Chapter 7
Director-General of CERN

On 1 January 1981, Herwig Schopper became Director-General of CERN. It was a role that his entire career had prepared him for. Years of experience in managing and establishing laboratories across Germany, culminating with his time as chair of the DESY directorate gave him the managerial experience he needed, while his sojourns in Stockholm, Cambridge and Cornell had kept his research instincts sharp. The final ingredient in his preparation for what is arguably the biggest job in particle physics is the time he'd spent at CERN in the 1960s and 1970s learning about this unique institution and its equally unique culture. "Before being able to take full responsibility for an organisation as diverse and complicated as CERN," he explained, "one has to get to know it from the inside, as well as understanding the world outside. When I came to CERN in 1970 as leader of the Nuclear Physics Division, I took over from the Swiss physicist Peter Preiswerk. It was a big honour to become his successor, and I learned a lot about CERN over those three years."

Herwig headed the Nuclear Physics Division for two years before taking on the role of experimental physics coordinator for one more year before he moved to DESY. "Bernard Gregory was the Director-General at that time," recalled Herwig, "and my immediate boss was the head of what was known as the Physics I Department. Giuseppe Cocconi had just handed over to Jack Steinberger. Both were outstanding physicists, Steinberger later received the Nobel Prize, and both were remarkably strong personalities. Neither liked to do administrative work, which resulted in me taking on some of the tasks of the Research Director."

Herwig remembers one young physicist from his time as division leader particularly strongly. "One day a relatively young guy, but very ambitious, came to me and asked for money," recalled Herwig. "His name was Carlo Rubbia, and when I asked what experiment he was involved in, he listed about a dozen. He was always full of new ideas, and when I asked why he wanted to start yet another experiment, we had a rather heated discussion. Carlo had a fiery temperament, but in the end we always reached an agreement, and Carlo later succeeded me as Director-General."

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Fig. 7.1 Giuseppe Cocconi preparing for an interdivisional meeting at CERN in 1975. “Cocconi had a great sense of humour,” recalled Herwig. “He would often say to me: “the world is mad except you and me, and I’m not sure about you”” (©CERN, All rights reserved)

When Herwig arrived at CERN in 1970, there was no collider in operation at the laboratory: the physics programme was built around fixed-target experiments. The Intersecting Storage Rings (ISR) were under construction, and they would bring collider physics to CERN for the first time in 1971, changing the laboratory, and the field, forever. In fixed-target experiments, the particles that emerged were analysed using detectors built around large and complicated magnets. This led to another memorable interaction for Herwig. “It turned out that no new experiments could be approved because there was a limited number of analysing magnets available,” he recalled. “So one day I went to see Bernard Gregory, bypassing the directors, and I asked if we could buy a few more analysing magnets so we could approve more experiments. Gregory laughed and said, ‘Look, somewhere there must be a limitation. If it’s not the analysing magnets in the end it might be the capacity of the cafeteria or the number of parking spaces.’ Many years later, I thought about that remark very, very often because it taught me that sometimes you have to make decisions against the obvious rational arguments. Gregory was a wise man with great foresight. Ironically if you come to CERN today you might easily get the impression

Fig. 7.2 A formidable gathering in the CERN auditorium. From second left to right, James Cronin, Jack Steinberger and Leon Lederman—Nobel Prize winners all. Cronin is in conversation with CERN's Jean-Pierre Stroot (©CERN, All rights reserved)

that cafeteria and parking capacity are indeed the present limits of CERN." In the end, no more analysing magnets were bought in the early 1970s, and Herwig does not recall whether Rubbia got his extra experiment. The arrival of colliders, however, would soon mark a new departure for both men.

During his three years as a division leader at CERN, Herwig learned to admire the vision of the laboratory's founding fathers. He came to appreciate that the procedures they had put in place provided a powerful blueprint for international collaboration in science and were essential for the success of the organisation. "One was the rule that there should be no national quotas, either for the employment of staff or for the adjudication of contracts to companies," he explained. "The guiding principle should be that the best scientists are welcome if they can contribute to the scientific success of CERN." This principle applied even beyond the boundaries of CERN's member states. “The participation of Polish and Israeli scientists, for example, was possible right from the beginning and they made essential contributions,” he continued. “In the meantime, these countries have become member states.” Herwig also came to appreciate CERN’s approach of placing orders with the companies best able to fulfil the contract, rather than applying some form of *juste retour*. “Contracts were given to the lowest bidding firm that was technically able to fulfil the contract,” explained Herwig. “There is no rule of *juste retour* at CERN as there is in some other international organisations—that only increases the cost since a firm might know that it is their turn for the next contract.”

When Herwig left CERN for DESY in 1973, his apprenticeship for the top jobs in the field was complete. He maintained close relations with CERN, being elected to the organisation’s Scientific Policy Committee in 1978 and chairing the ISR Committee from 1973 to 1976. “This was an extremely interesting time from the physics point of view,” he said, “and it also provided me with the opportunity to get to know many people who were essential during my time as DG.”

Electing the New Director-General and Reunifying the Lab

The circumstances surrounding the election of Herwig as Director-General were somewhat unique in the history of CERN. In 1971, with the approval of the SPS, CERN had been split into two laboratories, CERN I and CERN II, with two Directors-General (see Chap. 4). A few years later, however, the CERN Council had taken the decision to reunify the two into a single administrative structure. “Although CERN had officially been recombined in 1976 with the appointment of John Adams as Executive Director-General and Leon van Hove as Research Director-General,” explained Herwig, “there still remained much to do to unify the two labs when I arrived in 1981.” The new Director-General would also be tasked with developing a full proposal for a new project to succeed the SPS, and then building it assuming that it was approved.

The new Director-General would also assume office in the first year that the SPS was to run as a collider, and to complicate matters further, the Council had decided that CERN’s budget would henceforth remain constant in real terms. Finding a single candidate with the experience to manage such a complex agenda was a tall order, and in the end, it was Herwig’s combination of scientific track record coupled with managerial experience, both inside and outside CERN, that won the day. He took up the post on 1 January 1981.

Although the SPS had been sited adjacent to the existing CERN site, by the time that decision was taken the CERN Council had already appointed John Adams to be Director-General of the new laboratory. From 1971, therefore, CERN was run as two separate entities, the original Lab I, which was responsible for the basic programme under Willibald Jentschke, and Lab II, which had the task of building the SPS under Adams’s direction. When Jentschke’s term ended, the labs were partially reunited with Adams as Executive Director-General, and Leon van Hove as Research

Director-General. It was when their mandate came to an end that the CERN Council had decided to reunite the laboratory fully under a single Director-General. This became one of Herwig's most difficult tasks.

The usual procedure for selecting a Director-General of CERN involves closed-door discussions throughout the fourth year of the current mandate. Candidates are put forward and debated, each member state delegation advances arguments, consults with ministries and gradually the process converges on a single candidate who is appointed by a unanimous vote of the council at its December meeting. In 1979, Herwig Schopper was a clear front runner. It was already evident by this time that the SPS's successor would be an electron machine, a large electron–positron collider (LEP), and as head of a laboratory that had made its reputation on electron machines, he was a natural choice to lead CERN from its proton-dominated past to a future electron–positron facility.

All was not done and dusted, however, since despite Herwig's clear suitability for the job, unanimity was proving elusive: Italy was not convinced. The Italian delegation was worried that Herwig would not do everything possible to get the new project to Geneva, but rather that he would favour DESY. The Italians also had their own candidate, Antonino Zichichi. Things seemed to be at an impasse, and the clock was steadily ticking towards 1 January 1981, the start date for the new mandate. Things were resolved by a caller at Herwig's door.

"One Saturday afternoon in December 1979, the doorbell rang," recalled Herwig, "it was Nino Zichichi. We were old friends, and he'd come to discuss the Italians' concern that my heart would still be beating for DESY, and that I would not fight for LEP in Geneva. I told Nino that LEP was too big a project for DESY and that I would fight as hard as I could to get the project to Geneva if I were made DG." The next time that Herwig visited CERN for a committee meeting, Zichichi organised a meeting for him in a hotel with the Italian delegate to the CERN council, Umberto Vattani, and it was agreed that Herwig should be invited to the next meeting of the Committee of Council on 29 February 1980. After his presentation, and a quick phone call to Rome, the vote was held and a press release was issued noting that: "the 12 delegations unanimously supported the appointment for five years of Professor Herwig Schopper to the post of Director-General of the organization from 1st January 1981."

"The whole operation was guided very skilfully by the Council president, Jean Teillac, who even had the courage to send me a letter of appointment dated 29 February 1980, which made it possible to look immediately for my successor at DESY," explained Herwig. "My nomination was formally approved in a special Council meeting on 25 April, on which occasion the Italian ambassador expressed warm congratulations." Herwig acceded to the top job in particle physics in Europe, with a metaphorical mountain to climb to get LEP approved and constructed during his five-year term. He spent the rest of 1980 preparing to hand over the reins at DESY to Volker Soergel, and to take over the running of CERN from 1 January 1981.

He also immediately started work with Adams and van Hove on a new proposal for LEP to put to the Council in June 1980 as the delegations had requested. "I developed a very good working relationship with Adams and van Hove," he recalled.

"We prepared a new proposal based on an earlier study known as the pink book, but with an important difference. Instead of building a whole new pre-accelerator system, CERN's existing accelerators, the PS and SPS, would be used as pre-accelerators." This brought the cost of the project down to from well over a billion Swiss Francs to 950 million. It was an important step, but LEP's approval would still require a lot of hard work once Herwig took up office at CERN. In 1980, however, developing the proposal along with preparations for the transition at DESY kept him busy. "Sometimes I had to do the work of two DGs and even start the new job almost a year early without being paid," he said with a smile.

