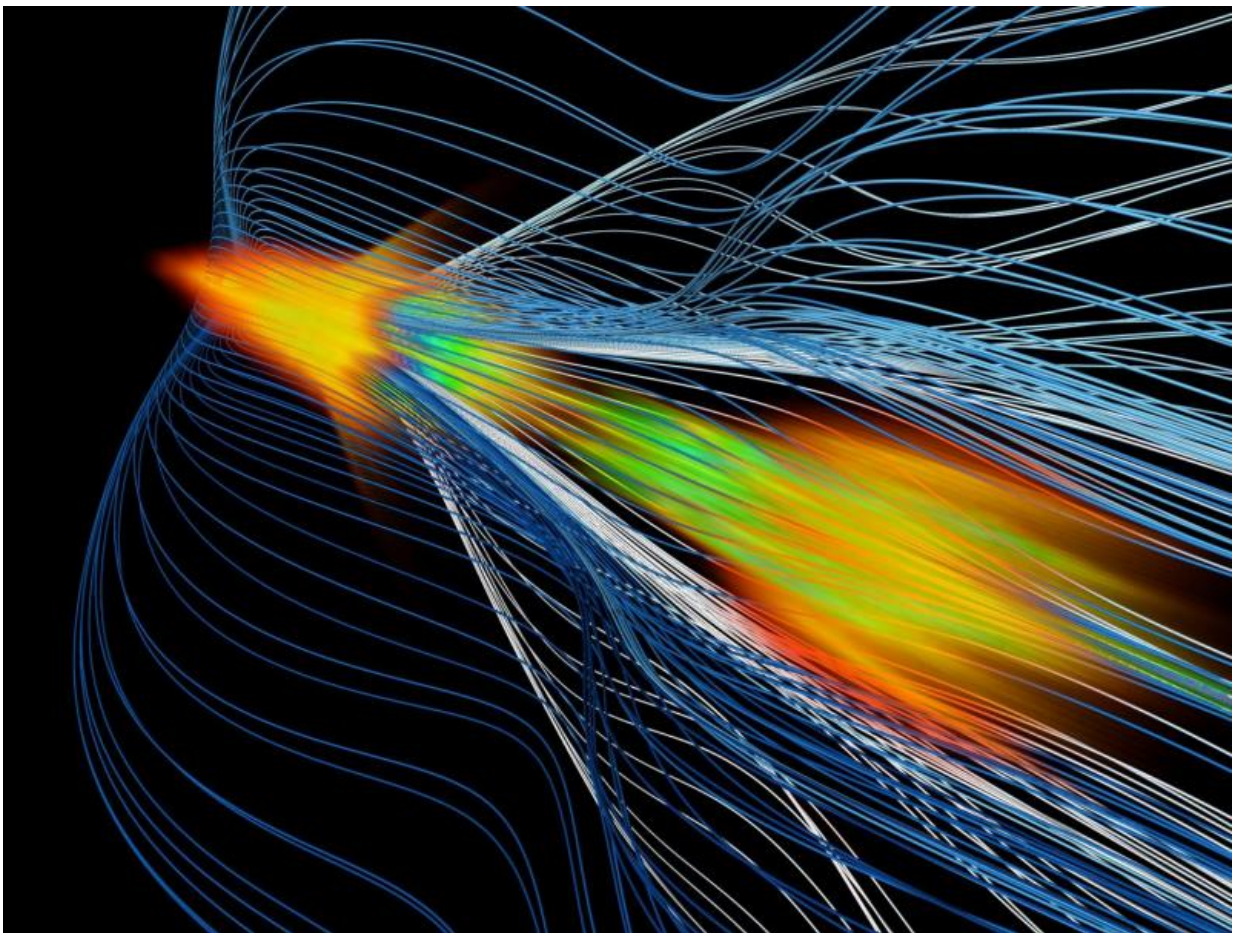


Antimatter catches a wave: Accelerating positrons with plasma is a step toward smaller, cheaper particle colliders

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Simulation of high-energy positron acceleration in an ionized gas, or plasma -- a new method that could help power next-generation particle colliders. The image shows the formation of a high-density plasma (green/orange color) around a positron beam moving from the bottom right to the top left. Plasma electrons

pass by the positron beam on wave-like trajectories (lines) Credit: W. An/UCLA

A study led by researchers from the U.S. Department of Energy's (DOE) SLAC National Accelerator Laboratory and the University of California, Los Angeles has demonstrated a new, efficient way to accelerate positrons, the antimatter opposites of electrons. The method may help boost the energy and shrink the size of future linear particle colliders - powerful accelerators that could be used to unravel the properties of nature's fundamental building blocks.

The scientists had previously shown that boosting the energy of charged particles by having them "surf" a wave of [ionized gas](#), or plasma, works well for [electrons](#). While this method by itself could lead to smaller accelerators, electrons are only half the equation for future colliders. Now the researchers have hit another milestone by applying the technique to positrons at SLAC's Facility for Advanced Accelerator Experimental Tests (FACET), a DOE Office of Science User Facility.

