

LEP physics

Construction of the 27 km LEP electron-positron Collider at CERN pushes relentlessly forward. Less evident, but just as vital, is the work for the four big detectors which will be ready to intercept LEP's first colliding beams towards the end of 1988 (see May issue, page 1). Despite these day-to-day reoccupations of construction and preparation, the ultimate aim of this mammoth project is to do new physics.

The possibilities for opening up new areas of physics for exploration and measurement were spelled out in detail before the project was accepted by CERN Council in 1981. However in the meantime the W and Z particles, the carriers of the weak nuclear force, were discovered at CERN in 1983, providing dramatic confirmation of electroweak unification.

At CERN and elsewhere, evidence continues to accumulate in favour of the Quantum Chromodynamics (QCD) picture of inter-quark forces. Together, electroweak unification and QCD are the twin pillars of the 'Standard Model' of today's physics.

Electron-positron collisions at presently available machines at the German DESY Laboratory in Hamburg and at Stanford in the US have revealed no sign of the long-awaited sixth 'top' quark, the big missing link in the Standard Model. However some clues are provided by the UA1 experiment which benefits from the higher energies at CERN's proton-antiproton Collider.

Meanwhile theorists have continued their efforts to extend the Standard Model. No evidence for any of these new ideas, some of them very appealing, has been found, but they will stand or fall by what is found at LEP.



(Photo CERN 612.3.86)

Günther Wolf, then chairman of the LEP Experiments Committee, suggested to John Ellis and Roberto Peccei, the two theorists on the Committee, that the time was ripe for a further survey of the physics possible with the new machine. Five main areas were identified, and working groups were set up containing experimenters from the four LEP collaborations and theorists.

The five areas are — precision studies around the Z (the carrier of the electrically neutral part of the weak nuclear force); so-called 'toponium' consisting of a top quark bound to its antiquark; searches for new particles; high energy LEP running beyond the foreseen initial level of around 50 GeV per beam; and QCD and heavy quark physics.

Called 'Physics at LEP', the findings of the working groups have now been published in two weighty tomes which should serve as a useful handbook for the experimentalists once the data starts to roll in.

Another breakthrough for the LEP electron-positron Collider at CERN.

Z physics

The working group commissioned to look at physics around the Z came to number of definite conclusions:

- the mass and width of the Z peak should be easily measurable at LEP;
- the use of polarized (spin oriented) beams is seen as a 'natural' requirement;
- inferring the number of types of neutrino should be easy;
- any new heavy particles (fermions) coming from additional quark families should have detectable effects;
- the elusive Higgs boson (the source of mass in the electroweak theory) might remain so if the particle is heavier than about 50 GeV;
- the delicate forward-backward asymmetries in this sector should give important precision measurements.

After an epic journey from the Soviet Union by ship, barge and lorry, one of the modules for the magnet of the DELPHI experiment at LEP finally arrives at CERN.

(Photo CERN 108.4.86)

Toponium

The study of the bound states of top quarks and their antiquarks is seen as an ideal laboratory for the Standard Model, but a lot depends on just where the states are going to be found. If they fall right on top of the Z near 93 GeV then a lot of work will be required to unravel them.

If the toponium ground state turns out to be lighter than the Z (as UA1 hints), current estimates of LEP performance indicate that it should be possible to find several higher states in experiments taking a few months.

