Global from the get-go?

By Kathryn Grim

Experiments in particle physics have decades of experience as thoroughly international collaborations. Can the giant accelerators that power these experiments make the leap to go global as well?

Illustration: Sandbox Studio

At a recent meeting of scientists at CERN on the border of France and Switzerland, a physicist recalled words of wisdom imparted to him by a professor of literature: "Physics is wonderful," the professor said. "At least it teaches scientists to speak French."

Although the comment elicited a chorus of self-deprecating proclamations about physicists' language skills, it did highlight the reputation physicists have earned for working together across borders. This model of international collaboration has been the norm among experimentalists like those at the meeting for decades. Thousands of scientists from dozens of countries now spend their days and nights at CERN, the laboratory that hosts the Large Hadron Collider, the world's highest-energy particle accelerator. The US Department of Energy and National Science Foundation contributed $531 million to the construction of the collider and its experiments, and 1700 US scientists are involved today. Similarly, experiments at Fermilab's Tevatron can cite decades of collaboration among scientists worldwide speaking nearly 100 languages.

But the practice of collaborating internationally to design and construct the enormous accelerators that power these experiments has emerged only recently. And the world's next big, one-of-a-kind particle collider will require even greater cooperation than any of those that preceded it.

Too big to tackle alone

Scientists from across the globe contributed to building accelerators such as HERA at DESY laboratory in Germany, RHIC at the DOE's Brookhaven National Laboratory and the LHC at CERN. But in each of those cases, one laboratory drove and managed the project and operated the accelerator. Scientists are now working on ways to govern projects as global communities from the beginning.

These giant particle colliders take at least a decade to build and are meant to last for decades more. Their costs reach multiple billions of dollars. In practice, this dictates building only one global machine at a time, which means all regions must work together in order to participate in scientific progress. The process of building an international collaboration and agreeing on the location of a new machine takes time.

"The ideal way to make anything would be monolithically in one country, but our ambitions have grown beyond that," says Barry Barish, director of the Global Design Effort for the proposed International Linear Collider. "On the other hand, pulling together the world's talent is a very powerful thing."

Particle colliders allow researchers to create and study exotic particles in conditions similar to those in the early universe. Collisions at higher and higher energies allow scientists to explore the fundamental nature of matter over wider and wider ranges. In general, the larger the particle accelerator, the higher the energies it can reach, allowing scientists to test theories such as supersymmetry and extra dimensions.

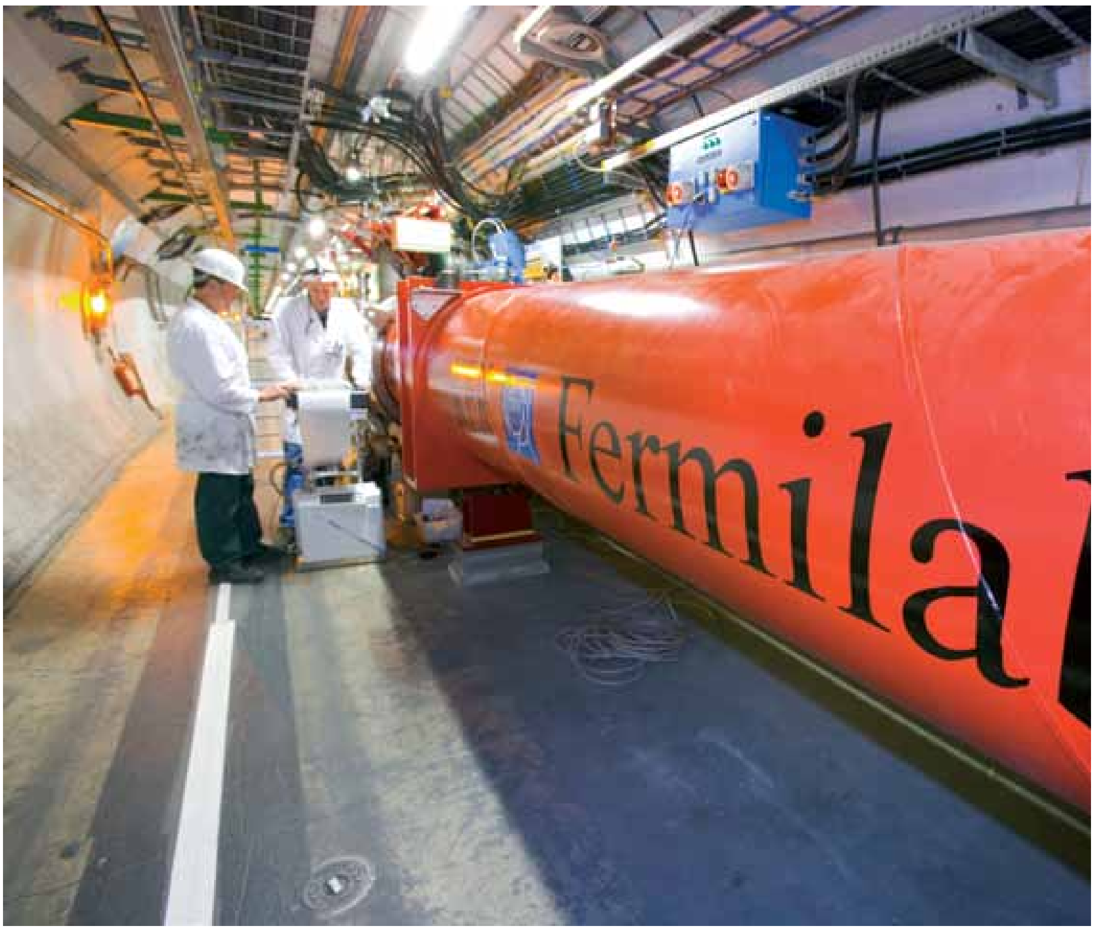
"There's no point in getting smaller," says Lyn Evans, LHC project leader. "We've got to be able to address the big issues."

