has to meet, one of them is clearly not negotiable: It must be accessible to all nations of the region, including Israel. Israel made it clear at the Paris meeting that it is not offering to host the facility—there would undoubtedly be resentment if it did—but it is vital to the project's success for two reasons. One is that without Israel's involvement it would hardly look like science for peace. The other is that in one small country the Israelis have more expertise in synchrotrons and their use than the rest of the region put together. There are more than 20 Israeli teams working on synchrotrons around the world, and the country is an associate member of the European Synchrotron Radiation Facility, whose machine in Grenoble is one of the world's biggest and best. Israel thus has many academics interested in using such a facility, and it also has industries that might conceivably wish to participate.

Being able to attract such fee-paying users will undoubtedly decide the project's success. Many in Paris felt that the German estimates of $10 million for the upgrade, $10 million for infrastructure at the new site, and about $4 million for running costs was at best optimistic. Various possible donors were discussed, including the European Union's Mediterranean development budget and U.S. aid toward the Middle East peace process, which runs to billions of dollars. Closer to home, there are the oil-rich Arab states. None of these were represented in Paris, but if they could be persuaded to join the project, they could be a valuable source of cash.

But as James Vary of the International Institute for Theoretical and Applied Physics at Iowa State University in Ames points out, the big sum up front is not the most serious worry. "After the money for science for peace, you still need money for science." And the Middle East is not renowned for its generous research budgets. Khaled Elshuraydeh of Jordan's Higher Council for Science and Technology estimates that Arab governments spend on average 0.2% of their mostly rather modest national incomes on R&D. A state-of-the-art synchrotron, together with the beamlines needed to channel its x-rays and the experimental setups required to use them, would be a very big fish in a small pool—possibly, given what else might be done with the money, an inappropriately big fish.

The researchers' solution to this would be to increase the size of the pool. As Miguel Virasoro, director of the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy, points out, there is no conservation law keeping Middle Eastern research budgets at their current low level. The need to make accommodations for the synchrotron could be a way of focusing attention on research. "This means that governments [have to] raise it to a higher level on their agenda," agrees Vary. But for that to work, there have to be researchers and they need to be nurtured and trained now, even if the synchrotron will not start work for several years. The Abdus Salam center already runs courses in synchrotron radiation applications, which have been put to good use by the Thais in setting up their center based around the Japanese synchrotron and also by the Brazilians, who built their own light source from scratch. According to Stanford's Winick, the U.S. Department of Energy might be willing to provide training at its facilities, although it would not cover all the costs.

By the end of the Paris meeting, the disparate group of participants had organized themselves into an interim council for the project with various committees looking at different aspects, such as training and funding. Arabs and Israelis nominated each other to the committees with a clear concern both to get the right people and the right balance. In this genuinely good-natured and open tone, the Paris meeting proved that the builders and users of synchrotrons are a community in more than name. "It's amazing how open people are here," said a watching particle physicist. "If only we could transmit this spirit to the people back home," said Voss. Even if it can't be transmitted directly, they'll do their best to put it into a storage ring. –OLIVER MORTON

Oliver Morton is a writer in London.

PHYSICS

Will the Higgs Particle Make An Early Entrance?

A raison d'être for the potent accelerator now being built at CERN in Europe, this long-sought particle may be within reach of an existing U.S. machine

BATAVIA, ILLINOIS—When physicists at the Fermi National Accelerator Laboratory discovered the top quark 4 years ago, the choice of music to play over the lab's public address system was obvious: Cole Porter's "You're the Top." Now they—and their colleagues from another major particle physics laboratory, CERN, in Geneva, Switzerland—are speculating that a new theme could soon be in order: "You Turned the Tables on Me."

The music would celebrate the Higgs boson, an eagerly sought particle believed to account for the origin of all mass, including that of the top quark. Most estimates had placed the mass of the Higgs itself too high for Fermilab's Tevatron accelerator to create it—leaving the search for the Higgs to CERN and its Large Hadron Collider (LHC), a far more powerful accelerator that won't be completed until at least 2005. But now it looks as if Fermilab might just be able to steal a march on CERN.

