattices.

An experimental test of quark thermodynamics is the ultimate aim of high energy heavy ion collision studies. Experiments were started at CERN and Brookhaven just five years ago, and have so far used only rather light ions (silicon-28 and sulphur-32). J. Schukraft (CERN) summarized the present experimental situation, concentrating on the overall conditions reached so far, on evidence for thermalization, and on possible probes of the early phase of the produced matter.

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At the DESY Theory Workshop, R. Barbieri of Pisa provided a theory overview of solar neutrinos, neutrino masses and neutrino mixing.

The achieved energy densities are indeed sufficient for deconfinement. There are clear nuclear effects which point to an onset of thermalization and indicate the formation of very dense initial systems.

The third day of the workshop was given over to astroparticle physics. I. Appenzeller (Heidelberg) reviewed the current status of structure in the Universe. The known mass in the Universe forms a sponge-like structure with 'walls' of galaxies, clusters and superclusters, and intervening 'voids'. Structure is observed to at least sizes of 300 Mparsecs (galaxies are in the 0.01 to 0.3 Mpc range while clusters go from about 1 to 20). Beyond 500 – 1000 Mpc the mass distribution appears to be more smooth.

M. Turner (Fermilab) discussed the formation of structure in the Universe. This is in a certain sense an initial data problem: given the matter content and the initial density fluctuations at the epoch when the Universe becomes matter-dominated, one may evolve the system and determine the typical final structures produced by gravitational growth of fluctuations. There is no 'Standard Model' of structure formation, only different scenarios corresponding to different choices of matter content and density fluctuations. The limits on irregularities in the microwave background put stringent limits on the initial fluctuations. The matter content is not so well determined, apart from the fact that the baryonic matter content is constrained from primordial nucleosynthesis.

Turner discussed some recent observations which suggest a considerable amount of non-baryonic dark matter. He presented in detail one possible scenario for structure formation, with most of the Universe consisting of so-called cold dark matter (for example light neutrinos, axions, neutralinos) and where the initial fluctuations are scale-invariant. The result is that galaxies form first and the larger structures later (even now).

The experimental status of solar neutrinos, neutrino masses and mixing was reviewed by M. Spiro (Saclay). Direct mass measurements of the three known species of neutrinos yielded so far only upper bounds, 9.5 electronvolts for the electron neutrino, 170 keV for the muon neutrino, and 35 MeV for the tau neutrino. Other bounds come from double beta decay limits (December 1991, page 16). If neutrinos are massive, they can mix, giving neutrino oscillations. So far there is no evidence. Evidence for a 17 keV neutrino (April 1991, page 9) is still controversial.

The new solar neutrino experiments SAGE and GALLEX may help resolve the solar neutrino problem – the conflict between the flux of solar neutrinos predicted by calculations and the observed levels – as they can see neutrinos from the dominant proton-proton fusion reaction. Initial data is appearing, but Spiro urged physicists to 'wait and see'.

In the closing talk, John Ellis (CERN) summarized our understanding of phase transitions in the early Universe. In the quark-hadron transition quark confinement made its first appearance, the quarks combining to form strongly interacting elementary particles. Although lattice studies have given semi-quantitative results for this transition for very low baryon density, there remains a need for corresponding studies of baryon-rich systems, such as possible quark stars.

In the electroweak phase transition, the W and Z bosons acquired mass, unlike the photon. This transition is sensitive to the as yet unknown masses of the Higgs boson and the top quark, and could lead to bounds on these masses. In addition, this transition could be responsible for matter dominance in our present Universe.

Beyond both these transitions lies the question of the fate of the Standard Model at temperatures higher than the Planck mass (10^{19} GeV). Ellis concluded with a 'triple symbiosis' of theory, with model and lattice calculations; experiment, with heavy ion studies as well as particle searches; and cosmology, with neutron stars, element abundances and the baryon asymmetry of our Universe.

From H. Satz and A. Ringwald

LHC milestone

At the December meeting of CERN's Council, the Organization's Governing Body, the delegates from the 16 Member States unanimously agreed that the LHC proton-proton collider proposed for the 27-kilometre LEP tunnel is the 'right machine for the advance of the subject and of the future of CERN'. Detailed information on costs, technical feasibility and prospective delivery schedules, and involvement of CERN Member States and other countries, together with an outline of the LHC experimental programme, its goals and its implications, including funding, will be provided before the end of 1993 so that Council can move towards an LHC decision.