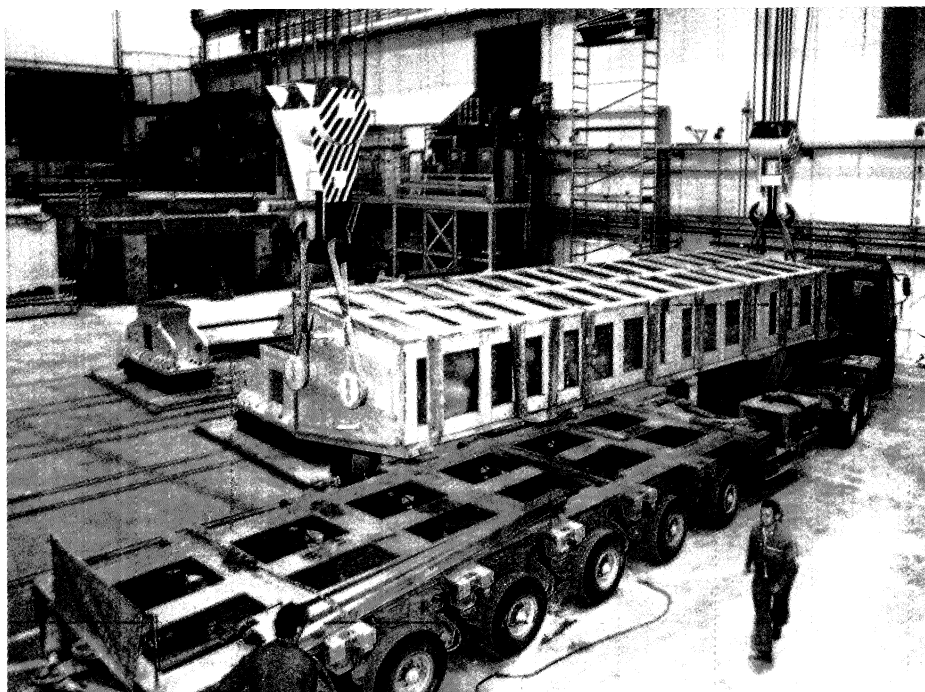
If toponium is heavy, it becomes more difficult to manufacture and its physics becomes correspondingly more difficult.

Toponium physics is seen as complementary to Z physics, providing incisive tests of many current theoretical ideas.

New particles

In their efforts to unify all the forces in Nature and to correlate their very different strengths, theorists have conjectured many different new particles.

The working group entrusted with looking at the implications for LEP of these new particles stressed the importance in their view of the 'Mass Problem' — the origin of mass in the electroweak sector through the 'Higgs mechanism'. Their report provides experimenters with a comprehensive listing of many of the predicted properties of the Higgs and related particles and how they might be picked out from the LEP data, if they weigh less than about 100 GeV.



Higher energies

The task of the fourth working group was to look into the physics implications of running LEP beyond the initially planned level of about 50 GeV per beam.

'In the course of this study', their report states, 'it became evident to us that the physics potential of running LEP II (i.e. higher energies) is considerable, of a level comparable, if not greater, to that of the initial stage of LEP'.

As well as opening up the possibility of producing new particles (as looked into by the third working group), higher energies could also find evidence for any deeper substructure of matter inside the quarks and leptons, considered as pointlike and indivisible in the Standard Model. The discovery of a new layer of matter would in itself make LEP a turning point in the history of physics.

In addition, higher energies

would explore new areas of the Standard Model, where there are still many unmeasured parameters.

In conclusion, the group reiterates 'it is of interest to push the beam energy to the maximum possible value'.

The importance of higher energies at LEP has stimulated a workshop on this physics to be held in Aachen from 29 September to 1 October. (Further information from Workshop LEP 200, III. Physikalisches Institut RWTH Aachen, Physikzentrum, Sommerfeldstrasse, D-5100 Aachen, West Germany.)

QCD and heavy quark physics

The fifth working group underlined the importance of electron-positron annihilation as a window on quark dynamics, pointing out the successes obtained at existing (lower energy) electron machines.

The expected physics around

Around the Laboratories

the Z peak and the high expected Z yield of several million a year (compared with the hundred or so found in several years at the CERN proton-antiproton Collider) open up detailed QCD studies.

This group also covered photon-photon collisions, where photon messenger particles interact with each other rather than an electron or positron target, providing an additional physics window.

As well as probing for the top quark, LEP would open up the spectroscopy of the fifth (beauty) quark, of which only the surface has been scratched so far.

