Twenty-One Years Establishing ECCD Stabilization of NTMs in DIII-D*

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Since the seminal predictions [1] in 1997 of how narrow radially localized electron cyclotron current drive could stabilize neoclassical tearing modes (NTMs) by replacing the "missing" bootstrap current in an island, DIII-D has been at the forefront of experimental validation. The previous commencement of 110 GHz gyrotron installation on DIII-D enabled this. The first *complete* stabilization (following ASDEX-Upgrade) of an NTM (m/n=3/2) using two gyrotrons injecting 1 MW was achieved in 2000. The most recent DIII-D experiments are in a low-torque ITER baseline scenario and mimic the ITER geometry for ECCD aligned to the q=2 surface as shown in Figure 1. Initially there was no real-time capability for ECCD alignment on a rational surface; the development of alignment progressed from fixed mirrors with mirror angle or toroidal field changed shot-to-shot, to closed-loop control of the entire plasma major radius and thus island location *or* control of toroidal field and thus ECCD location, to moving the mirrors during a discharge [2]. The subsequent increase in the numbers of gyrotrons (and thus EC power) and the real-time mirror control to keep the ECCD "scalpel" on a given q=m/n surface allows tests of simultaneous preemption/avoidance of both 3/2 and 2/1 modes in the IBS in DIII-D. Real-time logics for gyrotron power management progressed from applying after a saturated mode, to always-on CW for preemption of the mode, to turning on with detection of a growing mode. Comparison of CW to standby ECCD to "catch" a growing mode to "subdue" it with return to standby is under yet further development as ITER will need to keep the *average* EC power for NTM stabilization at a minimum in order to maximize Q.

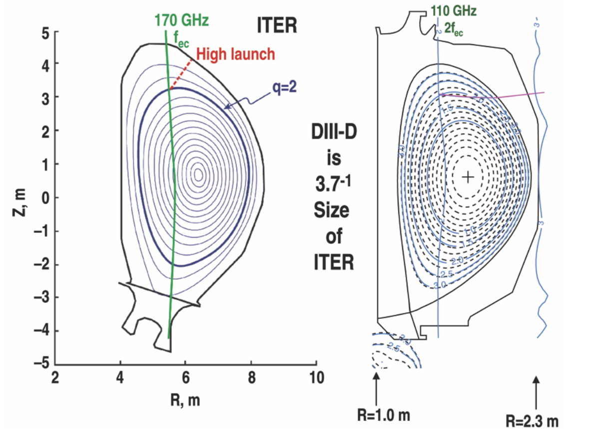

Fig. 1. *Cross-sections of ITER and of a DIII-D ITER Baseline Scenario discharge showing the launch of rays (170 GHz 1*fce and 110 GHz 2*fce respectively) to drive co-ECCD at q=2.*

*Work supported by the US DOE under DE-FC02-04ER54698.

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