Following the vote, Council President Sir William Mitchell said 'this is a historic occasion'. 'The LHC project now exists', he added.

The vote followed a special extended Council session on the LHC Project on 19 December before extended delegations from CERN Member States and invited guests from other nations. They heard presentations from Scientific Policy Committee Chairman Chris Llewellyn Smith on the physics potential for LHC, from European Committee for Future Accelerators (ECFA) Chairman J.-E. Augustin on the LHC user aspects, and from CERN Director General Carlo Rubbia in the LHC project and the future of CERN. This special meeting helped prepare the ground for Council's vote the following day.

At a special session of CERN Council on the LHC project on 19 December, Director General Carlo Rubbia spoke on the LHC project and the future of CERN.

Following the special session, Council delegates voted unanimously that 'the LHC is the right machine for the advance of the subject and of the future of CERN'.

(Photo CERN HI 47.12.91/5)

CERN's 17th Member State

At the December Council session, delegates voted unanimously to admit the Czech and Slovak Federal Republic as CERN's 17th Member State, as from 1 January.

The Czech and Slovak Federal Republic has an excellent tradition in physics, with research centres in Prague, Bratislava and Kosice. Work at CERN dates back to the early 1960s when Prague physicists collaborated in bubble chamber experiments. For a period, Czechoslovak physicists maintained only indirect contact with CERN via the Joint Institute for Nuclear Research in Dubna, but in the 1980s formal collaboration was reestablished with Czechoslovak physicists working in the UA2 and Helios experiments.

Current participation includes an important collaboration in the Delphi experiment at LEP. The country's high energy physics research programme will be expanded in the next few years to exploit the new opportunities offered by the CERN programme.

The move continues CERN's new spirit of pan-Europeanization. Established originally among West European States, the Organization extended its membership to Poland last year. Discussions with other European countries are at an advanced stage, with Hungary prominent in the queue of prospective Member States. Outside Europe, cooperation agreements have been signed with Australia, Chile, China and India, while the Russian Federation and Israel now participate in CERN Council meetings as official observers.

The December Council meeting also approved the new composition of the Laboratory's Directorate under Director General Carlo Rubbia: Pierre Darriulat, Walter Hoogland and John Thresher as Research Directors; Gunther Plass as Director of Accelerators, Helmut Weber as Head of Administration; Hans Hoffmann as Director for Technical Support; Giorgio Brianti as Associate Director for Future Accelerators; Roy Billinge as Associate Director for Informatics; and Christian Roche as Associate Director for Forecast and Planning. Bjorn Brandt, Swedish delegate to the Finance Committee, was elected as the Committee's new Chairman and Gunther Wolf of DESY becomes a member of the Scientific Policy Committee.

Council also stood in memory of Gosta Funke of Sweden, Council President from 1967-9 and Finance Committee Chairman from 1961-3, who died in December aged 89.

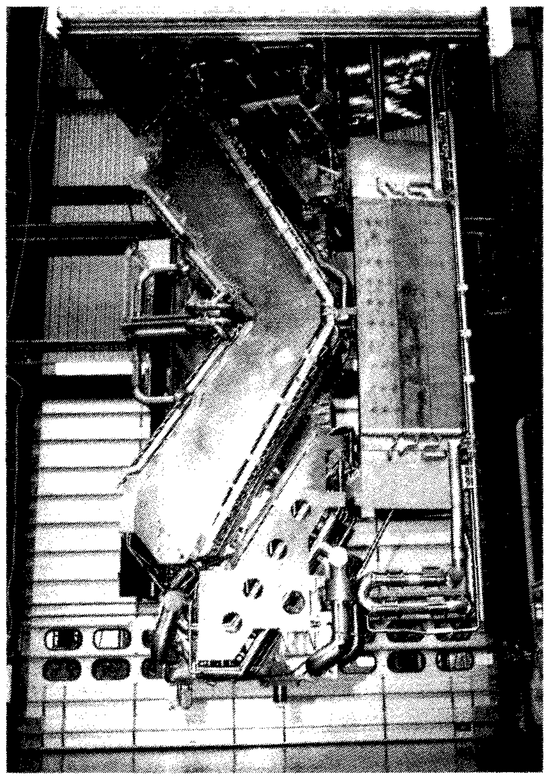


Photo shows the 8 m high magnet assembly at JET.

