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Non-axisymmetric magnetic fields effect on rotation and turbulence in KSTAR

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In a fusion device like KSTAR, a "divertor" helps manage exhaust and impurities. The first experiments used a carbon divertor. H-mode power threshold (P_{TH}) without extra magnetic fields when there are no extra non-axisymmetric fields in the plasma with conditions like a toroidal magnetic field of 1.8 T, and an electron density of 2×10^{19} m^{-3}, P_{TH} is very low under about 1 MW of neutral beam power in KSTAR with carbon-divertor.

In this study, we investigate the contrasting effects of resonant and non-resonant magnetic fields on the P_{TH} in KSTAR with carbon divertor. Utilizing high-precision non-axisymmetric in-vessel control coils, we observed that resonant magnetic perturbations with specifically the n=1 and n=2 components considerably affect the power required for H-mode access, whereas non-resonant fields have little to no impact even at the highest applied currents. KSTAR's unique magnetic environment, characterized by an intrinsic n=1 non-axisymmetric field that is an order of magnitude lower than in other devices [1], and a toroidal field ripple of only 0.05% [2], makes it particularly sensitive to small resonant variations. Initially, we hypothesized that such sensitivity would be directly linked to changes in plasma rotation shear, expecting that even non-resonant fields which modify plasma rotation without directly influencing particle or heat transport would yield similar variations in P_{TH}. However, our results contradict this assumption: while resonant fields elevate the threshold significantly, non-resonant fields do not alter it measurably.

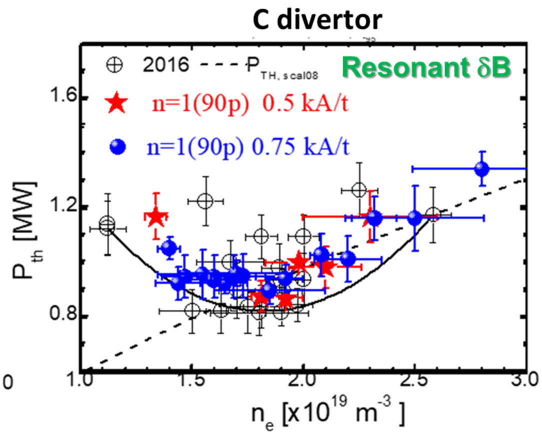

Figure 1. P_{TH} is vastly scattered for no RMP. Vastly different intrinsic error fields, presumably resonant RMP have not been duly factored in power scaling law.

These findings suggest that P_{TH} is influenced not only by rotation shear but is also strongly affected by turbulent transport mechanisms driven by resonant perturbations. This stochastic involvement of turbulence appears to be a key factor in raising the threshold. The implications for future devices such as ITER are substantial. It is likely that ITER may not require dedicated corrections for non-resonant magnetic fields, but rather, ensuring high-quality control over resonant magnetic field perturbations will be critical for reliably achieving H-mode, especially under conditions of minimal auxiliary heating.

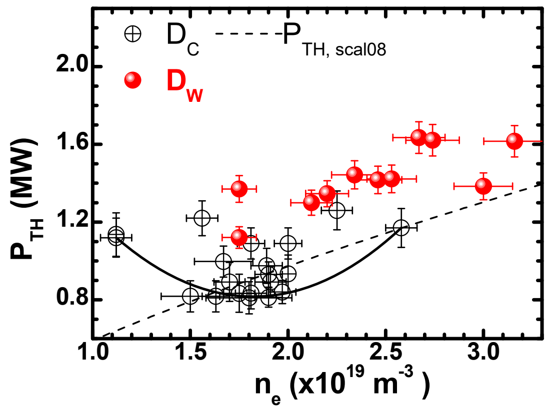

Figure 2. P_{TH} for the density roll-over in the KSTAR with the tungsten divertor in red as compared with carbon divertor in black without RMP. Increased P_{TH} in tungsten divertor as compared with full carbon PFC.

Recent experiments at KSTAR have focused on comparing tungsten divertors with carbon divertors for managing plasma emission and impurities. The studies revealed that using a tungsten divertor increases P_{TH} compared to a carbon divertor, which is unexpected given that all-metal plasma facing components (PFC) devices typically exhibit lower H-mode thresholds and reduced Z_{eff} than all carbon PFC. Since experiments on AUG have shown that partial metallic walls yield P_{TH} similar to those observed with all-carbon PFC [3], we anticipated that KSTAR under all-carbon PFC would display comparable thresholds. However, the elevated threshold observed with the tungsten divertor is likely due to high Z_{eff} impurities. Further investigation into the effects of boronization is needed to determine whether surface conditioning can mitigate these impurity effects and improve the operational efficiency of tungsten divertor configurations in fusion devices.

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