

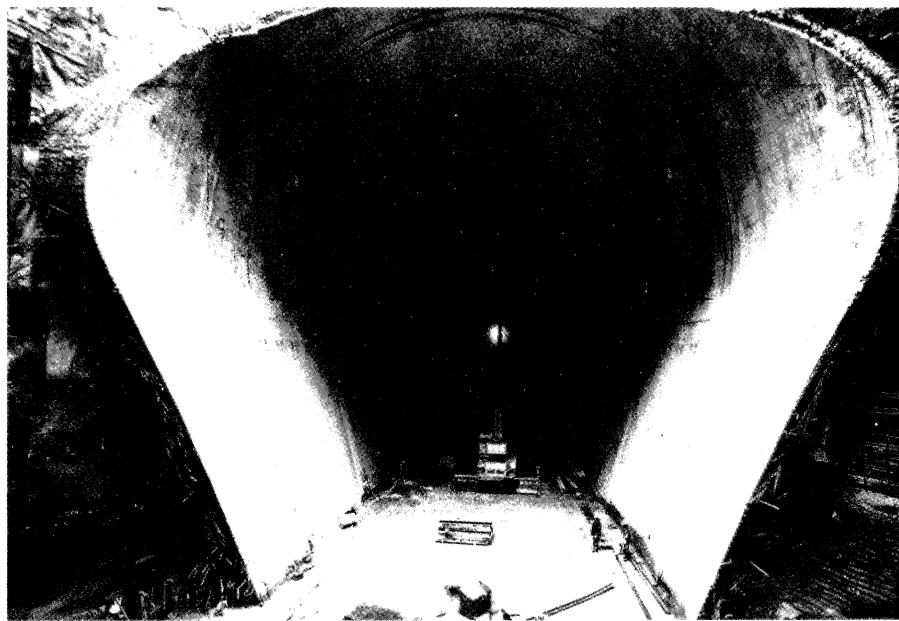
Focus on LEP

When it begins operations early in 1989, the LEP electron-positron Collider now being built at CERN will provide beams of some 60 GeV (120 GeV collision energy). However with superconducting radiofrequency acceleration equipment complementing the conventional units, the beam energy eventually could be boosted to about 100 GeV per beam. In parallel with LEP construction, a vigorous development programme for these superconducting cavities has been underway at CERN.

The physics objectives and experimental requirements for running LEP at these higher energies were examined in detail at a 'LEP 200' workshop held in Aachen, West Germany, from 29 September to 1 October, organized by the European Committee for Future Accelerators (ECFA) and the Rheinische-Westfälische Technische Hochschule.

The consensus of the Aachen meeting was that the new physics available through higher energy LEP beams could be handled by the four experiments now being built, with only minor modifications.

CERN Scientific Policy Committee Chairman Don Perkins had been lined up to give the concluding talk at Aachen, but ended up giving it instead several weeks later at a LEP Experiments Committee session at CERN. Perkins split the LEP 200 physics into three areas: 'surefire bread and butter' — precision measurements of the properties of the W boson (the carrier of the beta decay force); 'probable jam' — searches for the Higgs mechanism or whatever is responsible for symmetry breaking in the electroweak picture; and 'possible cake' — new exotica, expected or not.



Now taking shape are the large underground caverns to house the four big experiments being assembled for CERN's new LEP electron-positron Collider. Seen here is the giant cave for the L3 experiment, some 45 metres below ground.

In conclusion, Perkins said that 200 GeV collision energies in LEP would provide a solid programme of physics for the years 1995-2000 which would not otherwise be accessible. He advocated 'getting on with it'.

The LEP Experiments Committee meeting also provided a useful opportunity to review progress right across the LEP front.

