Onset conditions of helical cores in tokamaks for extrapolation to ITER

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Large, spontaneous $m/n = 1/1$ helical cores are predicted in tokamaks such as ITER with extended regions of low- or reversed- magnetic shear profiles and q near 1 in the core. Their impact on ITER has not yet been fully quantified. Beneficial effects can include flux pumping and preventing sawteeth. On the other hand fast ion confinement is predicted to degrade significantly and the ensuing rotation breaking could be detrimental to tearing mode and microturbulence suppression. The threshold for the spontaneous symmetry breaking is determined using VMEC scans, beginning with reconstructed 3D equilibria from DIII-D and Alcator C-Mod based on observed internal 3-D deformations. The helical core is a saturated internal kink mode; its onset threshold, shown by the black line in Fig. 1, is proportional to $(dp/d\rho)/B_t^2$ around $q = 1$.

Below the threshold, applied 3-D fields can drive a helical core to finite size, as in DIII-D. The helical core size thereby depends on the magnitude of the applied perturbation. Above it, a small, random 3-D kick causes a bifurcation from axisymmetry and excites a spontaneous helical core, which is independent of the kick size. The onset threshold is very sensitive to the q-shear in the core. Helical cores occur frequently in Alcator C-Mod during ramp-up when slow current penetration results in a reversed shear q-profile, which is favorable for helical core formation. A comparison of the helical core onset threshold for discharges from DIII-D, C-Mod and ITER, shown by the markers in Fig. 1, confirms that while DIII-D is marginally stable, C-Mod and especially ITER are highly susceptible to helical core formation without externally applied 3-D magnetic fields.

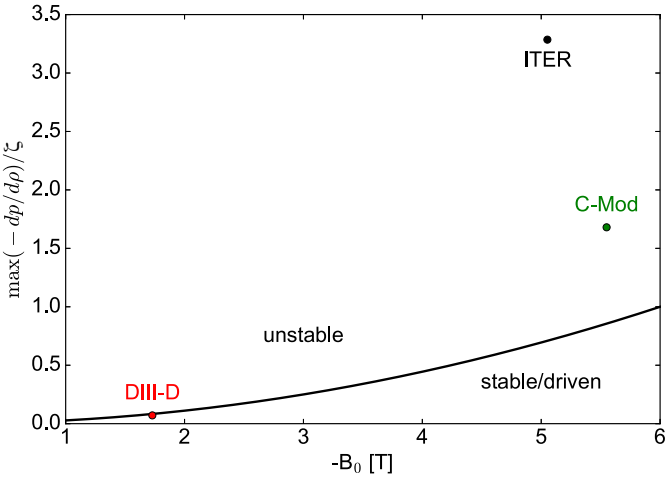

Figure 1: *Onset of helical cores for an ITER mock-up discharge (15 MA, H-mode), compared to 3-D reconstructed DIII-D and C-Mod discharges. The y-axis is normalized so that the thresholds for all machines coincide, with:* $\zeta_{DIII-D} = 2.545$, $\zeta_{ITER} = 0.5$ *and* $\zeta_{C-Mod} = 0.145\ 10^6 Pa$.

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