The LEP Proposal

In March 1975, particle physicists from around the world gathered in New Orleans for a topical seminar to discuss the future of the field. Herwig was there in his capacity as chair of the DESY directorate. "The main outcome of the meeting was that the next big facility should be a very big accelerator (VBA), constructed as a world machine," he recalled, "and that an international study group should be established with its headquarters at CERN." Two months later, the subject was being debated in the Scientific Policy Committee at CERN, which delivered a report to the laboratory's Committee of Council, and before long, the VBA had morphed into the Large Electron–Positron collider, LEP. "It's not clear who at CERN first suggested the construction of such a machine," said Herwig, "but already in New Orleans, the talk was of an electron machine, and from a European perspective, it seemed like a natural continuation of the tradition that began with AdA and ADONE in Italy, ACO in France and DORIS and PETRA at DESY. Anyway, CERN took the initiative before the international study group that the New Orleans meeting had advocated really got off the ground."

Studies for LEP got underway in earnest at CERN in 1976, but the idea was not universally popular at a laboratory that had made its name with proton machines. The SC, PS, SPS and ISR were all proton machines, and the SPS was soon to be converted into a hadron collider, colliding protons and antiprotons in a bid to discover the W and Z particles, carriers of the weak nuclear interaction. The SPS collider project was approved by the CERN Council in 1978, and it carried with it the hopes of a generation of experimental particle physicists. There was good reason for optimism: in 1973, a team led by Frenchman André Lagarrigue had identified so-called weak neutral currents for the first time. Although not a direct observation of the neutral carriers of the weak force, the Z particles, this was compelling evidence for the electroweak theory advanced by Glashow, Weinberg and Salam, and discovery was only a matter of time and energy.

Perhaps paradoxically, the success of CERN's hadron machines in advancing the emerging standard model of particle physics, in tandem with theoretical developments, pointed inexorably towards an electron machine as the next facility that the world's particle physicists would need. While the SPS collider was widely expected to discover the W and Z particles, it would not produce these particles in sufficient numbers to study them in fine detail, and nor would it provide the pinpoint precision that would be required. Deliberations on a possible proton–proton or electron–proton collider at CERN soon petered out faced with the undeniable logic of LEP. A series of designs for LEP was advanced, mainly under the guidance of John Adams, and each was dissected in CERN's Scientific Policy Committee (SPC), of which Herwig was a member, until a feasible, and affordable, proposal emerged.

The first decision the accelerator designers had to make was the energy reach of the new machine. It would have to be able to produce Z particles in the first instance, and although they had yet to be discovered, their mass was expected to be below 100 GeV, pointing to a beam energy of 50 GeV per beam. To study the electrically charged W particles, however, which would be produced in pairs at an electron–positron machine, the required energy would have to be roughly twice as much. Then there was the question of whether to build a linear collider or a circular one. Here, the economic argument prevailed: for energies below around 300 GeV, a circular machine was much more cost-effective, and would have the advantage of being able to collide the same beams many times over. "It is not surprising that it took some time to agree on a final energy for LEP," said Herwig. "The energies suggested fluctuated up and down, leading to different circumferences for the ring being advanced." The challenge was exacerbated by the limited space available between Lake Geneva and the Jura mountains, with the unknown geological challenges their limestone structure presumably concealed.

The first study group convened in 1976 opted for a design with a 50 km circumference and a beam energy of 100 GeV, sufficient to produce W particle pairs, but it had significant drawbacks. When the LEP 100 proposal went to the SPC, it was quickly rebuffed. Although able to do everything the physicists needed, it would have involved tunnelling deep under the Jura mountains with long access tunnels and the cost was simply too high. The LEP study group was sent back to the drawing board.

In 1978, the group presented a proposal for LEP 70, which would come to be known as the blue book study. It proposed a ring of 22 km, which would avoid the worst of the difficult geology under the Jura, and accelerate beams to 70 GeV, with a later upgrade to 100 GeV per beam when superconducting accelerating cavities became available. It too was rejected on the basis that higher energy with conventional cavities was desirable, and that the experimental areas foreseen were not large enough. A pink book succeeded the blue, this time with Herwig as a co-author, as by this time he'd been elected to be the next Director-General of CERN, and much of 1979 was spent discussing its feasibility. The pink book design upped the circumference from 22 km to 30.6 km, and the beam energy with conventional accelerating cavities to 86 GeV, but it was back to unknown geological conditions and potentially too high a cost. It was not until Herwig was firmly settled in office that the final design, with a 27 km ring, would be approved, allowing construction to get underway.

A New Style for CERN

Before LEP, every new CERN project had been funded independently of CERN's basic research programme, with CERN member states in principle being able to opt in or out as they saw fit. With LEP, however, that was about to change. Long discussions with member state governments made it clear that some countries wanted to participate in the basic programme but not in the LEP project, while at the same time, the LEP proposal relied on using existing CERN facilities that were part of the basic programme. "An impossible situation seemed to be emerging," said Herwig, "so I said to the Council that LEP should become part of the basic programme with the consequence that it would have to be approved and funded by all the member states." As a result, the December 1980 Council meeting concluded with the statement that: "If the inclusion of the LEP project phase 1 in the scientific activities and long-term budget estimates is agreed by the Council with no member state voting against, this will constitute approval of the LEP project phase 1." This made Herwig's task clear: he needed to obtain a unanimous vote in the Council, with possible abstentions, for the LEP project to go ahead. Furthermore, he was asked to present a definite proposal to the Council for its June 1981 meeting, along with a financing scheme that would integrate LEP into the CERN basic programme with no additional funds. The Council was making it clear that the days of extra funding for new projects was over.

Hardly had Herwig got his feet under the desk of his 5th floor office in CERN's main building than he was off on the road touring the capitals of CERN's member states to drum up support for the project. "Most of the opposition came from colleagues in other fields," he recalled. "They feared that it would not be possible to build LEP within a constant budget, and that their budgets would suffer as a consequence." To win them over, Herwig realised that he had to change the mind-set at CERN. "CERN was organised into divisions, each one responsible for accelerators, or physics or services," he explained. "Each was highly competent in its domain, but they all worked quite independently of each other. Their budgets were known only to the DG and a few other people. I realised that for LEP to be built under the conditions required by the Council, I'd need to organise it as a project that cut across all the divisions." The challenge was exacerbated by the fact that Herwig also had two independent laboratories to unify into one. "John Adams was a very strong personality," he explained, "and he commanded great loyalty among his staff."

The accelerator builders at the former CERN II expected an accelerator physicist to be appointed to lead the LEP project, but Herwig surprised the community by appointing an experimental physicist, Emilio Picasso, instead. "Many were disappointed," he recalled, "but Emilio had worked on experiments that required close collaboration with the technical divisions, and he enjoyed enormous respect not only among the physicists, but also among the accelerator engineers." In addition to appointing Picasso as project leader and a member of the directorate, Herwig also established a new division for LEP, and appointed the leading accelerator physicist, Günther Plass, to be both the division's leader and Picasso's deputy. It was an arrangement that worked well. “Emilio Picasso was the right person to bridge the gap between the staff of CERN I and CERN II. He did a great job, and we became close friends,” said Herwig. “This proved important when we had difficult decisions to take together as the project advanced.”

Herwig’s mandate was a pivotal one for CERN, marking the transition from a constantly growing organisation to a steady state. Up to the 1980s, new projects benefitted from extra resources, and once a project was approved, CERN was responsible for providing all the necessary infrastructure, for both accelerators and detectors. The laboratory’s personnel and budget had grown steadily since the organisation’s creation in the 1950s, and in addition there were projects, such as the Big European Bubble Chamber (BEBC), that were funded outside the core budget by groups of member states with a specific interest. In the case of BEBC, these were largely France and Germany. When Herwig presented the project for LEP that he’d developed with

Fig. 7.3 Herwig in conversation with Emilio Picasso at the XI International Conference on High Energy Accelerators, which was hosted at CERN in July 1980 (©CERN, All rights reserved)

Adams and van Hove to the Council in June 1980, the Council made it very clear that this situation had to change. They wanted LEP built within a constant budget, and with no extra personnel. Furthermore, they wanted that budget to be lower than the one he had inherited: 629 million Swiss Francs in 1981.

At 1300 million Swiss Francs, the budget for LEP in the pink book design was clearly impossible under such conditions, and a more modest proposal needed to be developed. Consultation with tunnelling experts led to the conclusion that the tunnel needed to be pulled back from under the Jura mountains to avoid financial risk. "After long and sometimes heated discussions, we decided to reduce the circumference of LEP to about 27 km, and move it somewhat out of the Jura," Herwig explained. "Fortunately, the clever LEP design group found a way to keep the phase 1 beam energy of 50 GeV, even with the reduced size." Not everyone was convinced that Herwig had gone far enough, and he received letters from people including John Adams and Carlo Rubbia urging him to move the machine completely from under the Jura by reducing the circumference to around 20 km, but Herwig stuck to his guns. "These opinions gave me some headaches and sleepless nights," he recalled, "but finally I decided to maintain the tunnel circumference at 27 km." Herwig was thinking ahead. "Reducing the size would not have impaired LEP's performance considerably, but I decided to take the risk attached to tunnelling under the Jura because one thing we could not change in the future is the size of the tunnel," he explained. "I thought we should have the biggest tunnel possible, and that proved to be an important factor when planning the LHC project, making it possible to reach interesting energies."

Herwig approached the first big test of his mandate, the June 1981 CERN Council meeting, armed with a new design for LEP, this time contained within the pages of a green book, and ready for some tough discussions. The green book design, which came to be known as the stripped-down LEP, presented the project as an evolving machine to be completed in two phases, with phase 1 being a factory for Z particles. Phase 2, which would bring superconducting radiofrequency (RF) technology to bear and produce W particle pairs, was left for a later decision. Herwig planned to draw on the expertise developed in part by his teams when he was in Karlsruhe to develop that technology while phase 1 was underway.