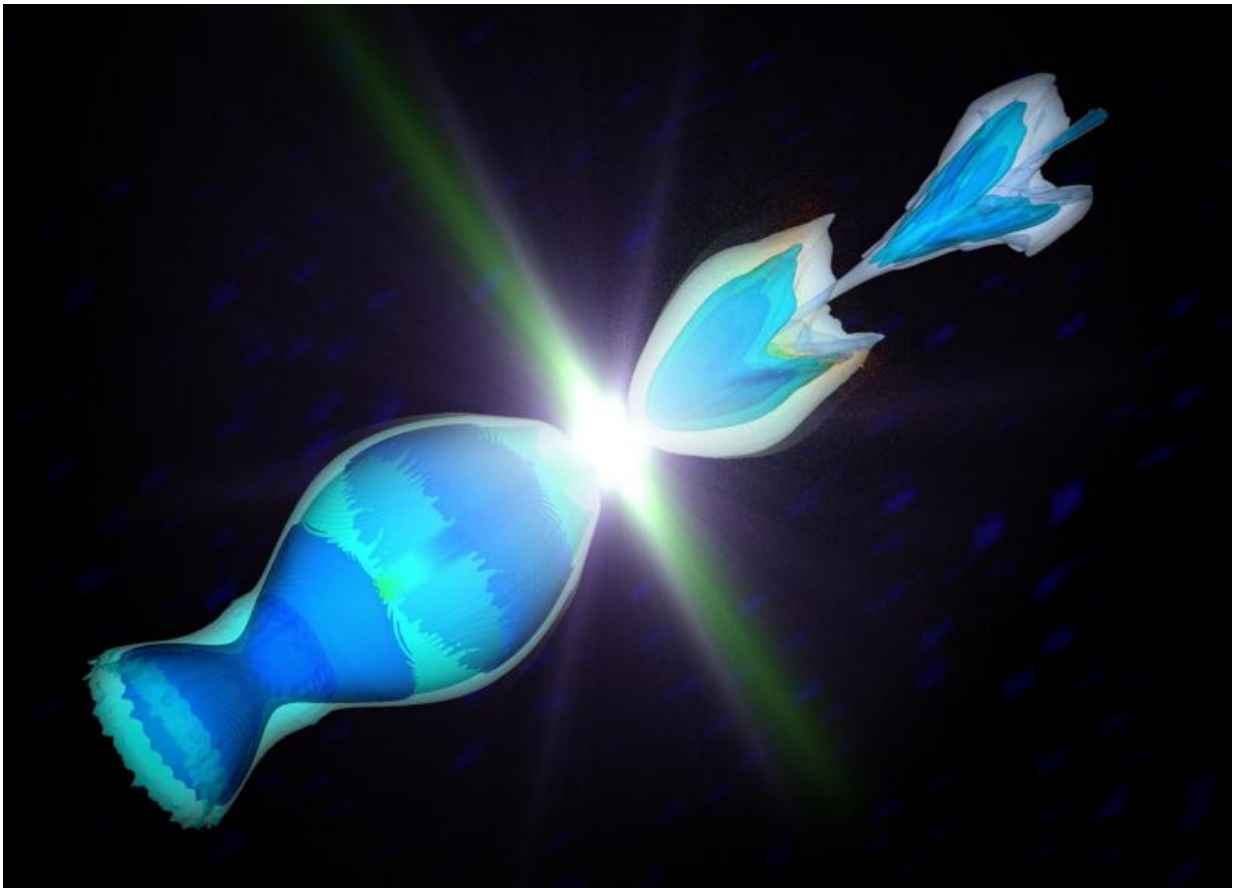
"Together with our previous achievement, the new study is a very important step toward making smaller, less expensive next-generation electron-positron colliders," said SLAC's Mark Hogan, co-author of the study published today in *Nature*. "FACET is the only place in the world where we can accelerate positrons and electrons with this method."

SLAC Director Chi-Chang Kao said, "Our researchers have played an instrumental role in advancing the field of plasma-based accelerators since the 1990s. The recent results are a major accomplishment for the lab, which continues to take accelerator science and technology to the next level."

Shrinking Particle Colliders

Researchers study matter's fundamental components and the forces between them by smashing highly energetic particle beams into one another. Collisions between electrons and positrons are especially appealing, because unlike the protons being collided at CERN's Large Hadron Collider - where the Higgs boson was discovered in 2012 - these particles aren't made of smaller constituent parts.

"These collisions are simpler and easier to study," said SLAC's Michael Peskin, a theoretical physicist not involved in the study. "Also, new, exotic particles would be produced at roughly the same rate as known particles; at the LHC they are a billion times more rare."