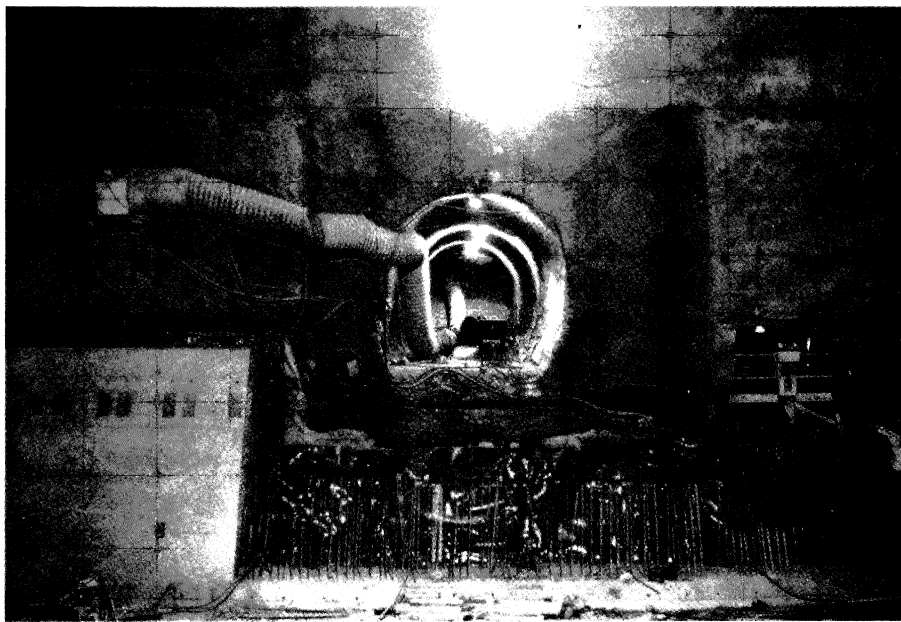
Introducing the proceedings, CERN Director General Herwig Schopper reminded the audience that it was five years since CERN Council finally gave LEP the go-ahead, and recalled the motivation behind the decision.

The LEP machine is funded from CERN's normal annual budget of Member State contributions with no additional resources. For the experiments, most of the finance comes from the collaborating institutes. It was fairly certain at the outset that the new venture of building a machine costing at least 900 million Swiss francs with no special extra budget would require

some belt-tightening, added to which there was the tightrope of coordinating the financing of the experiments. Nevertheless the courageous decision to embark on the mammoth project was taken in order to provide for CERN's long-term future.

With civil engineering for the 27 kilometre tunnel and its associated infrastructure now nearing completion, the total bill can be estimated with some confidence. A continual theme throughout LEP construction has been to use time as a contingency, so that unexpected costs could be offset by applying the brakes at the construction site. Following an appeal by Schopper, some CERN Member States are generously advancing future payments to cover a bulge of expenditure in the construction period. However despite all the difficulties and complications, the overall construction schedule is being largely respected. LEP start-up is now scheduled for early in 1989.

Some 150 metres below ground under the Jura mountains is this pit to house the ALEPH experiment. Although deep underground, this is in fact the highest point of the tilted LEP ring.



The status of construction was covered by Project Director Emilio Picasso. While the tunnelling machines have practically completed their allotted task and preparations for the four large underground experimental areas are well advanced, a major remaining preoccupation is the few hundred metres of tunnel still to be cut through difficult water-bearing layers under the Jura mountains.

This section of LEP tunnel is blasted out rather than cut by machine. Careful precautions have been taken from the outset, involving frequent stops. Some water seepage has been encountered, although nothing on the scale of the flooding during the construction of some major transportation tunnels. The final breakthrough for the LEP tunnel should occur early next year.

Picasso described how judicious modifications to the original construction schedule had enabled the overall timescale to be respected to within a few months. However, despite this rearrangement of stra-

tegies, repercussions in other areas could not be avoided, particularly the handover dates for some of the experimental zones.

With the end of civil engineering work in sight, attention turns to the myriad of components for the machine. The supply of LEP components has been 'a great success', said Schopper, indicating that careful design had enabled valuable savings to be made. Picasso proudly listed the material already at CERN, including 63 per cent of the main dipole magnets, 70 per cent of the radiofrequency acceleration equipment, and 90 per cent of the getter strip for vacuum pumping.

In parallel, the injection system for LEP is being prepared. The EPA electron-positron ring which takes particles from the new injection linac has achieved its design current, and the performance of the new electron beam in the downstream 'Proton' Synchrotron is being studied. One tunnel connecting LEP with the SPS synchrotron, the final link in the injector chain,

has been cut, while another remains to be done. The SPS is being prepared for its new electron role.

Finally Picasso turned to the theme of the Aachen workshop, the use of superconducting radio-frequency cavities to boost the energy of LEP beams towards 100 GeV. Different scenarios are possible, each with its own price tag. Parallel installation of the two technologies would provide some increased energy, but further advances would follow either replacement of conventional r.f. by superconducting, or by building additional galleries to house the new equipment.

The detailed status of construction work for the four experimental areas and their infrastructure was covered by Franco Bonaudi. Nimble work will be required to install cranes, gangways, shielding, rails, pipework, power supplies, etc. as quickly as possible, with the eager experimentalists beating at the door.

