tric fields in space is because there are ions that neutralize them," Parker explains. "But you do find magnetic fields, so you can put a limit on how many magnetic charges there are." It would take a lot to neutralize the magnetic fields of the earth or the sun, he says. But the galaxy has a magnetic field too, and it is very weak, only 3 microgauss. "So you ask, how many free monopoles could you tolerate before they short out the galactic field?" His answer corresponds to a monopole flux of no more than 10^{-14} per square centimeter per second—about 10,000 or 100,000 times smaller than the flux implied by Cabrera's event.

"You have to be careful," says Parker. "Just because something upsets what you know doesn't mean it's wrong. Cabrera is a serious and careful man. But I don't think the Stanford result is a monopole."

The issue may not be in doubt much longer. Cabrera's new detector should be working soon, and other researchers will doubtless be trying to replicate his results with their own detectors. His result comes at a time of ferment in the field. In the April 1982 issue of *Scientific American*, Trower and his colleague Richard A. Carrigan, Jr., of Fermilab write, "The art of searching for massive monopoles is now at one of those engaging moments in science when a wealth of ideas, many of them quite bizarre, are at war on paper and over lunch tables."

A major problem is that no one is certain how monopoles interact with ordinary atoms. If one were moving near the speed of light it would certainly leave a trail of ionization. But monopoles are so massive they would probably move relatively slowly. (Parker estimates 300 kilometers per second.) In that case their magnetic fields would only mildly perturb the surrounding atoms. If a detector depends on ionization, slow-moving monopoles might sail through without doing a thing. Another major problem is that no one really knows where the monopoles are. They might be trapped in the iron core of the earth, for instance.

But suppose the Stanford event does turn out to be real. Cabrera, for one, will be both delighted and astounded. The grand unified theories will gain enormous impetus. And Parker, like many others, will go back to work with gusto—he expects to have fun figuring out where his astrophysics has gone wrong. "It's a very entertaining dilemma," he says.

—M. MITCHELL WALDROP

LEP Detector Competition Opens at CERN

The huge accelerator will have room for four experiments at first, each costing about $30 million and involving about 250 physicists

It was standing room only, and there was not much of that, in the auditorium of the European Organization for Nuclear Research (CERN) the morning of 24 March. Hotel space in Geneva, CERN's Swiss home, was scarce, as high energy physicists came in droves to hear the first public presentation of the proposed detectors for LEP, the gigantic electron-positron collider that the laboratory hopes to begin building by the end of the year.

Attendees heard pitches from seven groups, six of whom described detailed plans for mammoth particle detectors. Each of these beasts—no other word is appropriate—typically would weigh well over 2000 tons, would cost about $30 million, and would require the efforts of physicists from about 20 institutions. Attendees also heard CERN's directors paint a picture of a laboratory so financially strapped after building LEP itself that there will be relatively little left over for the winning detectors. In a reversal of past practice, the major financial burden will fall on the members of the experimental collaborations. Moreover, two of the would-be collaborations involve major U.S. participation. There is thus the interesting and unresolved double-sided question: how much of its expensive new machine does Europe want to leave open to American physicists and how much of its tight high energy physics buget does the United States want to spend overseas?

CERN secured the approval of its member states to undertake the LEP project last December, about a year and a half after formally submitting a proposal. To get the go-ahead, the laboratory had to convince the European countries that it could build the $500 million accelerator without an increase in its annual budget. It also had to get the member states to keep up their contributions to CERN, whose budget had been dropping in the late 1970's. However, lately it has been approximately constant before figuring in slight increases for Swiss inflation, and this year CERN is spending a total of about $340 million.

Construction has not yet begun, partly because of formal procedures required by the French and Swiss governments. CERN hopes to have all this cleared away by the end of the year and to begin signing the first civil engineering contracts, as well as ordering equipment, at that time. CERN's Director-General, Herwig Schopper, told the LEP audience that his goal is to have an operating accelerator with one or more detectors in place by the end of 1987. Perhaps the performance of neither the accelerator nor the detector(s) would be up to specs at first, but the idea is to have something running and improve from there.

The purpose of LEP, which is a circular machine of 27 kilometers circumference, is to allow physicists to explore in detail the energy region in which two of the forces that control the behavior of elementary particles, the electromagnetic and the weak, have comparable strengths. The weak force is weak in the sense that any reactions that can proceed by way of the electromagnetic or the strong nuclear force will take place before processes governed by the weak force. If elementary particles can be squeezed closely enough together, however, the weak force grows stronger. At collision energies of 80 to 90 billion electron volts (GeV), the electrons and positrons that circulate in opposite directions in LEP will be so tightly compressed that the weak force equals in strength the electromagnetic.

