High-Z Wall Transition on DIII-D to Enable Fusion Pilot Plant-Relevant Research

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The DIII-D National Fusion Facility is preparing for a major transition from graphite to tungsten (W) plasma-facing components (PFCs) to enable reactor-relevant studies of plasma scenarios, core-edge integration (CEI), and plasma-material interaction (PMI) for next-step fusion devices. This transition supports the mission of future fusion pilot plants (FPPs) by enabling direct validation of plasma boundary behavior, control strategies, and material survivability in high-Z environments. The Full Wall Change-Out (FWCO), targeted for implementation in 2028, follows a staged approach that prioritizes W coverage in regions with high plasma contact and peak heat flux, while retaining flexibility for future optimization. The first-phase installation will include the lower divertor and areas around the outboard midplane poloidal limiters, using ~5 mm thick bulk W tiles mounted on copper pedestals (Fig. 1). In recessed or lower heat-flux regions of the main chamber wall, thin W coatings (<1 mm) on molybdenum or stainless steel substrates are being considered. Coating application techniques under evaluation include cold spray, vacuum and plasma spray, and chemical vapor deposition. The design emphasizes geometric flexibility, ease of replacement, and safe handling during operation and maintenance.

The proposed material layout and mechanical interfaces are guided by detailed modeling of 3D heat flux patterns, optimization of limiter geometry, and assessments of impurity sources using boundary plasma simulations. W coverage will be concentrated in areas with high likelihood of plasma interaction, while fallback strategies including partial coverage with non-W high-Z alternatives (e.g., Mo or SS) are maintained for less exposed regions.

A structured Physics Validation Review (PVR) is underway to ensure compatibility of the planned full-metal wall configurations with DIII-D's diverse plasma scenario portfolio. The ongoing PVR indicates that key advanced scenarios, including Advanced Tokamak (AT), negative triangularity (NT), and quiescent H-mode (QH-mode), remain viable in high-Z environments, provided core W accumulation is effectively managed. Active control methods under evaluation include strike-point sweeping, ECH impurity flush-out, edge impurity seeding, and optimized plasma shaping. The PVR also emphasizes the importance of defining CEI performance metrics tailored for high-Z conditions to guide further scenario development and experimental targeting. These efforts will inform not only the final wall design but also near-term scenario refinements and operational strategies.

Building on the PVR findings, a dedicated tungsten tile testing campaign is planned for execution after the FY26 experimental run. A broad set of tile assemblies, including both W coatings and bulk W elements, will be installed in the lower divertor to test coating integrity, impurity generation, and material degradation under DIII-D-relevant transient and steady-state heat fluxes.

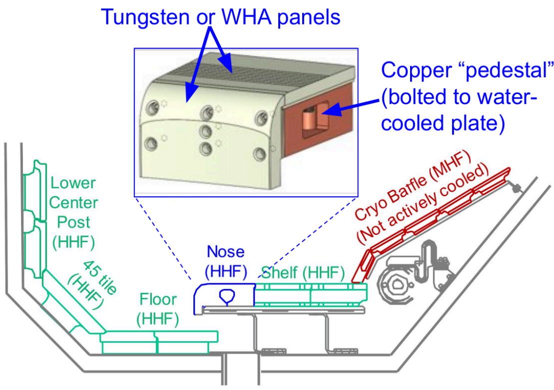

Figure 1: Current DIII-D lower divertor design concept: tungsten panels on copper pedestals.

The wall transition will leverage DIII-D's unique capability to investigate short-pulse, high-performance plasma scenarios using flexible shaping, advanced actuator control, and comprehensive diagnostics in a metal-wall environment. This experimental flexibility is crucial for developing the physics basis and control strategies necessary for ITER, long-pulse tungsten machines such as EAST, WEST, and KSTAR, as well as future fusion pilot plants.

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