Herwig had accepted the inevitability of the Council's desire to construct the machine under a constant budget, and against the advice of his colleagues, went to the Council meeting prepared to accept stable funding at 629 million Swiss Francs per year, which he considered to be realistic if the timescale for construction was extended by one year. If that was not enough, time would provide the contingency, because Herwig had already accepted that further funding would not be forthcoming. He also recognised that even if extra funding were possible, it would not be in CERN's interests because it would pit particle physics against other fields of science, and that would be detrimental to the scientific endeavour as a whole.

As well as reducing the circumference of the machine to 27 km, further savings on civil engineering were made by foreseeing four experimental halls instead of the eight in the pink book, and, in a new departure for CERN, only a token amount was included for experimental infrastructure. The cost of the experiments would have to be borne by the collaborating institutes that proposed them. This was a completely new approach for CERN.

Herwig emerged from the Council meeting bruised but not beaten. He had achieved neither approval for LEP, nor the constant budget that he'd argued for, "Some delegations wanted to come down to 610 million Swiss Francs per year," he recalled, "and we ended up with 617. That might not seem like a huge difference compared to what I asked for, but over the eight-year construction period of LEP, it would add up to 96 million." Even Herwig's attempts to have the materials part of the budget indexed were met with a resolute "no" from the council, he'd have to go back each year to argue for that. The bid to get LEP approved fared only slightly better. Eight of CERN's 12 member states voted in favour of the stripped-down LEP, with Denmark giving a positive vote ad referendum. "It was not completely clear what that meant," said Herwig. Three-member states asked for more time to reach a decision. "For a few months, the trembling continued, and I spent much time visiting member state capitals," said Herwig, "The big sigh of relief only came at a special Council meeting on 30 October when LEP was approved unanimously."

Herwig had succeeded, but at a price. These Council meetings had changed the way CERN operated for ever. No longer would CERN enjoy rising budgets and personnel, and no longer would CERN cover the cost of the experiments it hosted. Although indexation has been granted since Herwig's time in office, in real terms, CERN's budget has not risen since the 1980s, and the personnel has fallen while the user community has grown dramatically. Herwig was not a popular Director-General at this point of his mandate, but time has vindicated his approach. "I had no choice but to accept what the Council wanted," he said, "but it went against all the tradition of CERN." There were vociferous calls from the CERN staff for his resignation. "But I told them that I could only step down once, and that if I did, the situation would not change," he recalled. An uneasy truce was declared as CERN's new era began.

The price to be paid was a significant one, with many parts of the CERN programme being cut back or stopped altogether. "The ISR, the only proton–proton collider in the world, had to be stopped in 1983, a particularly painful decision," recalled Herwig. Along with the ISR went BEBC, much of the fixed target programme at the PS, and a significant amount at the SPS. The operation of the synchrocyclotron, CERN's first accelerator was reduced from 6000 hours per year to 4000, and even accelerator R&D, essential for the future of the laboratory, was cut back to focus exclusively on the superconducting RF technology that would be essential for LEP's phase 2. A mere 1% of the CERN budget went into the R&D needed for the long term. "I lost many friends," said Herwig ruefully, "but fortunately I later regained most of them."

Fig. 7.4 Herwig in discussion with representatives of the CERN Staff Association early in his mandate as Director-General (©CERN, All rights reserved)

A Nobel Discovery

One significant survivor of the cuts was the SPS collider programme—it had been that or the ISR, and the higher-energy machine was the obvious choice. Herwig was nevertheless in for a surprise. The project to convert CERN's big machine into a collider had been taken before the changes ushered in in 1981, and as Herwig was to discover, it had had its own funding challenges. "When I became Director-General, I learned that this special programme had never been formally approved at the Council," he recalled. The conversion of the SPS to a collider was carried out within CERN's accelerator development programme, and the Council had not formally allocated resources for it. A similar story was true for the experiments: two underground area (UA) experiments had been discussed in the scientific committees:

UA1, under the direction of Carlo Rubbia, and UA2 with Pierre Darriulat as its spokesperson, but neither was fully funded. “When I came in Rubbia and Darriulat asked for more money to complete the equipment of these two experiments,” Herwig recalled. “There was no money for them in the budget, but certainly it was clear that these were key experiments, so we had to go on.” Herwig managed to eke out some funding for UA1 and UA2, with the Council’s blessing, but much of the funding for these flagship experiments was found outside the CERN budget. “This is very interesting because UA1 and UA2 are the first examples of two big collaborations at CERN that were partially financed through outside contributions,” he explained. “They became the prototypes of the big experiments at LEP and the LHC. Although they were formally under the direction of CERN, under the strong leadership of Rubbia and Darriulat, they achieved a certain independence.”

Data-taking at UA1 and UA2 began in 1981, and the following year the two experiments had clear signs of new particles. “Just before Christmas, Carlo Rubbia and Pierre Darriulat came to see me in my office, independently, and each showed me their data very confidentially,” said Herwig. “It was clear they both had evidence for the W.”

With the exception of the prime minister of one CERN member state, who had requested to be informed directly (see Section “A Prime Ministerial Visit”, In his own words: A prime ministerial visit) the world discovered the news through a CERN press release issued on 21 January 1983. Discovery of the Z boson followed in the summer. The following year, the discoveries of the carriers of the weak interaction were crowned with the award of the Nobel Prize to Carlo Rubbia and Simon van der Meer, the engineer whose invention of a technique known as stochastic cooling had made the endeavour possible. Stochastic cooling enabled beams to be stored in such a way as to increase the number of collisions dramatically.

It is rare for a Nobel Prize in Physics to be awarded so soon after the research is conducted, and, with the prize going to a maximum of three individuals, increasingly rare for experimental physicists to be rewarded. UA1 and UA2 were both collaborations numbering dozens of researchers, but with a little help from Herwig, the Nobel committee found good reason to single out Rubbia and van der Meer.

“A delegation from the Nobel committee came and asked to see me,” he explained, “we had a nice lunch and they told me privately and in strict confidence that there was a proposal to give the Nobel Prize to Carlo Rubbia and Simon van der Meer, but the committee had problems agreeing to it.” First, they discussed van der Meer. Famed for his tendency to avoid the usual publication route, van de Meer’s work on stochastic cooling had been published as internal CERN reports, and not in peer reviewed journals. This gave the Nobel committee a problem, as the Nobel recognises only work that has been subject to peer review. That was an easy problem for Herwig to solve. “The next day I called Simon to my office and told him to write a summary report about his beam cooling method and get it published in a peer reviewed journal,” said Herwig. “Of course, there was no problem passing peer review, and he did it within two weeks.”

Carlo Rubbia’s case proved more of a challenge and raised an issue that still bothers Herwig today. “They told me that the Nobel Prize can be given only for

Fig. 7.5 Herwig presides at the announcement of the discovery of the W boson in January 1983. He is flanked on his right by Carlo Rubbia and Simon van der Meer, and on his left by Erwin Gabathuler and Pierre Darriulat (©CERN, All rights reserved)

a discovery or invention, and the W and Z particles were neither, because they had been predicted by theory," explained Herwig. "I suggested that they could give him the prize for his whole career, but they ruled that out because according to Alfred Nobel's testament, the prize is always given for something specific, so then I suggested awarding it to the whole collaboration, but they turned that down as well." Herwig argued that many theoretical predictions turn out to be wrong, and without experimental verification, they are worth very little, but the Nobel committee members told him that the prize can only be given to a maximum of three people, according to the will of Nobel himself. "I told them that there's nothing in Nobel's testament that specifies three people only," said Herwig, "and after long discussions they told me the real reason—they wanted to keep the Nobel Prize popular." The delegation from Stockholm explained to Herwig that as the subject matter of the scientific Nobel Prizes was frequently beyond the grasp of the general public, they wanted to create heroes. “This is a problem that is still not solved,” said Herwig, “the same difficulty arose with the Higgs particle, when the question came up again, and again they gave the prize to the theorists only and not to the experiments, but I repeat the theories would be worth nothing if they had not been verified by experiments. So, I regret that the big collaborations of today, starting with the collaborations at DESY discovering the gluon, then UA1 and UA2, going on to LEP and now the LHC collaborations cannot receive the Nobel Prize. It’s a pity because progress in science is possibly only through strong collaboration between theory and experiment. Both are necessary and the public should be properly informed to understand it. What can we do?”

Herwig had to think hard to come up with a way of convincing the committee members that they could award the prize to Rubbia. He hit on the idea of using that same justification as that used for van der Meer. “I told them that if they were to give the prize to Simon van der Meer for cooling, they could use the same argument for Carlo Rubbia,” he recalled. Cooling was the key to the SPS collider’s success, it allowed sufficiently intense beams of antiprotons to be accumulated to generate enough collisions to make the discovery possible, and although it was van der Meer’s technique that was used, Rubbia had proposed one of his own when he lobbied to convert the SPS into a collider. “Carlo Rubbia had proposed a different method,” Herwig explained, “he proposed injecting heavy lambda particles into the SPS, which would decay into protons and antiprotons. This idea was never realised because it turned out that Simon van der Meer’s method was much more efficient, but it allowed me to argue that they could give the prize to Rubbia as well. I also argued that they should at least mention the UA1 and UA2 collaborations.”

How much influence that visit to Geneva had on the Nobel committee’s deliberations will remain forever sealed behind closed doors in Stockholm, but the prize did indeed go to Rubbia and van der Meer in 1984, with a citation that read: “This year’s Nobel Prize for Physics has been awarded to Professor Carlo Rubbia and Dr Simon van der Meer. According to the decision of the Royal Swedish Academy of Sciences the prize is given “for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of the weak interaction.” The presentation speech delivered by Professor Gösta Ekspong of the Royal Swedish Academy of Sciences also mentioned the two collaborations, albeit not by name. “Perhaps there is good reason for awarding the scientific Nobel Prizes to individuals instead of collaborations, unlike the Peace Prize, which is awarded in Oslo and can go to organisations. Individual winners do achieve a certain degree of recognition, which they can use to lobby governments to support science,” concluded Herwig, “but there should be some way to recognise the work of the large collaborations as well.”