People and things

On people

Robin Marshall of the UK Rutherford Appleton Laboratory has been appointed Professor of Experimental Physics at the University of Manchester, taking up his duties in April. Since 1978, he has led the RAL team involved in the JADE and H1 experiments at DESY, Hamburg. Manchester collaborates in H1 as well as the Opal experiment at CERN, and has begun preparations for the proposed LHC collider at CERN.

New Award

The new Faraday Cup award, sponsored by Bergoz and worth $5000, for innovative beam instrumentation will henceforth be presented at the annual Accelerator Instrumentation Workshop. Nominations to Jim Hinkson or Greg Stover, Lawrence Berkeley Lab, MS 46-125, 1 Cyclotron Road, Berkeley, CA 94720.

Franz Plasil of Oak Ridge Laboratory, Tennessee, chaired the Organizing Committee of the recent 'Quark Matter '91' meeting, the ninth International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, held in Gatlinburg, Tennessee, from 11-15 November. Dedicated to the memory of Leon Van Hove, the meeting attracted about 50 per cent more physicists than originally planned, reflecting the current interest in the interface between particle and nuclear physics. Even just at CERN, this research attracts more than 500 scientists.

T.G. Pickavance 1915-1991

T.G. ('Gerry') Pickavance, who died on 12 November, was one of the enthusiasts who worked hard to ensure that the United Kingdom became a Member State of CERN, although his relative youth at the time prevents him from being thought of as one of its founding fathers. He went on to play important roles in CERN affairs: advisor to the cyclotron project and Chairman of the European Committee for Future Accelerators (ECFA) in 1970. For many years he was scientific advisor to the UK CERN delegation.

His particle physics research career began at Liverpool under James Chadwick. At the end of World War II he moved to the Atomic Energy Research Establishment at Harwell, under John Cockcroft, as Head of the Cyclotron Group. Pickavance would almost certainly have moved to a senior post at CERN if Cockcroft had been prepared to release him. Instead he took charge at Harwell of a 600 MeV proton linear accelerator project. This ambitious machine was never completed, but served as a basis for the design of the 50 MeV injector for the CERN PS.

In 1957 Pickavance became the first Director of the UK's Rutherford Laboratory, charged with the task of building the 7 GeV Nimrod proton synchrotron and creating a Laboratory for visiting scientists. In 1969, he left the Rutherford Laboratory to become Director of Nuclear Physics for the UK Science Research Council.

Sadly the physics community was soon deprived of his talents. On a trip to a conference in Bologna he became ill with pneumonia, followed by a stroke which left him partially paralysed and seriously impaired his speech. His wife and family have always spoken with gratitude of Antonino Zichichi's efforts in securing for him the best possible medical treatment in Bologna, which may well have saved his life. Although forced to retire in 1972 at the age of 57, Pickavance always retained his enthusiasm for physics and, right up to his death, held court at his UK home for many friends.

He was awarded the order of Commander of the British Empire (CBE), elected Fellow of the Royal Society and a Visiting Fellow of St. Cross College, Oxford. He received an honorary doctorate from London's City University and the Glazebrook Medal and Prize from the UK Institute of Physics.

From Godfrey Stafford

T.G. ('Gerry') Pickavance 1915-1991

SSC Laboratory

Superconducting Super Collider Laboratory

We're about to change the way we look at the universe.

The SSCL, located just south of Dallas, Texas, is rapidly moving to become the premier center of particle physics research in the world. Major activities at the SSCL include design and construction of the 20 TeV proton collider and its associated complex of accelerators and detection apparatus as well as research in particle physics.

As part of the SSC Laboratory team of scientists, engineers and computer scientists, you'll be doing work which will have incalculable consequences for the future of science and technology, as well as the growth of human knowledge.

ASSOCIATE DIRECTOR: COMPUTING DIVISION

We seek an exceptional scientist with management experience to provide strong leadership as Division Head of the newly established Computing Division. The Computing Division, at the forefront of scientific computing hardware and software, provides leadership, guidance and planning for scientific computing policy and environments; develops, operates and maintains central computing resources, support operations of distributed facilities and establishes/maintains the laboratory computer networking system. The Division Head should have experience with currently available mainframes & workstations, as well as UNIX, VMS and PC operation systems. Additionally this Division will do research and development in computing methodology, techniques and software relevant to the anticipated needs of its users. Division staff will be the contact points for joint development projects with industry and university groups. The Division Head, reporting to the Laboratory Director, will manage and lead a current staff of 75 people which is expected to increase to 100+ over time.

