CERN Council Defers LEP Approval

The Geneva laboratory will have to wait a little longer to build the machine that will carry European particle physicists into the next century

When the governing council of the European Organization for Nuclear Research (CERN) assembled last month to consider officially for the first time a proposal to build the first phase of the 100-billion-electron-volt (GeV) Large Electron-Positron (LEP) accelerator, none of the 12 member states entered any objections, and 9 were willing to vote yes. But the representatives of the three remaining countries (the Netherlands, Norway, and Sweden) had not yet received permission to commit their nations to LEP with its 950-million-Swiss-franc ($475 million) price tag. Because CERN has a tradition of waiting for a consensus before moving ahead on new projects, a start on construction of the new accelerator will have to wait awhile longer. If LEP clears the approval process at the next council meeting, in October at the earliest, construction could begin early next year, with the first experiments in 1987. There is, however, some local opposition to LEP. On the same day as the council meeting, environmental activists got a French court to revoke permission that had been temporarily granted by French authorities for CERN, which straddles the Franco-Swiss border near Geneva, to dig an exploratory tunnel. The French government is now appealing to a higher judicial body—the Conseil d'Etat—for a reversal of the decision.

CERN scientists had been "quietly optimistic" that approval of the LEP project would come at the June council meeting, Erwin Gabathuler, the laboratory's director of research, told *Science* in May. A proposal to build the giant accelerator was formally presented to the council a year ago, and it was hoped that a year of deliberation and politicking by the member states would be enough. A scientific consensus that LEP was the right machine had long since formed. Unhappily, the economies of the European nations are suffering from declining outputs and swelling inflation and unemployment, so that approval of CERN's annual budget of more than 600 million Swiss francs, which LEP would not increase, is no longer automatic.

There is just a touch of irony here. CERN was formed in 1954 as a means for European high energy physicists to recapture their pre–World War II dominance in a field that had been lost to the Americans. Lately it has been customary for U.S. scientists to bemoan the higher level of expenditures for high energy research in Europe (which they claim is about double that in the United States) that threatens American preeminence. Now it seems that the Europeans have attained full parity with their compatriots across the Atlantic in their need to struggle on a "limited" budget.

Another interesting twist is that since its founding, CERN has been a laboratory for accelerating protons. Western Europe's other big particle physics center, the Deutsches Elektronen-Synchrotron (DESY) laboratory in Hamburg, with a budget about one fourth as large as that of CERN, had been the home of large electron machines. Although LEP is in the latter category, CERN rather than DESY will be building this machine. The switch reflects the current fashion among particle physicists, who have confidence that electron-positron colliding-beam storage rings will produce the kind of information they want. It also is the result of CERN's position as *Europe*'s high energy laboratory with the influence and wherewithal to get the machine it wants. Although DESY has a strong international character, it is still thought of as a *German* institution (see box on page 530).

CERN scientists did not always have an electron-positron collider in mind. In 1971, the laboratory put into operation a daring machine called the Intersecting Storage Rings (ISR), which comprised two separate proton rings that intersected in eight places where collisions took place. The ISR eventually reached an energy of 31 GeV in each proton beam, producing a collision energy of 62 GeV, by far the highest in the world at the time and still the champion by almost a factor of 2. Then from 1971 to 1976, CERN built the Super Proton Synchrotron (SPS), a 450-GeV fixed-target accelerator. In his farewell address to the CERN Council last December, John Adams, who with Leon Van Hove was co-director-general of the laboratory, recalled that "It seemed reasonable back in the early 70's . . . that the next machine for CERN would be another proton-proton collider similar to the ISR but of much higher energy per beam."

Two factors intervened. One was that, in the United States, researchers at the Brookhaven National Laboratory had a similar idea. In 1974, Brookhaven proposed building a $127-million facility in which two beams of 200-GeV protons would collide head on. The project eventually was approved in 1978 with 400-GeV proton beams at a cost of $275 million. At the same time, CERN's budget grew rapidly in the first half of the 1970's during the construction of the SPS. By 1974 it was apparent that the growth could not continue, and the laboratory was told by its governing council to reduce its spending. With a time of limited resources clearly at hand and with accelerators becoming larger and more expensive, physicists in Europe and in the United States have argued that the sensible course is to build complementary not competitive machines.

The second and possibly more important factor in the decision to build LEP was the success of electron-positron colliders in probing the new physics of quarks and leptons. Much of the excitement in the elementary particle physics of the 1970's was caused by the discovery (and subsequent study) of two new "flavors" of quarks to go with the three varieties that were originally postulated and also of a heavy lepton, the tau particle. Although signs of the charm and bottom quarks also appeared in fixed-target proton accelerators, the electron-positron colliders proved to be best suited for detailed studies. The tau particle has been seen only in the colliders.

When they smash into one another, the electron and positron are annihilated, and the energy released is converted into new particles. The particles created correspond only to those having rest masses less than or equal to the very precisely tuned collision energy of the storage ring. Thus, the events are quite "clean." In proton machines, the beam energy may be well controlled, but the effective collision energy varies over a wide range because the proton is a complex object consisting of three quarks and the gluons that bind the quarks together. Therefore, a whole spectrum of particle interactions of different energies takes place. An experimentalist has to search through all of these to find the ones of interest; in other words, the events are "dirty."

