Big Physics Provokes a Backlash

Should 900 people collaborate on a single experiment? Such megacollaborations are stifling their field, say some physicists

Unwinding at a Dallas restaurant during an international physics conference last summer, a group of young physicists confess that they met some of their experimental collaborators for the first time that day. Indeed, some of the researchers on this experiment—Fermilab's Collider Detector Facility (CDF)—may never cross paths. That's because there are 365 of them, scattered over 33 institutions spread across four countries. Today, most experimental particle physicists belong to one of a few similar megacollaborations: vast networks of assorted physicists who jointly gather, analyze, and publish data from a single vast piece of equipment—the particle detector. And today's collaborations may seem puny in a few years' time. More than 900 physicists have already signed onto a single experiment at the Superconducting Super Collider (SSC), which is scheduled to be up and running soon after the year 2000.

This is no way to explore the fundamental constituents of nature, charge some of the field's most distinguished members. The most outspoken of these, Nobel Prize–winning physicist Melvin Schwartz of Brookhaven National Laboratory, complains that these huge groups suffocate new ideas and discourage initiative. The individual physicist gets stuck in a remote corner of an experiment and must be content with a small piece of uniformly distributed credit. The result, he says, is a pack mentality, in which everyone "marches in lock step" along the safe paths marked by mainstream theory. No wonder, Schwartz maintains, the field hasn't come up with any surprises for more than 15 years.

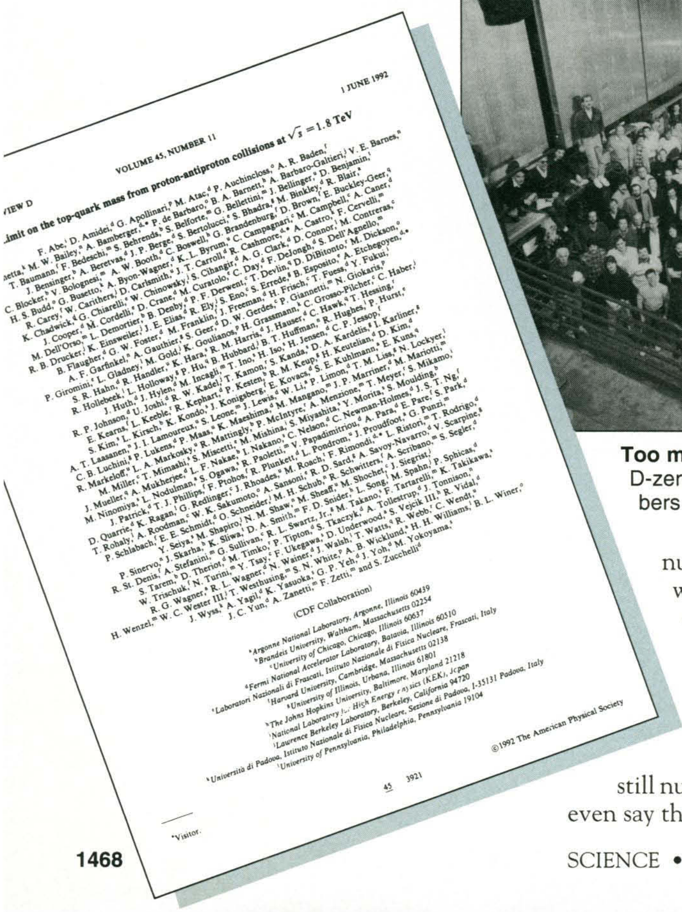
And it's not as much fun any more, say many physicists. "When I got into this field I wanted to be proposing experiments and running them," says University of Illinois physicist Steve Errede. "The reality is that it's becoming more and more of a bureaucracy." Adds Illinois physicist Gary Gladding, "I don't know if people were meant to work in such big groups." He now works on a collaboration numbering around 150 people, "but working with 1000—I can't conceive of that."

It's no surprise to hear the most outspoken criticisms of big collaborations coming from Schwartz and his colleagues at Brookhaven, where many groups still number under 100. Some physicists even say they suspect Schwartz is criticizing the competition in an effort to save his own lab's particle physics program, which the Department of Energy plans to close down in 1997. (A new Brookhaven project, the Relativistic Heavy Ion Collider, will go on because it is classified as nuclear physics.) But from many physicists outside Brookhaven—even ones specializing in the mammoth experiments Schwartz deplores—comes a murmur of agreement. "It's a bad time for the field," says David Cline of the University of California, Los Angeles (UCLA), another veteran particle physicist who fears that triple-digit collaborations "turn off" many of his students.