The Superconducting Super Collider invites applications from outstanding candidates with an advanced degree, preferably a PhD in Physics or Computer Science, who have had significant experience with computing as practiced in a particle physics research environment, along with management and supervisory experience.

To Apply: Send Complete Resume and Salary History
Fax: 214-708-5592
Mail: SSC Laboratory
2550 Beckleymeade Ave.
MS-2050 / 3438-LB
Dallas, Texas 75237

An Equal Opportunity/Affirmative Action Employer.
As always the SSCL strongly encourages minorities and female candidates to apply.

UNIVERSITY OF COPENHAGEN

The Niels Bohr Institute

Applications are invited for a Chair (Professorship) in **Experimental Physics** at the Niels Bohr Institute, to commence November 1, 1992.

The professor will be appointed as a Civil Servant under the Ministry of Education and Research. The annual salary will amount to approximately 360.000 Danish kroner.

The chosen candidate is expected to take part in the experimental research activities of the Niels Bohr Institute, - either in low- and medium-energy nuclear physics in connection with the Tandem Accelerator Laboratory and accelerators abroad, - or in experimental high-energy particle physics in connection with the Institute activities at CERN.

The professor will also participate in the university teaching at all levels. The language of instruction is Danish, but English will be accepted for the first two years of the appointment. In the evaluation of the applicant, importance will also be given to teaching experience and qualifications.

Information about research plans, facilities and staff at the Niels Bohr Institute may be obtained from the Director, Blegdamsvej 17, DK 2100 Copenhagen Ø, Denmark.

Applications should include a curriculum vitæ, a complete list of publications, copies of scientific publications and further documentation which the applicant wishes to be considered, and a brief outline of proposed research. Information concerning the applicant's teaching experience, to be evaluated by the Study Board, should also be enclosed. The material should be submitted in triplicate together with a complete list of the material.

After evaluation of the applicants' qualifications by a specially appointed Evaluation Committee, the Committee's report will be sent to all applicants.

Applications are to be addressed to Her Majesty the Queen of Denmark, and sent to the Faculty of Natural Sciences, Panum Instituttet, Blegdamsvej 3, DK - 2200 Copenhagen N, Denmark. The closing date for receipt of applications is April 1st, 1992.

Research Associate Experimental High Energy Physics

The J.W. Goethe Universität Frankfurt/Main, Institut für Kernphysik, is involved in the CERN Heavy Ion Program and is seeking a

Research Associate

to take part in the preparation of new experiments and in the analysis of the ongoing experimental work (NA35, NA49).

A Ph.D. in experimental physics and experience in the field of ultrarelativistic nucleus-nucleus collisions are requested.

The successful applicant will be offered an indefinite contract. The salary is defined by the German BAT regulations.

Applicants are requested to submit within 3 weeks of publication date curriculum vitæ, list of publications, statements of research interests and names of three references to

Prof. Dr. R. Stock
Institut für Kernphysik
Aug. Euler Str. 6
D - 6000 Frankfurt/Main 90
Tel. 49-697984240

Theodorus J. Sluyters

Theodorus J. Sluyters, who retired at the end of June after 27 years at Brookhaven, died of a heart attack on 17 November while vacationing in his native Holland. He was 63 years old.

Sluyters had many friends in Laboratories all over the world. He earned his physics PhD at Amsterdam in 1958. After working at the F.O.M.-Laboratory in Amsterdam, and then at CERN, he joined Brookhaven in 1964. In 1971-72 he was visiting professor at the KEK Laboratory in Japan. Sluyters was a member of the Dutch Physical Society, the British Interplanetary Society, and the American Physical Society.

In the early 1970s Sluyters and his colleagues at Brookhaven began working on the development of ion sources. Pioneer work on negative hydrogen ion (H-) sources suggested a superior injection technique for high energy accelerators. This programme soon showed that negative ions of hydrogen isotopes can also have applications for plasma heating of fusion devices. Negative ion injection has since become a standard technique at proton accelerators, making possible, for example, a doubling of the Brookhaven Alternating Gradient Synchrotron (AGS) beam intensity. Later the group built a spin-polarized H- source for experiments with polarized protons at the AGS.