Future particle colliders will require highly efficient acceleration methods for

both electrons and positrons. Plasma wakefield acceleration of both particle types, as shown in this simulation, could lead to smaller and more powerful colliders than today's machines. Credit: F. Tsung/W. An/UCLA/SLAC National Accelerator Laboratory

However, current technology to build electron-positron colliders for next-generation experiments would require accelerators that are tens of kilometers long. Plasma wakefield acceleration is one way researchers hope to build shorter, more economical accelerators.

Previous work showed that the method works efficiently for electrons: When one of FACET's tightly focused bundles of electrons enters an ionized gas, it creates a plasma "wake" that researchers use to accelerate a trailing second electron bunch.

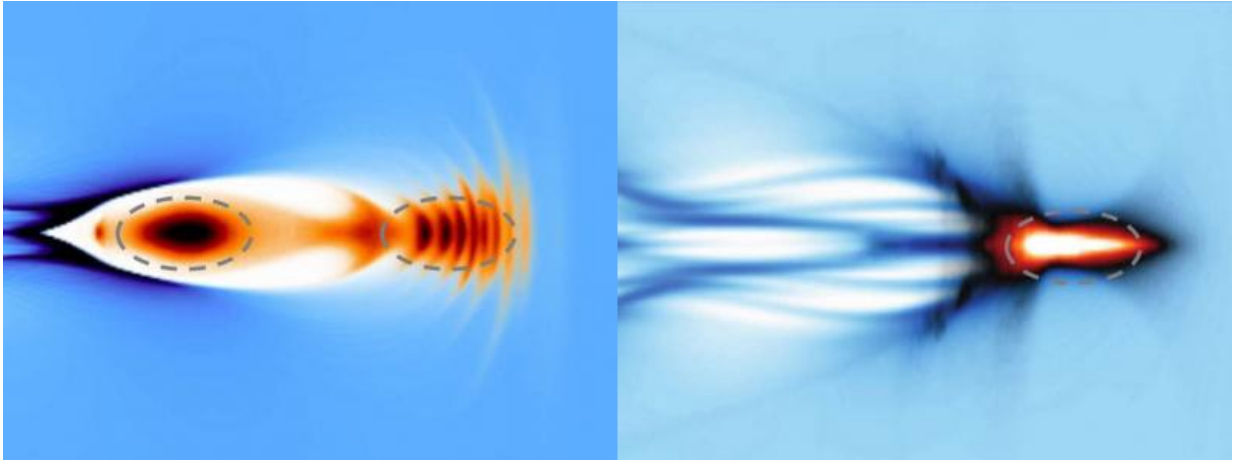
Creating a Plasma Wake for Antimatter

For positrons - the other required particle ingredient for electron-positron colliders - plasma wakefield acceleration is much more challenging. In fact, many scientists believed that no matter where a trailing positron bunch was placed in a wake, it would lose its compact, focused shape or even slow down.

"Our key breakthrough was to find a new regime that lets us accelerate positrons in plasmas efficiently," said study co-author Chandrashekhar Joshi from UCLA.

Instead of using two separate particle bunches - one to create a wake and the other to surf it - the team discovered that a single positron bunch can interact with the plasma in such a way that the front of it generates a wake that both accelerates and focuses its trailing end. This occurs after

the positrons have traveled about four inches through the plasma.



Computer simulations of the interaction of electrons (left, red areas) and positrons (right, red areas) with a plasma. The approximate locations of tightly packed bundles of particles, or bunches, are within the dashed lines. Left: For electrons, a drive bunch (on the right) generates a plasma wake (white area) on which a trailing electron bunch (on the left) gains energy. Right: For positrons, a single bunch can interact with the plasma in such a way that the front of the bunch generates a wake that accelerates the bunch tail. Credit: W. An/UCLA

"In this stable state, about 1 billion positrons gained 5 billion electronvolts of energy over a short distance of only 1.3 meters," said former SLAC researcher Sébastien Corde, the study's first author, who is now at the Ecole Polytechnique in France. "They also did so very efficiently and uniformly, resulting in an accelerated bunch with a well-defined energy."

Looking into the Future

All of these properties are important qualities for particle beams in

accelerators. In the next step, the team will look to further improve their experiment.

"We performed simulations to understand how the stable state was created," said co-author Warren Mori of UCLA. "Based on this understanding, we can now use simulations to look for ways of exciting suitable wakes in an improved, more controlled way. This will lead to ideas for future experiments."

Although plasma-based particle colliders will not be built in the near future, the method could be used to upgrade existing accelerators much sooner.

"It's conceivable to boost the performance of linear [accelerators](#) by adding a very short plasma accelerator at the end," Corde said. "This would multiply the accelerator's energy without making the entire structure significantly longer."

More information: Multi-gigaelectronvolt acceleration of positrons in a self-loaded plasma wakefield, *Nature*, [DOI: 10.1038/nature14890](https://doi.org/10.1038/nature14890)

Provided by SLAC National Accelerator Laboratory

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