Experiments

Progress for the OPAL detector is well advanced, declared Aldo Michelini and despite a few inevitable slippages no critical delays are foreseen. Advanced prototyping, module construction and calibration are proceeding in parallel.

Prototype tests have gauged performance and established realistic operating conditions for the inner portions of the detector, and a 'clean room' at CERN is now ready for assembly to start.

After delivery of components and coil winding at CERN, full coil tests are scheduled for next summer.

Another vital OPAL component is the large lead-glass electromagnetic calorimeter. Assembly and calibration are proceeding well, and already large modules are in principle ready for mounting in the main detector.

Acceptance testing of incoming hadron calorimeter modules is progressing well, while the general rhythm of component shipments is accelerating. The arrival of a VAX 8700 computer is an important milestone for the data acquisition system.

The installation schedule, revised to fit in with the latest LEP civil engineering news, looks a bit cramped at first glance, but careful modifications to a flexible plan should ensure that a workable detector will be ready on Day One.

Sam Ting described how the large octagonal elements for the L3 magnet are now taking shape near where eventually they will be lowered underground. The muon chambers to be installed inside the magnet are 'going quite well' and cosmic ray tests have performed (136 micron resolution) better than the design figure.

Components for the hadron calorimeter are arriving from all over the world (USSR, US, Switzerland, China, West Germany, India) albeit at different rates. Production in China of the famous BGO crystals for the electromagnetic calorimeter is well in hand. Under stringent testing, the acceptance rate for completed modules is nearing 100 per cent, testifying to mastery of this new technology. The design for the inner vertex chamber, based on the instrument developed for the Mark J experiment at the German DESY Laboratory, is being finalized in ETH Zurich.

Unlike the other three experiments, L3 will not be pushed in

and out of the LEP beams and has no installation 'garage'. According to Ting, this means that the interplay between LEP infrastructure and L3 is 'very complicated'. An extra shaft will facilitate the task, but a substantial level of preinstallation on the surface is called for. Ting saw little room to manoeuvre.

Jack Steinberger admitted that building the ALEPH detector is 'more tedious and harder than we expected', however thanks to valiant efforts by the collaborating institutes there is every reason to be optimistic.

In a similar meeting earlier this year Steinberger had singled out the assembly of the electromagnetic calorimeter, with its mass of wiring, as a bottleneck. However the first module to be supplied had performed well under test. This had been good news, said Steinberger.

The magnet coil and cryostat is expected at CERN in April after preliminary testing at Saclay. Meanwhile the return yokes have been equipped for hadron calori-

metry, the assembly taking place in the old BEBC bubble chamber hall at CERN, alongside OPAL's electromagnetic calorimeter.

A big effort is being made to coordinate the development of ALEPH software (for data management, data acquisition, simulation and event reconstruction) by the widely scattered collaborating institutes.

With a delayed handover date for the DELPHI experiment's pit, Ugo Amaldi voiced his concern about the tight installation schedule. Meanwhile the big superconducting solenoid will soon be finished and the complete magnet should arrive from the UK Rutherford Appleton Laboratory next September. Some delay in the availability of the pit could be clawed back by testing the magnet at CERN above ground prior to lowering it into place.

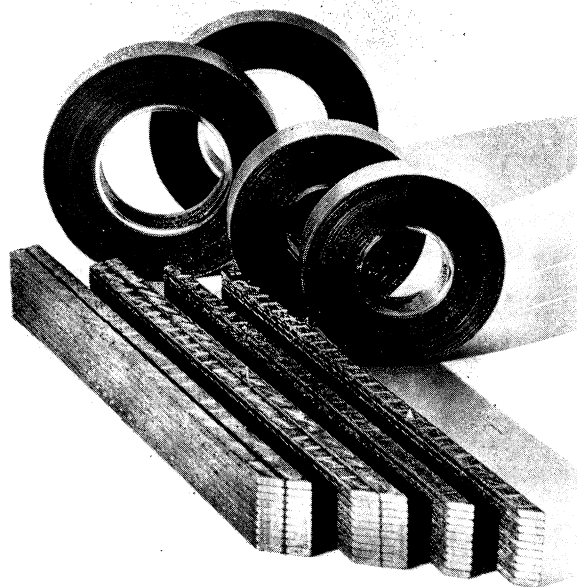
Delivery of hadron calorimeter components is proceeding 'routine-

Some 100 metres under the French-Swiss border is this cavern for the OPAL experiment.

