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# How DIII-D Can Access New Plasma Regimes with More ECH to Close Long Pulse Fusion Pilot Plant Knowledge Gaps

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The DIII-D research program will close key gaps in knowledge for the design and operation of long-pulse tokamak fusion pilot plants (FPPs) by deploying increased electron cyclotron heating and current drive power to reach and study more relevant plasma regimes. The U.S. is focused on low capital cost compact FPPs on the path to commercialization. Steady-state or long-pulse inductive tokamaks are a potential path, but these have four broad categories of knowledge gaps for processes at and inside the first wall: (1) Core-edge integration: how do we sustain high fusion power density in the core while exhausting heat and particles without damaging plasma-facing materials? (2) Core optimization: how do we achieve sufficient energy confinement and MHD stability for high fusion gain and high non-inductive current fractions for long-pulse or steady-state? (3) Detrimental transient avoidance: how do we avoid or suppress large NTMs and ELMs? (4) Plasma-material interactions: which first wall and divertor structural materials are acceptable? Adding a significant amount of flexible ECH power to DIII-D will enable access to new plasma target regimes designed to study and help close these gaps. Guided by publicly available compact FPP design studies, DIII-D plasma targets have been chosen that are designed to match a few but not all key FPP metrics simultaneously to study a particular gap question. For example, core-edge integration in an H-mode based, long-pulse, inductively sustained scenario would be well investigated with access to DIII-D plasmas having pedestal collisionality less than ˜0.2, neutral penetration depth less than the pedestal width, betaT>=5%, H98y2>=1, and fG,ped>=0.9. This would allow assessment of edge plasma dynamics when the high-pressure pedestal structure is set by transport rather than deep neutral fueling, and would be an ideal regime to study radiative and/or detached divertor operation in. Other plasma targets are defined for investigating optimal core transport and stability with FPP relevant values, such as low rotation, Te/Ti>=1, and low fast ion fraction, and for investigating NTM suppression. Predictive integrated modelling using the physics-based IPS-FASTRAN code will be presented that quantifies –with systematic evaluation of uncertainties due to limited physics models - the minimum needs for additional ECH power for a few different target scenarios. This includes delivered power and current drive versus radius, gyrotron frequency, and X- or O-mode operation, assuming existing launch geometries. Preliminary modeling already predicts that with 20 MW of NBI power (another planned upgrade), 8.4 MW of 170 GHz X3-mode plus 5.6 MW of 137 GHz O2-mode would enable DIII-D plasmas close to or exceeding all the simultaneous metrics in the example above.

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