

Design of the W7-X fusion device enables it to overcome obstacles, scientists find

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PPPL physicist Novimir Pablant. Credit: Elle Starkman/PPPL Office of Communications.

A key hurdle facing fusion devices called stellarators—twisty facilities that seek to harness on Earth the fusion reactions that power the sun and

stars—has been their limited ability to maintain the heat and performance of the plasma that fuels those reactions. Now collaborative research by scientists at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and the Max Planck Institute for Plasma Physics in Greifswald, Germany, have found that the Wendelstein 7-X (W7-X) facility in Greifswald, the largest and most advanced stellarator ever built, has demonstrated a key step in overcoming this problem.

Cutting-edge facility

The cutting-edge facility, built and housed at the Max Planck Institute for Plasma Physics with PPPL as the leading U.S. collaborator, is designed to improve the performance and stability of the plasma—the hot, charged state of matter composed of free electrons and atomic nuclei, or ions, that makes up 99 percent of the visible universe. Fusion reactions fuse ions to release massive amounts of energy—the process that scientists are seeking to create and control on Earth to produce safe, clean and virtually limitless power to generate electricity for all humankind.

Recent research on the W7-X aimed to determine whether design of the advanced facility could temper the leakage of heat and particles from the core of the plasma that has long slowed the advancement of stellarators. "That is one of the most important questions in the development of [stellarator](#) fusion devices," said PPPL physicist Novimir Pablant, lead author of [a paper describing the results](#) in *Nuclear Fusion*.

His work validates an important aspect of the findings. The research, combined with the findings of an [accepted paper](#) by Max Planck physicist Sergey Bozhenkov and a paper under review by physicist Craig Beidler of the institute, demonstrates that the advanced design does in fact moderate the leakage. "Our results showed that we had a first

glimpse of our targeted physics regimes much earlier than expected," said Max Planck physicist Andreas Dinklage. "I recall my excitement seeing Novi's raw data in the control room right after the shot. I immediately realized it was one of the rare moments in a scientist's life when the evidence you measure shows that you're following the right path. But even now there's still a long way to go."

Common problem

The leakage, called "transport," is a common problem for stellarators and more widely used fusion devices called tokamaks that have traditionally better coped with the problem. Two conditions give rise to transport in these facilities, which confine the plasma in magnetic fields that the particles orbit.

These conditions are:

- Turbulence. The unruly swirling and eddies of plasma can trigger transport;
- Collisions and orbits. The particles that orbit [magnetic field](#) lines can often collide, knocking them out of their orbits and causing what physicists call "neoclassical transport."

Designers of the W7-X stellarator sought to reduce neoclassical transport by carefully shaping the complex, three-dimensional magnetic coils that create the confining magnetic field. To test the effectiveness of the design, researchers investigated complementary aspects of it.

Pablant found that measurements of the behavior of plasma in previous W7-X experiments agreed well with the predictions of a code developed by Matt Landreman of the University of Maryland that parallels those the designers used to shape the twisting W7-X coils. Bozhenov took a detailed look at the experiments and Beidler traced control of the

leakage to the advanced design of the stellarator.

"This research validates predictions for how well the optimized design of the W7-X reduces neoclassical transport," Pablant said. By comparison, he added, "Un-optimized stellarators have done very poorly" in controlling the problem.

Further benefit

A further benefit of the optimized design is that it reveals where most of the transport in the W7-X stellarator now comes from. "This allows us to determine how much turbulent transport is going on in the core of the [plasma](#)," Pablant said. "The research marks the first step in showing that high-performance stellarator designs such as W-7X are an attractive way to produce a clean and safe fusion reactor."

More information: N. Pablant et al, Investigation of the neoclassical ambipolar electric field in ion-root plasmas on W7-X, *Nuclear Fusion* (2020). [DOI: 10.1088/1741-4326/ab6ea8](https://doi.org/10.1088/1741-4326/ab6ea8)

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