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DIII-D and EAST research towards long-pulse high-performance tokamak operation

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Coordinated experiments on DIII-D and EAST are developing the physics basis of fully non-inductive, high poloidal-beta (βP) plasmas for application to steady-state high performance operating scenarios in ITER and Fusion Pilot Plants (FPPs). By optimizing at low plasma current and high plasma pressure, high-βP operation reduces disruption risks and requirements on external current drive, while improving the energy confinement quality through Shafranov shift suppression of turbulence (α stabilization). The robust α stabilization mechanism scales favorably with pressure, and does not require external momentum injection, nor a carefully tailored current density profile.

On DIII-D, high βP and high density have enabled fully noninductive operation with highly self-organized plasma profiles exhibiting robustness to external perturbations and excellent confinement quality (H98≥1.5). The values of βN≥3.5, H98≥1.5, q95˜7 achieved simultaneously on DIII-D, match the normalized performance of a Q˜17 compact fusion pilot plant design point [1]. Recent experiments have achieved world-leading results in core-edge integration research, demonstrating high core performance simultaneous with full detachment and small/no ELMs [2].

Experiments on EAST have made progress in extending performance of long pulse H-mode using RF-only heating and current drive [J. Huang, this meeting]. Even though these latest experiments achieved βP and βN values comparable to those that in DIII-D result in the formation of a large radius ITB (βP>2 and βN˜2) values, an ITB is only visible in the Te profile, at ⍰˜0.3. Transport analysis reveals that the EAST plasmas are limited by ITG turbulence, despite the low ion temperature gradients. Adding heating to electrons or ions in the modeling cannot significantly increase the pressure gradient at mid-radius, unless the q-profile is modified with a higher qmin, or a deep fueling source is added. Various experimental approaches are being pursued on EAST, including early heating or broader profiles of the external current drive to create a high qmin profile. Results of upcoming experiments will be discussed.

[1] R.J. Buttery et al., Nucl. Fusion 61 (2021) 046028
[2] L. Wang et al, Nature Comm. 12 (2021) 1365

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