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While the discovery of new quarks and heavy leptons is of considerable intrinsic interest, the primary significance of these findings is that, in concert with certain other important experimental results of the 1970's, they lend credence to the proposition that a particular type of quantum field theory may be the appropriate one for describing all of elementary particle physics and, by extension, all of the physical world. One feature of these so-called gauge theories is that one or more massless particles (vector bosons) carry each of the forces of nature between interacting particles. The photon is the mediator of the electromagnetic force between electrically charged particles, and a set of eight gluons bears the strong nuclear force between quarks in the gauge theories of these interactions.

There is no analogous gauge theory with a massless vector boson for the weak force that is involved in certain elementary particle decay processes and in reactions between neutrinos and other particles. To describe the weak force successfully, theorists had to find a way to incorporate three massive vector bosons (almost 100 times as heavy as the proton). And to do this, they had to combine the weak and electromagnetic forces in a "unified" gauge theory that started with four massless bosons, which then split into the photon and the three weak force carriers by a process called spontaneous symmetry breaking. Theorists now want to invoke a second round of symmetry breaking in order to unite all three forces into a grand unified theory (gravity is still beyond reach in this endeavor). Thus, physicists consider verification of the unified electro-weak theory to be their number one priority.

European physicists expect LEP to be the primary tool for this verification because of its energy and the cleanness of the events it produces. With a collision energy of 100 GeV (50 GeV in the electron beam and 50 GeV in the positron beam), the giant accelerator will be powerful enough to create any of the three vector bosons. The Z^0 at 90 GeV will come in fantastically large quantities of almost 50,000 per day, but the W^+ and W^- at 80 GeV may be so scarce at one per day as to be barely detectable. However, a modified SPS, in which protons and antiprotons circulate in opposite directions in the same ring and collide head on at designated points, will be starting up this autumn (*Science*, 10 July, p. 191), and this CERN machine will be the first with enough energy to create the vector bosons that must be found if the unified theory is correct. Theorists caution that merely finding these particles at the predicted energies will not be enough to prove the gauge theory. Many details have to come out in just the right way, and it is the less cluttered events together with a higher rate of producing the vector bosons that make LEP seem to be the ideal machine for the job.

CERN

Access to reconnaissance gallery

This 70-meter-deep pit leads to the reconnaissance gallery that was being dug under the Jura Mountains to explore geological and hydrological conditions before a French court stopped CERN's work on the project.

Some adherents of proton machines argue that with some luck the SPS proton-antiproton collider and an even higher energy one under construction at the Fermi National Accelerator Laboratory near Chicago will, in the words of one booster, "be able to test much of weak interaction physics before LEP is built." But as Van Hove noted in his final address to the December CERN Council session, "On the basic choice for the long-range future of CERN, a convergence of views emerged surprisingly fast in the European high energy physics community." The laboratory started drawing up plans for a large electron-positron machine in 1976. By May of the following year, the European Committee for Future Accelerators recommended that an electron-positron storage ring with a collision energy of 200 GeV (possibly 140 GeV to start) be "the prime candidate for a major European project for the 1980's."

Plans for LEP have been through several incarnations resulting from a tug of war between the desire for the highest possible energy and the most interesting physics on the one hand and the recognition of fiscal constraints on the other. The CERN scientists first designed a 200-GeV machine that would be 50 kilometers in circumference. The large size is to minimize synchrotron radiation. The power radiated must be replenished by feeding in more radio-frequency power to keep the electron energy up, making the electricity costs enormous.

The plan that was finally submitted to the CERN Council last June took account of the fact that, even with its tremendous 30.6-kilometer circumference, a 170-GeV version of LEP with conventional radio-frequency cavities would be a voracious consumer of electricity—200 megawatts when operating at full power, or one-fifth the output of a typical nuclear power plant. So the council agreed to consider a stripped-down version of LEP with a collision energy of 100 GeV. With the development of superconducting cavities that would more efficiently convert electricity to radio-frequency energy to accelerate electron and positron beams, the energy could later go as high as 260 GeV.

Herwig Schopper, the new director-general of CERN, told *Science* that the decision to accept the smaller LEP reflected a fundamental philosophical change. It also signifies a new humility on the part of accelerator builders, some of whom were badly burned by the present generation of electron-positron storage rings. The 38-GeV PETRA at DESY and the 36-GeV PEP at the Stanford Linear Accelerator Center have largely reached their design energies, but have failed to attain the expected luminosities, a parameter that measures how often particles collide. A low luminosity means a paucity of data. As they found to their dismay, accelerator designers do not yet understand all the complex nonlinear interactions between the colliding beams and cannot reliably calculate how well their machines will perform. Schopper says that CERN initially planned to build an essentially complete LEP except for radio-frequency cavities and power supplies that would later be added to raise the energy, but now it will build LEP with the minimum of components necessary to get it running and then let it evolve to overcome the particular limitations it meets.

