HIGH-ENERGY PHYSICS

Will Fermilab Find Its Future By Looking to the Stars?

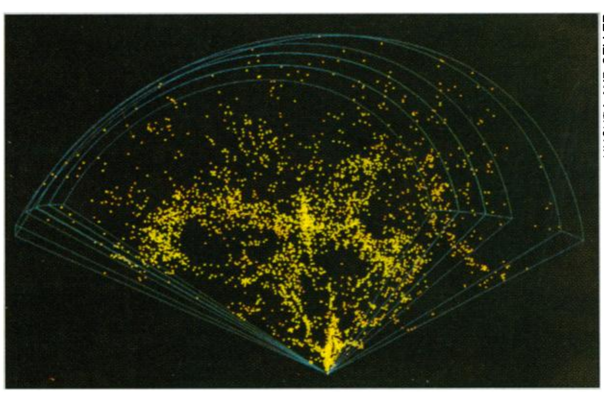
To some Fermilab researchers, their laboratory's latest venture is a match made in heaven. To others, it's pie in the sky. Researchers at the country's premier particle physics laboratory are getting stirred up over plans to broaden the laboratory's traditional focus on subatomic particles. Particle physics is a resolutely earthbound effort done in giant accelerators, but in the late 1990s, Fermilab will be turning its sights outward by taking part in a $25 million, multi-institution effort to map the positions of nearly a million galaxies.

Fermilab's part in the enterprise, the Sloan Digital Sky Survey, will be limited to lending its expertise in computers and data handling and making a modest starting contribution of $500,000. But this could be just the beginning of a larger foray, says Edward "Rocky" Kolb, one of a handful of cosmologists already at Fermilab. "We foresee the sky survey as the first step in a program in high-energy astrophysics." That's just what worries particle physicists like Chris Hill. "It would be fine if there were more money than you needed," he says. But in a time of tight budgets, he thinks Fermilab should stick to its basic mission. "We are set up to do high-energy physics. That's our mandate." What's more, he and others are skeptical of arguments that particle physics and astrophysics are natural partners.

To Fermilab director John Peoples, though, the search for new research horizons is simple prudence. "Fermilab's future in particle physics has to go beyond accelerators," he says. The lab's current centerpiece, the 4-mile-long accelerator ring called the Tevatron, should soon find its major quarry, a particle called the top quark. After that, Fermilab physicists expect to harvest interesting physics from the machine for a couple of years more. But once the larger Superconducting Super Collider starts up in Texas around the beginning of the next century, there will be little money left to operate large accelerators elsewhere, and the Tevatron's days will be numbered.

As a way of hedging Fermilab's bets, an expanded presence in astrophysics seemed the natural choice, says Peoples. There's a strong link between these seemingly disparate fields of science—the study of particles too small to imagine and the observation of the whole universe—at least according to Leon Lederman, a Nobel Prize–winning physicist and former Fermilab director. As he and University of Chicago/Fermilab cosmologist David Schramm wrote in their book *From Quarks to the Cosmos*, "The laws of nature that control and order the microscopic world, and those that determined the creation and evolution of the universe... are beginning to look identical." Advances in one arena should push advances in the other.

Even Fermilab's first foray into astrophysics has implications for particle physics, says cosmologist Kolb. The sky survey, to be done at a telescope now being built at Apache Point, New Mexico, by Fermilab, the University of Chicago, Princeton University, and the Sloan Foundation, will show how extensively galaxies and clusters of galaxies hang together in a vast network of sheets and bubbles. Combined with other observations, the survey may help explain what pulled together galaxies and larger structures in the universe. That something, say many astronomers, may be a sea of as-yet-unidentified subatomic particles—and the patterns of galaxy clumping may betray some clues to the identity of this "dark matter." Ultimately, Kolb would like to see Fermilab mount a full-scale search for dark matter, by building a series of subterranean detectors that would lie in wait for stray dark matter particles.


HUCHRA AND GELLER

New territory. Fermilab's galaxy survey will surpass this earlier one, by John Huchra and Margaret Geller of the Harvard Smithsonian Center for Astrophysics.

But Hill doesn't buy the connection. "People say that astrophysics will reveal something about particle physics," he says. "That's about as likely as saying a dinosaur dig will reveal something about molecular biology." The reason, he says, is a difference in style. Particle physics, like biology, is an exact, highly refined science, while astrophysics and cosmology are more speculative, with less hard data and no controlled experiments. For that reason, he says, "the information flow goes only one way," from particle physics to cosmology. Nobody is going to discover a new particle by making a galaxy survey, he says.

Not that cosmology is bad science, adds Hill. He has worked in the field himself—"That's how I realized how little convergence there is," he says. But, adds Fermilab physicist Robert Bernstein, it's an unaffordable luxury for a particle physics lab in a time of tight budgets—and, off the record, several of his colleagues agree.

Nor do Bernstein and some other Fermilab physicists agree that the laboratory will soon need a new mission, outside of high-energy physics. "The impression out there is that there's nothing for Fermilab to do once they find the top quark," says Bernstein. "That's not true." Take the study of B and K particles, matter made up of exotic constituents produced only by accelerators or energetic cosmic rays. These may offer clues to time's arrow—whatever it is that distinguishes "forward" from "backward" in time. Most subatomic processes would look identical if you were to run a film of them backwards, explains Bernstein. Only a few rare "charge-parity violating" processes, involving B and K particles, can tell forward from backward and follow time's arrow. Fermilab can study the processes with the Tevatron and smaller accelerators now, and many physicists would like to expand those capabilities.

That's a future far more consistent with Fermilab's forte—studying very precisely controlled sources of particles—than the future envisioned by Kolb, say Hill and Bernstein. But one experimental prospect has both cosmologists and particle types excited: the "long baseline experiment." In this still-unfunded experiment, a calibrated beam of the ephemeral, supposedly massless particles called neutrinos would be sent all the way from the Tevatron to an underground detector in Minnesota.

The goal would be to see whether the neutrinos switch identity during their journey, from one of the three neutrino types to another. If so, theorists say, neutrinos would have to have mass—a finding that would revolutionize both cosmology and particle physics. Neutrinos with a trace of mass would give cosmologists a candidate for the dark matter, and they would give particle physicists an escape from the theory known as the Standard Model, which has defined and limited particle physics for more than a decade.

But doing the experiment requires the $185 million "main injector," a proposed upgrade to the Tevatron. And that kind of financial worry, more than philosophy, may go to the heart of the current controversy over Fermilab's future, says Kolb. "The controversy over this is 98% driven by the fact that the budget is so bad," he says. "The lab is really starving. We're like rats in a cage when the food starts running out. We start biting each other's feet."

–Faye Flam