Sluyters was a forceful organizer of people and events. In 1971 he organized the first Symposium on Ion Sources and Formation of Ion Beams, and from 1977 he and his colleagues have sponsored a broader Symposium, held every three years at Brookhaven, on the Production and Neutralization of Negative Ions and Beams; these meetings have become the most important on the subject worldwide.

Theodorus J. Sluyters

In 1983 Sluyters became deputy head, and in 1986 head of the AGS Accelerator Division, overseeing the longterm upgrade programme to prepare the AGS for higher intensity operation and heavy ion operation with the new Booster. From 1990 until his retirement he was Deputy Chairman of the AGS Department.

With unbounded energy and enthusiasm, Sluyters was a generous colleague and friend. He chose early retirement with extensive plans to enjoy many years of travelling. His sudden death left his many friends shocked, with a deep feeling of loss. He was buried in Amsterdam on 21 November.

His colleagues

Sakharov Remembered

'Sakharov Remembered – A Tribute by Friends and Colleagues' is the title of a remarkable volume about a remarkable man. Edited by Sidney D. Drell and Sergei P. Kapitza and published by the American Institute of Physics, New York, in cooperation with the Physical Society of the USSR, it covers both the life and the contributions to science of a man who was looked on by many as a living saint.

Some of the material has already been published – in Moscow in a special issue of 'Priroda' ('Nature') and in the US in 'Physics Today'. These essays are supplemented by other contributions, by many poignant photographs, and by a panel discussion ('On Free Thought') organized in Moscow by 'Priroda'.

The book is a worthy memorial to a man who 'was a moment in the conscience of humanity'.

Books

'Elementary Particles and the Universe', edited by John H. Schwarz and published by Cambridge University Press (ISBN 0 521 41253 6, hardback) includes essays from a two day-symposium at Caltech in 1989 marking the 60th birthday of polymath Murray Gell-Mann, with additional contributions from friends and colleagues.

Meetings

The XV International Conference on High Energy Accelerators will be held in Hamburg, Germany, from 20-24 July, organized by DESY and sponsored by IUPAP. Further information from HEACC 92 Conference Office, DESY, Notkestrasse 85, 2000 Hamburg 52, Germany, fax +49 40 8969-7305, e-mail HEAC92 at DHHDESY3.BITNET

The Third International Symposium on the History of Particle Physics will be held at the Stanford Linear Accelerator Center (SLAC) from 24-27 June. Co-sponsored by SLAC and

FACULTY POSITION EXPERIMENTAL HIGH ENERGY PHYSICS
The Ohio State University

The Department of Physics invites applications for a tenure track faculty opening in Experimental High Energy Physics. We are looking for a person with a strong record and outstanding promise as a researcher, who will also be a good teacher.
Present research interests of our group of nine faculty include studies of heavy quarks and tau leptons, neutrino oscillations, high energy electron-proton collisions, and detector development for the SSC. Experiments are now running or staging at CESR, Fermilab, and HERA.
Applicants should send their curriculum vitæ and the names of at least three references to :

Richard Kass, Search Committee Chair
Department of Physics
The Ohio State University
Columbus, OH 43210

Applicants will be screened beginning March 1, 1992 and will be accepted until the position is filled. Pending final administrative approval, the department hopes to fill this vacancy by Autumn, 1992. The Ohio State University is an equal opportunity and affirmative action employer.

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of California, Riverside, expects to make a faculty appointment in the area of experimental high energy physics on or after July 1, 1992. This tenure-track appointment will be at the level of Assistant Professor. The department is seeking candidates with outstanding research records and strong commitment to teaching. The individual appointed will be expected to join, for the near term, the ongoing Riverside research program in high energy proton-proton and proton-antiproton collisions. Please send a resume and arrange to have at least three letters of recommendation sent to

Chair, Search Committee
Experimental High Energy Physics
Department of Physics
University of California, Riverside
Riverside, California 92521

The deadline for receiving applications will be February 29, 1992. Any applications received after this date will be considered only if an appointment is not made from the original pool.

The University of California, Riverside, is an Equal Opportunity, Affirmative Action Employer. Minority and women candidates are encouraged to apply.