LEP, which may have a lifetime of 20 years or more, will be built in stages. The basic machine, to be completed by the end of 1987, is called phase one and is to have a collision energy of 100 GeV (50 GeV in the electron beam, 50 GeV in the positron). Ultimately, the energy could go as high as 260 GeV. The electron and positron beams are not continuous, but are in the form of packets or bunches a few centimeters long. With four bunches of each type of particle, collisions can

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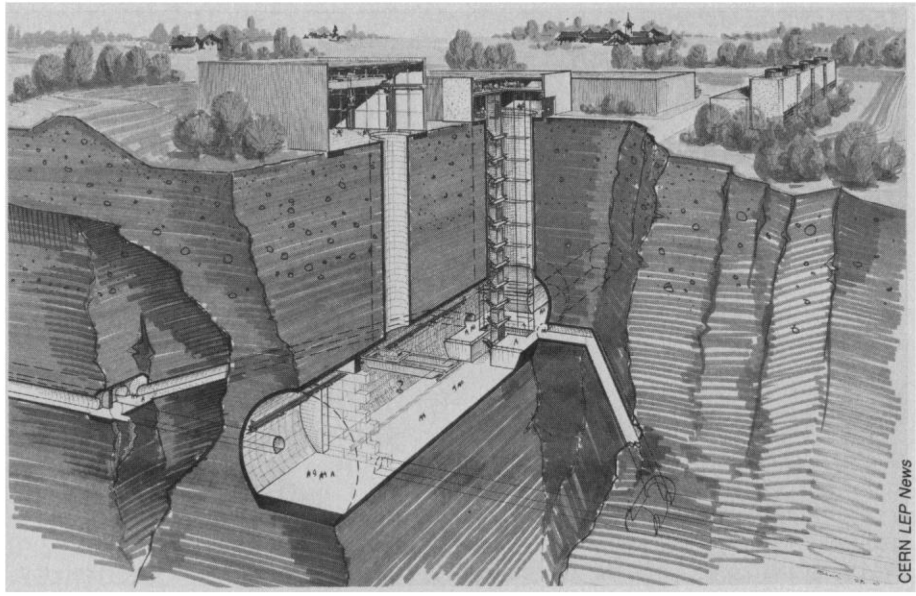
occur at eight locations around the LEP ring. But CERN can only afford four experimental halls for phase one.

Last June, CERN notified high energy physicists that it was ready to receive letters of intent from collaborations planning on submitting detailed proposals for experiments. In the meantime, a LEP Experiments Committee was established with Günter Wolf of the German Electron Synchrotron (DESY) laboratory in Hamburg as the chairman. The crowded convocation of 24 to 25 March at CERN was the first public meeting of this group. The intent was to review the letters of intent, seven in all, that had been received. In reply to some complaints that it was premature to begin selecting experiments when there were more than 5 years before LEP would be operating, Schopper said that the schedule for building detectors was already very tight. So, on with the show.

And it was quite a show. For starters, six of the seven collaborations submitted letters that did considerably more than sketch out their ideas. As several observers commented afterward, it appeared as if the groups had prepared full, detailed proposals and then turned in abbreviated versions of these. The depth of detail together with the large sizes of the collaborations (one listed 238 members) and the abundant evidence of prior research, such as the development of prototypes, all indicate that no one was risking being left in the dust. The pressure to put on polished performances at the public review was also intense as collaboration members from out of town spent the days before the meeting in hotel rooms honing their presentation.

The reason for the competitiveness is that LEP is destined to be western Europe's primary high energy machine in the 1990's. In addition, the physics at the energies where the weak and electromagnetic forces become comparable is expected to be rich. While the first signs of the highly prized W and Z particles may show up in CERN's SPS in its proton-antiproton collider mode of operation (*Science*, 21 May, p. 836), LEP will be able to investigate these and other putative particles, such as the Higgs boson and the top quark, exhaustively and thereby provide the information to check theorists' models of the subnuclear world. CERN has always been careful to emphasize that there are no plans to close down proton beam experiments at the SPS once LEP gets running, but there are always those doubt-inspiring words "who can tell what the physics will dictate 5 years from now" that most of the CERN directors have uttered at one time or another. In Hamburg, DESY has plans for a giant accelerator of its own, but its prospects are uncertain at the moment. European high energy physicists have a big stake in being in on LEP.



