Drifting and bouncing particles can maintain stability in fusion plasmas

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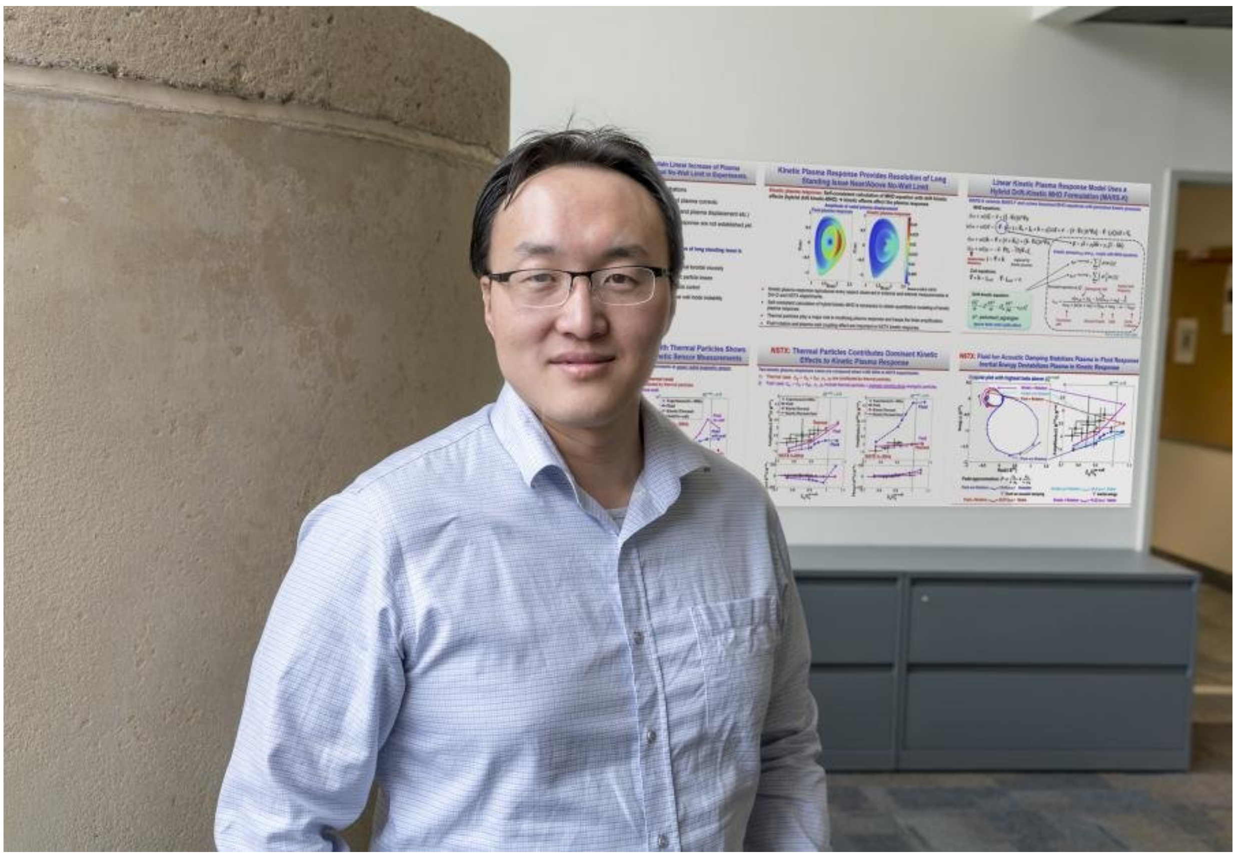

Credit: US Department of Energy

A key challenge in fusion research is maintaining the stability of the hot, charged plasma that fuels fusion reactions inside doughnut-shaped facilities called "tokamaks." Physicists at the U.S. Department of

Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL), have recently found that drifting particles in the plasma, which consists of free electrons and atomic nuclei, can forestall instabilities that reduce the pressure crucial to high-performance fusion reactions inside these facilities.

Fusion, the power that drives the sun and other stars, is the fusing of light elements in the form of plasma that produces massive amounts of energy. PPPL scientists seek to study and replicate fusion by heating the plasma to superhot temperatures inside a tokamak and confining it under pressure in spiraling, magnetic fields. Physicists use the term "beta" to characterize how the pressure of the heat produced by a tokamak compares with the pressure of the magnetic field used to contain the plasma.

Research led by Zhirui Wang used data from the National Spherical Torus Experiment (NSTX), a spherical tokamak at PPPL shaped like a cored apple that produces high-beta plasmas. Findings of the study explain how particles that drift and bounce within the fields can stabilize high-pressure and high-performing plasmas.

Such particles become trapped and bounce back and forth within a limited portion of the magnetic fields instead of traversing their entire circumference around the machine. The portions themselves can drift around the machine. The bouncing and drifting can dissipate energy that might otherwise destabilize the plasma and interfere with fusion reactions, the physicists found.

Researchers first noticed discrepancies between the NSTX data and simulation predictions. Modifying the code to take the trapped particles into account improved the agreement by producing simulations suggesting that the plasma would remain stable longer under high pressure, as the NSTX experiments showed. "We found that tokamaks can go to a higher beta because the plasma will be stabilized by these kinetic effects," said Wang, lead author of a paper describing the results in the journal Nuclear Fusion.

Improved kinetic simulations could also lead to better predictions and control of plasma instabilities known as edge-localized modes (ELMs), which appear at the edge of high-confinement plasmas and by unleashing large amounts of energy to the wall can significantly damage plasma-facing components in a fusion reactor. Better predictions would allow scientists to foresee when an ELM is about to occur and adjust magnetic controls so the instability is either mitigated or completely suppressed before it erodes the materials surrounding the fusion plasma.

Overall findings of this research could lead to improved achievement of high-performance fusion plasmas in present day tokamaks and in ITER, the international experiment under construction in France to demonstrate the feasibility of fusion power.

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