But there's no unanimity about what should be done. Schwartz and a few other physicists, notably Nick Samios, director of Brookhaven, and Martin Perl of the Stanford Linear Accelerator Center (SLAC), argue for breaking open the large groups. They recommend that more high-energy physicists say no to the massive experiments that have become a staple of the field and venture into independent, "entrepreneurial" investigations that can be done on a smaller scale. Though Schwartz and like-minded physicists accept the need for large accelerators and detectors to nail down some of the more elusive goals such as the Higgs particle, they argue that the detectors should serve as common facilities where small groups can pursue their own experimental goals rather than as the centerpieces of single huge experiments.

"That would lead to chaos," retorts Harvard physicist Gary Feldman, arguing that high-energy physics has just become too complex for the kind of freewheeling approach Schwartz advocates. And leaders of big groups such as Fermilab's CDF and the SSC's Solenoidal Detector Collaboration (SDC) say that if run wisely, large groups can give participants enough freedom to pursue long-shot possibilities.

FERMILAB


VOLUME 45, NUMBER 11

1 JUNE 1992

...imit on the top-quark mass from proton-antiproton collisions at $\sqrt{s} = 1.8$ TeV

(CDF Collaboration)

©1992 The American Physical Society

45 3921

Too much company? Participants in Fermilab's D-zero collaboration flank their detector; CDF members share authorship of a recent paper *(left).*

Yearning for small science

Schwartz and some of his Brookhaven colleagues would like to restore the kind of vitality and prolific energy they remember from the 1960s, and which they say is missing in

Brookhaven: A Physics Enterprise Zone?

When physicist Melvin Schwartz bemoans the 300-person megaexperiments that have become routine in particle physics and calls for more small, flexible research groups (see main text), he's not just talking in abstractions. Schwartz has a concrete example of the kind of "entrepreneurial physics" he favors: the high-energy physics program at Brookhaven National Laboratory, where Schwartz became a staff scientist last year. Brookhaven, he says, has a tradition of encouraging small science and allowing people to pursue their own ideas, even far-fetched ones.

Outside scientists who once worked there agree that Brookhaven is more open to new and risky ideas than many other laboratories. Says Yale physicist Michael Zellar: "Brookhaven definitely encourages the entrepreneurial spirit." University of Massachusetts, Amherst, physicist Mike Kreisler says that while he was at Brookhaven, "I was able to do things that other people thought were too experimental." He points out, however, that the lab's flexibility is partly a function of the smaller scale of the experiments at Brookhaven's Alternating Gradient Synchrotron (AGS). "At Fermilab anything you propose will cost several million dollars, while at Brookhaven you can do things significantly cheaper." Another former Brookhaven physicist, Tom O'Halloran of the University of Illinois, agrees. "The experiments are more manageable," he says. And that opens the way to some risky experimental ventures.


BROOKHAVEN

Piecing together Brookhaven's future. RHIC director Satashi Ozaki and one of the collider's magnets.

Schwartz has personal experience of Brookhaven's openness to high-risk projects. When he arrived there, he had just taken a decade's leave from particle physics to run his own company, and he came back to physics eager to go off on his own research tack. The laboratory management, he says, was accommodating. His first project was an effort to make "atoms" with exotic particles—muons and pions—in place of the electrons and protons of ordinary atoms. The effort had only limited success—he did manage to create some "pi-mu atoms" but didn't discover any new physics in the process. Still, he insists, this is the kind of thing you have to try.

That kind of high-risk venture is continuing at AGS, says Brookhaven physicist Derek Lowenstein. Some of his colleagues are using AGS to look for "exotics" such as glueballs—particles made entirely of the "gluons" believed to bind quarks together in the nucleus. Others are trying to make particles containing six quarks instead of the two and three quarks that make up all known particles. And still other AGS physicists are investigating whether the proton can change its size. Oddly, says Lowenstein, protons fired at large nuclei sometimes slip right through, as if they temporarily shrink.

AGS is now operating under a death sentence; the Department of Energy plans to shut down Brookhaven's particle physics program in 1997. But AGS will have a successor: the Relativistic Heavy Ion Collider (RHIC), which will be classified as nuclear physics rather than particle physics. And once RHIC is up and running in 1997, it will operate in the same spirit as AGS, says RHIC's director, Satashi Ozaki. Instead of serving a specific experimental program—a search for some theoretically predicted particle, say—it will give physicists a chance to go fishing.