Spain Re-joins CERN: An Excursion in a Wheelchair

The advent of the LEP project brought growing prestige to CERN as a symbol of European success, triggering an enlargement of the laboratory's membership that continues to this day. The first new country to join, or more accurately re-join, was Spain. A member state of CERN from 1961 to 1968, by the 1980s, Spain was ready to come back to the fold. "A key person in the renaissance of particle physics in Spain was Juan Antonio Rubio who had studied at the university of Madrid and joined experiments at CERN," said Herwig. "Thanks to his influence the Spanish central government took a positive attitude. Parliamentary approval nevertheless turned out to be rather complicated because Spain is a collection of 17 autonomous regions, and they all had to agree."

Early in the new year of 1982 the Schopper family went on a skiing holiday near Chamonix in the French Alps. "I made the big mistake of trying to compete with my children," recalled Herwig. "I had taught them to ski but by now they were better than me. As a result, I had a bad accident and broke my leg in a very complicated way." Herwig was taken to the Cantonal Hospital in Geneva, where he found himself lying in a hospital bed parked in a corridor, near the bottom of the priority list. "It was the middle of the ski season, I think the car show was on in Geneva, leading, ironically, to many traffic accidents and so the hospital was very busy and the wards were full," said Herwig. "One day my wife came to look for me and she couldn't find me. Since mobile phones had not yet been invented, it was difficult to stay in contact with the outside world." By this time, Herwig's daughter Doris, a doctor who had very good relations with the head of the department for internal medicine, was away on a mission for Médecins Sans Frontiers in Central America. "So she couldn't help me," explained Herwig. "On the third day of waiting, though, one of the student doctors asked me whether I was Doris's father, so at least I had somebody to talk to. He even talked to the head of his department to get me a bed, which was quite revolutionary since patients were never housed in departments other than the one that was responsible for them." Eventually, Herwig's leg was operated on, and he left the hospital in a wheelchair with his leg in plaster, ready to negotiate Spanish membership of CERN.

While still in hospital, Herwig received a message that the Spanish government desperately wanted him to visit Madrid to clarify some unsettled issues concerning Spain's membership of CERN. It seemed that there was a one-week window in which to secure the approval of parliament, and if that window was missed, the opportunity might well disappear. "So, despite the fact that none of my family could accompany me I agreed to go. In the wheelchair, with my leg in plaster," said Herwig. "It turned out that the questions were very easy to answer, and the negotiations with the minister were settled in just a few hours."

Herwig's reward was not just that Spain formally re-joined CERN on 1 January 1983. "The minister asked whether I had been to Toledo," explained Herwig. "Since my answer was negative, he had me taken there by car, where I found out that museum visits are much less tiring in a wheelchair. They also put me up in one of the famous

Paradores, which had no lift. Getting up to the first floor on my broken leg was a nightmare. It was a visit I'll never forget."

Herwig stayed in close contact with Juan Antonio Rubio, who became a division Leader at CERN and went on to be employed by the Spanish government in various capacities before being appointed Director-General of the Centre for Energy, Environmental and Technological Research (CIEMAT) by the Spanish Ministry of Education and Science in 2004. "To my great regret he passed away much too early in 2010," said Herwig, "and I lost another friend."

Portugal: Much Work in a Beautiful Country

Three years to the day after Spain re-joined CERN, Portugal also became a CERN member state. Once again, the driving force was an individual physicist with a big vision for science in his country.

CERN sets conditions for membership in order to ensure that prospective new member states are able to benefit fully from their investment in the laboratory. One of these is that the country must have an active particle physics research community. "Universities in Lisbon and Coimbra had a famous history in physics but the whole structure was old fashioned and not adapted to modern science," recalled Herwig. "A dynamic physicist, Mariano Gago, who had spent some time working in France wanted to change this." An electrical engineer by training, Gago had turned his hand to particle physics at Paris's prestigious Ecole Polytechnique. "It was largely thanks to Mariano's efforts that Portugal became a member of CERN," said Herwig, "along with Gaspar Barreira and Armando Policarpo he also established LIP, the Laboratory of Instrumentation and Experimental Particle Physics, as a focal point for Portugal's involvement in CERN experiments. He became a great personal friend."

Gago went on to become Portugal's Minister for Science, Technology and Higher Education, and was succeeded at LIP by Gaspar Barreira. This allowed him to further his advocacy for science. "Mariano was instrumental in transforming Portugal into a modern country as far as science and education are concerned," said Herwig, "and I remember him being a very active member of the CERN Council during my mandate as Director-General."

After Herwig's retirement, Gago joined the long list of people seeking to tap into his long experience. "He asked me to join an advisory committee for LIP," Herwig recalled. "I accepted and that led to a ten-year association with Portuguese science." Herwig went on to chair the LIP committee, and later joined a government committee set up to advise on the development of science in Portugal. Herwig was active in the subcommittee on physics, which he also went on to chair. "I had the opportunity, and the responsibility, to influence activities in the most prominent Portuguese universities," he recalled, "which meant hard work and difficult discussions, but it was worth it. My contacts with Portuguese colleagues were always based on mutual respect and recognition, and never derailed into fruitless argument."

Fig. 7.6 A visit from the Portuguese Minister for Foreign Affairs, Jaime Gama in 1985. Jose Mariano Gago is standing centre, behind the minister (©CERN, All rights reserved)

Mariano Gago passed away in 2015 leaving a strong scientific legacy in Portugal and beyond. Today, LIP is an institution with a large and diverse programme, participating in several international collaborations and with activities ranging from IT to medical applications. "When Mariano's health no longer allowed him to fulfil all his obligations, he was greatly supported by his colleague Pedro Abreu," recalled Herwig. "This was no accident, Pedro is outreach coordinator at LIP, and Mariano was a great supporter of education and outreach. I owe Mariano special gratitude for introducing me to Portuguese history. He explained to me the importance of Henry the Navigator who, it is said, was a strong supporter of science and may even have set up a scientific school for navigators. Mariano used to joke that Henry was centuries ahead of CERN! With Mariano, I lost a real friend and I much regret that he could not enjoy all the successes that he had initiated and completed for longer."

Fig. 7.7 Italy's Foreign Minister, Giulio Andreotti (centre) also visited in 1985, accompanied by Antonino Zichichi (left) (©CERN, All rights reserved)

Water at the End of the Tunnel

When civil engineering for LEP got underway in 1983, it was the largest construction project in Europe until work began on the Channel tunnel in 1988. Hundreds of workers descended on the Geneva region to work on the project, and temporary accommodation sprang up to house them all in the largely rural Pays de Gex region of France. Before that could happen, however, there were some more tweaks to be made concerning the machine, above all its precise location. The tunnel's placement was once again shifted to move more of it from under the Jura, leaving less to be excavated in the difficult terrain of the mountains, and reducing the maximum depth of the access shafts from 600 m to 150.

The trigger for the change came in the form of a note in Italian from Emilio Picasso to Herwig. "Italian was the language he always used when he was very worried," said

Fig. 7.8 Herwig (right) discussing the LEP project with the President of France, François Mitterand, and the President of Switzerland, Pierre Aubert, on the occasion of the LEP ground-breaking ceremony on 13 September 1983 (©CERN, All rights reserved)

Herwig, who as a consequence took the note very seriously. In it, Picasso summarised the geological risks identified by an expert from the prestigious Swiss Federal Polytechnic Institute (ETH), in Zürich, and it made for sobering reading. Water up to 20 atmospheres in pressure had been identified through test borings, along with several geological faults that the green book design would have to cross. The experts from ETH had identified a series of factors that could lead to a delay of up to 16 months at a cost of up to 17 million Swiss Francs. This is not a risk that Herwig was prepared to take. "We decided to displace the main ring towards the east by several hundred metres," he explained, "bringing it more out of the Jura and closer to the airport." The resulting position left only three kilometres of the tunnel under the Jura to be excavated by explosives, with the rest in molasse sandstone, which could be excavated using a tunnel boring machine.

There was another advantage to the new position too. "The land needed for access shafts had to be acquired by the two host states," explained Herwig. "In Switzerland, a popular vote is necessary for the acquisition of land by government, and that could have taken a long time. The new position of the ring had just one access point in Switzerland, and that was on land that had already been made available to CERN for the SPS. All the other access points were situated in France, with the shafts at points six and eight just a few metres outside Switzerland." The precise position of the ring was kept under wraps for a long time, and was known only to Herwig, Emilio Picasso and a few other experts at CERN because they thought it could have

Fig. 7.9 In conversation with German delegate Josef Rembser in the margins of a CERN Council meeting in 1983. In the following years, Rembser went on to be vice-president and then president of the Council (©CERN, All rights reserved)

immediate consequences for the price of land. “We didn’t even tell the Council at first,” said Herwig, “because we were worried that information would leak out.”

Having identified where the ring would be placed, the next challenge was surveying, bearing in mind that the geometry of the accelerator could not be adapted to the terrain. It had to be a precise geometrical figure comprising eight circular arcs joined by eight straight sections. The margin for error around the entire 27 km ring was just a few centimetres. Added to that, the tunnel was to be situated as close as possible to the surface, which rises from Lake Geneva towards the Jura mountains. It was therefore designed with a slope of 1.4% to keep it to a depth of 150 metres at most. “Probably for the first time in Europe, a satellite system, NAVSTAR, was used for geodesy,” explained Herwig. “It helped us to establish a network of survey points, which was checked continuously for its stability—the survey points were stable to 2

Fig. 7.10 Herwig welcomes His Holiness the Dalai Lama to CERN in 1983, and receives the traditional gift of a scarf, or khata, symbolising respect (©CERN, All rights reserved)

mm over several years." Another new device, known as a terrameter, which had been developed in the USA for earthquake research, was also deployed in mapping out the future LEP tunnel. It measured distances to the incredible precision of 1 mm over a kilometre by using two laser beams of different wavelengths to eliminate errors due to fluctuations in atmospheric temperature and pressure.

