Advances in understanding core transport of DIII-D high β_p scenarios

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Abstract: We present new results advancing the understanding of core transport in the DIII-D high β_p scenario[1], which is characterized by a large radius internal transport barrier(ITB) in all the kinetic channels and is a promising scenario for fully non-inductive operation. Due to the strong α (Shafranov-shift) stabilization effect, the ion thermal transport is mostly neoclassical in the ITB region, and CGYRO modeling predicts the dominant instability to be a trapped electron mode(TEM) when operating at moderate q_{95}(~6)[2]. The TEM can be further suppressed when operating at higher q_{95}, which enhances the $\alpha(\sim q^2\nabla p)$ stabilization of drift-ballooning type modes. High α in high q_{95} experiments can destabilize a micro-tearing mode(MTM) which then regulates the ITB strength[3], consistent with the general observation that the magnetic fluctuation amplitude decreases with decreasing q_{95} in the measured temporal dynamics. The MTM eigenfunction is tightly localized around its rational surface and can be efficiently destabilized by high q and low magnetic shear s, suggesting the MTM is a slab mode. Nonlinear simulation of the MTM shows the fluctuation energy tends to accumulate at the longest wave number, consistent with experimental observations of low-n tearing modes, which exists steadily with amplitude quite low($\delta B_{n=1} < 5$ Gauss) in these conditions. Extrapolation to future reactor conditions suggests that the MTM is likely to be stabilized due to reduced collisionality. Instead, a slab electrostatic mode can emerge as the dominant instability of the ITB region at high q_{95} operation[4], challenging the use of existing reduced transport for predicting these scenarios.

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1. Garofalo, A.M., et al., *Compatibility of internal transport barrier with steady-state operation in the high bootstrap fraction regime on DIII-D.* 2015. Nucl. Fusion, **55**(12): p. 123025.
2. Ding, S., et al., *The dominant micro-turbulence instabilities in the lower q 95 high β p plasmas on DIII-D and predict-first extrapolation.* 2019. Nucl. Fusion, **60**(1): p. 016023.
3. Jian, X., et al., *Role of microtearing turbulence in DIII-D high bootstrap current fraction plasmas.* 2019. Phys. Rev. Lett. **123**(22): p. 225002.
4. Jian, X., et al., *Role of microtearing mode in DIII-D and future high-β p core plasmas.* 2021. Phys. Plasmas **28**(4): p. 042501.