After all, theorists can't offer a lot of guidance to the terrain RHIC will be opening. RHIC will accelerate heavy nuclei, such as gold, to nearly the speed of light and crash them together. Physicists, used to colliding individual protons and electrons, sometimes describe the prospect as "colliding two garbage cans." In the wreckage, RHIC designers expect the machine to perform a new sort of alchemy, transforming gold into something much more valuable—new states of matter reminiscent of the early universe. The extraordinary density of the colliding nuclei, they say, should briefly recreate the hot soup of particles that filled the seething universe just a split second after the Big Bang. But just what will turn up there is a mystery, Schwartz says.

That kind of rich experimental terrain is perfect for mining by small, flexible groups, say Schwartz and Ozaki. Ozaki does plan to have two big detector projects, staffed by scores of physicists, at two of the six collision points on RHIC. But at least three of the others will be open to smaller groups. The more hands in the project, the better. You never know, Ozaki says, "you might find something valuable by colliding two garbage cans."

–F.F.

particle physics today. "Many physicists grew up in an environment where groups were small and the same physicists did the planning, ran the experiment, analyzed data, and wrote papers," says Brookhaven physicist Derek Lowenstein. "Groups had four or five people, at most 15." But as physicists reached for higher-energy collisions, the detectors got bigger and more complicated and the available money got sucked into fewer projects. More physicists ended up collaborating. "Now there are hundreds to an experiment," says Lowenstein. "It's a different world."

With that new world has come a wholesale change in the nature of the physicist's work, says sociologist Mark Bodnarczuk, who observes physicists by working as a quality assurance manager at Fermilab and who spoke on the topic at a history of physics conference in California last June. He finds special aptness in the catchy way physicists refer to big projects as factories—the much-discussed "B factories," for example, specialized accelerators meant to explore the properties of particles containing bottom quarks (*Science*, 22 March 1991, p. 1416). Physicists coined the term "factory" to refer to the large numbers of particles these accelerators will churn out, but Bodnarczuk thinks large physics experiments are starting to run like production lines as well. "Doing physics now means writing 100,000 lines of Fortran code for some type of tracking package," he says. "If that isn't mundane factory work, what is it?"

Besides stifling creativity in existing projects, says Schwartz, the situation endangers physics' future as well, by discouraging bright young investigators who don't want to be restricted to a niche. "There is a danger that...you won't get the best and brightest—the well-rounded individuals who want to do science and build experiments." Cline adds that the megacollaborations make it hard for young people to get recognition. "It isn't that your ideas don't filter down into the project. It's just that you never get credit," he says. "You lose your creative visibility" in the one-size-fits-all approach to authorship. Agrees Illinois' Errede: "It's disconcerting."

Still, Bodnarczuk suspects that this style of science may just come with the territory.

High-energy physics today is an unpromising field for small, high-risk experiments, he says. The current theory of particles and forces, known as the "standard model," has withstood all tests so far. And the only still undiscovered particles it predicts—the top quark and Higgs particle—take tremendous energies to create and vast apparatuses to detect. Concludes Bodnarczuk: "When you have to go the scale of CDF and LEP [two big projects] and the standard model is predicting as well as it is, nature limits the options."

Schwartz and some of his contemporaries, such as SLAC's Perl, don't buy this. They say the fault lies not in the particles but in the physics community. Physicists are limiting their own choices, says Perl, by hopping on the same bandwagons. "There are books on how to find the Higgs particle—meetings on how to find the Higgs particle. The thing to do if you are young is not look for the Higgs particle," he says, adding: "I would not spend my time looking for the top quark or [tests of] QCD [quantum chromodynamics]," both popular quests today. "I would try to look for things other people consider to be trash."

Many of his colleagues cite Perl as an object lesson in this kind of initiative. Working within a big group, the SPEAR experiment at SLAC, he succeeded in discovering something new and unexpected—the tau particle, a heavier relative of the electron. But that experiment, done in the 1970s, was designed without specific goals, he says, allowing people on the project to go off on tangents. As SLAC director Burton Richter recalls in *The Second Creation*, Robert Crease and Charles Mann's history of particle physics, "We wanted to look for new phenomena."

Perl now says that if he were submerged in one of the huge, single-minded groups of today, he might never have made the discovery. He just wouldn't have had the freedom. Schwartz wants to change all that. Even as the apparatus needed to explore new terrain in physics gets bigger and bigger, he thinks, the way should be open for physicists to set off on high-risk investigations like Perl's. "If high-energy physics is going to survive, one is going to have to make room for the individual entrepreneur," he says. And he has a plan for doing so.

