Colliders spur hunt for antimatter answers

Hoping to escape the doldrums of a monotonously successful theory, particle physicists are scrambling to launch two new vessels on a race into the unknown.

The craft are particle smashers at the KEK High Energy Accelerator Research Organization in Tsukuba, Japan, and the Stanford (Calif.) Linear Accelerator Center (SLAC). The underground machines promise to carry researchers deep into an ill-mapped realm of physics known as charge-parity (CP) violation. After years of construction (SN: 10/16/93, p. 245), workers on both sides of the Pacific are this week gingerly firing up the particle beams of their newly assembled electron-positron colliders.

"It's like launching a space lab. It's a big adventure," says Gerard Bonneaud of the École Polytechnique in Palaiseau, France, who is working on the SLAC machine.

Both projects are running at full throttle, with teams on duty around-the-clock. "This is a ferocious competition," says Tom Browder, a KEK collaborator at the University of Hawaii in Honolulu.

Once in full operation by the end of this summer, the colliders should make copious B mesons, or Bs. These particles are suspected of being especially prone to CP violations. After another year, the machines, called B factories, may reach their design rates of some 30 million pairs of Bs and anti-Bs per year at SLAC and about three times as many at KEK.

By exposing instances of CP violation suspected to lie in B decays but unaccounted for in the prevailing theory, the colliders offer physicists a chance to finally confound the 20-year-old theory known as the standard model.

"Every experiment we've done has been confirming [the standard model]. We're getting bored," says theoretical physicist Helen R. Quinn of SLAC. "Only discrepancies with established theory teach us anything new."

"CP violation is one of the main scientific questions at the end of this century," Bonneaud adds. By exploring it, scientists hope to explain why the universe is made up almost exclusively of matter despite having likely started with a 50-50 mix of matter and antimatter.

Some process in the early universe must have favored matter over antimatter, they surmise; otherwise, the two types of substance would have annihilated each other by now. Uncovering that asymmetric process would tell us "essentially why we are here in this world," says KEK collaborator Kazuo Gotow of the Virginia Polytechnic Institute and State University in Blacksburg.

Physicists believe that matter triumphed because of a slight bias in the laws of physics. Scientists have found, for instance, that the fundamental particle interaction known as the weak interaction occasionally applies unequally to particles, creating a CP violation.

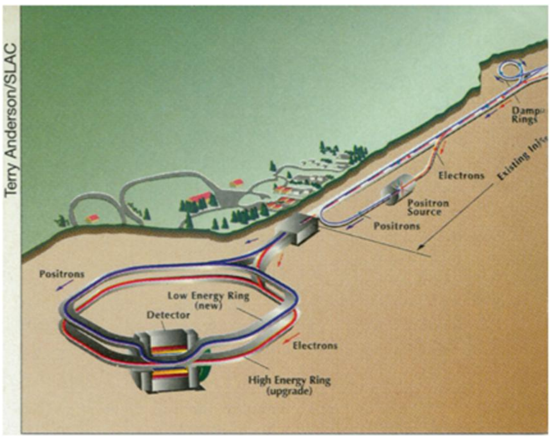
Decays of only one class of particle, made up of kaons and antikaons, have shown unmistakable signs of this CP violation. In February, however, physicists at the Fermi National Accelerator Laboratory in Batavia, Ill., announced a strong hint of CP violation in B-meson decays as well (SN: 2/20/99, p. 118).

To get a definitive measurement of CP violations, the B factories will first study the so-called golden mode, in which a B or an anti-B disintegrates into a J/psi particle and a K-short, a type of kaon. Scientists expect the factories to operate for a decade or more, giving them time to probe others of the dozens of modes of B breakdown.

The two new B factories, which cost roughly a quarter billion dollars each, are taking the novel tack of colliding electrons and positrons of unequal energy. The momentum of the mismatched collisions drives the Bs and anti-Bs at a known speed along the direction of the more energetic electron beam. The motion gives physicists a timeline by which to clock minute differences in the B and anti-B decay rates. These discrepancies signal CP violation.

Accelerators at Cornell University, Fermilab, and in Germany are also hot on the trail of CP violation in Bs, but they use different techniques to make the particles. —*P. Weiss*

Terry Anderson/SLAC



Electron beam (red) meets positron beam (blue) head-on in a detector in California tuned to recognize B-meson decays.

Chaotic reflections within a glittery eye

The structure is simple: four shiny spheres stacked like cannonballs to form a pyramid with a triangular base. The view between the spheres, however, is spectacularly complex.

The three spheres of one of the pyramid's faces frame an intricate pattern of multiple reflections. Described as a fractal, that pattern displays the complexity of the paths taken by light traveling through the structure.

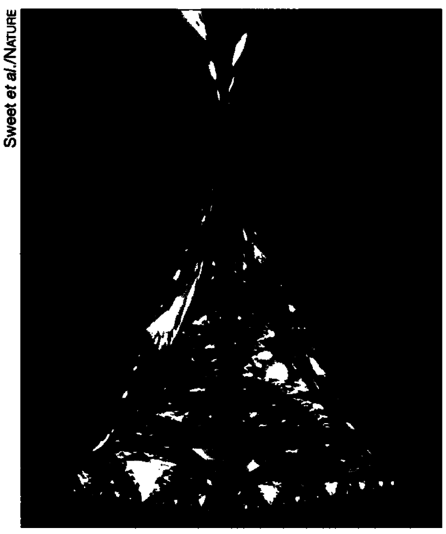
For example, a light ray entering the inner chamber reflects from sphere to sphere in such a way that, for certain incoming paths, it's impossible to predict from which face the ray will emerge. David Sweet, Edward Ott, and James A. Yorke of the University of Maryland in College Park report this finding in the May 27 NATURE.

Their laboratory model could prove useful for characterizing a physical phenomenon known as chaotic scattering, the researchers say.

To map exit points, Sweet and his coworkers place the four-ball pyramid on a translucent white sheet illuminated from below and put colored poster board outside two of the three exposed faces. A camera in the dark records light emerging from the uncovered opening on the remaining exposed face.

The resulting image registers a pattern of blue, red, white, and black that depends on the light's path. A blue patch within the image, for example, would represent the paths of light rays that reflected off the blue board at some point.

Sweet et al./NATURE



A camera captures an intricate fractal pattern created by multiple reflections in a pyramid of four shiny spheres framed by red and blue poster board.

Conversely, when researchers aim a laser into the pyramid at a blue patch in the image, the beam produces a bright spot on the blue board, indicating where the light emerges. The image also contains boundary regions where the four colors inextricably intertwine. A laser beam directed at these areas appears through all four openings because it hits all the colors. Computer simulations reveal that an infinitely narrow laser beam's path would be unpredictable. —*I. Peterson*