Once LEP had been mapped out on the surface, the reference points had to be transferred underground. "A simple plumb line would not do," recalled Herwig, "we had to take the curvature of the Earth into account since the verticals at opposite sides of the ring were not parallel, but rather converging towards the centre of the Earth." So precise was the model that even distortions to terrestrial gravity caused by the large mass of the Jura were accounted for. Once transferred underground, the tunnelling machines were guided by laser beams. "As a result, the real axis of the tunnel never deviated by more than eight centimetres from the plan," explained

Herwig. “For a 27 km sloping tunnel with just eight access points 3.3 km apart, this is an extraordinary achievement.”

With the survey complete, tunnelling could begin. The strategy was to use two tunnel boring machines starting at the lowest point on the ring next to Geneva Airport and progressing uphill in opposite directions around the ring. This would provide safety in case water was encountered, as it would run away from the workface. The more difficult terrain under the Jura had to be excavated by the more laborious process of pilot borings at the workface to investigate what lay beyond, followed by blasting with explosives.

Work began with the access shafts, some of which presented challenges of their own because the molasse is covered by a layer of unstable moraine, which was in places so deep that the ground had to be frozen to −22 °C before excavation could begin. In the end, the two tunnel boring machines became three, working at different points around the ring. The tunnelling in the molasse went smoothly and was complete by January 1987. Under the Jura, however, it was a different story. In September 1986, high pressure water broke into the tunnel about 15 m behind the workface, leading to work stopping at that point for eight months. When work resumed, new techniques had been developed to ensure that it would not happen again. “Resin was systematically injected at the front of the tunnel,” explained Herwig, “and the tunnel walls were immediately lined by spraying concrete on to them to prevent rockfall and water ingress. The tunnel walls were also strengthened by a metallic

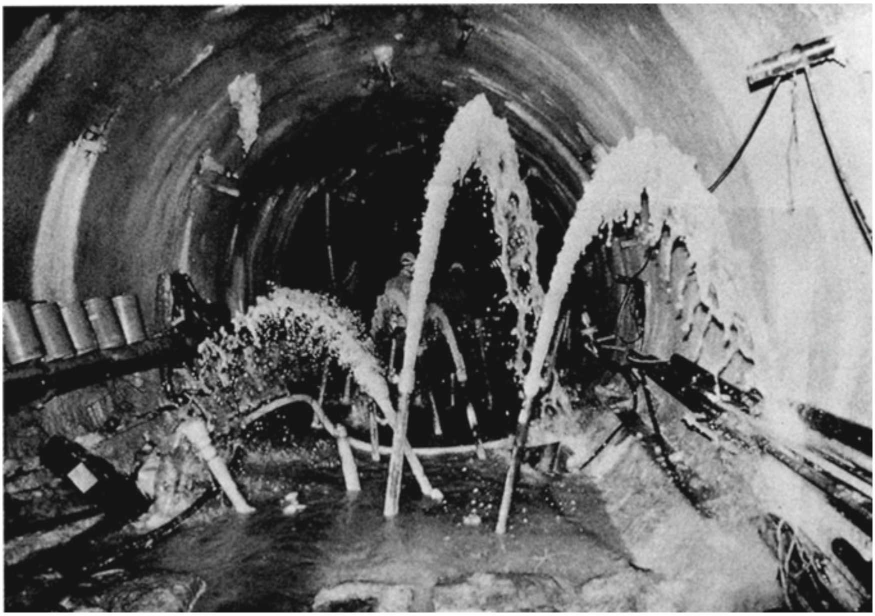

Fig. 7.11 Water ingress under the Jura mountains led to a temporary halt to tunnelling in 1986 (©CERN, All rights reserved)

vault to resist the water pressure." The delay was partly made up by equipping a short access tunnel leading to the section under the Jura to carry equipment so that tunnelling could continue while the water ingress was being dealt with. Finally, on 8 February 1988, Herwig Schopper and Emilio Picasso found themselves standing deep underground on either side of a thin wall of rock that was all that remained to be excavated. "When the dust from the final blast settled," said Herwig, "we cut a blue ribbon, which was the only obstacle left."

Fig. 7.12 Herwig and Emilio Picasso cut the ribbon at a ceremony to mark the end of the excavation of the LEP tunnel in 1988 (©CERN, All rights reserved)

Fig. 7.13 Herwig Schopper and Abdus Salam present the 1986 Dirac Medal to Yoichiro Nambu at the International Centre for Theoretical Physics (ICTP) in Trieste on 23 July 1987 (© ICTP Photo Archives/Ludovico Scrobogna)

Building the Machine

It's tempting to think of LEP as a rather conventional machine, a scaled-up DORIS or PETRA, but the reality is very different. LEP posed many significant technical challenges, and generated a lot of innovation in accelerator technology, from concrete magnets to superconducting RF and vacuum technologies.

Perhaps the most surprising innovation came in the form of LEP's 3392 concrete bending magnets. Traditional electromagnets consist of iron cores with coils of wire to produce a magnetic field. The sheer size of LEP made this approach financially out of the question, and a more economical solution was needed. The magnetic field required for LEP phase 1 was a modest 0.135 T, and even for LEP II, only double that would be required. That meant that a correspondingly modest amount of iron would be needed, but a very rigid geometrical shape was necessary. The LEP engineers came up with a design that consisted of 1.5 mm thick low-carbon steel laminations separated by 4 mm and encased in concrete. Rather than using coils, aluminium conductor bars were threaded through the C-shaped concrete yokes to produce the magnetic field. Nothing like this had ever been done before. LEP's concrete magnets served the machine well throughout its operational lifetime, for an investment of about half what conventional electromagnets would have cost.

LEP's vacuum system was another first, allowing a pressure of under a million millionth of an atmosphere, which in turn allowed beams to circulate for several hours before the machine needed to be refilled. The secret was a technique called getter pumping, which was deployed at LEP in the form of a thin ribbon of zirconium–aluminium alloy running around the ring in a channel inside the machine's vacuum chamber adjacent to the pipe in which the beams circulated. This alloy worked like fly paper for molecules, so when all the air had been pumped out using conventional vacuum pumps, the remaining air molecules would stick to the ribbon. Periodically heating the ribbon to 400 °C would free the trapped molecules, reconditioning the getter for future use.

Another of the most challenging components of LEP was the RF systems that accelerated the beams. "In the first phase of LEP, copper cavities had to be used since no other technology was available," said Herwig. But LEP's copper cavities were anything but conventional. RF systems are big consumers of energy. "The electricity cost for the accelerating system turned out to be the dominant part of the operating cost of LEP," Herwig continued. But LEP's design offered a solution to minimise the cost. The machine had been designed to operate with four bunches of particles circulating in each direction, so the cavities would be idle for much of the time and a technique was developed to reduce their energy consumption when they were not actually accelerating beams. "An accelerating cavity consists of several cells in which electric fields oscillate at radio frequencies in such a way that the field points in the right direction to accelerate the particles at the moment a bunch arrives at the cell," explained Herwig. "The fields are produced by electric currents flowing in the walls of the cavities, and even for copper, these currents produce considerable thermal losses." LEP's engineers designed a system in which the field would be transferred to the most energy-efficient structure available, a sphere, when it was not accelerating beams. This led to the striking shape of LEP's copper cavities—a cylinder with a sphere on top, and it allowed the electricity bill for the RF system to be reduced by 40%. LEP's phase 1 RF system consisted of some 128 cavities covering a total distance of 300 metres and installed in two of the tunnel's straight sections.

All in all, the 60,000 tonne LEP accelerator consisted of thousands of components, all of which had to be lowered into the tunnel via a few narrow shafts and delicately manoeuvred into place around the ring. An overhead monorail was installed in the tunnel to transport people and equipment, and on 4 June 1987, the first magnet was ceremonially installed by French Prime Minister, Jacques Chirac, and Swiss President, Pierre Aubert. "A crash programme of installation got underway in September," said Herwig. "As soon as part of the tunnel had been vacated by the civil engineering crews, the installation of components started." Just under two years later, the giant machine was ready to be brought to life.

The Decisions Were Made at the Bar

As LEP had been approved with just a token budget for the particle detectors that would record the machine's electron–positron collisions, a new way had to be found to build these devices. The two big experiments at the SPS collider, UA1 and UA2, set the example to a certain extent, but the LEP detectors would take the new model further still.

The first step to forming the large collaborations that would run the LEP experiments took place at an International Conference on Experimentation at LEP held in Uppsala, Sweden, in June 1980. Jointly organised by the European Committee for Future Accelerators and Uppsala University, this initial conference was followed by a series of ECFA workshops and culminated 12 months later in the Swiss alps, at Villars-sur-Ollon, in a Club Med resort hotel. "The *gentils organisateurs* seemed disappointed that all we wanted to do was sit at the bar and talk physics instead of taking part in all the activities they were putting on," recalled Herwig. "One of my Danish colleagues, Hans Bøggild, summed up the atmosphere in verse: *There once was a place called Villars, A palace with more than one star, They talked about LEP, The future of HEP, But decisions were made at the bar.*"

The decisions were momentous ones, laying down the procedure for forming collaborations and approving proposals for detectors. "My aspiration was to enable as many scientists as possible to do research at LEP," recalled Herwig. "I said that the detectors would be considered as facilities able to perform many experiments and put forward the analogy that the large collaborations were more like a flotilla of small ships rather than a single big ship with one captain. Over time, these small units would combine to carry out common tasks but go their own way to pursue their particular research interests. Some might even break off to join a different flotilla. By and large, this is what happened."

