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Scientists Find a Shortcut to Map Conditions for Sustainable Fusion

Results derived from a new computer code are the first to map the full range of conditions required to reliably and safely sustain fusion reactions by alpha particle heating, and could facilitate the development of fusion as a clean and abundant source of energy.

PROVIDENCE—Fusion takes place when the atomic nuclei—or ions—in hot, electrically-charged plasma fuse and release energy. The temperatures in these fusion plasmas can reach more than 100 million degrees, igniting the plasma and producing high-energy alpha particles so the plasma heats itself. One challenge for a fusion reactor is how to contain the alpha particles in the vessel long enough for them to efficiently heat the plasma. These fast particles can excite waves in the plasma and be lost, or transported, to the vessel wall rather quickly, much in the same way a surfer rides waves to the beach.

Scientists at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) have collaborated with colleagues from other leading U.S. research institutions to develop a method for rapidly distinguishing among various plasma conditions—forming a type of map that highlights regions where alpha particles will likely be well confined and fusion can safely and reliably take place. The new method could help pave the way to the design and construction of fusion devices that can produce a steady flow of fusion energy for generating electricity. Such devices include ITER, a huge international project that is being built in France to demonstrate the practicality of fusion power.

The new study illustrates for the first time the full range of plasma conditions needed to maintain a self-sustaining fusion reaction, and delineates the regions where fast ion driven waves can occur inside the plasma causing unacceptable alpha particle transport.

"We have found a relatively simple way to quantify these requirements in terms of such easily accessible parameters as plasma pressure, temperature and density," said Nikolai Gorelenkov, an author of the paper that describes the method, which was published online in the journal Physics of Plasmas in August.

The researchers used a new computer code to calculate and plot the regions where fusion reactions can and cannot be easily maintained, an example of which is shown in Figure 1. The results demonstrate the correct combinations of temperature and a quantity called "beta"—the ratio of the pressure of the plasma to the pressure of the magnetic field that confines it—that are required to have good control of the alpha particles and keep the fusion reaction going.

"The importance of identifying the regions where fusion can take place cannot be overstated when building new devices," said Gorelenkov.

In the past, however, a single point on that figure would have taken the largest supercomputers in the world to calculate self-consistently. Now, with this simplified model, the entire "map" can be produced on a personal computer.

Collaborative work on this paper came from the Institute for Fusion Studies at The University of Texas at Austin; the DIII-D research project at General Atomics in San Diego; and the University of California, Irvine.

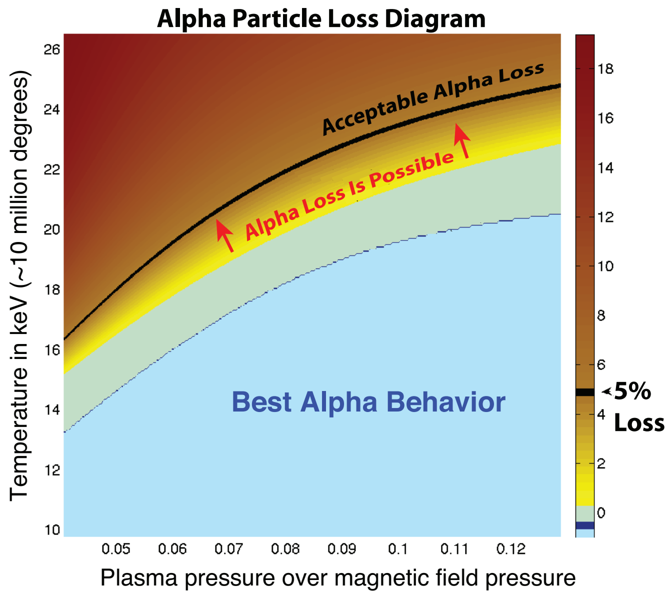

Figure 1. A diagram showing regions of plasma temperature (vertical axis) and beta (horizontal axis) in which fusion will be easiest to maintain ("Best Alpha Behavior") in magnetic confinement devices.

Paper: "1.5D quasilinear model and its application on beams interacting with Alfvén eigenmodes in DIII-D," published in Physics of Plasmas, v.19 (2012) 092511.
By K.Ghantous, N.N. Gorelenkov, H.L. Berk, W.W. Heidbrink, M.A. Van Zeeland.

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Abstracts:

UO7.00005	**Validation of quasilinear models for fast ion relaxation due to Alfvén Eigenmodes for burning plasmas**
Session	**ITER and Magnetic Fusion Development**, Room: 556AB, Thursday, November 1, 2012 2:48 PM–3:00 PM