LEP experimental hall

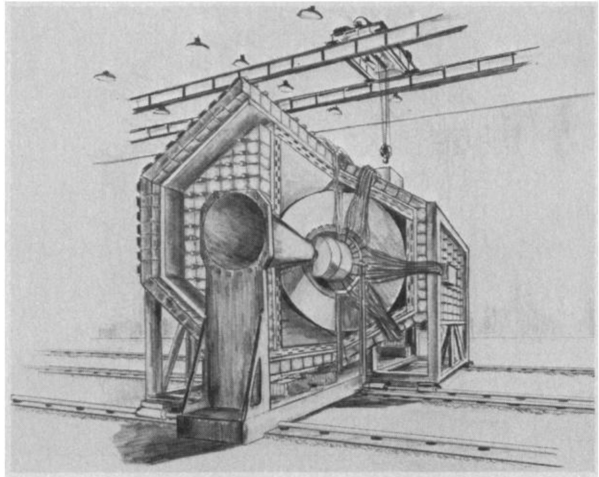
The LEP tunnel, which runs across the foreground of this artist's impression, will be 80 meters underground, on the average. The experimental halls will be accessible by way of the two vertical shafts. During machine operation, the detector will be in the forward part of the hall and will surround the LEP beam pipe. The center part of the hall, which is shielded from radiation by the concrete blocks, is for assembly and maintenance.

The decision of the LEP Experiments Committee will be doubly important because the experiments it chooses will also set the direction of European high energy physics for many years. One of the issues that observers have been interested in concerns the variety in the proposed detector designs: would they all be nearly identical, general-purpose systems or would they tend to be specialized, each for different experimental goals? As compared to fixed-target accelerators, such as electron and proton synchrotrons, colliding beam machines can service fewer experiments simultaneously, and they have much lower event rates. These factors have tended to drive physicists to build general-purpose detectors that would run for years and measure everything possible all the while. Nonetheless, the two present state-of-the-art electron-positron colliders at the Stanford Linear Accelerator Center (SLAC) and at DESY of 35- and 40-GeV collision energy have taken slightly different tacks. The DESY machine has five large detectors, four not markedly different in either concept or capability, and a fifth more specialized. There are also five large detectors at SLAC, but they are considerably more diversified. Specialized means that a detector concentrates on measuring one characteristic of particle collisions much better than the others.

What did CERN get? On the basis of the letters of intent, LEP seems on the road to becoming what one CERN physicist called "a maxi-PETRA" (PETRA is the name of DESY's large collider). Four groups turned in plans for general-purpose detectors that were very similar to one another, and one came up with a different idea for an instrument that also had all-around capabilities. A sixth collaboration of American institutions submitted a proposal for a more modest detector of markedly different design.

Some of the detectors have rather Greek-sounding names or acronyms. There is, for example, DELPHI for DEtector with Lepton, Photon, and Hadron Identification. The four more or less identical proposed detectors (and their spokesmen) are DELPHI (Ugo Amaldi of CERN), ALEPH (Jack Steinberger of CERN), OPAL (Aldo Michelini of CERN), and ELECTRA (Roger Cashmore of Oxford University). All turned in proposals costing about $30 million, and all consist of international (including the United States, Canada, Israel, and Japan) collaborations of 20 or so institutions. All have the same basic structure: a cylindrical, gas-filled chamber for tracking charged particles; a superconducting, solenoidal magnet; electromagnetic calorimeters; hadron calorimeters; and (with one exception) external muon identifiers. The iron in the hadron calorimeters also serves as the magnetic flux return for the magnets and weighs 2000

The LOGIC detector



J. Kirkby, SLAC

This artist's conception shows the detector with one quadrant missing. The cylinder in the center is a drift chamber for tracking particles. The spherical structure is the ring-imaging Chrenkov counter for particle velocity measurements. The blocks on the outer layer are scintillator modules for energy determination. In a revised proposal, the 2400 scintillator modules have been replaced by 22,000 lead glass blocks. The cone-shaped structure on the end is part of the unique open axial field magnet system.

to 2500 tons. Calorimeters measure the energy of the particles stopped in them. Anything that penetrates the thick iron of the hadron calorimeter and registers in the muon identifier is, by process of elimination, a muon.