At Villars, it was decided that four of the potential eight interaction regions would be used for detectors, and that letters of intent should be submitted to a LEP Experiments Committee, which would be established in 1982. Proposals would be evaluated on their scientific merit, technical and financial feasibility, and the strength of the collaborations submitting them. Approvals were expected to come in 1983, leaving four years for construction. Crucially, groups from non-member states of CERN would be welcome to take part.

The size of the collaborations that came together following the Villars meeting was unprecedented, with the proposals listing dozens of institutes and hundreds of individuals. They were far bigger than the UA1 and UA2 collaborations. "I also raised a problem of some sociological importance at Villars," recalled Herwig. "The large number of names that would be appearing on the papers would make it hard to appreciate any individual's contribution, so I suggested that common papers about the design and construction should include all names, but specific analyses only those of the people doing the analysis, or alternatively, those names should come first instead of just listing people alphabetically. I completely failed to gain acceptance of this proposal, and the issue is still with us today."

Fig. 7.14 Herwig adopts a suitably solemn expression during a visit to CERN by His Holiness, Pope John Paul II in 1982 (©CERN, All rights reserved)

"In March 1982, the LEP Experiments Committee, very competently chaired by Günther Wolf, began its work evaluating the six proposals that had been submitted," said Herwig. "They were named ALEPH, DELPHI, ELECTRA, L3, LOGIC and OPAL." For the next four months the committee examined every aspect of these proposals, and in July, put forward ALEPH, DELPHI, L3 and OPAL for conditional approval. "ELECTRA and OPAL were very similar, as were DELPHI and LOGIC," explained Herwig, "and we had to ensure diversity among the experiments approved. I was against a brutal rejection of the refused experiments, preferring to give their proponents a fair chance to join the approved ones. In an earlier open meeting of the committee, I'd warned them that the final judgement would not be based only on a strict evaluation of the proposals, but also on factors like degree of technical risk and geographical diversity among member and non-member states. Someone remarked that the committee looks at the science while the Director-General takes care of the politics, and that's pretty much the way it was."

Herwig also had another reason for approving the four experiments, but he kept it to himself at the time. "It was the first time that such complicated and expensive collaborations were tried without a legally responsible officer," he explained. "Two

Fig. 7.15 The support tube at the heart of the L3 experiment was among the more imposing components of CERN's flagship project for the 1990s (©CERN, All rights reserved)

of the collaborations were headed by strong individuals, while the other two were organised in a more democratic way. I was not sure which model would work best, so I wanted two of each."

A decade later, the procedure for international collaboration that was developed from Uppsala to Villars went on to become the model for the experiments at the LHC, but with one important difference. "To my surprise both models of collaboration at LEP worked very well," explained Herwig, "But it is interesting to note and, worthy of a sociological study, that when the LHC experiments were established, the democratic model was preferred."

The scientific rationale for the approval was that two detectors, ALEPH and OPAL, were general purpose devices, with OPAL employing tried and tested technology while ALEPH put forward new techniques. DELPHI and L3 were more specialised, each with a different focus. Geographically, they brought together over 100 institutions and some 1000 researchers, mostly from the CERN member states, but also from Canada, China, East Germany, Hungary, Israel, India, Japan, Poland, the USA and the USSR. The committee asked for some changes to be made, and after these were done, conditional approval was given on 18 November 1982.

Before LEP, CERN experiments had all been named for their location and number, hence underground area (UA) 1 and 2, or north area (NA) 1 and so on. Sometimes, the collaborating institutes would create acronyms from their names, hence CERN, Dortmund, Heidelberg, Saclay became CDHS, but when Warsaw joined the collaboration, the name didn't change. "When I was at DESY, I liked the tradition of using acronyms for machines and detectors, so I tried to encourage that at LEP, with mixed success," he recalled. ALEPH, contracted from Apparatus for LEp Physics; DELPHI, the DEtector with Lepton Photon and Hadron Identification; and the Omni-Purpose-Apparatus at LEP, OPAL, all went along with Herwig's request, but the collaboration behind the third proposal to be submitted remained simply the L3 collaboration. It was led by Nobel laureate, Sam Ting. "When I asked Samuel Ting to propose an attractive name, he suggested SAM," said Herwig. "I told him it was not very elegant to use his first name for the detector, but he replied that it had nothing to do with that, SAM stood for "Schopper Approves Me." A few weeks later, he came back with the name Magellan, but the collaboration voted that down on the basis that Magellan, when discovering the Philippines, had been shipwrecked and slain by the natives, which was hardly a good omen for an international collaboration. L3 remained L3."

Slowly but surely, components began to arrive at CERN and the four detectors started to take shape in their caverns. "It always seemed to me like a little miracle that all the parts of these very sophisticated detectors arrived from all corners of the world, fitted together and worked," said Herwig. "It was a huge challenge to get them built in such a short time. To a large extent it was thanks to Horst Wenninger, who I had appointed as technical coordinator for the experiments, that the thousands of different parts fabricated in many laboratories fitted together with extremely high precision."

By the time the detectors were complete, at least one experiment had already proved to be a success: CERN had successfully changed its business model, with the laboratory itself covering just 15% of the total cost of the detectors. Forty-seven percent came from member state institutes, and the remaining 38% from non-member state institutes. The demographic of CERN had also changed, with increasing numbers of non-member state physicists involved. In 1989, the year LEP started up, the number of American physicists at CERN exceeded the number of CERN member state physicists doing their research in the US for the first time.

An Eye on the Future: Superconducting Cavities and Magnets

By the summer of 1989, LEP was ready to start, and four large collaborations were hungry for data. For much of the decade, CERN had put most of its eggs in the LEP phase 1 basket, but not all. Herwig Schopper also had an eye on the future. “Superconducting cavity development in Europe began in my group at Karlsruhe in the 1960s,” said Herwig. “I invited Herbert Lengeler from CERN to come to Karlsruhe and lead the superconducting cavity group, which he did for about two years, and when he went back to CERN, he set up a superconducting RF group there.” The group was not able to advance the technology sufficiently for LEP I, but design choices were made to ensure that the superconducting cavities for LEP II would be compatible with the infrastructure of LEP I, so they could simply be exchanged. By the time LEP I had done its job in the mid-1990s, Herwig’s mandate as CERN Director-General was long over, but the superconducting RF work his teams had begun in Karlsruhe in the 1960s had paid off: superconducting cavities replaced the copper ones as LEP moved into phase 2.

CERN’s longer-term future was always in Herwig’s mind. In 1984, a workshop organised by CERN and ECFA in Lausanne and at CERN, examined the possibility of installing a hadron collider in the LEP tunnel. This was not surprising: the decision to increase the LEP circumference to 27 km was mainly taken with a view to installing a proton machine to follow LEP. At the time, the USA was discussing a huge machine called the Superconducting Super Collider (SSC) in order not to lose the lead in particle physics to LEP. The SSC was planned to reach energies much higher than could be achieved by a hadron collider in the LEP tunnel, but that didn’t mean that a hadron collider at CERN could not be competitive with the SSC. “In a hadron collider, it’s the collisions between quarks that provide the interesting physics,” explained Herwig, “and since the energy is shared between the quarks, the higher the intensity of the beams, the greater the number of collisions between high-energy quarks.” By designing CERN’s hadron collider to have much more intense beams, it could be far more competitive with the SSC than the difference in beam energy might suggest. “It was at Lausanne that these discussions started to happen,” said Herwig, “and even though the SSC was never built, it shaped the development of the Large Hadron Collider into the powerful research tool that it is today.” Prototyping for the extremely powerful magnets that such a machine would require also got underway on Herwig’s watch.

CERN Under the Microscope: The Kendrew and Abragam Committees

Another feature of Herwig Schopper's mandate as CERN Director-General was the intense scrutiny that science budgets in general, and CERN's in particular, were under through the 1980s. Once the CERN Council had made it clear that the laboratory would have to operate under a constant budget, one member state, the UK, went a step further, setting up a committee with Herwig's old friend John Kendrew in the chair. Its remit was to review UK particle physics, and in particular the UK's financial contribution to CERN. One year later, the committee, consisting largely of scientists from fields other than particle physics, delivered its report. While praising the scientific excellence of CERN, it recommended that the UK should remain a CERN member state until LEP was complete, but then withdraw if the UK's subscription could not be reduced by 25%. "It took me some time to understand what was behind this recommendation," explained Herwig. "Unlike many CERN member states, the UK did not have a dedicated budget line for CERN: the UK contribution was channelled through the Science and Engineering Research Council (SERC) instead, so CERN was in direct competition with other research budgets. To exacerbate the situation, the CERN budget had to cover all CERN expenses, not just research, so it took up a large fraction of SERC's overall spending. If the CERN contribution increased because of the Sterling to Swiss Franc exchange rate, the SERC budget suffered. CERN's annual budget is about the same as that of a large university, but SERC did not have to pay all the costs of universities, so this arrangement seemed unfair to me."

It took a direct intervention from the UK prime minister to resolve the situation. "When Margaret Thatcher visited CERN, I had explained these difficulties to her," Herwig recounted. "At the end of her visit, she told journalists that she was convinced that the UK's contribution to CERN was well spent." In 1987, the UK formally decided not to give notice of withdrawal from CERN, but the intense scrutiny was not over. By this time, another committee had been established, this time by the CERN Council itself, but at the instigation of the UK delegation. It was chaired by the renowned French physicist Anatole Abragam and was established in February 1986. Its mandate was to review the cost effectiveness of CERN's use of human and material resources, along with employment conditions at the laboratory.

The Abragam committee consisted mostly of industrialists and people with experience in modern management methods. One of them was Miguel Boyer, president of *Banco Exterior de España* and a former finance minister. When the committee came together for the first time, Abragam distributed the tasks among the committee members, and CERN's finances went to Boyer. "As a former minister, he was accustomed to a certain lifestyle," recalled Herwig. "So he checked into top hotels and turned up for meetings in a chauffeur-driven limousine. Since CERN had to pay the expenses of the committee, I told Abragam this was not acceptable, and he made it clear that I'd have to talk to Boyer if I wanted things to change. It turned out to be easier than I expected, Boyer understood completely and spent his time in Geneva more modestly after that. A bigger problem was Carlo de Benedetti."