As the Tevatron and other accelerators have measured particle masses more precisely and theorists have refined their calculations, the best estimates for the Higgs mass have narrowed. Those calculations, the subject of intense discussion last week at a conference* here at Fermilab, near Chicago, "tell us the Higgs has to be rather light," says Marcela Carena, a CERN theorist on leave at Fermilab. "This is where the Tevatron becomes interesting," she adds. The calculations imply that the Tevatron, newly upgraded at a cost of $260 million, just might spot the Higgs before the LHC does. But the Fermilab-first scenario could depend on whether the upgraded Tevatron is allowed to run for longer than the 2 years now planned—and on whether the Higgs's low mass has opened the way to a surprise winner, CERN's current accelerator (see sidebar).

Particle factory. Fermilab's Tevatron accelerator may have a shot at the Higgs.

The Higgs is crucial for modern particle theory, which is based on an interplay of symmetries but must also explain why particles in nature have wildly different masses. A "Higgs field," which is envisioned as permeating all of space like a sort of unchang-

* 7th International Conference on Supersymmetries in Physics (SUSY99).

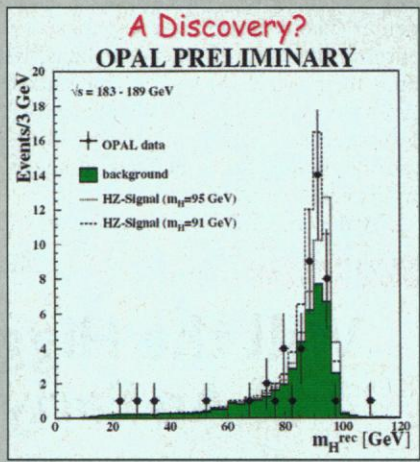
A Tentative Nondiscovery of the Higgs

BATAVIA, ILLINOIS—Don't think of elephants. Now, are you thinking of elephants?

This classic psychological ploy captures the dilemma facing one scientific collaboration at the Large Electron-Positron collider (LEP), a particle accelerator at CERN in Geneva, Switzerland. The subject of the "don't think of" scenario is the Higgs boson, the hypothetical particle that is thought to explain how everything else in the universe—including all the particles in elephants—acquired its mass. The collaboration, called OPAL, is trying to dampen speculation that a handful of unexplained events in its data point to a Higgs discovery. The result is to fuel the rumors.

"It's not an effect—but may be interesting," said Eilam Gross of OPAL and the Weizmann Institute of Science in Rehovot, Israel, during the SUSY99 conference here last week. Gross's disclaimer, given as he presented a viewgraph on the data, drew knowing titters from the audience. He explained that the gap between the data points and the green peak of expected "background" counts could either represent a statistical fluctuation or the first hints of a Higgs with a mass of about 91 billion electron volts (GeV), or 97 times the mass of a proton. "It's exactly the right sort of Higgs mass," said Gordon Kane, a theorist at the University of Michigan, Ann Arbor, who adds that the signal should soon be either "golden or gone" as more LEP data stream in.

LEP has been smashing together electrons and their antimatter counterparts, positrons, at gradually increasing energies, and Gross said that the intriguing data came from runs since 1997 at collision energies from 183 to 189 GeV. If a Higgs materialized briefly in the debris of those collisions, it would be expected to decay most often into a bottom quark and an anti–bottom quark, each of which would be manifested as a "jet" of protons, neutrons, and pions in the OPAL detector. Because other particles created in the collisions—especially the Z boson, which mediates the weak nuclear force—would produce similar events, their expected contribution is a "background" that must be carefully subtracted from the overall count. Still, said Gross, the subtraction leaves an excess of remaining counts that has only a 4% chance of being a statistical fluke.



Don't even think it. A viewgraph shows a slight excess of events over the expected background (green), at a plausible Higgs mass.

