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Discovery provides a path to safe, clean, plentiful **energy**

The construction of a major new experimental fusion facility called ITER in Cadarache, France, will enable researchers to test the feasibility of fusion power. A Princeton Plasma Physics Laboratory discovery could help the giant reactor achieve success.

FUSION — the energy-producing reaction that powers our sun and most stars — can be a safe, clean and virtually limitless source for generating electricity on Earth, ending reliance on fossil fuels and curbing greenhouse-gas emissions. In the sun, gravity traps particles inside an ultra-hot charged cloud of gas known as plasma, forcing them to fuse and release their energy. On Earth, we use powerful magnets to force plasma particles to fuse and release their power at temperatures many times hotter than the center of the sun.

At the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL), which is managed by Princeton University, scientists have been making great strides in determining how to trap those particles in doughnut-shaped facilities called "tokamaks" — fusion devices that confine the plasma in magnetic fields in place of gravity.

Now, PPPL scientists have for the first time reproduced the key elements that double the tokamak's ability to prevent heat and energy loss that could slow or halt fusion reactions. Finding the factors that enable a doubling of the confinement of particles inside a plasma marks a major advance on the path to fusion energy and to creating an artificial sun on Earth to help power the world.

"This discovery provides understanding of a path to improved plasma performance," said Michael Zarnstorff, deputy director for research at PPPL. "It will enable physicists to predict with confidence the heating power required to keep plasma well-confined and to provide energy for the world."

This doubling of confinement, which has been poorly understood, is vital to current and future fusion devices, sometimes called "star jars," on the planet. The new understanding stems from a computer simulation that shows how a barrier can form to prevent the escape of heat and energy in plasmas.

PPPL scientists used a sophisticated computer code to show how the formation of the barrier occurs and reduces the turbulence at the edge of the plasma that produces such losses. The simulation took three days and 90 percent of the capacity of Titan, the fastest U.S. supercomputer, which can perform 27,000 trillion calculations per second.

"After 35 years, the fundamental physics has been simulated, thanks to the rapid development of the computational hardware, software and detailed physics understanding," said Choong-Seock Chang, managing principal research physicist at PPPL and leader of the nationwide team that developed the sophisticated code and produced the model.

Full understanding of the spontaneous transition to this mode, called high confinement, or H-mode, is essential for the demonstration of the feasibility of fusion power planned for a new international fusion facility known as ITER under construction in France. Operators of the seven-story, 23,000-ton machine must achieve H-mode to reach the goal of producing 10 times more energy than ITER will consume.

Understanding the transition will allow operators to predict the heating power needed to reach H-mode. The goal: to have predictions that are more accurate than projections based on today's tokamaks, since conditions inside ITER, the largest and most powerful fusion facility so far conceived, will be significantly different.

Coming enhancements of the code will be part of the Exascale Computing Project, a nationwide program to develop computers that will run up to 50 times faster than Titan, improving U.S. security, economic competitiveness and scientific capability. PPPL leads an initiative that will develop the first complete model of an entire fusion plasma that could fuel a promising new era of energy production. **–By John Greenwald**