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Confinement Improvement in the High Poloidal Beta Regime towards Steady State Tokamak Operation and Application to Fusion Reactor

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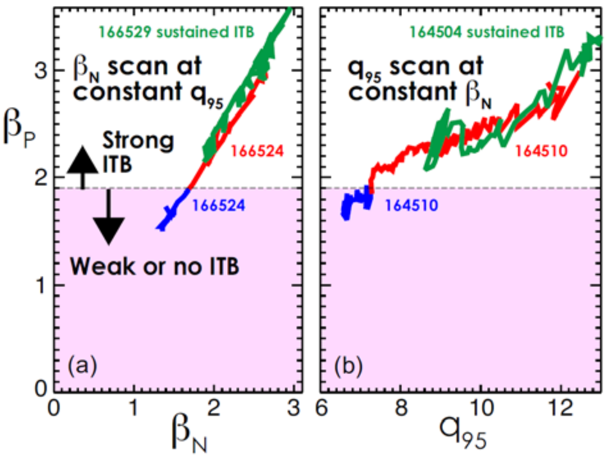
Systematic experimental and modeling investigations on DIII-D and EAST show attractive transport properties of fully non-inductive high β_p plasmas. Experiments on DIII-D show that the large-radius internal transport barrier (ITB), a key feature providing excellent confinement in the high β_p regime, is maintained when the scenario is extended from $q_{95} \sim 12$ to 7 and from rapid to near-zero toroidal rotation. The robustness of confinement versus rotation was predicted by gyrofluid modeling showing dominant neoclassical ion energy transport even without E×B shear effect. The physics mechanism of turbulence suppression, we found, is the Shafranov shift, which increases local rational shear and is essential and sets a β_p threshold for large-radius ITB formation in the high β_p scenario on DIII-D. This is confirmed by two different parameter-scan experiments, one for β_N scan and the other for q_{95} scan. They both give the same β_p threshold at 1.9 in the experiment. The experiment trend of increasing thermal transport with decreasing β_p is consistent with transport modeling. The very first step of extending high β_p scenario on DIII-D to long pulse on EAST is to establish long pulse H-mode with ITB on EAST. This report shows the first 61 sec fully non-inductive H-mode with stationary ITB feature and actively cooled ITER-like tungsten divertor in the very recent EAST experiment. The successful use of lower hybrid wave (LWH) as a key tool to optimize current profile in EAST experiment is also introduced. Results show that as the electron density is increased, the fully non-inductive current profile broadens on EAST. The improved understanding and modeling capability is also used to develop advanced scenarios for CFETR. Overall, these results provide encouragement that the high β_p regime can be extended to lower safety factor and very low rotation, providing a potential path to high performance steady state operation in future devices.

References

[1] A. M. Garofalo, et al, Nucl. Fusion **55**, 123025 (2015)
[2] M. A. Beer, et al, Phys. Plasmas **4**, 1792 (1997)
[3] A. M. Garofalo, et al, 26th IAEA Fusion Energy Conference (Kyoto, Japan, Oct. 17-22, 2016) [EX/4-3]
[4] J. Li for CFETR Team, 8th US-PRC Magnetic Fusion Collaboration Workshop (Princeton, NJ, USA, June 28-30, 2016)

Figure: β_p evolution for (a) β_N scan experiments. DIII-D SN# 166529 with sustained ITB is shown in green. Red line represents the sustained ITB phase of SN# 166524, while blue line stands for un-sustained ITB phase of SN# 166524; (b) q_{95} scan experiments. The lines have the same meanings as in (a) but for different discharges as indicated.



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