The CERN member states combined forces to build the LHC, the newest high-energy accelerator to push the boundaries of particle physics. Later the United States, Japan, Canada, India, and Russia joined them.

If you're going to build a major research instrument that is one of a kind, it has to be international, says Steve Holmes, recent associate director of Fermilab and currently project manager for a proposed new accelerator, Project X. This allows countries to pool their resources and talent, to hone technological skills they have, and to acquire new ones they don't.

From a control room at Fermilab in Illinois, US scientists can remotely operate the CMS experiment at CERN's Large Hadron Collider in Europe. This Remote Operations Center exemplifies the model of global collaboration that has long prevailed for particle physics experiments.
Photo: Reidar Hahn, Fermilab

Scientists and engineers from Fermilab and from Japan's KEK laboratory designed, built and shipped advanced high-tech quadrupole magnets to Switzerland for the Large Hadron Collider accelerator at CERN. Can future accelerator builders go beyond this level of worldwide contribution to become truly international efforts from the start?
Photo: Reidar Hahn and Fred Ullrich, Fermilab



Finding stable funding

Divvying up the work of an international particle accelerator project is complicated.

In the United States, for example, science funding comes from the national budget, approved annually by Congress. This makes long-term planning difficult.

"It's very difficult to plan a multi-year project when you don't know what the budget is going to be next year," says Victor Kuchler, a designer of conventional facilities for the International Linear Collider project.

In an attempt to deal with this, government relations group Lewis-Burke Associates has drafted proposed legislation that would allow the director of the Office of Science and Technology Policy to designate "International Science Zones" for projects or programs valued at more than $5 billion. An ISZ project or program would be eligible for a special appropriations process in which Congress would agree upon funding more than a year in advance. It would also offer foreign scientists an expedited visa process and allow for the formation of a federal interagency group to guide the ISZ.

TOP: Contributing laboratories around the globe placed their stamps on Cryomodule I, part of a setup at Japan's KEK for testing components for the proposed International Linear Collider

MIDDLE: A technician at Jefferson Lab in Virginia performs one step of a process for polishing superconducting radio-frequency cavities. These cavities, which accelerate particles with great efficiency, are at the heart of two proposed global accelerator projects, the International Linear Collider and a muon collider.

BOTTOM: In the true spirit of global collaboration, scientists who work on siting, civil engineering, and accelerator technologies for the proposed International Linear Collider meet at an international workshop in Beijing.

Photos courtesy of ILC Global Design Effort

Working across borders

The people involved in an international collaboration must work across time zones and language barriers. On top of that, they must build a budget that countries can manage despite the fluctuating differences between their currency values. Many collaborations invent their own currencies to set the value of in-kind contributions. Scientists designing the proposed International Linear Collider estimate the machine will cost 6.7 billion ILC units, a currency based on 2007 US dollars. A superconducting magnet that meets requirements is worth a certain number of ILC units as an in-kind contribution, no matter how much money and manpower a country spent to make it.