In general, these detectors are designed to have a three-dimensional particle-tracking capability with higher spatial resolution than generally available up to now. They also emphasize a large number of small modules in the calorimeters to give these devices a much improved spatial resolution. However, there are some differences between the proposed detectors. The DELPHI group wants to use a new kind of Cherenkov counter that will give the velocity of the particles passing through. From the momentum of the particle, as determined by its curved track in the magnetic field of the central chamber, and its velocity, physicists can deduce its mass and hence its identity. The charged particles that live long enough to reach the outer layers of a detector are electrons, muons, π mesons, K mesons, and protons.

The fifth proposal, which is so far nameless, was drawn up by a group headed by Samuel Ting of the Massachusetts Institute of Technology. Some observers have, however, called it "the Great Wall of China," in part because of the astounding amount of iron that will go into the detector, about 8000 tons. Unlike the other proposed detectors, Ting's would have a conventional, nonsuperconducting magnet 12 meters long and 12 meters in diameter that completely surrounds all the components of the experiment. In his presentation at CERN, Ting called it a magnetic cave. The detector is the next generation version of Ting's Mark-J at DESY, and is aimed at high-precision measurements of photons, electrons, and especially muons that emanate from electron-positron collisions. The largest volume of the detector is devoted to muons, in fact.

As it happens, China is also playing an active role in the collaboration with two institutions from Beijing and Hofei as members. Just as important, China will be the source of raw material—not iron, but germanium for the electromagnetic calorimeters. Calorimeters work by measuring the intensity of light showers generated when high energy particles strike them. Ting wants to use bismuth germanate or BGO for this purpose. BGO provides a high energy resolution as compared to more conventional materials, and also a high spatial resolution given by the size of the BGO crystals. Ordinarily, BGO would be far too expensive to use as extensively as Ting envisions (12,000 crystals of 1 by 1 by 20 cubic centimeters each) but the use of material from China and the development of lower-cost crystal-growing techniques will, it is hoped, make it feasible.

The sixth proposal, LOGIC, with Jasper Kirkby of SLAC as spokesman, would have a cost two-thirds that of the larger detectors. Its magnet design is quite different from the others, a so-called open geometry so that particles do not have to go through the magnet coil on their way to components of the detector. The group's letter of intent describes LOGIC as a special-purpose detector for particle identification. Like DELPHI, it relies on the new ring-imaging Cherenkov counters. It also has a very fine-grained lead glass calorimeter with 22,000 lead glass blocks.

CERN expects to avoid having to make outright rejections of formal proposals. With so much of Europe's high energy physics budget tied up in LEP, the laboratory will be under considerable pressure to provide for as many European scientists as possible. The mechanism to achieve this will be a "soft" selection process. In July, "signals" will go out from the LEP Experiments Committee, which in a second meeting in late May completed what one participant called an unprecedentedly detailed technical examination of the letters of intent, as to which are looked upon most favorably. There will then be a period of rearrangement, perhaps some forced marriages, as members of the discouraged collaborations seek new homes. During this time, for example, the LOGIC collaboration, which needs European members to be politically acceptable, would grow to three times its present size, if it were one that had received a green light to continue. Similarly, the members of the seventh collaboration consisting of 20 Italian physicists led by Antonino Zichichi of CERN, who have argued that they and many others are indeed interested in LEP but are too busy with existing experiments to prepare a proposal, could find places in the approved groups. If all goes well, in September, a formal call for proposals will go out; four will be received; and four will be selected.

Financing the winning proposals may present some problems. Erwin Gabathuler, one of CERN's directors, told the March LEP meeting that CERN would have only a bit over $25 million to put in toward the four detectors, thus placing a considerable financial burden on the institutions in the collaborations. All of the six collaborations submitting letters of intent with specific detector designs have American institutions as participants. The U.S. groups are mainly funded by the Department of Energy. In its most recent meeting, the High Energy Physics Advisory Panel that counsels the energy department heard DOE officials say that the cost of supporting all the American participants in LEP, if all experiments were approved, would be over $33 million. About $19 million would go to Ting's collaboration, and $10 million to LOGIC. This would be "a significant fraction of DOE's university high energy physics program," said Bernard Hildebrand to HEPAP.

Panel members asked to hear a presentation on the LEP proposals at their next meeting in August, preferably by the principals involved. But already evident was a certain amount of concern at spending so much U.S. money on LEP. One cause of unease is the strong likelihood that the detectors will cost up to 50 percent more than the present estimates. The current requests "are just the tip of an iceberg," said one HEPAP member. Another worry is that SLAC will almost certainly be building an innovative new accelerator, the Stanford Linear Collider, that will compete with LEP in some respects. A subsequent article will discuss this machine.

—ARTHUR L. ROBINSON