UTRECHT UNIVERSITY

The Department of Physics and Astronomy of the University of Utrecht (Netherlands) has an opening in the subatomic physics group for a

Professor of Experimental Physics

[full time vac.nr. 566/63065]

The group with a staff of about 40 (including Ph.D.students and technicians) and about 15 undergraduate students performs research in the field of nuclear physics and high-energy physics with an emphasis on the thematical overlap of both disciplines, the subatomic physics. Electron and hadron experiments are carried out at national (Amsterdam, Groningen) and international (Geneva, Caen, Bonn) facilities.

The applicant is expected to play a leading role in the research programme and to take an active part in the teaching of subatomic physics, the general teaching programme of the faculty as well as the management tasks. We are looking for an experimental physicist with a broad knowledge and proven originality in the fields of experimental nuclear physics and/or high-energy physics, particularly in subatomic physics. The candidate should have experience and quality in scientific teaching (which, after two years, should also be done in Dutch). Furthermore good management abilities are required. The annual salary amounts to approximately Hfl. 100,000.– to Hfl. 150,000.– depending on experience.

More information may be obtained from Prof. R. Kamermans, P.O. Box 80.000, 3508 TA Utrecht, tel. +31 30 532517/531492. Those wishing to recommend candidates are also invited to contact him.

Applications with a curriculum vitae, a list of publications and the names of three referees, should be sent to the Dean of the Department ☆ Prof. dr. H.P. Hooymayers ☆ Princetonplein 5 ☆ P.O. Box 80.000 ☆ 3508 TA Utrecht, within 4 weeks after appearance of this announcement.

UNIVERSITE CATHOLIQUE DE LOUVAIN, BELGIUM
Department of Physics

FACULTY POSITION IN EXPERIMENTAL PHYSICS

The Rector of the Catholic University of Louvain (UCL) in Louvain-la-Neuve, Belgium, invites applications for a full-time academic position beginning in fall of 1992. Applicants will have a Ph.D. or equivalent and postdoctoral experience. The appointed person is expected to teach physics courses in the university and play a leading role in both shaping and implementing the research program of the Institute for Nuclear Physics of UCL.

Presently this program includes experiments pertaining to the following domains of investigation :

- physics with radioactive ion beams (e.g. study of nuclear reactions of astrophysical interest) ;
- nuclear reactions induced by heavy ions ;
- fundamental interactions and symmetries ;
- high energy physics : neutrino induced reaction ; neutrino oscillations ;
- nuclear physics applied to medicine and radiobiology ;
- solid state physics studies using nuclear techniques.

At the beginning, only a good knowledge of English is required but, as the candidate is expected to teach physics in French, he should acquire a reasonable command of the language within two years. Rank and salary will depend upon qualification and experience. Candidates should send a curriculum vitae, a research program (short and long term), three letters of recommendation and a copy of their five most representative publications to Professor P. Macq, Rector of UCL, Halles Universitaires, Place de l'Université, 1, B-1348 Louvain-la-Neuve, Belgium. Closing date for applications is March 31, 1992.

For further information, especially about the current research programs of the Institute,, write or call Professor J.-P. Antoine, Chairman of the Department of Physics, Chemin du Cyclotron, 2, B-1348 Louvain-la-Neuve, Belgium, Tel. +32.10.47.32.94, Fax +32.10.47.24.14.

Fermilab, the meeting is organized around the central theme of 'The Rise of the Standard Model' of particle physics from 1964-79. Topics include the growth of large international collaborations, the transition from fixed target to colliding beam work, the unification of the weak and electromagnetic forces, and the development of the quark model. Speakers include physicists, science historians and philosophers, and sociologists. Meeting chairpersons are Lillian Hoddeson and Michael Riordan. Further information from Nina Adelman Stolar, SLAC Public Affairs Office, MS 70, PO Box 4349, Stanford, California 94309, USA. Phone 415-926-2282, bitnet nina at slacvm or fax 415-926-4999 or telex 3722871 stanuniv.

The Seventh International Symposium on Very High Energy Cosmic Ray Interactions will be held at the University of Michigan in Ann Arbor, Michigan during the week 21-27 June, 1992. These symposia, held biennially over the past decade, focus on the nature of the interactions of elementary particles and nuclei at the highest attainable energies as studied with cosmic rays and at high-energy particle accelerators. Lawrence W. Jones of Michigan is chairman of the Local Organizing Committee. Information may be obtained from: ISVHECRI, University of Michigan, Department of Conferences and Seminars, 541 Thompson Street, room 112; Ann Arbor, Michigan, 48109-1360, USA, Telefax: 313-764-1557, E-mail: David H. Frankel at ub.cc.umich.edu.

