DPP19-2019-000396

Abstract for an Invited Paper
for the DPP19 Meeting of
the American Physical Society

Advances in physics understanding of high poloidal beta regime towards steady-state operation of CFETR

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Experimental and modeling investigations on EAST and DIII-D show how plasma current profiles, turbulent transport and radiation properties self-consistently evolve toward fusion relevant steady state conditions. Integrated experiments on EAST demonstrate that high β_P (~2.0), fully non-inductive, moderate bootstrap current fraction (f_{bs}50%) plasmas are maintained over 40 current relaxation times with metal wall, low rotation and small ELMs at high density (n_e/n_{GW}~0.80) and using only RF H&CD. The current density profile was broadened at higher density and higher β_P operation, with an increase of f_{bs}, leading to a slightly reversed shear profile, which contributes to the increase in energy confinement, similar to observations on DIII-D. The improved confinement was observed at high β_P, consistent with lower electron turbulence measurement. The achieved small ELMs facilitate RF power coupling in H-mode phase and reduce divertor sputtering/erosion. Low tungsten concentration was observed at high β_P with a hollow profile in the core region. Reduction of the peak heat flux on the divertor with f_{rad} up to 40% was compatible with high β_P scenario by using active radiation feedback control. Modeling and physics experiments confirmed synergistic effects between ECH and LHW, where ECH enhances heating and current drive from LHW injection, enabling fully non-inductive operation at higher density. On DIII-D, high normalized fusion performance results from a large radius (ρ~0.7) internal transport barrier, observed at high β_P (>2.0) and high normalized density (n_e/n_{GW}~1.0), and consistent with the effect of Shafranov shift stabilization of turbulence. Excellent confinement in this regime is insensitive to plasma rotation. These results increase confidence in the extrapolation of the high β_P regime to steady state scenarios for CFETR.