LEP Revolution Under Way at CERN

Building a high-energy accelerator is always a complex job, and the electron-positron collider near Geneva is no exception

A visitor to the European Organization for Particle Physics (CERN) tours the laboratory's Super Proton Synchrotron (SPS), which is about 7 kilometers in circumference, on an electric motor scooter. But what will it take to get around LEP, the Large Electron Positron storage ring with its 27-kilometer girth that CERN hopes to have running by the end of 1987?

One asks the question because LEP's immense physical size seems to symbolize the headaches acquired by CERN officials as they struggle to get their machine approved and built. There is a LEP revolution under way at CERN that involves the laboratory's relations with its French and Swiss neighbors, with its own staff, and with prospective users of the giant accelerator.

LEP is not a perfectly circular ring but has eight straight sections where collisions between counterrotating beams of electrons and positrons can occur. About five-sixths of LEP's 27-kilometer circumference is in the eastern end of the French department of Ain. Locally the area is known as the Pays de Gex. The remainder is in the Swiss commune of Meyrin, just outside Geneva. Compared with the intense politicking that accompanied choosing a site for LEP's predecessor machine, the SPS, which several countries but especially Germany wanted to have, the approval process went quite smoothly. However, the start of civil construction of LEP is in the hands of the French authorities despite the fact that CERN's governing body, the CERN Council, gave its final blessing to the project last December.

The ultimate cause of the delay is the ambivalent attitude toward CERN in the Pays de Gex. Before the laboratory was established in 1954, the area was a sleepy agricultural land. During the 1960's, the population mushroomed in step with the dramatic growth at CERN. Today more than half of the inhabitants either work at CERN or commute into Geneva. Hardly any local industry has developed, so that the economic health of the Pays de Gex is closely tied to that of CERN. For this reason, all the communal mayors but one have supported the LEP project, which is central to CERN's continued vitality.

There is the additional hope that, this time, companies contracting to work on LEP will establish permanent offices in a yearning-to-be-born industrial park in St. Genis, just down the road from CERN. And communes are dusting off old master plans in the hope that the French government will finance the building of new roads needed to truck dirt and debris out of the underground tunnel that will house LEP.

But nobody likes to be an economic slave. And, although one of CERN's directors, Robert Levy-Mandel, has been engaged full time as a liaison, there has been resentment that the LEP project was presented as a fait accompli without prior consultation with the communities under which the LEP tunnel would run and which would be affected during the 5-year construction period. Finally, ambitious local politicians were quick to exploit fears of environmental damage by LEP, the biggest concern being water.

As originally proposed, LEP was to be a machine 30 kilometers in circumference, 12 kilometers of which were to run under the nearby Jura mountains. Winter snows in the mountains are a major source of water for surface and underground rivers in the Pays de Gex. Since the geological and hydrological states of the LEP site were not known in detail, fears that the drilling and blasting of the LEP tunnel could disrupt the water sources were not unreasonable. CERN officials pointed out that the prospect of flooding while digging the LEP tunnel did not enthrall them either. So, the laboratory obtained an order from the Prefect of Ain that allowed it to bore a "Reconnaissance Gallery" running 3 kilometers from the base of the Jura to a point deep underneath the mountains. While the digging was in progress, several groups and individuals from the Pays de Gex combined to file, in January 1981, a suit in Lyon, the seat of the department of Ain, asking the Administrative Tribunal there to rescind the order. The court granted the request on 25 June 1981, forcing work to stop.

The French Conseil d'Etat in Paris reversed the decision on 18 December. But, in the meantime, French authorities became convinced that the relatively modest amount of land (25 hectares) and subsurface rights needed by CERN for LEP might not be obtainable without governmental intervention. They therefore asked that a procedure begin that would culminate in a Declaration of Public Utility that would give the government the authority to directly lease land to CERN, if necessary. For its part, CERN had to prepare an Environmental Impact Study that would be used in the public review process leading up to the granting of the declaration. This spring, CERN finished the document, which LEP project director Emilio Picasso likes to say is thicker than the LEP technical specifications. CERN hopes for a decision by the end of the year and has sent out requests for bids on civil engineering and some equipment.

