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Improved Confinement Induced by Fishbone at Dominant Electron Heating and Low Input Torque on EAST

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The baseline scenario with $q_{95} = 3$, $\beta_N = 1.8$ and $H_{98y2} = 1$ is foreseen for ITER to achieve its fusion gain $Q = 10$ scientific goal. Under the ITPA-IOS joint activities [1], great efforts have been made to explore and demonstrate the ITER baseline scenario on various tokamak devices, such as JET, DIII-D, AUG and JT-60U. Note that these plasmas are mostly heated by beam injection, differing from ITER conditions of dominant electron heating and low external torque.

EAST has been equipped with sufficient radio-frequency wave heating-power to realize ITER-like operation conditions, making itself as a unique platform to investigate physics in ITER-like conditions and provide important reference for future ITER operation. In the 2019 EAST campaign, stable plasma operation with β_N ~1.6 and H_{98y2} ~ 0.9 at q_{95} ~ 3 with injected torque T_{inj} = 0.56Nm has been achieved for the first time by using 2.5MW lower hybrid wave heating and current drive, along with 2MW beam power (Fig. 1). The core electron temperature T_{e0} ~ 3keV measured by Thomson scattering is 2 times higher than the ion temperature T_{i0} ~ 1.5keV that given by the charge exchange recombination diagnostics. The $n = 4$ resonant magnetic perturbation coil is applied as an integrated control technique of ELM mitigation (f_{ELM} = 400-600Hz) and high-Z impurity exhaust, while showing little degradation impact on plasma performance. In the plasma core region, sawtooth oscillation is observed by soft X-ray diagnostic, suggesting the existence of $q_0 < 1$.

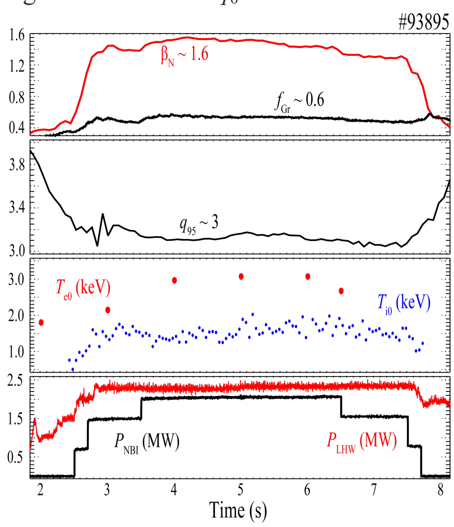

Figure 1. Stable plasma operation at β_N~1.6 and q_{95} ~ 3 heated by 2.5MW LHW and 2MW NBI on EAST.

At very similar plasma parameters of q_{95} ~ 3.2, n_e ~ 3.5×10^{19}m^{-3} and total injected power of 4MW, improved confinement is observed when sawtooth oscillation evolving into fishbone activity, seen Fig. 2. In the case with sawtooth, central peaked T_e along with flat distribution of n_e and T_i in the core region ($\rho < 0.4$) is found from plasma kinetic profiles. While the internal transport barrier structure is observed in all three channels of T_e, n_e and T_i during the occurrence of fishbone activity. In addition, the q profile obtained from current profile reconstruction algorithm developed on EAST [2] reveals similar variation found on AUG [3], changing from monotonic type in sawtooth into central flat with q_{min} close to 1 during fishbone. Linear analysis by TGLF and NLT transport code indicates consistent results that in the core region the ITG mode dominant during fishbone activity, while the TEM mode dominant in sawtooth case. Power balance analysis performed by ONETWO code shows that both of χ_e and χ_i are lower than the neoclassical level.

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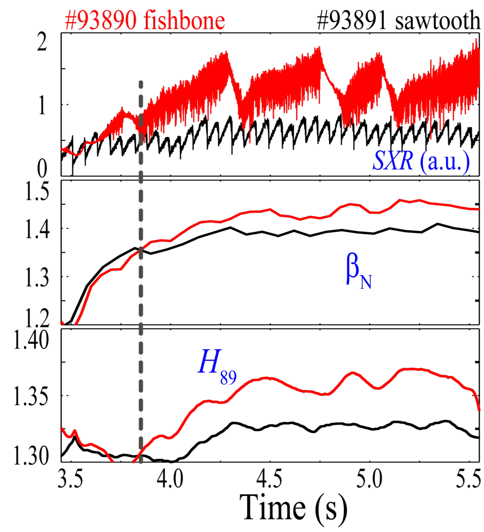

Figure 2. Improved confinement induced by fishbone activity (in red color) comparing to that of sawtooth case (in black color).

References

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[3] Gruber O. *et al* 1999 *Phys. Rev. Lett.* 83 1787