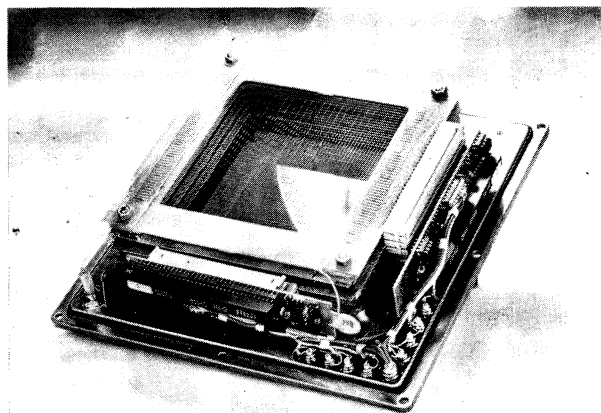


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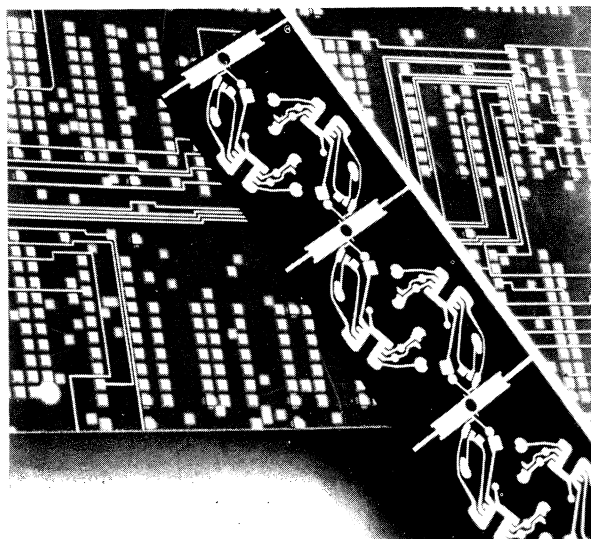
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At the lowest point of the LEP ring, but still some 100 metres below ground, is the cave for the DELPHI experiment.

(Photos R. Lewis)

ly' while the complement of inner muon chambers should be complete in May. Ingenious prototype machines developed for manufacturing the High Density Projection Chamber (electromagnetic calorimeter) have shown their worth and additional units are being constructed in Italy. The first production HPC module has reproduced the performance attained with the prototype. Construction of all track chambers is going according to schedule.

Another DELPHI success story is the development of high density

integrated circuitry for flash analog-digital converters (see May issue, page 17) by French industry which have now found extensive markets.

Albert Diddens of NIKHEF (Amsterdam) took over to describe the preparations for DELPHI's Ring Imaging Cherenkov (RICH) for par-

ticle identification. After extensive prototype tests giving satisfactory results, assembly should begin next summer.

Despite the nightmare risks at the outset, and all the ups and downs of a mammoth construction project, all is going remarkably well for LEP.



Around the Laboratories

FERMILAB Proton synchrotron for cancer therapy

Fermilab has collaborated with the Loma Linda University Medical Center (LLUMC) in California to evolve the design of a small proton synchrotron appropriate for use in cancer therapy. The conceptual design for a 250 MeV synchrotron has been published and it is hoped that industry will pick up the technology and that many such facilities will eventually be built.

Radiation has been used for cancer therapy since Becquerel discovered radioactivity and Roentgen discovered X-rays. Before World War II, most radiation therapy used photons, although Ernest Lawrence and his collaborators made some

tests with neutrons. The use of protons was originally proposed by Robert Wilson in 1946 as one of the uses of the cyclotron he built at Harvard. This cyclotron is still used for therapy and has pioneered treatment for many kinds of disease, both malignant and benign.

Work at Berkeley has used heavy ions and there has also been work at a cyclotron in Uppsala (Sweden), at KEK and Chiba in Japan, and particularly in the Soviet Union, using accelerators at ITEP in Moscow, Gatchina in Leningrad, and at JINR in Dubna. Pions have been used at Los Alamos and SIN. All these accelerators were originally built for physics and have been adapted with great ingenuity for therapy; there has never been an accelerator built specifically for proton therapy.

Neutrons have been used in several centres, particularly the Hammsmith Hospital, London.

The primary advantage of protons is the unique ability for localizing the dose distribution. Cancer therapy is a competition between killing malignant cells and killing healthy cells in the body tissue near the tumour. The dose distributions from photons and neutrons cannot be precisely localized to the tumour site but, as Wilson pointed out in his first paper on the subject, the dose from protons can be localized to within a millimetre or so in depth because most of the proton energy is deposited in a sharp peak at the end of the range in matter. Heavy ions share this advantage and have greater biological effectiveness, but ion accelerators are substantially more costly.