5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

A Stationary Ion Internal Transport Barrier Discharges with the Support of Fast Ions in Diverted Configuration on KSTAR

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Stationary ion internal transport barrier (ITB) discharges have been established in a diverted configuration at $q_{95} \sim 4$ on KSTAR. To obtain the stable ion ITBs, the L-H transition was avoided by keeping low density [1] and upper single null configuration, which are unfavorable to the H-mode transition in KSTAR. The high performance of this scenario is mainly attributed to fast ions, so we coin it Fast Ion Roled Enhancement (FIRE) mode.

The FIRE modes exhibit stationary performance ($\beta_N > 2.2$, $H_{89L} > 2.4$) comparable to hybrid scenarios [2] with L-mode or I-mode-like edge without edge localized modes. Long-pulse operations up to 20 s have been achieved with high fusion performance with Ti(0) above 10 keV and almost fully non-inductive current drive with the neutral beam injection as the main heating scheme with the power close to P_{LH}. These discharges do not require delicate control such as q profile or kinetic profiles to sustain the high-performance phase. High internal inductance in these discharges could enhance the beta limit [3]. In addition, there is no notable impurity accumulation observed as indicated by the more or less constant impurity Carbon III in last row of figure 1.

The analysis reveals that FIRE mode exhibits ITB characteristics in the ion energy channel. Firstly, the normalized Ion Temperature Gradient (ITG) length, R/L_{Ti}, is higher than the critical value [4] of the ITG mode. Secondly, Power balance analysis with ASTRA [5] incorporating NUBEAM [6] and NCLASS [7] shows the reduction of the effective ion heat diffusivity and the S-curve behavior in the relation between the ion heat flux and the ion temperature gradient [8]. Lastly, temperature fluctuations are reduced around the ITB foot.

The high amount of fast ions is thought to play a critical role in the ion ITB of FIRE mode. The ITB foot is strongly correlated with the fast ion density profile. Linear gyrokinetic simulations through GKW [9], conducted with scanning the thermal ion density and gradient, shows that the fast ion can stabilize the ITG turbulence via electromagnetic, alpha stabilization [10], low ion density gradient effect, and so on [11].

This FIRE mode is suggested as a new advanced scenario for steady-state high performance with low divertor heat load, which doesn't require sophisticate feedback control of profiles in KSTAR.

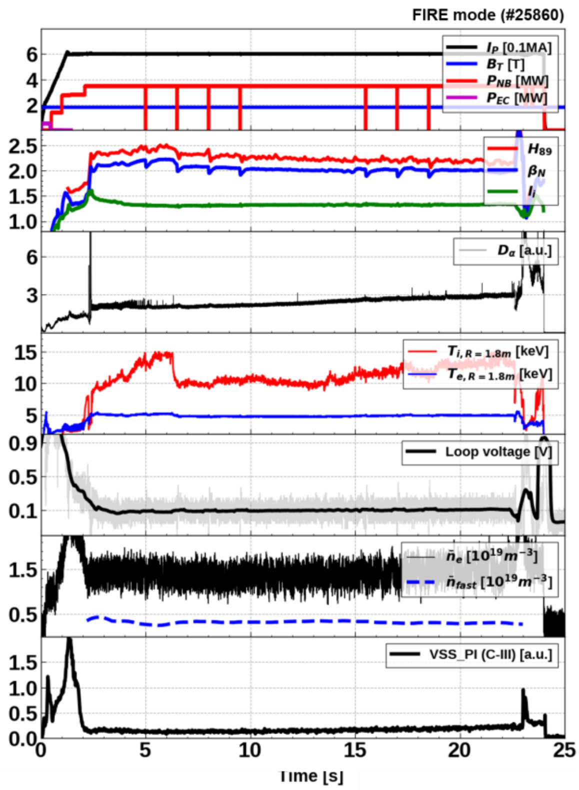

Figure 1. The time evolution of main parameters of stationary ion internal transport barrier discharge, FIRE mode in KSTAR (#25860).

References

[1] J-W. Ahn, et al, Nucl. Fusion **52** (2012) 114001
[2] Yong-Su Na, et al, Nucl. Fusion **60** (2020) 086006
[3] E.J. Strait, Phys. Plasmas **1** (1994) 1415
[4] S.C. Guo, F. Romanelli, Phys. Plasmas **5** (1993) 520
[5] G. Pereverzev, et al., IPP-Report IPP (2002) 5/98
[6] A. Pankin, et al., Phys. Commun. **159** (2004) 157
[7] W. A. Houlberg, et al., Phys. Plasmas **4** (1997) 3230
[8] P. H. Diamond, et al., Phys. Rev. Lett. **78**, (1997) 1472
[9] A. G. Peeters, et al., Phys. Commun. **180** (2009) 2650
[10] C. Bourdelle, et al., Nucl. Fusion **45** (2005) 110
[11] M. Romanelli, et al., Plasma Phys. Control. Fusion **52** (2010) 045007