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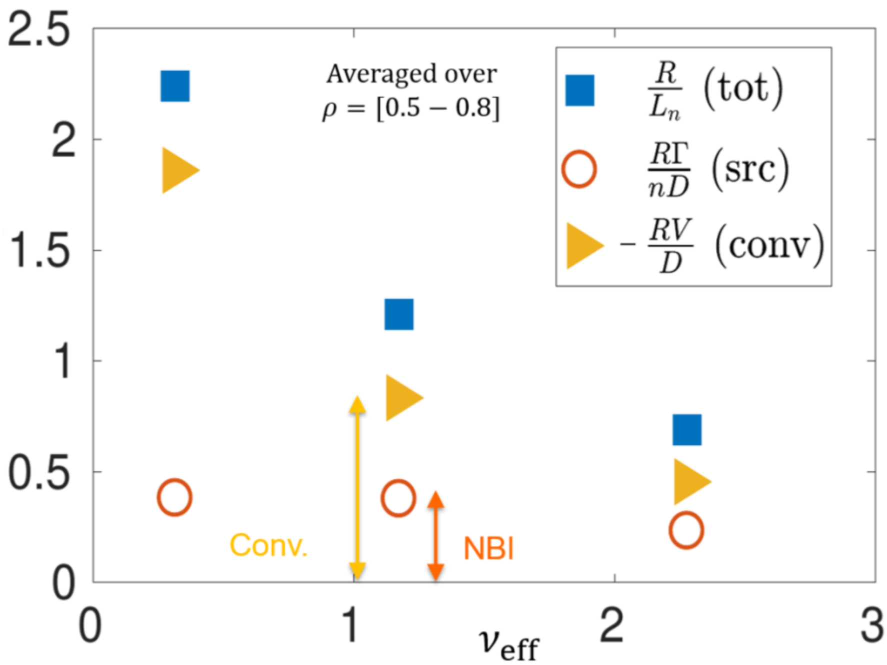
DIII-D Scientists Identify New Peaks in Fusion Power

Transport effects raise the density in the plasma core



Courtesy General Atomics

Density peaking increases with decreasing collisionality (blue squares). The largest increases in peaking are linked to changes in electron transport (yellow triangles) and not changes in core fueling (red circles). This shows that peaked density profiles can be obtained at low collisionality without core fueling.

The Science

Scientists at the DIII-D National Fusion Facility have found that in high-confinement plasmas, the density in the center of the plasma rises naturally. However, in previous experiments it was not possible to assess whether this increase was the result of direct deposition of particles or turbulent transport. In new experiments at DIII-D using novel experimental techniques, researchers were able to separately measure the deposition of particles and turbulent transport. The research showed that the increase is the result of electrons being transported through turbulence up a slope. This occurs through a complex interaction of the turbulence with the particle orbits. Reactors cannot be fueled in the core where most fusion reactions occur, but this research demonstrates that a higher core density is possible without direct core fueling. This approach could result in improved fusion performance.

The Impact

In a plasma, fusion events happen when deuterium and tritium in the plasma collide and fuse together. A higher plasma density increases the chances of such collisions. In fact, doubling the density leads to four times more fusion. DIII-D scientists have discovered that this hypothesized density “peaking” effect is important and have significantly advanced the understanding of this process. The result could raise the fusion power output from ITER.

Summary

Scientists conducted experiments at DIII-D to identify this density peaking effect. To do so, they had to strip out effects from particles being deposited in the core of the plasma by DIII-D's particle beam heating systems. They did this by carefully observing plasma behavior with pulses of gas and seeing how it traveled through the plasma.

This work is an important confirmation of theoretical expectations of such peaking, and provides a basis to refine models and develop projections for future fusion reactors. These techniques were also used to separate out the attractive "pinch" density peaking effects from the natural turbulent diffusion of particles away from the core. Diffusion arises because a peaked density in the core drives additional outward motion of particles (much as a compressed gas will move into a less dense area of a container).

DIII-D is equipped with many remote measurement systems to measure the turbulence itself. These provide powerful validation of state-of-the-art simulations of the turbulence, and a basis for predictive turbulent transport models that balance the pinch with the dissipation, thus determining the density profile. These encouraging results show that even without core fueling, peaked density profiles are possible, which should have a positive impact on the fusion power output of reactors.

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Publications

S. Mordijck, et al., “Collisionality driven turbulent particle transport changes in DIII-D H-mode plasmas,” *Nuclear Fusion*, **60**, 066019. [DOI: 10.1088/1741-4326/ab81aa]

Related Links

DIII-D Scientists Unravel Challenge in Improving Fusion Performance, General Atomics press release