That level of certainty is not considered strong enough for a claim of discovery in particle physics—particularly because, according to Gross, LEP's other three detectors see no clear evidence for a peak there. The fact that the suggested value for the mass is almost precisely the same as that of the Z boson has raised eyebrows. "It's probably just a misunderstanding of their background," says Georges Azuelos of the University of Montreal and the ATLAS collaboration of the Large Hadron Collider, a much larger accelerator to be built in the LEP tunnel.

Nevertheless, Gross and others pointed out that within the next year or so, when LEP reaches its ultimate energy of 200 GeV, it should be capable of a firm detection of the Higgs if its mass is anywhere below 109 GeV. (Much of the collision energy goes into creating other particles.) After that, Fermilab's Tevatron has a shot at the discovery if the mass is below about 180 GeV (see main text). "If God is on our side," said Gross, playing on the almost theological significance the discovery would have for particle physics, "let Higgs appear this year. Amen." —J.G.

ing voltage, spoils the perfect symmetry and results in the array of different masses. Quantum-mechanical excitations of the field should yield the Higgs particle itself, just as photons, or particles of light, emerge from a smooth electromagnetic field. The Higgs particle should be shaken loose by sufficiently energetic collisions in accelerators.

"One of the raisons d'être of the LHC was to discover the Higgs," says Georges Azuelos of the University of Montreal and the LHC's ATLAS collaboration. As Fermilab theorist Joe Lykken explains, "The thinking was that [the Higgs mass] could be as high as 1000 GeV"—or 1000 billion electron volts, about 1000 times the mass of a proton. Although the upgraded Tevatron hurls particles together with 2000 GeV of energy, not all that energy goes into creating new particles. As a result, making heavy Higgses in detectable amounts seemed likely to require the 14,000-GeV, $5 billion LHC.

Gradually, the mass estimates changed. Because quantum mechanics lets any one kind of particle temporarily exist as another particle, their measured masses are all closely related. So a refined top-quark mass, say, leads to a better estimate of the Higgs mass. Those refinements alone have pushed the estimated Higgs mass to below 230 GeV. But it also turns out that the Standard Model of particle physics—the accepted theory of particles and forces—goes haywire at very high energies unless the Higgs mass is less than 180 GeV. And a more comprehensive theory called supersymmetry, still hypothetical but popular among theorists, would be "strongly disfavored" unless the mass is below roughly 130 GeV, says Carena. Many of the new estimates emerged from a multi-institutional Higgs Working Group convened at Fermilab last year, she says.

The clearest signature of a low-mass Higgs would be its decay into a bottom quark and its antimatter counterpart, an anti–bottom quark, which would be manifested as "jets" of particles. But because of LHC's great energy and particle-beam intensity, it would generate massive numbers of jets by other processes and would have to rely on much-less-common decay patterns to detect a low-mass Higgs. Calculations Azuelos presented at the meeting suggest that it might take the LHC several years of running to discover a light Higgs.

As a result, says Azuelos, "there are chances that it will be seen at the Tevatron." Speaking of physicists working on the LHC, Azuelos says "of course they are concerned" about that possibility, but "they are not worried about it"—as the Higgs will have to be studied in detail no matter where it is found, and the LHC is well suited to doing so by making the particles at a brisk pace.

The chance that the Tevatron will stake the first claim on the Higgs will rise, says Gordon Kane, a particle theorist at the University of Michigan, Ann Arbor, if Fermilab's new director, Michael Witherell, decides to push for more Tevatron run time. Witherell says, noncommittally, that he likes the idea. "All of the indirect evidence we have tends to push the Higgs mass down to the low end of the range," he notes—"which is our end." At the same time, he cautions that the mass estimates are not airtight and that any time-consuming upgrades or repairs to the Tevatron could erode its lead over the LHC. But if the Tevatron hits the right note in time, it could have particle physicists singing "Goin' to Chicago." —JAMES GLANZ

CREDIT: EILAM GROSS/CERN, OPAL