Physicists as entrepreneurs

The essence of Schwartz's prescription is a change in the way physicists define an experiment. For high-energy physicists today, "experiment" means "detector"—a huge assemblage of particle-sensitive materials and electronics, designed to record collisions in a particle accelerator. As detectors get bigger and more complex, it can take hundreds of people just to build them—and all those detector builders are included in the collaboration along with the scores of other physicists who collect and analyze the data. Only the physicists and engineers who build the accelerator itself are not considered part of the experiment.

It's time to divorce some of the detector builders from the experiment, treating them more like the accelerator builders, says Schwartz. That would bring the group down to a more practical size, making it more flexible and responsive to new ideas from its members. But that's just a first step. Next, Schwartz would like to end the remaining big groups' monopoly on the detectors, breaking them up into smaller teams that would develop their own research programs and compete for time at each facility.

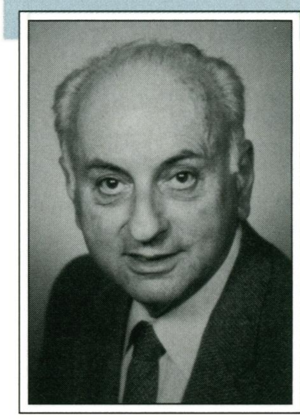
Ideally, he says, he'd like to see his colleagues use the detectors more the way astronomers treat their big expensive telescopes: as common facilities on which small groups or even individuals could pursue their own ideas. That would mean designing detectors not as single-purpose experiments tailored to find some particular particle but as versatile instruments. Physicists could still go after the big goals—such as the Higgs particle—but these searches would not be considered the sole function of the detector. As a case in point, he cites work at Brookhaven's Alternating Gradient Synchrotron (see box). There, people are looking for new ways to put together the basic building blocks of matter—the quarks—testing the size of the proton, and seeking rare processes that current theory doesn't explain.

As a model for other laboratories, however, Schwartz's scheme won't work, warns UCLA's Cline, who agrees with Schwartz's diagnosis of trouble but not with his prescription. The data coming out of the detectors are too complex, too ridden with pitfalls, for a handful of experimenters to collect and interpret on their own, he says. Cline has an ally in George Trilling, head of the 900-member SDC experiment at the SSC. "It's too difficult for people who had nothing to do with building the detector to do the physics," says Trilling.

But Trilling and Melvin Shochet, co-leader of CDF, acknowledge Schwartz's point about the need to make room for individual initiative. Both say they have provisions for doing so. For Shochet, it means governing the CDF group in a democratic fashion, with big decisions made through committees. Individual members of the collaboration are free to propose new methods of analysis and new search strategies, he says. And the collaboration isn't moving in lockstep toward a single experimental goal, Shochet adds. While the experiment is best known for pursuing the top quark, he says only 30 or 40 members are involved in that search. Others are looking for other new processes or particles that might show up at the unprecedented energies of the powerful Fermilab accelerator. "People at CDF work on whatever analysis interests them," he says. Trilling plans to run his 900-member experiment similarly.

"High-energy physics is going to have to make room for the individual entrepreneur."

–Melvin Schwartz


BROOKHAVEN

The limits of democracy

But Cline is skeptical of even this middle ground. A large collaboration, he says, has to be run as a tight ship. Democracy may make the group happy, he says, but he doesn't think it gets the best results. Cline worked under Carlo Rubbia, legendary for both discovering the W and Z particles and retaining absolute rule over his group at CERN. And though that style may take its toll on other members of the collaboration, Cline thinks, it pushes the field ahead faster than either Schwartz's libertarian approach or Shochet's parliamentary one. "Rubbia was an intellectual leader," says Cline.

Schwartz responds that Rubbia's experiment single-mindedly went after confirmation of a theoretical prediction. No surprises came out. And surprises, Schwartz says, are what keep the field healthy and vigorous.

Surprises are just what physicists are hoping for from the SSC. In Schwartz's view, that hope puts high-energy physics in a bind. The experiments planned for the SSC are larger and, Schwartz would have it, more cumbersome than any contemplated so far. And yet researchers are counting on those collaborations to succeed in doing what smaller experiments have failed to do over the past 15 years: shake the standard model, or at least extend it.

Trilling doesn't take the organizational challenge lightly. Faced with an experiment comprising nearly 1000 people that will be 10 years in the making, he admits that "we may run into major obstacles we haven't seen yet." And that's nothing compared to the future Cline foresees. He's calculated that if the present trend continues, by 2020 everyone in the field will be in the same experiment. "That's the trend," he says, "though it's a sad trend."

–Faye Flam