Also in the meantime, CERN has moved the LEP trace twice, and the water problem seems to be solved. A reduction in the circumference from 30 to 27 kilometers in March 1981 had the effect of reducing the distance LEP traveled under the Jura to 8 kilometers. Then, last December, LEP designers rotated the trace a few degrees into Switzerland to further diminish the sub-Jura burrowing to 3 kilometers. A bonus was avoiding wells in the commune of Echenevex, whose troublesome mayor had been one of the plaintiffs in the suit at Lyon.

L'Association Gessienne de Protection de la Nature (AGENA) was another. At one time, a substantial fraction of AGENA's membership came from CERN, and the organization devoted itself to environmental causes. But there was what the local press called a "strange silence" from AGENA on the subject of LEP. Then, after an internal shoot-out resulted in the resignations of many of the CERN members, AGENA burst into action. After joining in the lawsuit, the group from time to time made apocalyptic claims of pollution, radiation, and weapons applications. These were easily refuted by CERN spokesmen, but an uninformed public could not always tell who to believe. The fact that CERN followed the traditional institutional pattern in insisting that each LEP trace was the best site possible up to the last moment before a move did not help its credibility either.

If LEP's size helped to propel CERN into unwanted confrontations with its neighbors, LEP's budget is responsible for internal turmoil within the laboratory

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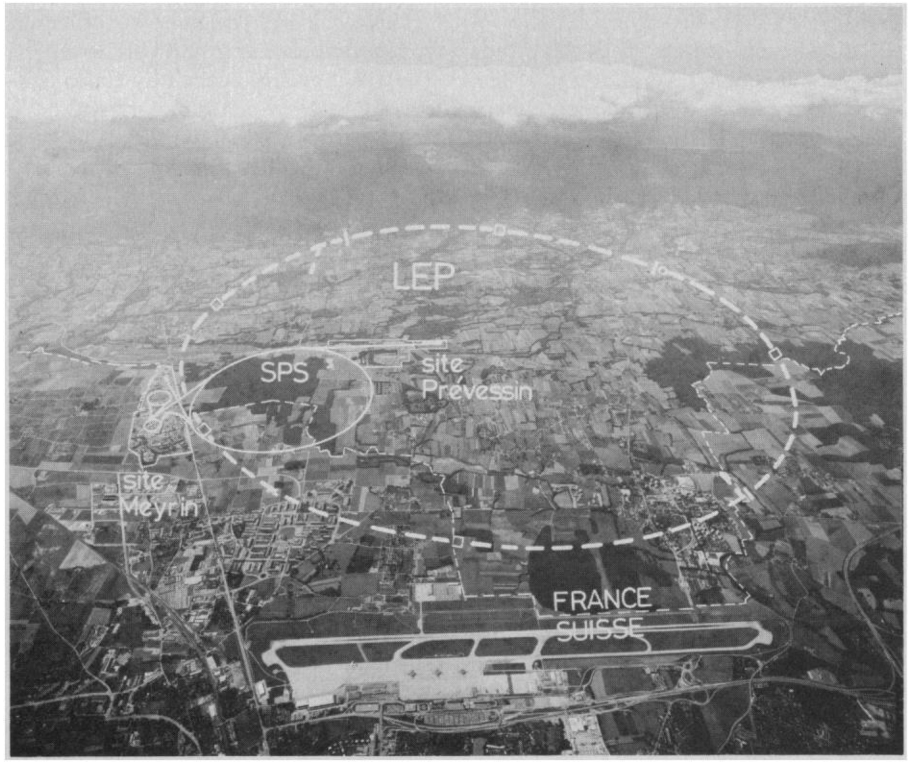

CERN

Aerial view of the Pays de Gex

LEP will "nestle" between the Jura mountains and Geneva's Cointrin airport.

itself. The machine is to be built in stages. Phase I, which is the only one approved by the CERN Council and which will begin running in 1987, has a round-number construction cost of 910 million Swiss francs. (There are 2.1 Swiss francs to the dollar at press time.) Staff salaries are not included, nor are four particle detectors to examine the outcomes of collisions between electron beams of 51 billion electron volts (GeV) and positron beams of the same energy. Later phases of LEP would increase the beam energy to 130 GeV and add up to four more detectors.

Although CERN spent a comparable amount during the 1971 to 1976 construction years of the SPS, there is a significant difference between the two projects. It is that CERN's member countries came up with a supplemental budget expressly for the SPS that was added to the laboratory's basic program. To get approval for LEP, however, CERN had to agree to build the machine entirely within its basic program, which stands at 644 million Swiss francs this year and is expected to remain steady during the construction period.

