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Electron density window on the suppression of spontaneous neoclassical tearing mode with high fraction of bootstrap current

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Plasma major disruptions are the major threat to limit the tokamak steady-state operation and even to destroy the devices. Future fusion reactors will be operated in high confinement conditions where high fraction of bootstrap current appears, which means neoclassical tearing mode (NTM) will become the major source contributing to major disruptions. NTM is very dangerous for reactor-scale tokamak devices due to its harmfulness for the achievable plasma beta and its threat for leading to potential major disruptions. Given this potential economic loss by damaging experimental devices, the mitigation and/or active control of NTMs are of high priority for the performance in advanced devices such as ITER and future reactors.

In general, the triggering of NTM can be avoided via eliminating the source of seed islands. However, the spontaneously growing NTM without seed islands still can be observed in many experiments. Recently, TCV experiments observed that there existed a region where the spontaneous NTM can be suppressed while varying electron density show in figure 1 [1], which may probably be related to the electron diamagnetic effect. The observation provides a new idea to avoid spontaneous NTM in future fusion devices. It is essential to make the best of this property for better operations of future large-scale tokamak devices. The purpose of this work is to numerically investigate the physics mechanism behind the window of electron density under high fraction of bootstrap current using self-developed 5-field 3D MHD code (MHD@Dalian) [2-3] including the electron diamagnetic effect. Aiming to provide theoretical supports to the effective suppression of spontaneously triggering NTM and thus to avoid disruption for experiments via investigating the relation between the threshold of NTM triggering and the electron diamagnetic effect, as well as the influence of different kinds of key plasma parameters on the density window.

Numerical investigations show that the electron density window exists in the same order of the experimental operation, as shown in figure 2. Increasing magnetic shear in the vicinity of the rational surface or increasing electron density both can trigger NTMs, which show good agreement with the TCV experiments. The diamagnetic drift frequency is in the same order of the experimental observation and gradually decreases during the nonlinear evolution, which is also shown in TCV experiments [1]. With increasing the fraction of bootstrap current, the NTM triggering window is broadened. Interestingly, increasing electron beta can move the triggering window towards high density direction, which show good favor in future high beta operation scenario. Moreover, other key plasma parameters on the density window are all systematically investigated and discussed in details.

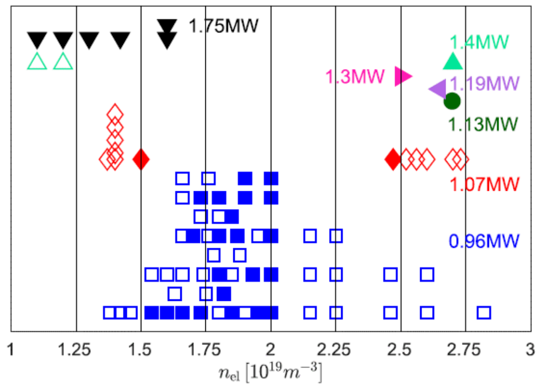

Figure 1. Electron density window of spontaneously triggering NTM observed in the experimental discharges of TCV tokamak [1].

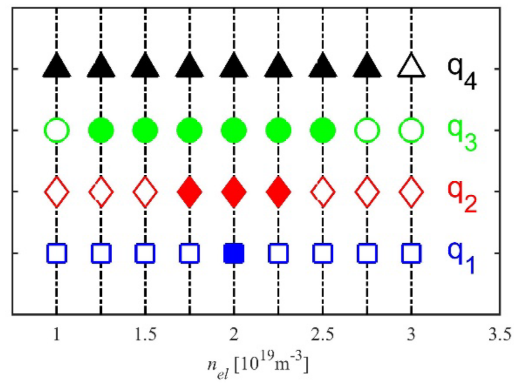

Figure 2. Electron density window of spontaneously triggering NTM obtained via numerical simulation of MHD@Dalian Code.

References
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