Should LEP have been closed?

Physicists at the Large Electron-Positron collider at CERN appeared to be on the verge of discovering the elusive Higgs boson last autumn, when the management decided to shut the machine. **Olivier Callot** explains why he thinks the closure was a mistake

November 2000 was a very busy and hectic month at CERN, the European laboratory for particle physics on the French-Swiss border near Geneva. Researchers at the Large Electron-Positron (LEP) collider – the world's biggest accelerator – were apparently close to discovering the elusive Higgs boson when CERN's management decided to dismantle the collider. They took the decision despite strong requests from the large user community that LEP should be kept open for another year.

The 27 km-circumference LEP collider had been producing collisions since August 1989. It was the first machine to study the Z^0 boson and the first to study W^+/W^- pairs, the particles that transmit the weak force. The available energy from the collider had been steadily increased over the years. By last autumn, physicists had hiked its centre-of-mass energy to more than 206 GeV.

Among the aims of the 1500 physicists who were working on LEP's four experiments – ALEPH, DELPHI, L3 and OPAL – was the search for new particles. The most important of these was the Higgs boson, the last missing piece of the Standard Model of particle physics. The Higgs boson is thought to provide all other particles with mass. If it does not exist, the Standard Model would be in trouble.

Each experiment had, at the time of closure, published about 200 physics papers. About one-third of these papers contained measurements that confirmed every facet of the Standard Model with ever-increasing precision. Another third were tests of other aspects of high-energy physics, such as quantum chromodynamics – the theory of the strong force. The remaining papers described experimental progress in the search for new particles.

Although no new particles had actually been discovered, physicists at LEP were able to set a lower limit of $112 \text{ GeV } c^{-2}$ for the mass of the Higgs boson – a value that cannot be computed from the Standard Model alone. The theory can, however, provide an upper limit on this mass, because the Higgs boson affects some of the electroweak measurements via second-order corrections. This upper limit was found to be about $250 \text{ GeV } c^{-2}$.

Hints of the Higgs

The situation changed during the summer. One of the four LEP experiments – ALEPH

Is that it? – one of the Higgs candidates, seen in the ALEPH detector

– began to see an excess of events in the small mass window where the Higgs could show up. This window lay between the lower limit of $112 \text{ GeV } c^{-2}$, and the kinematical limit, which by the summer had reached about $116 \text{ GeV } c^{-2}$. The kinematical limit is basically set by the fact that the mass of the Higgs boson plus the mass of the accompanying Z boson, which weighs $91.2 \text{ GeV } c^{-2}$, cannot exceed the available collision energy.

“We were all shocked and unable to understand the committee's thinking.”

On 5 September, six days before LEP was due to shut, the committee in charge of LEP experiments (known as the LEPC) was so convinced that these results hinted at the Higgs boson that it decided to keep LEP open until 2 November (see “CERN extends search for Higgs” *Physics World* October 2000 p5).

The extra data taken in September and October were scrutinized and the results were presented by the Higgs working group to a special session of the LEPC on 3 November. The presentation so clearly pointed to evidence for a Higgs boson that the entire audience, which consisted of several hundred physicists packed into CERN's auditorium, gave a standing ovation after hearing the results. They were convinced that the

LEPC should call for LEP to continue running for another year.

The case to keep LEP open

The scientific case can be summarized as follows. Researchers on the L3 detector had spotted a sequence of particle decays that appeared to be different from events seen so far. There was a three-standard-deviation chance that these decays revealed a Higgs boson that had a mass of $115 \text{ GeV } c^{-2}$ with the expected properties. In other words, it had the expected decay behaviour, the right distribution of candidates between experiments, and the significance evolved with the accumulated statistics in the right way. Three standard deviations (or 3 sigma) means that the probability that the measurements were caused by statistical fluctuations was less than 2 in 1000.

LEP's machine experts already had a technique up their sleeves for turning the energy of the accelerator up another notch. A further run in 2001 at these higher energies would have increased the significance of the effect to more than five standard deviations (or 5 sigma), which means that the uncertainty in the measurements would have been reduced to three parts in 10 million. This is

the threshold for claiming a discovery!

Any scientist would have jumped at this golden chance to solve an outstanding question of fundamental physics. It was particularly important to take that opportunity because CERN's member states are about to invest more than SwF 3bn in building the Large Hadron Collider that will replace LEP.

For a modest 3% of that cost, we could have had the answer next year. Who would have missed that chance of a lifetime? Apparently, the members of the LEPC were too shy, or too bureaucratic, to take this chance, for they failed to make any recommendation to keep LEP running. They should at least have proposed to the CERN council, which has the financial and political authority, to extend the life of LEP –

despite the (modest) increased cost and the extra delay in building the LHC that this would have involved.

On the morning of 3 November, all of LEP's physicists believed that they were in the throes of writing history, having seen the shadow of the Higgs. They felt that they were about to start another year of experimental runs, with a clear and fascinating goal in sight. Enthusiasm was equally high in the accelerator sector, and it was felt just as much by the technical and administrative staff, all of whom were proud to contribute to such a discovery after years of hard work.

That evening, once the LEPC's decision to do nothing was known, we were all shocked, destroyed and unable to understand the committee's thinking. Immediately, huge efforts were made to try to convince those bodies with higher authority – CERN's research board and, ultimately, the committee of council. The whole weight of the CERN management was pushing to close LEP, while 90% of the high-energy-physics community wanted to solve this outstanding scientific question. The management won. (See "CERN split over collider closure" *Physics World* December 2000 pp5–6.)

A disaster for staff?

The scientific result is clear. A few publications will be produced with the LEP data,

End of the road – the L3 experiment at LEP, which is now being dismantled

describing an indication for the Higgs. Fermilab in the US will push its Tevatron collider to try to confirm the signal. On paper, they have a chance, but there is no guarantee that they will collect enough data before the LHC starts in 2006.

The LHC will not be able to obtain such a result before the end of 2007 – and that assumes that everything goes to plan. We now have to wait seven years before we can obtain new data, knowing that if the Higgs particle really was $115 \text{ GeV } c^{-2}$, this information would have helped in the design of the next generation of linear colliders, turning them into "Higgs factories".

Politically, the closure is a disaster. How can we continue to work so hard only to be

told that a scientific discovery is not as important as following plans? The way the CERN management has handled the decision process is a collection of mistakes. Who can believe in a scientific committee that appears unable to judge such a case? Who can accept a management that is unable to explain its choice to its staff?

The lab crew and several thousand physicists using the CERN machines have lost their motivation and lost confidence in the CERN management's scientific motivation. Can we build the next machine in these conditions? Can CERN continue to be the flagship of European science if it fails to put science before management, in the process handing US physicists the chance to make this major discovery their own?

● An official statement on LEP's closure is at press.web.cern.ch/Press/Releases00/PR14.00ELEPstop.html

● More reactions against the closure are at alephwww.cern.ch/~janot/LEPCO/Lepco.html

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