A NATO Advanced Study Institute will be held from 12-25 July in Il Ciocco near Lucca (Tuscany), Italy, on Particle Production in Highly Excited Matter, directed by G. Bellettini, H.H. Gutbrod, and J. Rafelski. It is intended for young scientists, such as final-year graduate students and postdocs, and will focus on the study of highly excited nuclear matter and quark-gluon plasma formation by observation of particle production and emission. All enquiries to: Hans H. Gutbrod, CERN, PPE-Division, 1211 Geneva 23, Switzerland, e-mail gutbrod at cernvax.bitnet fax: +41 22 782 4897. Students eligible for a NATO fellowship should send a short one-page CV and a letter of recommendation. Deadline for applications is 1 March.

The 10th International Symposium on High Energy Spin Physics will be held in Nagoya from 9-14 November. Information from the Symposium Secretariat, Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464, Japan. Fax +52-783-0365, e-mail kekvax::spin92 or spin92 at jpnkekvx

1992 CERN School of Physics

The next CERN School of Physics will take place from 13-26 September in Monschau (near Aachen), Germany. The topics covered will include Field Theory, Electroweak Interactions, QCD, Beyond the Standard Model, CP Violation and the Experimental Higgs Search; with additional lectures on electron-positron machines and on LEP results. Further information from Miss S.M. Tracy, CERN School of Physics, CERN – DG-A, 1211 Geneva 23, Switzerland, e-mail tracy at cernvm.cern.ch Telex: 419000 cer ch Telephone: + 41 22 767 27 24, Telefax: + 41 22 782 30 11. Closing date for applications is 30 March.

CERN Courier changes printer

This edition of the CERN Courier was printed by Lannoo Printers, Tielt, Belgium, breaking with a 12-year tradition dating from 1979, when the printing has been handled (apart from a short break in 1985) by Presses Centrales, Lausanne, Switzerland. As well as their continual reliability, quality and attention to detail, Presses Centrales also expertly guided the journal through the rapidly developing technology of publishing and printing in the 1980s.

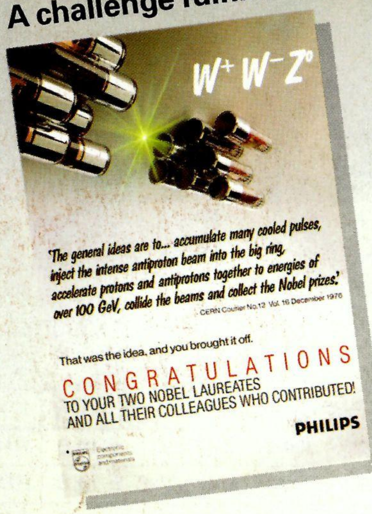
Back in 1979 all text was prepared as typescript, often heavily annotated, and sent to the printer by mail. This was manually typeset (rekeyboarded) and the results returned as galley proofs for checking and dummy page makeup. A second production stage involved checking the subsequent page proofs. Repeated keyboarding was onerous and error-prone, and called for vigilant reading.

With the advent of electronic mail, CERN Courier material increasingly became available as computer files for editing on the screen. Soon these spellchecked files could also be marked-up on the screen by the Editor and forwarded to the printer by modem, with a dummy page layout produced by desk-top publishing.

The CERN Courier's easy access to computer systems has also acted as a catalyst for the printer, hastening the introduction of some new techniques. As well as cutting out drudgery and improving turnround, the net result has decreased the ever-present risk of error.

The CERN Courier thanks Presses Centrales Lausanne for their courtesy, skill, enthusiasm and reliability.

A challenge fulfilled



A challenge unfolding

To accumulate many proton pulses, inject two proton beams into the LHC ring in the LEP tunnel, accelerate the protons in twin-aperture superconducting magnets to energies of 8 TeV, collide the beams and collect the Higgs.

We wish CERN every success in launching the Large Hadron Collider enterprise. And for this challenge, as always, count upon our phototube design-in support to help bring it off again.

Still setting the standard

Philips Components

PHILIPS

PHILIPS