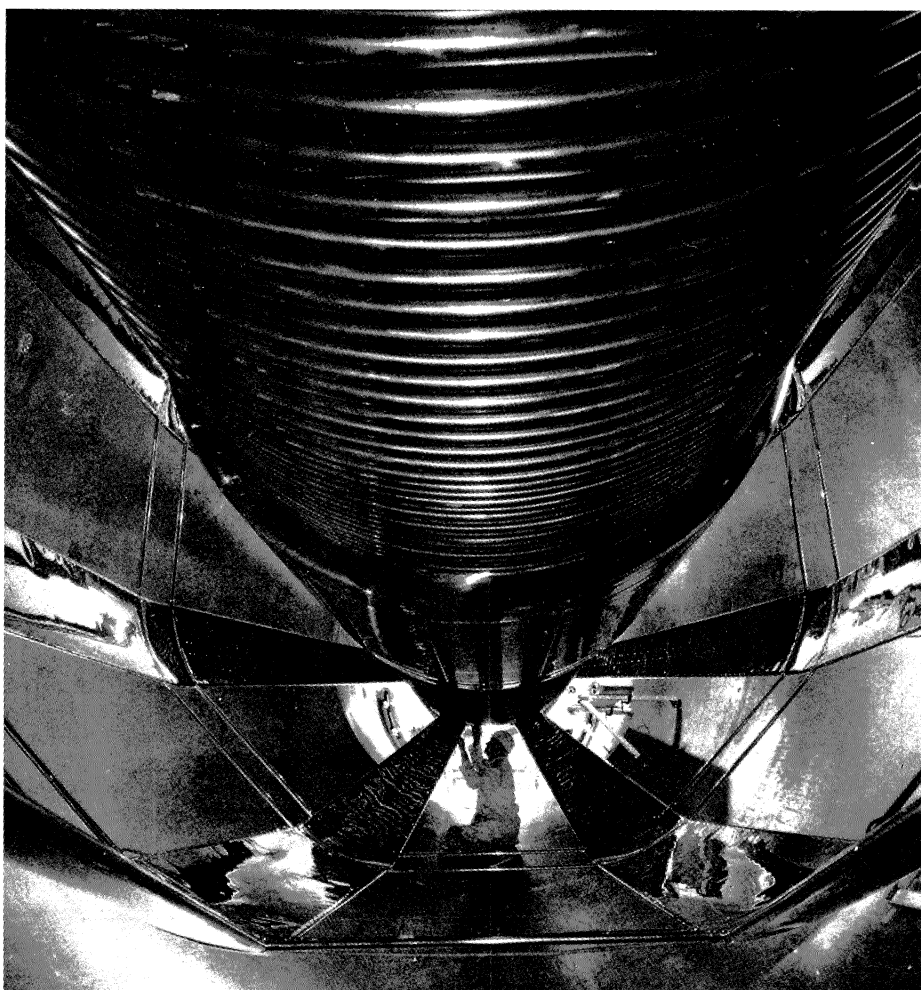
This could provide a further batch of particles which have unusual properties under the combined CP operation (switching particle to antiparticle and left to right). CP violation, currently restricted to the neutral kaons, is not well understood. 'It will not surprise many of us if CP violation becomes the Achilles heel of the Standard Model', the group concludes. 'LEP experiments are certainly well equipped to take aim at that!'

When the data starts to roll in, the pronouncements of the 'Physics at LEP' study may reflect more our current ignorance than enlightenment. But that is why LEP is being built — to explore the unknown.

Heavy ions

CERN's venerable Linac 1, which normally provides 50 GeV protons, accelerated in April a beam of oxygen 6+ ions to MeV (12.5 MeV/nucleon), the injection energy required for CERN's heavy ion research programme later this year. Meanwhile Brookhaven takes another step towards its long term project of a relativistic heavy ion collider (RHIC). In April, oxygen ions from the Tandem Van der Graaff were transferred to the AGS, Alternating Gradient Synchrotron,

the first time this venerable 26-year old machine had seen anything other than proton beams. The heavy ion programme will be helped by the advent of a Booster at the AGS (enabling, amongst other things, fully stripped ion species beyond sulphur to be injected into the AGS) for which construction has been authorized (see January/February issue, page 21). A prototype magnet for the Booster is now under test.



Inside the pressure vessel of one of Brookhaven's twin Van de Graaff machines which now provide heavy ions ready for acceleration in the Alternating Gradient Synchrotron.