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Inside Job: DIII-D study finds sweet spot for frozen pellet injection

Fusion fueling study at the DIII-D National Fusion Facility evaluates the impact of pellet injection location and size to integrate fueling with heat management.

CHICAGO—A new study at the DIII-D National Fusion Facility shows how scientists could get more fuel into the heart of a fusion device, making fueling more efficient and supporting the high plasma performance future fusion power plants will need. The study centers on tiny frozen hydrogen pellets fired at high speed into the plasma, where they melt and release their fuel from the inside rather than relying on gas added as fuel around the outer edge. This approach could be an important step toward sustaining the high-performance plasmas needed to make fusion a practical energy source.

Fusion devices need a steady supply of hydrogen fuel to sustain fusion reactions. Most current experiments add that fuel as gas near the outer edge of the plasma, where it must work its way inward before it can contribute to fusion reactions.

Pellet fueling offers a more direct approach. Cryogenically frozen hydrogen pellets can travel farther into the plasma before melting and releasing their fuel, increasing the fuel density where fusion reactions occur and potentially improving efficiency and plasma performance.

That capability could be especially important for future power plants, where gas injection alone likely will not be enough to achieve the conditions needed for sustained fusion performance. But getting fuel deeper into the plasma creates another challenge.

“Pellet fueling gives us a way to deliver fuel deeper into the plasma, where it can be used more efficiently,” said Sophie Gorno, a researcher at Oak Ridge National Laboratory. “At the same time, our work shows that we must comprehend how that fueling changes the heat reaching the walls, where it could create new risks. Understanding that full cause-and-effect relationship is vital to designing future fusion systems that can achieve strong performance while protecting the machine.”

Each pellet causes a rapid increase in fuel inside the plasma. That change can push heat and particles outward toward the divertor, the part of the machine designed to remove heat and spent fuel. Too much heat reaching the divertor could damage its materials over time.

Using a pellet injection system developed by Oak Ridge National Laboratory, researchers varied the size and injection location of pellets during experiments at DIII-D. They used

the facility's diagnostic systems to measure how the plasma responded and compared those results with computer simulations of the plasma edge and the divertor (Figure 1).

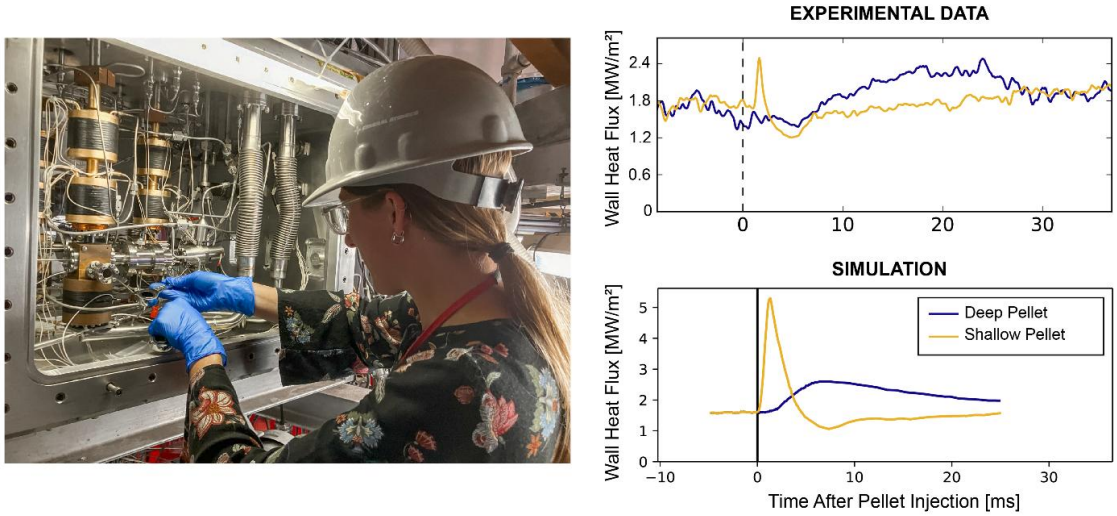


Figure 1: (left) Sophie Gorno works on the ORNL pellet injector at DIII-D. (right) Plots of the measured (top) and simulated (bottom) effects of hydrogen fuel pellet injection on heat flux at the tokamak wall, showing that shallow pellet injection leads to a sharp heat flux while deep pellet injection leads to an extended period of lower heat flux.

The team found that the depth at which a pellet releases its fuel plays an important role in how much heat reaches the divertor. Pellets that deposited fuel deeper inside the plasma produced an increase in heat over a longer period, while shallower pellets caused a brief, sharper increase followed by a reduction.

"One of the most important findings is that there may be a sweet spot for how deep the pellets should go," Gorno said. "If we can find that balance, we may be able to fuel the plasma efficiently while keeping heat at the divertor under control. We also found that cooling the divertor can further reduce the impact on the machine walls."

The results could help scientists and engineers design fusion systems that treat fueling and heat management as connected challenges. Many future fusion devices, including the international fusion project ITER and planned commercial devices such as the SPARC tokamak being built by private fusion company Commonwealth Fusion Systems, are expected to rely on pellet fueling to reach the plasma conditions needed for high fusion performance. The goal is to develop more integrated computer models to better predict how pellets will travel through future fusion plasmas, how efficiently they will deliver fuel, and how they will affect conditions from the plasma core to the machine walls.

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Abstract

KI02/2 Understanding Pellet-Fueled Divertor Dynamics to Mitigate Detachment Burn-Through in Future Reactors

Session KI02: Divertor Exhaust, Detachment, and Plasma-Facing Components

2:00 PM–5:00 PM, Wednesday, November 4, 2026
Room: Hilton Chicago, International South, Second Floor