De Benedetti was the CEO of Olivetti. "In the very first meeting," recalled Herwig, "he asked me about the turnover of staff at CERN, which was about 5–6% per year. He took this as meaning that CERN was a sclerotic organisation and told us that Olivetti had a turnover of about 30% per year. This turned out to be due to an early retirement programme, and the committee took great interest in that. They ended up recommending a similar programme to CERN, but unlike Olivetti, which just pushed people into Italy's state pension fund, such a programme would create a financial burden for CERN's pension fund."

As well as recommending an early retirement scheme, the Abragam committee suggested that international status not be granted to non-professional staff, so they would fall into the social security systems of CERN's two host states, the introduction of performance-related pay and promotion, a reduction in the granting of indefinite contracts, and a range of recommendations for the management of CERN's accounts and pension fund. The committee did not recommend, despite the UK delegations request to do so, a reduction of 25% in CERN's overall budget.

"In some shape or form, most of these recommendations were implemented," said Herwig, "leading again to calls for my resignation. When the Council agreed to the early retirement scheme, they did not allocate resources to cover the cost to the pension fund, so that had to be compensated from the already depleted CERN budget. I had no choice."

And the Answer is Three: The First Results from LEP

By July 1988, the first octant of LEP was ready and positrons were injected into the machine for the first time. It was a moment of triumph for CERN, demonstrating that the injector chain, consisting of a new facility to produce and store electrons and positrons, along with the PS and SPS, was working to plan, and that there were no obvious show stoppers with the LEP machine itself. One year later, LEP was complete, and CERN chose 14 July, the bicentenary of the storming of the Bastille, to test the whole machine for the first time. "The control room was packed as the engineers and technicians anxiously watched the first attempt to coax a beam around the ring," recalled Herwig. They needn't have worried—the beam sailed round with barely a hitch, and LEP commissioning was underway. On 25 July, electrons were successfully injected for the first time, and by 12 August, beams of electrons and positrons were circulating in opposite directions around the ring at the injection energy of 20 GeV. The RF accelerating system was turned on to boost the beams up to around 46 GeV. Everything was ready for LEP's first collisions, and all eyes turned to the control rooms of the four big experiments. Early in the evening of 13 August, things were not looking too promising as the beams were lost, but the decision was taken to try again. At 21:43, LEP's operators once again started to accumulate beams. Seen from the experiments' control rooms, progress seemed painstakingly slow, but at 22:52, the monitor screen, known as LEP page 1, displayed the word ‘ramp’, indicating that the beams were being accelerated. At 23:00, the electrostatic separator plates keeping the beams apart at the collision points were switched off, and ‘ramp’ was replaced by ‘collide’. For 16 agonising minutes, nothing happened, but then on the event display monitor in the OPAL control room, the unmistakable image of a Z-particle decay appeared. “By the time a printed copy of the event had been brought from OPAL to the LEP control room, a further five events had been reported,” recalled Herwig. “LEP was underway and a new era in experimental physics had begun.”

On that first night, ALEPH and L3 also reported their first collisions, with DELPHI joining the party the following day. Beams had not quite been lined up in DELPHI, but as soon as that was fixed, data started to flow in LEP’s most speculative detector

Fig. 7.16 Carlo Rubbia and Herwig Schopper in a crowded LEP control room on 14 July 1989 awaiting the new accelerator’s first beam (©CERN, All rights reserved)

Fig. 7.17 Playing the piano at his only public performance—a ceremony to mark 25 years of service for CERN staff in 1988. Helga Schmal, who served as assistant to Directors-General from Willibald Jentschke to Luciano Maiani, turns the pages (©CERN, All rights reserved)

as well. After more fine tuning of the machine, a pilot run began on 20 September and continued to the end of the year.

The first big question that the LEP experiments had to address was the number of generations of fundamental particles that exist. The kind of matter we consider ordinary, which makes up everything visible in the universe, consists of up quarks, down quarks and electrons, along with the neutrino predicted by Wolfgang Pauli in 1930. Cosmic rays had revealed a second generation consisting of strange quarks, charm quarks, muons and muon-neutrinos, and members of a third family—bottom quarks and tau particles—had also been discovered by the time LEP started up. Studying the decay of Z particles offered a way to find out if there were more generations to be discovered, assuming that any as-yet undiscovered neutrino was light enough to be produced by a Z particle decay.

It would be a quick measurement to make, but the LEP experiments had a race on their hands. The Stanford Linear Accelerator Center (SLAC) in California had added bending arcs to the end of its two mile long linac, allowing it to accelerate electrons and positrons and bring them into collision with enough energy to produce

Fig. 7.18 Herwig shows the CERN *Livre d'Or* to husband-and-wife visitors, the author Friedrich Dürrenmat and filmmaker Charlotte Kerr (©CERN, All rights reserved)

Z particles. The Stanford Linear Collider (SLC) had been operating since April, and by the time LEP started up, Stanford physicists were showing results based on a sample of 233 Z particle decays. LEP's collision rate was much higher than that of the SLC, so it was only a matter of time before the LEP experiments would overhaul the American collider, but the race to publish the so-called Z line shape was real.

When the collision energy of electrons and positrons reaches the energy of the Z particle, a peak appears in the distribution of events containing particles the Z can decay into. This is called the Z line shape, and it is sensitive to the number of generations of fundamental particles. The detectors at LEP and the SLC can detect all the types of particles that Zs can decay into, except for neutrinos, which escape the detector unseen. That allows physicists to model the line shape for any number of particle generations, assuming that the neutrinos are light enough in every generation to be produced in Z particle decays. By comparing the measured line shape to predictions for two, three or four generations, LEP and SLC physicists could determine how many generations there are. In August 1989, SLAC's sample of 233 events allowed them to say that the upper limit on the number of particle generations was 4.4.

When the LEP pilot run got underway, the LEP experiments were recording thousands of Z particles per day, and they were preparing to present their first results in October. Meanwhile SLAC was homing in on a definitive result, presenting updated results at the European Physical Society's September meeting in Madrid. It seemed almost inevitable that the data would show that the three known generations were all there are, and confirmation was soon delivered. On 13 October 1989, CERN issued a press release with the title "First Physics Results from LEP." It included the news that "there are no other neutrino types in nature beyond the three associated with the electron, muon and tau particles." The final result from LEP, published at the end of LEP I running and combining the results of all four experiments, was that the number of light neutrinos is 2.9840 ± 0.0082. Three, in other words. Why only three kinds of neutrinos exist remains an open question to this day.

Herwig Schopper's mandate as Director-General of CERN was extended beyond the initial five-year term, but had nevertheless ended on 31 December 1988 when he passed the baton to Carlo Rubbia. When the machine was formally inaugurated on 13 November the following year in the presence of heads of state and government from CERN's member states, it was therefore Emilio Picasso who had the job of handing over the symbolic keys to the machine to the new Director-General. Although Herwig had no part to play in the ceremony, it was very much a celebration of his mandate. Not only had CERN succeeded in constructing the world's largest scientific instrument under particularly difficult financial conditions, but there were also 14 countries represented on the podium with Spain and Portugal having become member states during Herwig's mandate.

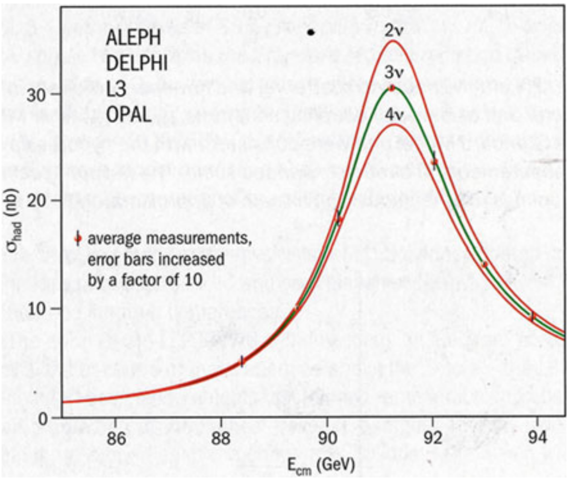

Fig. 7.19 The LEP experiments' measurement of the hadron production cross-section around the Z particle resonance. The curves show the predicted cross-section for two, three and four neutrino species with Standard Model couplings and negligible mass. This measurement clearly shows that there are three, and only three, types of neutrino (©CERN, All rights reserved)

Fig. 7.20 In 1996, L3's spokesperson, Sam Ting (left), shows a delegation from the US Congress around the experiment. Ting's colleague, Jim Allaby, is to the right (©CERN, All rights reserved)

In February 1989, Herwig Schopper turned 65. After an illustrious career he had earned his retirement, but Herwig had other ideas. He stayed on at CERN to re-join the ranks of particle physicists, becoming a member of Sam Ting's L3 experiment and contributing to the publication of several papers. Then it was off to UNESCO and other tasks.

The Future of CERN

Herwig retained a close attachment to CERN beyond his retirement. Having also retired from his professorship at the University of Hamburg, he stayed in Geneva and kept an office at CERN. "This gave me the possibility to continue to support CERN, at least in the background," he explained, "as a former member of the CERN Scientific Policy Committee, through my extensive personal contacts, and through publications and interviews in the media." CERN also proved to be a very strong and consistent source of support to Herwig later, when his post-retirement career led him to play a leading role in the establishment of new scientific international organisations (see Chap. 11).

Herwig cares deeply about the long-term future of CERN. "CERN is one of the most precious jewels of Europe, and beyond, and every effort should be made to keep it in operation in the long run," he said. "CERN is a symbol with respect to carrying out projects on time and within budgets. It has a very diverse programme, but always with big flagship projects that are outstanding on a global level. The present Director-General, Fabiola Gianotti, is following this tradition as an advocate for a large tunnel with a circumference of nearly 100 km, which, like the current tunnel, would host first an electron machine and then a proton one."