The contrast between the effects of the two budget situations on CERN is dramatic. As the SPS went into operation, the weight of experimental work naturally shifted toward this machine. Nonetheless, the older Proton Synchrotron continued to operate full steam, and the Intersecting Storage Rings or ISR (two interlacing rings that cross at eight points where beams of protons that circulate in opposite directions collide) expanded its program. Now, the financial pressure is so intense that the activities of these older accelerators are being curtailed.

One of the Proton Synchrotron experimental halls is to become an assembly area for LEP equipment next year. And, at the end of 1983, the ISR is to be shut down completely, despite the fact that a group of American nuclear physicists has offered to bring in non-CERN money to help operate the machine as a colliding-beam heavy ion facility. CERN's present Director-General, Herwig Schopper, earlier this year told the committee that schedules ISR experiments that the main requirements in 1984 would be space, people, and money.

A second effect of the different budget situations of the SPS and LEP is that CERN was able to hire about 400 new people during the construction of the earlier machine. CERN's staff, like its budget, is not expected to change during the time LEP is being built, so who is going to work on the new machine?

At a meeting last January of the Standing Advisory Committee of the CERN Staff Association, laboratory Technical Director Giorgio Brianti noted that about 300 persons now work on LEP, but that 650 would be needed by 1984. About 200 would become available as other activities closed out or as other CERN divisions became active in LEP, leaving a shortfall of some 150 persons. Picasso told *Science* that he had asked for 800 people to build his machine, perhaps leaving a larger gap still.

A measure of the desperateness to find the missing personnel is the strategy devised and now put into practice. In the past, persons wishing to transfer from one CERN department to another were required to inform their supervisors before any other action could be taken, a procedure that was liable to block the system, Brianti said. Under the new rules, published in CERN's weekly bulletin, notification of a supervisor could be deferred until later in the transfer process "following your informal inquiries." There is one celebrated instance in which a transfer was worked out to everyone's satisfaction until the supervisor learned that he would be losing a "slot" as well as a person, so he balked. Clearly the turmoil factor is high.

The turmoil extends, perhaps more significantly, to the effects of transfer on existing groups. For example, one of the activities from which people would be drawn is the conversion of the SPS into a proton-antiproton collider. The SPS is now scheduled to work in this mode for two of the six operating periods this year and presumably for similar durations in the future. However, it does not work well as a colliding-beam machine yet, and skeptics are not sure how long it will take to get up to specs. Moreover, there is an improvement program being planned that should further enhance performance. But, if SPS researchers go to LEP, it cannot help the proton-antiproton collider, which is CERN's most exciting project at the moment and is the only one in the world now capable of producing the W and Z particles of unified theory fame.

Schopper told the Standing Advisory Committee that he understood quite well the concern that LEP would be built at the expense of support for existing experiments. However, he put the burden on the experiments, saying that they must be organized in such a way that they suffered as little as possible.

Finally, LEP's character as a very expensive colliding-beam storage ring affects the experimental physicists who will be working there. Although no experiments can take place for almost 5 years, one influence is already active.

It might be too much to call it featherbedding, but that is the term that comes to mind. The European countries that finance CERN with contributions proportional to their GNP's expect that their high energy physicists will be able to participate in experiments there. It is a perhaps unfortunate characteristic of colliding-beam storage rings that they can simultaneously serve only a few long-running (and hence large) experiments rather than the many that fixed-target accelerators such as synchrotrons can handle at once. Phase I of LEP, in particular, will have four experiments.

The issue in competition for space at LEP is what to do with losing proposals. An entire CERN member state could lose out on LEP if its physicists were in the wrong group. CERN's solution, which is being implemented in the experimental selection process now going on, is in essence to have no losers; every European physicist who wants to work at LEP will find a place. The mechanism to achieve this is to allow a regroupment period between the preliminary approval of favored letters of intent and the call for final proposals during which those physicists on weaker teams would find places on stronger ones.

