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DIII-D Exploration of the D2+Kink Path to Runaway Electron Mitigation in Tokamaks

A novel path to runaway electron mitigation in tokamaks found by combining an impurity-free (deuterium) background plasma with current-driven kink excitation at low safety factor (qa) is being explored for its application to ITER and beyond. Realization of this scheme requires primary or secondary injection of deuterium and promotion of kink instability via limited actuation by the poloidal field coilset. This contribution will 1) summarize published DIII-D results [1], 2) present more recent database studies and 3) discuss a planned DIII-D experiment targeting open questions in this topic.

Discussion of published [1] results will focus on the details of the final loss and magnetic reconstruction of the candidate instability. The detailed dynamics of the kink MHD-driven final loss using fast interferometry support a prompt (sub-ms) conversion of RE to bulk Ohmic current without regeneration. Sub-ms loss of REs is predicted to be due to a near-complete MHD-driven prompt loss of the RE population. MHD instability magnetic reconstruction reveals that early instabilities at high qa (⊠ 4) are likely internal or resistive kinks (at higher poloidal mode number), while at qa ≈ 2 the most destructive instabilities are either internal or external kinks with low-order poloidal mode number (m=2). The HXR loss magnitude is found to be proportional to the perturbed magnetic field and exhibits a helical spatial pattern.

A recent database analysis reveals that similar dynamics to that discussed in [1] has also been observed in impurity-free vertically unstable RE beams, with large-scale MHD found as the plasma cross section contracts, lowering qa. This database also reveals that both a large RE current as well as a low qa promote the large kink amplitude needed to promptly deconfine the REs. The role of the background impurity content is found to modify the vertical instability dynamics but does not appear to clearly modify the kink amplitude if plasma current and qa are matched.

New DIII-D experiments are planned to assess several open questions related to this novel path to runaway electron mitigation. The experimental plan will be summarized, and if results are available by the time of the conference they will be presented in a preliminary fashion.

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[1] C. Paz-Soldan et al, Plasma Phys. Control. Fusion 61 054001 (2019)

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