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# Big Project Dead, Physicists Find Small Is Beautiful

By WILLIAM J. BROAD

Scattered bands of inventors are quietly laboring to insure that physics, three centuries after its birth, has a chance to keep advancing into its most challenging realms despite the recent collapse of its flagship project, the superconducting supercollider, which would have been the biggest science experiment of all time.

In universities and at research centers from coast to coast, inventors are toying with innovative ways to throw the age of gargantuan accelerators into reverse yet still achieve great energies of collision. They are relying on bright ideas rather than big budgets and tracts of land.

These inventors are trying to devise relatively small machines that would do the same kind of experiments that had been envisioned for the superconducting supercollider, or SSC, which was to have measured 54 miles around and cost up to $11 billion. In October, Congress canceled the half-built machine in Waxahachie, Tex., calling it an inordinate drain on the Federal budget.

Recently, scientists at the University of California at Los Angeles told of promising results in the search for a technique that one day might lead to a replacement device. They reported in Nature magazine on April 7 that a room-sized machine powered by a pair of lasers accelerated electrons on a plasma wave to nearly the speed of light, making them zip along much as a surfer rides the crest of an ocean wave.

"The SSC. is not the end of the line," Dr. Chandrashekhar J. Joshi, an electrical engineer who heads the six-person U.C.L.A. team, said in an interview. "Just when you think everything is done, young people surprise you with their creativity."

Particle accelerators slam together tiny bits of matter to create intense fireballs almost as hot as those that existed at the beginning of time during the Big Bang, the blast thought to have given rise to the universe. Condensing out of such miniature explosions are streams of subatomic particles that physicists believe are nature's most elementary building blocks.

The current generation of accelerators falls short of the very intense energies of collision needed to answer some of the most fundamental questions of all, like why does matter have mass?

Even with steady advances, the new machines might take decades to perfect, scientists say, and there is no guarantee of success. But progress is occurring and is deemed important, if for other reason than to build morale among high-energy physicists, who are still reeling from the SSC's death.

Dr. Martha A. Krebs, director of energy research at the Federal Department of Energy, which provides funds for much of the small-accelerator-development work, said in an interview that the U.C.L.A. advance "comes at a very nice time to indicate there's a strong future for the U.S. high-energy physics community."

She added: "The challenge is to get from where we are now to the time when these new machines can be built and implemented. There's a real opportunity for the U.S. accelerator community to be creative and innovative."

The evolution of atom smashers got under way in 1929 when Ernest O. Lawrence, the American physicist, invented the cyclotron. It fit in the palm of his hand. The device was built from borrowed magnets as well as some brass, glass and wire, all held together

Continued on Page B9

# Physicists Find That Small Is Beautiful

*Continued From Page B5*

with solder and sealing wax. The parts cost less than $10. Four inches in diameter, the device spun hydrogen nuclei in a circular path, boosting them to an energy of 80,000 electron-volts.

In contrast, the superconducting supercollider was to have a collision energy of 40 trillion electron-volts. The machine was to be 20 times more powerful than any existing accelerator and was to require 10,000 superconducting magnets of a technical sophistication never before attempted.

Over the decades, as most of the "easy" discoveries have been made, accelerators have grown in size. Now insights have to be wrestled from the very heart of nature.

For decades, the conventional method of acceleration has been to use radio waves, whose crests can impart great speed to subatomic particles. But if too much power is applied to the radio-frequency cavities, the technique starts to fail and produce spurious flows as the metallic atoms in cavity walls have their electrons torn loose.

The response was to build accelerators not in straight lines, as had been done for years, but in ever-expanding "race tracks" where particles went round and round. Powerful magnets kept them on the curving path. This step allowed packets of speeding particles to be accelerated a little bit each time they passed through a growing gauntlet of radio-frequency cavities, while keeping the cavities themselves operating below the point of deterioration. As needs grew for higher energies of collision, the race tracks had to be built larger and larger. By the late 1970's, long before the birth of the SSC plan in 1983, it was becoming clear to experts that the steady evolution of circular atom smashers one day would halt as they grew too expensive to build. Moreover, new ideas began to circulate that offered hope of eventually speeding subatomic particles in radically new ways.

