Son of FermiLab

Toward the marvels of 1 TeV physics

by Dietrick E. Thomsen

In a tunnel in the middle of the "village," the cluster of houses that was once the suburban tract called Weston and later became the first administrative home of the Fermi National Accelerator Laboratory (FermiLab), particle physics is meeting superconductivity. The confrontation may be a strain for both, but if it succeeds, it will provide very interesting physics at ultrahigh energies.

The tunnel is called the protomain, and its original purpose was to provide a realistic setting for the assembly and testing of magnet sections for the main ring of the 500-billion-electron-volt (500-GeV) accelerator. Now it is housing the second generation, providing a place to show what a combination of superconducting magnets and long-distance cryogenic refrigeration can do for the future of particle physics. The result will be the energy doubler, which, if the full project is authorized, will be a second ring of magnets (superconducting this time) and accelerating sections laid in the main tunnel, which will double the accelerator's energy, reaching the magic, and a few years ago, unbelievable, number of 1,000 GeV, one tera-electron-volt (TeV).

Particle physicists will not stop escalating. While they build one accelerator, they are already planning the next step. FermiLab was first planned for 200 GeV. It soon became clear that modifications in the design within the original budget could boost that to 500 GeV, and the option was taken. As construction for 500 GeV went ahead, the idea of the energy doubler surfaced. Room was left for a second ring of magnets in the layout of the main tunnel, and at first, FermiLab's Director Robert R. Wilson thought the doubler could be completed with money left over from the construction budget, but for certain fiscal reasons that did not prove possible. Now FermiLab has a separate authorization to build one-sixth of the total energy doubler circle, and if that works well, it hopes to get money for the rest.

It had to be superconducting. There was no other way to make it fit. Using conventional magnets to bend the path of protons traveling with energies up to one TeV into a loop would require a huge circle. A decade ago John P. Blewett of Brookhaven National Laboratory figured it would be 15 miles in circumference. Improvements in technology in the intervening time may have lessened the size of the conventional option, but it still would not fit the present tunnel. More important is the power. With superconductors one gets the necessary high magnetic fields for very little expenditure. With conventional magnets the power bill would gladden the hearts of Persian Gulf sheiks, but it would give American Congressional committees apoplexy.

But with superconductivity you get problems. The technology is far from being in the assembly-line stage. For example, there is refrigeration. To stay superconducting the magnets must be maintained at liquid-helium temperatures. This means setting up a series of refrigerators around the accelerator ring and pumping the cold helium up to 200 feet in each direction from the refrigerators and circulating it through the magnets and having it stay cold all the way.

The magnets themselves are the most serious technological problem. Superconducting magnets are generally made on a one-by-one basis according to a custom design. What the energy doubler needed was mass-produced superconducting magnets, 1,000 of them. The other key word is "cheap." The design goal is to get a superconducting magnet for something like the price of a conventional magnet in the present accelerator ring, $12,000. This would keep the cost of the energy doubler around $20 million. That would mean that for less than a tenth of the capital so far invested in FermiLab, the energy could be doubled.

As William Fowler tells the story, planning for the doubler began in 1971 —before the present main ring was operative—with a week's preparatory work by a group of interested FermiLab staff. By October 1971 they were having weekly meetings to review current superconducting-magnet technology. Their first hope was that they could copy an existing design and concentrate their effort on devising means of mass production. "We thought we could copy," says Fowler, "but we concluded we had to have our own program."

Improved designs became available thanks to the work of people at Brookhaven National Laboratory, where a storage-ring project called ISABELLE is under consideration, but these too proved unsuitable to copy, and the FermiLab people finally went to their own warm-iron design. Models were made and tested in the spring of 1973. The jump to full scale was made in the summer and fall of 1973. The magnets took longer to make than expected, but the first full-scale magnet, 20 feet long, was ready for test in February 1974.

It was a disappointment. It would not go to the full field that the models theoretically went. It would produce only half that. The models had been made with an existing superconductor, and in the full scale there were problems with its performance and with structures to retain the forces involved. To find the changes they needed to make, the designers went back to experimenting with short lengths and stopped building 20-footers. By fall 1974 they felt they had the problem solved and that they were building the final doubler magnet.

Two-and-a-half-foot lengths of this have now been tested, and they are approaching the design field quite satisfactorily. Work has begun on 10-foot sections, and six 20-foot sections are scheduled for construction in the period between February and June 1975. If they work as specified, the next step will be to assemble a prototype section of the doubler in conjunction with what the group hopes is the "final" refrigerator design.

From there things are a bit uncertain. In the recent flurry of budget cutting $6 million was removed from FermiLab's budget, and then $3 million of that was restored. It is not clear how much the doubler will suffer, but it may need a further infusion of money to complete the one-sixth of the circle contemplated. Meanwhile the refrigeration for the one-sixth circle has been ordered, and all the copper for the full circle has been purchased because of an opportunity to get high-grade copper at a very favorable price. After the one-sixth circle is completed, the people working on the project hope that experience with it and the demonstration of what it can do for the laboratory will convince the Government to finance the whole circle.

And then we'll be off to one-TeV physics and all the marvels that may be lurking in the ultrafine details of the structure of matter. □