Whether this or another project is ultimately pursued, Herwig believes that Europe should not abandon the model for international research that CERN has honed over the decades. "Such a project should not be built for national or regional prestige," he said, "but rather in a spirit of world-wide cooperation."

With his long career in research, stretching back to a time when Europe was emerging from a brutal period of conflict, Herwig is always mindful that CERN has a second strand to its mission. "In the present political situation," he explained, "one of the original ideas of CERN could become important again: science for peace. CERN was founded with the idea of helping to bring European countries together in peaceful cooperation, and it has contributed to this aim considerably." CERN's neutrality even played a role during the disarmament talks in Geneva in 1985. "In the wake of the Reagan–Gorbachev summit of November 1985, disarmament negotiations seemed to be getting nowhere," recalled Herwig. "One day the head of the US delegation, Alvin Trivelpiece, a physicist that I knew, called me to ask if I would invite the heads of the two delegations to dinner at CERN, where the neutral relaxed atmosphere might lead to a breakthrough. So I did, and that seemed to get things moving in the right direction."

Herwig's vision is that the CERN model could be applied in other fields, uniting humanity around common goals. "CERN's main product is the increase of fundamental knowledge concerning the laws of nature," said Herwig. "Fundamental research is independent of any economic, political or military interests, and this may be true for other fields as well. As a result of the CERN model, no other field is better integrated than particle physics into the cultural environment of so many countries around the world. I can think of many areas of research that would benefit from such an approach. I hope that for the future of CERN, and also research more generally, we can rekindle the spark exemplified by Denis de Rougemont and his 1948 European Cultural Conference. This would be my dream! CERN and science certainly cannot help to solve political crises. These are usually resolved by peace treaties or at least armistices. But such agreements are not worth the paper they are written on unless they are based on a minimum of mutual trust. The past has shown that science is a wonderful tool that can help create such confidence."

Fig. 7.21 With Queen Beatrix of the Netherlands and Prince Klaus at CERN in 1985 (©CERN, All rights reserved)

In His Own Words: Encounters with Remarkable People

A Prime Ministerial Visit

“In August 1982, we had a visit from Margaret Thatcher, she came to CERN because she was very interested in science. She introduced herself by stating that she did not want to be dealt with as a Prime Minister, but as a fellow scientist. She had a degree

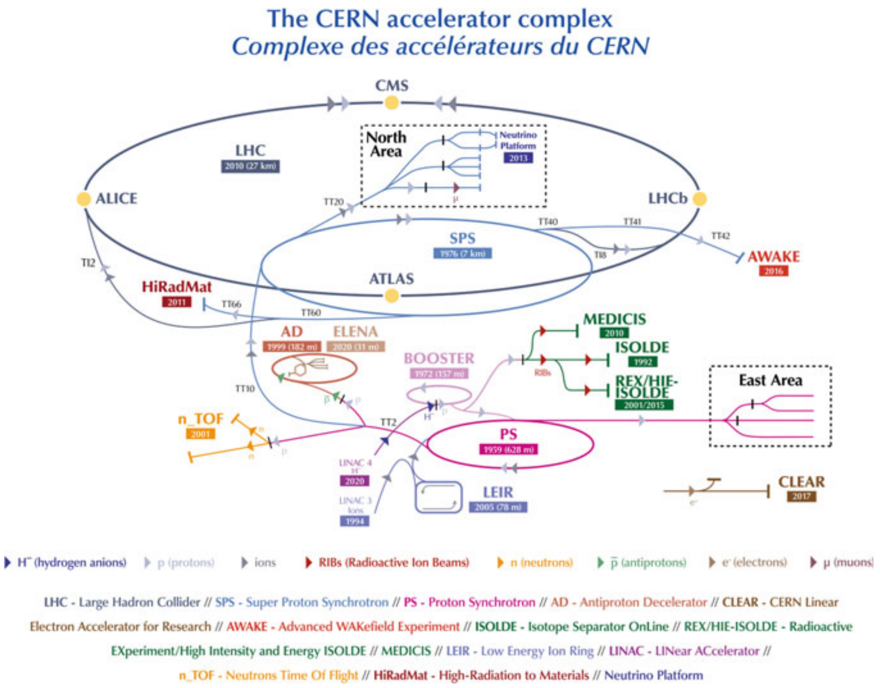

Fig. 7.22 The CERN accelerator complex in 2022 showing the diversity and complexity of the Laboratory's unique collection of research facilities. CERN's current flagship, the LHC, occupies the tunnel constructed for LEP during Herwig's mandate (©CERN, All rights reserved)

in chemistry. At lunch, she asked me the question, 'What will be the size of the next project after LEP at CERN?' I said, 'There will be no bigger ring at CERN because there is no more space. LEP is the last of the big rings at CERN.' Then she answered, 'I asked the same question of John Adams when he built the SPS and he gave me the same answer, why should I believe you any more than him?' Now many years later CERN is discussing a new tunnel with a circumference of about 100 km. One should never try to predict the future, because one never knows what might happen!

During her visit I introduced Mrs Thatcher to Carlo Rubbia. In August both experiments at the SPS collider, UA1 and UA2, were starting to see indications compatible with a W particle, but the uncertainty was still very large. After talking to Carlo, she was fascinated by the possible discovery, and she said to me, 'Well, Mr Director-General, I do not want to learn about the discovery from the press. I want to be informed before you go to the press.' I promised her that I would do this.

Then, when Carlo Rubbia and Pierre Darriulat showed me their data, I was afraid that rumours of this discovery would leak out to the press and Mrs Thatcher would be very angry for not having been informed before. That was just before Christmas 1982, and in January'83 there was a big international conference in Japan that I had to attend, so before I left CERN I called Rubbia and Darriulat and told them the story

Fig. 7.23 With British Prime Minister Margaret Thatcher and husband Denis to her left at CERN in 1982 (©CERN, All rights reserved)

of Mrs Thatcher, that she wanted to be informed early, and I said to them, ‘if you want to go public in January while I am in Japan, fine, you can go ahead, but before you do so, you have to send me a fax to Tokyo so that I can inform Mrs Thatcher that the announcement is imminent.’ Just to be sure that I would keep my promise, I wrote her a letter on 20 December saying that the discovery appeared to be imminent.

Soon after I got to Japan, I received a fax from Rubbia and Darriulat, email was not much used at the time, and I sent a fax to Mrs Thatcher, asking her to keep the news confidential until it was officially announced. She replied immediately, saying, ‘You can be sure I’ll keep it in strict confidence before it’s published.’ And a few days later there was a colloquium at CERN where the discovery was announced.

During her visit to CERN, Mrs Thatcher asked many pertinent questions demonstrating a real interest in physics. She was accompanied by her husband, and throughout the visit I was impressed at the tenderness between the two of them.

She may have been a very busy Prime Minister, but she clearly did not overlook the importance of her personal life."

An Interesting Collaboration

"Among the many remarkable people I had the opportunity to know over my career is Antonino Zichichi. Nino to his friends. Nino is an excellent physicist and was employed by CERN soon after its foundation. It's there that he carried out most of his research. I remember him having boundless energy and drive, which allowed him to achieve much beyond his CERN activities.

Antonino Zichichi was born in Trapani and educated in Palermo. He was always deeply rooted in Sicily. He once told me that the Sicilian mafia originated as a political organisation to liberate Sicily from foreign overlords. He also had some family connections to the catholic church in Sicily, and even to the Vatican. With this background Nino established a scientific teaching centre in the 1960s in Erice, a small, isolated town on a steep conical hill above Trapani. He called it the Ettore Majorana Foundation and Centre for Scientific Culture [1]. Erice is a beautiful place with a long history. There are stone plates there with Phoenician inscriptions, and during the Middle Ages it became the seat of several small monasteries. By the middle of the twentieth century, these were mostly abandoned and decaying. Nino somehow managed to get hold of a few buildings and he converted some of the rooms into lecture theatres where small workshops and courses could be organised. With CERN's support, the first ones dealt with nuclear and particle physics. Some of the monastic cells were converted into simple guest rooms for the participants. At one point when I was still at Karlsruhe, Nino asked me to help to stabilise the enterprise. I agreed to take the responsibility for organising courses for medium energy nuclear physics. Although the accommodations were quite rudimentary back then, the stay at Erice was quite charming. There was a beautiful view over the Mediterranean, and we could eat in one of the town's many restaurants. The whole setting is quiet and peaceful, and very conducive to learning. Originally the courses were organised during the academic vacations in summer, but as the centre's success grew, courses were extended to other fields of physics and beyond. Today, there are schools in Erice all year round. Most of the old monasteries are now integrated into the centre, which has become an important economic element of the town. The lecture halls are now perfect, the guest rooms quite comfortable and Nino has a grandiose office in one of the old towers dominating the whole scene. Nino, who has a good sense for publicity, named the centre after Ettore Majorana, who was a young Sicilian theoretical physicist who mysteriously disappeared in 1938. Over the years, Nino invited me to attend all kinds of interesting conferences, often involving Nobel Prize winners, and I had the opportunity to explore the beautiful island of Sicily.

Immediately after my retirement as Director-General of CERN, Nino asked me to help him with the 'World Laboratory,' which he'd set up in Lausanne in the 1980s. Although the title seemed to me somewhat pretentious, I agreed to become the chair of its management committee. Nino had obtained a budget of several million Swiss Francs from the Italian government to finance various projects in physics or other scientific domains in developed and underdeveloped countries. For a year I went almost daily to Lausanne. The administration was kept to a minimum and consisted of a professional manager, clerical staff and me with Nino as the President, of course. We managed to get things off the ground but after a bit more than a year the load became too heavy, and I stopped. I don't know what became of the World Laboratory after that."

Reference

1. https://ettoremajoranafoundation.it/the-history/