In 1980, Dr. Maury Tigner, a Cornell University physicist, led a Federal panel that recommended that about 4 percent of the Federal accelerator budget be invested in new ideas.

While the actual percentage has fluctuated up and down, the Energy Department over the last decade or so has succeeded in sowing enough seed money to spur significant growth. The general goal has been to develop linear accelerators that work without radio-frequency cavities and produce powerful gradients that speed particles to tremendous velocities over a relatively short distance.

**The U.C.L.A. Approach**

At U.C.L.A., Dr. Joshi's team has worked for years on a technique known as the beat-wave accelerator. In this approach, two lasers fire into a hydrogen gas and create a very hot state of matter known as a plasma. The lasers work at different frequencies, so their beams create in the plasma an instability that powers a series of energy waves through it at the speed of light. From a low-powered radio-frequency machine, electrons fired into this turbulent mix can be pushed to very high speeds.

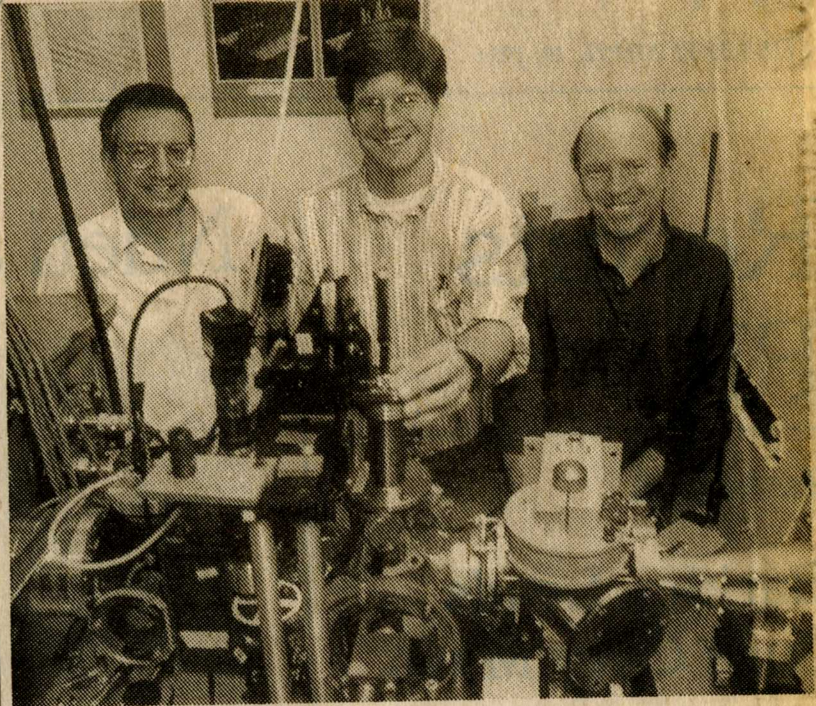
In the Nature article, Dr. Joshi and his team report accelerations 50 to 100 times faster than what can be achieved with today's radio-frequency machines. The rub is that the action occurred over a small distance — less than half an inch.

"We've shown that we can build a very fast car," Dr. Joshi said. "But we don't know if it will go very far." In the future, he added, his team plans to work on increasing the speed and the length of the acceleration area.

A commentary in Nature by Dr. Robert Bingham, a scientist at the Rutherford Appleton Laboratory in England, said the current round of U.C.L.A. work "surpassed all expectations" and promised to aid the development of "an entirely new type of technology for building high-energy accelerators."

At the Argonne National Laboratory in Illinois, scientists are pursuing another path to accelerating particles, the wake-field technique. In it, a cluster of electrons is shot down a straight accelerator beam line, trailing an electromagnetic wake all the way. A second cluster containing relatively few electrons is then fired down the line and gains energy at the expense of the first, as if by tailgating. Repetition of the process 1,000 or so times a second can accelerate electrons to nearly the speed of light.