A second important change from earlier LEP plans is to use the SPS as an injector of electrons and positrons into the collider. One advantage of so doing would be decreased cost because a new 22-GeV electron synchrotron would not have to be constructed for that purpose. But what is perhaps more significant is that the approval process would be simplified, or so it was hoped. Administratively, the use of existing facilities makes LEP an extension of the CERN basic program rather than a new activity in a supplementary program.

The effect of this seeming bureaucratese is important. The smaller countries participating in CERN, especially, have adopted the strategy of trying to get away with as little money as they can without letting European research wither away. With the basic program, council members do not have to convince their governments to spend "more" money on a "new project." And, Schopper points out, member states cannot withhold their contributions to the basic program without also withdrawing from the organization. CERN's prestige makes leaving difficult to do. Yet the laboratory's budget for the basic program is in general fixed, and this means that LEP must be built at the expense of other programs. The ISR, for example, will likely be shut down in 1983 when LEP starts absorbing large chunks of money.

At the same time that they have been trying to make LEP as easy as possible to approve, CERN officials have been taking pains not to convey the impression that the project is being forced on anyone. Thus, last year the council accepted the proposition that, in contrast to the usual two-thirds majority required for acceptance of the basic program, the 1982 budget with LEP included would have to pass with no dissenters.

Finally, as part of the LEP package submitted for council approval in June, CERN appended a proviso to assure that high energy physics funding at the laboratory would have to follow the course of the European economy and would not be insulated from the effects of possible further deterioration in the economic health of the member states.

In this light, it is of some interest that Schopper has said that once LEP is up and running there probably will be a quick request to increase its energy to 160 GeV to find W^+-W^- pairs. The one test that can discriminate between the unified theory and alternatives is a precise measurement of the rate of pair production, which should reach its maximum of 35 per day at 180 GeV. The eventual extension of the collision energy to 260 GeV and expansion from the initial four to eight experimental halls could add more than 400 million Swiss francs to LEP's cost. But the machine's usefulness might also be stretched to 20 years or more. The long-term future of CERN rides on this giant electron-positron collider, says Schopper.

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If CERN's budgetary problems were not enough to keep a director-general hopping, protests by environmental activists have also intruded. The concern stems from LEP's immense size. In order to allow the SPS to be an injector of electrons and positrons into LEP and also to leave open the future option of electron-proton collisions, the two rings have to be tangential at one point. The LEP machine would thus have to tunnel under the nearby Jura Mountains, which tower up to 1282 meters above CERN. The water for many of the nearby communities comes from underground watercourses within the mountains. The fear expressed was that disruption of these sources could accompany the process of digging the LEP tunnel by boring and possibly blasting through the rock. A related issue is that, although the land around the laboratory is rapidly becoming urban- or suburbanized, much of it is still rural farmland and some people would like it to stay that way.

Whether in response to these complaints or because of its own fears as to the safety and possible extra expense of boring through unstable rock with the danger of flooding from the watercourses 200 meters above, CERN has taken steps to address the first issue. By fine tuning the accelerator design, physicists were able to reduce the circumference of the LEP ring from 30.6 to 27 kilometers without increasing the electrical power needed to replenish the added synchrotron radiation losses that go with the smaller size. The new LEP design also calls for tunneling beneath the Jura for a distance of 8 kilometers rather than the previously planned 12 kilometers, so that the tunnel will no longer pass directly under the crest of the Juras, where the most sensitive rock formations lie.

Last fall, CERN started digging a test tunnel to explore the geological and hydrological conditions within the Juras. The tunnel, dubbed a reconnaissance gallery, will run from an already completed pit some 70 meters deep for about 3 kilometers from its starting point near the French village of Crozet to a point underneath the mountains. An article in *Le Monde* last October, which was generally supportive of the environmentalist cause, carried a quote from the mayor of Echenevex, another small town near Crozet. "If they want to dig in my commune, they will have to call the [riot police]," he exclaimed. Since the test tunnel digging started, the mayor backed off, but only far enough to take a different tack. With some environmental groups, he sued in a Lyon court to have CERN's permit to "provisionally occupy" for 3 years the agricultural land in the commune of Crozet and another neighboring area annulled. On 25 June, the court ruled in favor of the plaintiff. How much of an effect such tactics will have on stopping LEP is problematical because the activists seem to be in the minority.

When all is said and done, CERN will probably get its giant accelerator, but then the biggest trial of all could come. In the past, physicists have always proclaimed, "If we don't find what we are looking for, it will be even more interesting than if we do." A decade or so ago when observers rightly spoke of the elementary particle "zoo," these words may have been sincerely meant. Today, one suspects, it is different. With quarks and gauge theories and everything apparently coming together in the grand unified theories currently being bruited about, one senses that physicists will be more than just disappointed if the world of elementary particles turns out to be different than they now believe. LEP is being built mainly to verify the unified electro-weak gauge theory. "They will have a problem if nature is otherwise," says one critic.—ARTHUR L. ROBINSON