How well will the huge experimental collaborations that result work together? The UA-1 group, headed by Carlo Rubbia of CERN, which is looking for the W and Z particles when the SPS is working in its proton-antiproton collider mode, is often singled out as a model of future LEP teams. UA-1, which has about 125 active physicists, built a 2000-ton detector that cost $20 million. Based on the letters of intent, one can conclude that each LEP detector will weigh 2500 tons or more, cost $30 million, and be built by a group of 200 or more physicists.

For starters, the physics community has been pleasantly surprised that UA-1 (and also its competitor UA-2) has managed to build such a complex instrument in so short a time—3 years from approval to first data. So, the LEP collaborations will have an ambitious but attackable task. But it will not be easy. Members of UA-1 credit Rubbia's strong personality as the force that held the group together during a difficult time.

And there are many questions. How do you train students to be physicists in such large groups where specialization reaches an extreme? During the years-long construction period, physicists will have few or no publications on the subject on which their careers depend. Finally, an old question but one exacerbated by the complexity of the new detectors is, Who is to run and maintain the instrument once it is built? The natural tendency, already in evidence in UA-1, is for collaboration members to retreat to their home laboratories for more or less independent data analysis.

It is too early to tell if all this pain is only the outcome expected of any big change, or something more. One possibility is that elementary particle accelerators have reached their natural limit and that the era of ever larger machines is drawing to a close.

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Can Genes Jump Between Eukaryotic Species?

Biologists are beginning to take seriously the heterodox idea that genes can jump across the species barrier in higher organisms

Molecular biologists are now thoroughly comfortable with the idea that genes and other genetic elements have a certain mobility within a genome. Although it came as a considerable surprise initially, research of recent years has now firmly established the existence of a range of mechanisms, beyond classic recombination, that can cause heritable rearrangements of genetic material. Just as researchers are beginning to ponder on the mechanistic and evolutionary implications of dynamic DNA within a species' genome, there come the first strong indications that genetic mobility might extend across species barriers in higher organisms. If true, gene transfer between species will add yet another evolutionary dimension to the phenomenon of jumping genes in eukaryotic organisms.

Gene transfer between species is well known in prokaryotic organisms; it is the basis of transduction, transformation, and sexduction in bacteria. The current interest in interspecific gene transfer is, however, very much focused on eukaryotic organisms. "The theory of horizontal gene transfer is a salutary challenge to received views of a totally coherent evolution and orderly transmission of genes in eukaryotes." With this clear statement of the issue, Meinrad Busslinger, Sandro Rusconi, and Max Birnstiel, of the University of Zurich, concluded a recent paper on one of the most closely analyzed candidates for eukaryotic horizontal gene transfer (*1*).

The investigation of something as apparently fanciful and certainly unorthodox as gene transfer involving higher organisms must proceed in two stages. First, does it occur at all? Second, if it does occur, how common and how important is it? Current work is very much at the beginning of the first stage, but is directed with a keen eye on truly intriguing answers to the second.

Until recently there were just a few examples of apparent eukaryotic gene transfer. One clear case is that between *Agrobacter tumefaciens* and host plants in the etiology of crown gall tumor. A possible example of transfer in the reverse—eukaryote to prokaryote—direction involves *Progenitor cryptocides* and humans. This microorganism is found in close association with certain tumors and in culture secretes a protein apparently produced by the gene for human chorionic gonadotropin. Both these instances involve pathologies and might therefore be set aside as aberrant events. In any case they are generally not included in the small catalog of solid candidates currently being considered.

As Birnstiel and his colleagues point out, the advent of rapid DNA sequencing and gene cloning now allows the systematic search for transferred genes. This is certain to apply in the future, but the current list of four putative transferred genes came as fortuitous discoveries. These are the genes for the enzyme superoxide dismutase in *Photobacter leiognathi*, the symbiotic bacterium of the ponyfish; a family of histone genes in sea urchin; a subfamily of repeated sequences in sea urchin; and the leghemoglobin gene in legumes.

Superoxide dismutase is a widely distributed enzyme that appears to mop up harmful oxygen radicals. In eukaryotes the enzyme contains copper and zinc, in prokaryotes it contains iron, and a third form found in prokaryotes and mitochondria contains manganese.

When, in 1974, two French researchers, K. Puget and A. M. Michelson, reported the existence of a copper-zinc enzyme in the bioluminescent bacterium *P. leiognathi*, the anomaly quickly caught the attention of Irwin Fridovich of Duke University. Although Fridovich

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