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DIII-D Research Shows New Path to Control Heat Without Sacrificing Fusion Performance

New Shape and Volume Rise divertor at the DIII-D facility achieves efficient heat exhaust management and control of damaging edge bursts while maintaining a high-performance plasma.

CHICAGO—A long-standing roadblock on the path to practical fusion energy may be starting to give way. In a first-of-its-kind demonstration, researchers at the DIII-D National Fusion Facility showed they could tackle two major challenges at once inside a tokamak: stopping damaging bursts of heat and particles from the plasma's edge while also managing the steady heat leaving the machine. More importantly, they did both without weakening the high-performing plasma that fusion energy depends on. The results point to a possible way future fusion power plants could maintain the intense plasma conditions needed to produce energy while better protecting the machine components around them.

"Fusion depends on keeping the plasma extremely hot and strongly confined, but those same conditions can build pressure at the edge and trigger sudden bursts of heat and particles known as edge-localized modes, or ELMs," said Qiming Hu**,** research physicist at Princeton Plasma Physics Laboratory. "In a future power plant, those repeated bursts could damage surrounding components over time, so finding a way to stop them without weakening the plasma is critical."

Scientists use magnetic fields to shape and control plasma inside a fusion device known as a tokamak, including where the steady flow of heat leaving the plasma is directed. One promising shape, known as a double-null configuration, divides that exhaust heat between the top and bottom of the machine so no single area takes the full load. The catch is that this same shape has historically made the plasma less responsive to a separate set of magnetic fields used to suppress damaging ELM bursts.

Experiments at DIII-D point to a way past that roadblock: researchers may now be able to tame the exhaust heat and stop the damaging bursts without weakening the very hot plasma needed to make fusion possible.

In the experiments, the team completely suppressed ELMs in a strongly shaped double-null plasma while maintaining good confinement and high plasma performance. It was the first time researchers had demonstrated complete, reliable ELM suppression under these conditions.

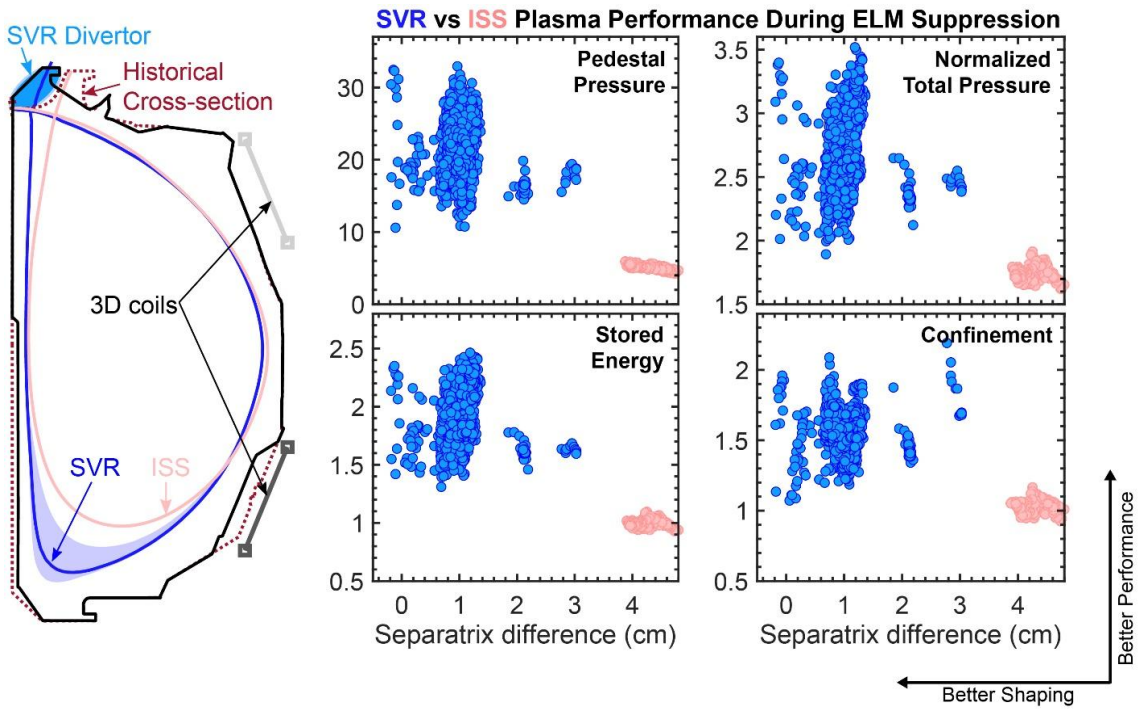


Figure 1: (left) Schematic of the DIII-D tokamak showing a cross-section with the Shape and Volume Rise (SVR) divertor and strongly shaped double-null plasma (blue) and a cross-section with the historical divertor showing a conventional single-null ITER-similar shape (ISS) plasma (red). (right) Plots comparing plasma performance between SVR (blue) and ISS (red) plasmas during ELM suppression across the indicated parameters, demonstrating the superior performance of the SVR plasma.

To do it, researchers used DIII-D's magnetic coils positioned above and below the plasma to carefully adjust the fields used to control ELMs. They tested different field strengths and configurations while changing the plasma shape, allowing the researchers to see how each adjustment affected the bursts, plasma performance, and heat reaching the divertors.

A key part of the advance came from DIII-D's new Shape and Volume Rise (SVR) divertor, the specific region of the machine designed to handle heat and particle exhaust (Figure 1). The SVR design was developed to give researchers greater ability to create strongly shaped plasmas. That stronger shaping turned out to be critical. Instead of weakening the plasma's response to the ELM-control fields, as seen in earlier experiments with conventional single-null ITER-similar shape (ISS) plasmas, it strengthened the response enough to stop the bursts while preserving high performance.

Together, the results show that three things future fusion power plants will need — a powerful plasma, control of damaging edge bursts, and an effective way to handle exhaust heat — can be achieved at the same time.

“What we’re learning gives future fusion designers more options for how they build and operate their machines,” Hu said. “The more of these challenges we can solve together, the closer we get to a system that can perform at a high level and keep doing so reliably.”

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Abstract

NI01/3 RMP ELM Suppression with High-Performance Operation in the DIII-D Double-Null Plasmas

Session NI01: Pedestal Physics, ELM Suppression, and Edge Transitions
9:30 PM–12:30 PM, Thursday, November 5, 2026
Room: Hilton Chicago, International North, Second Floor