Dr. James D. Simpson of Argonne said in an interview that his team had proved the basic feasibility of the wake-field approach and was preparing to switch on a demonstration project in the next few weeks. The driver is about 12 feet long, he said, and the acceleration area about three feet long. The goal is to demonstrate gradients of acceleration up to 10 times greater than those of radio-frequency cavities.

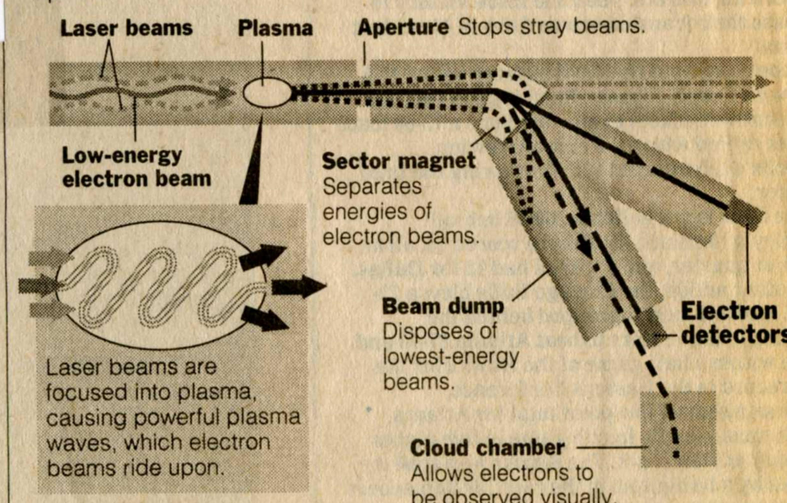


University of California, Los Angeles

Dr. Chandrashekhar J. Joshi, left, Dr. Kenneth Marsh, center, and Dr. Christopher Clayton, with plasma beat wave accelerator.

## Particle Accelerator on a Tabletop

New ways to study subatomic particles rely on speeding them to tremendous velocities over relatively short distances. The U.C.L.A. beat-wave accelerator uses two lasers firing at different frequencies into hydrogen gas to create a very hot and energized plasma. Waves of electric field, or plasma waves, move through it at the speed of light. Electrons fired into the plasma can be pushed to very high speeds.




*Source: Dr. Christopher Clayton, U.C.L.A.*

The New York Times; Illustration by John Papasian

**Making Use of Radiation**

Perhaps the most developed of the new acceleration methods is being tested at the Brookhaven National Laboratory on Long Island. The lab's Accelerator Test Facility, commissioned in late 1992, is running experiments on something known as the inverse Cerenkov effect. Cerenkov radiation, named after its Russian discoverer, P. A. Cerenkov, occurs when a charged particle travels through a medium at a speed faster than light can. The blue glow observed in the water around a nuclear reactor, and sometimes around submarines, is radiation of this kind.

In the acceleration method, the radiative process is reversed by firing a laser beam into a stream of electrons moving through a cloud of hydrogen gas, which acts as the Cerenkov medium. When the velocity of the light and particle are well synchronized, the electrons are speeded up.

In January, the technique was successfully tested at an acceleration level comparable to the current state of the radio-frequency art.

"It's the greatest ever seen from reverse Cerenkov," Dr. Wayne D. Kimura, the head of the experimental team, said in an interview. Dr. Kimura is vice president of STI Optronics Inc., a high-technology company in Bellevue, Wash.

The goal, he said, is eventually to achieve rates of acceleration 20 times greater than radio-frequency cavities. "There's a real need to get to these higher energies," he said.

Dr. Krebs of the Department of Energy echoed that comment, adding that her agency had "a big interest" in affirming its interest in the field.

"We have a commitment to working through the problems of this field after the SSC," she said. "We understand our responsibility and our stewardship."