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Neutral Particle Beams Work Better by Working Smarter

Enabling neutral particle beams to respond to plasma conditions in real time allows scientists to avoid instabilities and raise performance.

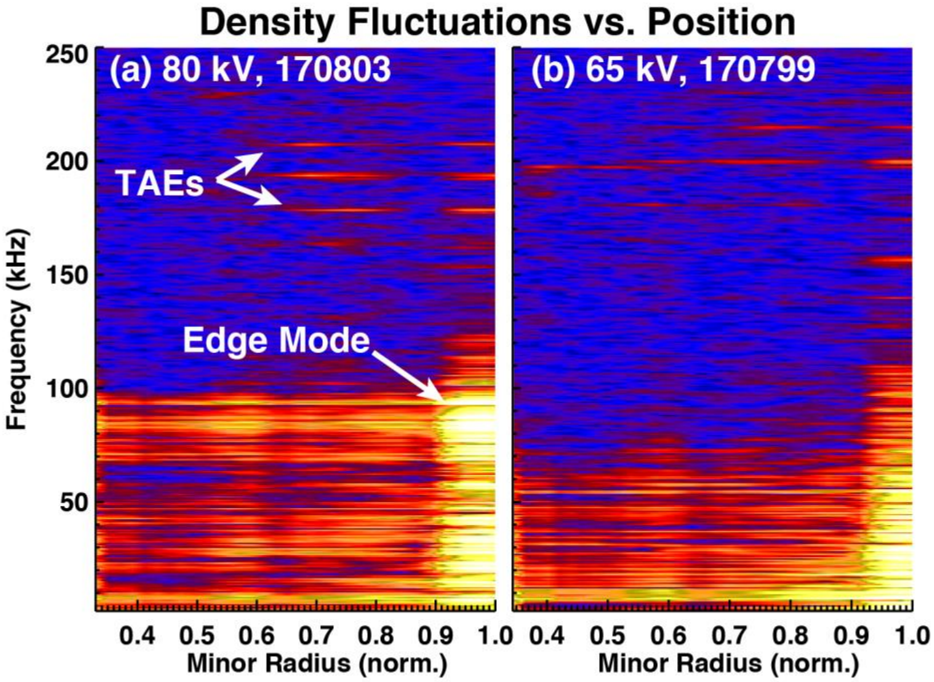

Image courtesy of the DIII-D National Fusion Facility

Fluctuations of plasma density are shown for a plasma with higher energy beams (left) and for lower energy beams (right). Since both cases have the same plasma conditions and total beam power, the difference in coherent wave activity is attributable to the beam energy changes.

The Science

Neutral particle beams that heat fusion plasmas in the DIII-D National Fusion Facility have been improved by an engineering upgrade that allows them to adjust their energy in real time. DIII-D is a tokamak, a device that uses magnetic fields to contain high temperature plasmas for research and development of fusion energy. Changing the particle energy of the beams as the plasma evolves reduces interactions with electromagnetic plasma waves, allowing the injected particles to remain within the plasma for a longer time and provide greater heating compared to a fixed (and higher) energy.

The Impact

This technique provides a new actuator to control high temperature, magnetically confined, fusion plasmas. Input heating to the plasma can now respond to the presence of plasma waves in order to ensure that the injected particles remain within the plasma for the longest possible time, thereby keeping the plasma hotter and better suited to generating fusion.

Summary

In recent experiments, the DIII-D team has shown that reducing the injection energy of neutral particle beams late in a plasma shot can actually increase plasma heating and current drive. Fusion experiments previously used neutral particle beams operating at the highest possible energy, and that energy was fixed for the duration of the experiment. The beam voltage sets the energy of the injected particles, and greater energy leads to hotter plasmas. In some conditions, however, these high-energy deuterium particles excite electromagnetic waves in the plasma and those waves can drive the beam particles out of the plasma prematurely, reducing their ability to heat the plasma to fusion conditions. The engineering change allows the beam to produce the same total power level at different values of particle energy. Injecting high power, but low energy, beams into a plasma can greatly reduce the number of electromagnetic waves produced in the plasma, as shown in the figure above.

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Publications

J. Rauch, et al., “Upgrade to DIII-D National Fusion Facility PCS and Neutral Beam Systems: In-Shot Variation of Neutral Beam Particle Energy,” *Fus. Sci. Tech.* **72**, 500 (2017) http://dx.doi.org/10.1080/15361055.2017.1333845

C.J. Pawley, et al., “Advanced control of neutral beam injected power in DIII-D,” *Fus. Eng. Des.* **123**, 453 (2017) https://doi.org/10.1016/j.fusengdes.2017.02.106

D.C. Pace, et al., “Control of power, torque, and instability drive using in-shot variable neutral beam energy in tokamaks,” *Nucl. Fusion* **57**, 014001 (2017) https://doi.org/10.1088/0029-5515/57/1/014001

Related Links

DIII-D National Fusion Facility: https://fusion.gat.com/global/diii-d/home