An international collaboration is affected by the interests and economies of a multitude of nations. If one country suffers a crisis, can the others pick up the slack?

Perhaps the most difficult question an international collaboration faces is: Where do we build the accelerator? Once the location is fixed, will the countries that were not chosen to host it continue to support the effort?

Spreading the benefits

The LHC is located on the border of France and Switzerland. Those countries provided the infrastructure that supports the accelerator. In exchange, France and Switzerland gain unique benefits from the great machine. Several thousand scientists working on the experiments give a boost to the French and Swiss economies as residents of the two countries. French and Swiss companies, along with other European firms, profit from the chance to provide contracted parts and service. And the accelerator serves as a source of national pride: The two countries have earned a reputation as centers of scientific excellence.

But other countries benefit from their involvement with the Large Hadron Collider as well, through the opportunity to participate in the design and construction of cutting-edge particle physics tools. US engineers, for example, built on their expertise from developing superconducting magnets for the Tevatron particle accelerator at Fermilab and the Relativistic Heavy Ion Collider at Brookhaven National Laboratory to contribute to the construction of the next generation of superconducting focusing magnets for the LHC. US firms supplied high-tech magnet components. Countries around the world have participated in the creation of a worldwide computing grid to share data from LHC experiments, and about a dozen countries continue to help CERN to store and distribute copies of data from the LHC.

Building the LHC involved balancing the ability and motivation of each country involved. Scientists from every nation wanted access to the research. They wanted to gain expertise in constructing the latest technology. They also had certain strengths. They could provide funding or share their experiences with different processes. The key was to divide the work in a way that made economic sense but also satisfied the participants.

A humbling lesson

US physicists were particularly interested in involvement with the LHC, as they were fresh from the cancellation of their own major accelerator project—the Superconducting Super Collider.

The United States had planned the SSC on its own but asked other countries to get involved when the cost began to expand beyond initial expectations. Understandably, other countries were reluctant to fund a project in which they felt no sense of ownership, not having served as designer or host. Congress pulled funding for the SSC in 1993.

"All of us who were lab directors at that time realized we'd reached the point that you couldn't build regional machines anymore; they were just too big," says John Peoples, then director of Fermilab. "We would be lucky if we could build just one machine in the world at a time."

The humbling experience showed US physicists that even a project they deemed to be of highest importance, even one that had been approved by the DOE and Congress, could fail, says Jim Strait, project manager for the US LHC Accelerator Project, who was heavily involved with the Super Collider.

US high-energy physics suddenly had lost its focus. The Department of Energy pulled together a panel to discuss the future. In the end, they decided to throw their weight behind the LHC.

"It was clear that the LHC was the next big thing," Strait says. "If we didn't work on the cutting-edge accelerator of our generation, we would be cut out of all sorts of things that we could learn from."

Just as designers of new cars or computers cannot expect to come up with the next big thing if they have failed to keep up with new developments, the physicists couldn't hope to build the next pioneering accelerator if they failed to participate in the LHC.

"You don't sit around saying, 'I hope the Europeans succeed,'" Strait says. "You say, 'How can we help?' In the end we got to build some really hard and cool stuff."

If Congress had not cancelled the US-built Superconducting Super Collider project in 1993, this tunnel in Waxahatchie, Texas, would have held the collider and its superconducting magnets, such as the one shown below at Fermilab. A failure to secure international partners to design and build the project is among the reasons for the SSC's demise.
Photos: Reidar Hahn, Fermilab and SSC

Planning the next step

The global physics community has kept the lessons of the SSC and the LHC in mind while planning for the next international accelerator project. This time, countries are working together from the beginning. Physicists have already demonstrated this attitude in developing three proposed accelerators: the International Linear Collider, the Compact Linear Collider and a muon collider. At a relatively modest scale, Fermilab has embarked on this path with its proposed new accelerator, Project X.

"If anything was learned from the SSC, it was that you cannot make a project into an international project if it doesn't start out that way," Kuchler says. "People have to take ownership from the beginning."

This time, physicists will strive to ensure that everyone has ownership, wherever the accelerator is located. They know that even if the next accelerator doesn't end up on their home turf, their cooperation with other countries is essential if they hope to have others' help should the one after that end up in their own backyard.