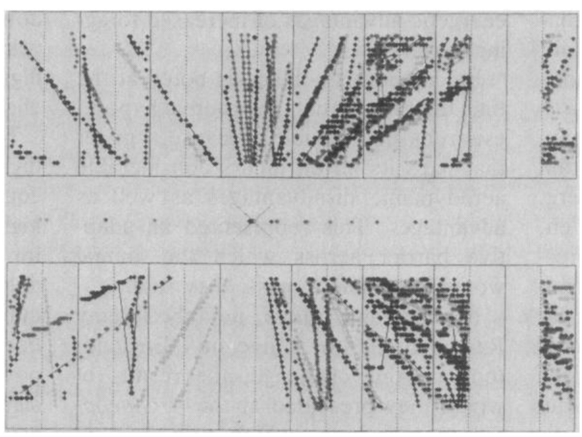
Proton-Antiproton Collisions at Fermilab

On 13 October at 3:30 a.m., after several weeks of frantic, around-the-clock running, researchers at the Fermi National Accelerator Laboratory near Chicago succeeded in obtaining proton-antiproton collisions in the Tevatron. With the proton and antiproton beams circulating in opposite directions, each with an energy of 0.8 teraelectron volts (TeV), the center-of-mass or collision energy was 1.6 TeV, now the world's highest. The previous record holder is a machine at the European Laboratory for Particle Physics (CERN) near Geneva, which can run continuously at a collision energy of 0.63 TeV or in a low-intensity pulsed mode at 0.9 TeV. "Everyone is incredibly happy," says John Peoples, who headed a key part of the project, the antiproton source (*1*).

Providing evidence for the collisions was the partially completed Collider Detector at Fermilab (CDF), a huge complex system that will weigh about 4500 tons and cost $65 million when finished. The CDF, which is being built by a collaboration of almost 200 physicists from ten U.S. universities and three Department of Energy national laboratories, from Italy, and from Japan, recorded ten collision events. Once the evidence was in hand, the collaboration hosted at 4 a.m. an appropriately big champagne party for the entire Fermilab accelerator staff.



1.6-TeV proton-antiproton collision

The innermost part of the CDF detector is the Vertex Time Projection Chamber. It comprises a set of eight gas-filled chambers. As high-energy particles fly away from the collision point, they leave wakes of ionized gas. The ions drift to the ends of their respective chambers, where they are detected, thereby providing a three-dimensional view of the particle tracks, a kind of electronic bubble chamber.

The reason for the rush was the presence of a squadron of bulldozers and other heavy equipment that was poised to begin a months-long project to construct an experimental hall for a second large detector and to make a final modification of the Tevatron that would allow the entire CDF, when completed next year, to fit into place around the accelerator where collisions occur. The original deadline was 1 October, but this was extended a few days at a time, partly in the hope of obtaining collisions in time for the official dedication of the Tevatron as a colliding-beam machine on 11 October with Illinois Governor James R. Thompson and DOE Secretary John S. Herrington in attendance.

The two main tasks to be accomplished to obtain collisions were commissioning the antiproton source and injecting the antiprotons into the Tevatron. The design specifications call for storing about 2×10^{11} particles in the part of the antiproton source known as the accumulator ring, when everything is working perfectly. Fermilab physicists stored their first antiprotons in mid-September, but the number was small, a few million. By the end of the month, they had increased that figure to a few billion and were satisfied that there were no fundamental problems standing in the way of doing better. Improving the performance was mainly a matter of tuning up the various parts of the system.

As dedication day came and passed, the count in the accumulator ring mounted to about 10^{10} antiprotons, and it was decided to begin injecting them into the Tevatron. At this point, responsibility shifted from Peoples and the antiproton source project to Helen Edwards, deputy head of Fermilab's accelerator division. Edwards had said in so many words, "If you can get me some antiprotons, I will make them collide." It sounds easy, but the process can be broken down into some 20 separate operations, each of which can result in some loss of particles.

In outline, antiprotons are squirted from the accumulator ring through a long transfer line into Fermilab's original proton-synchrotron, now known simply as the main ring. After being accelerated to 0.15 TeV in the main ring, they are transferred into the Tevatron, which lies in the same tunnel directly below the main ring. In the Tevatron, protons and antiprotons are accelerated together to the final energy, 0.8 TeV at present but 1 TeV eventually. One example of the kind of manipulation involved stems from the fact that the two beams are not continuous but comprise discrete bunches or packets of particles. In order for collisions to take place exactly in the center of a detector, the countercirculating bunches must be properly synchronized.

The procedure taken was to extract a "shot" of some 8×10^8 antiprotons from the accumulator, take some time to understand what happened when attempting to inject the shot into the Tevatron, and try another shot based on the new knowledge. According to Peoples, by the fourth shot, antiprotons were being reliably injected into the main ring. And collisions were finally obtained on the ninth and tenth shots early in the morning of 14 October. After the eleventh shot, the evidence for collisions was certain. By 5 a.m. parts of the accelerator were already being disassembled in preparation for the bulldozers and the civil construction project, which has a tight schedule of its own.

The collision rate measured by the CDF was about one millionth that hoped for eventually, and no one expected anything new or surprising in such a few events. The important thing, says Peoples, is that "Everything that was supposed to work, worked," a sentiment echoed by members of the CDF collaboration apropos their detector. The job now is to make it all work well enough for physics experiments when the collider experimental program begins next fall.—**Arthur L. Robinson**

Reference

1. A. L. Robinson, *Science* **229**, 1374 (1985).