9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

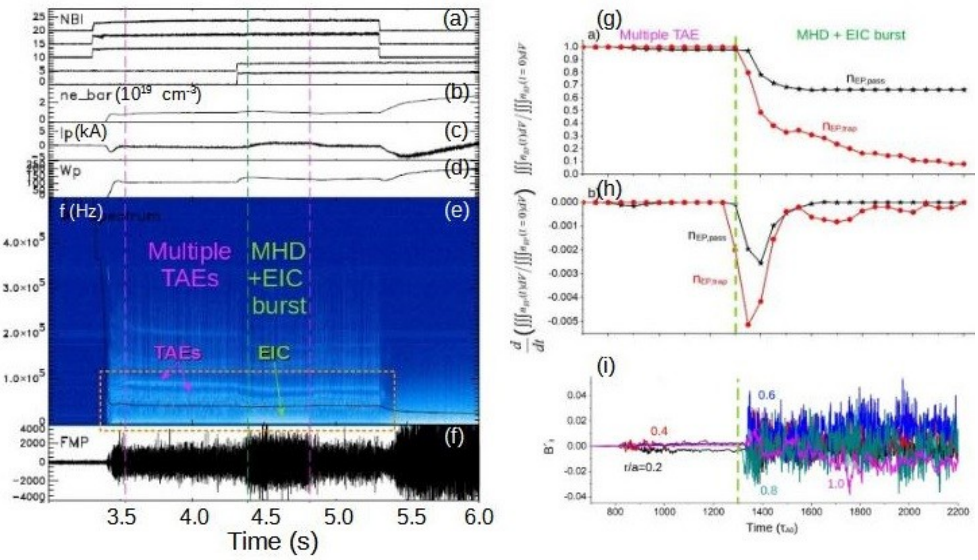
Bursting activity in LHD plasma induced by multiple EP populations

J. Varela[1], K. Nagaoka[2], H. Nuga[2], R. Seki[2], K. Ogawa[2], K. Tanaka[2], Y. Todo[2], D. Spong[3], L.Garcia[4], Y. Ghai[3], J. Ortiz[5], G. F.-Torija Daza[1], B. Breizman[1], F. Waelbroeck[1] and D. Del Castillo-Negrete[1]
[1]Institute for Fusion Studies, University of Texas at Austin. [2]National Institute for Fusion Science.
[3]Oak Ridge National Laboratory. [4]Universidad Carlos III de Madrid. [5]Aix-Marseille Université.
e-mail (speaker): jacobo.rodriguez@austin.utexas.edu

Bursting activity is observed in LHD plasma for operation scenarios strongly heated by the neutral beam injectors (NBI). Examples are the MHD burst [1,2,3] observed in configuration with intense tangential NBI heating and energetic-ion-driven resistive interchange modes (EIC) burst [4,5] in discharges with strong perpendicular NBI heating. MHD burst are connected to the destabilizing effect of passing energetic particles (EP) leading to unstable Toridal Alfven Eigenmodes (TAEs) in the inner-middle plasma region and EIC burst linked to helically trapped EP triggering EIC at the plasma edge. Present study is dedicated to analyze the LHD discharge 189008 heated by tangential and perpendicular NBIs, leading to the destabilization of a burst event showing features of both MHD and EIC bursts (fig. panels a to f). Experimental observations show the destabilization of TAEs in the frequency range of 40-80 kHz as well as a low frequency mode with 12 kHz consistent with EIC activity. Linear and nonlinear simulations performed with the gyro-fluid code FAR3d [6] including passing and trapped EP populations suggest MHD and EIC burst could be triggered due to the nonlinear destabilization feedback between different EP populations. The EIC is destabilized for a trapped EP β smaller compared to the β threshold obtained by the linear simulations, indicating the destabilizing effect of passing EP affects the trapped EP population stability. Once the EIC is triggered, a transition to the hard MHD regime occurs and a combination of a MHD and EIC burst is observed. The MHD burst causes up to 60% passing EP losses although the EIC burst leads to 90% losses of trapped EP population (panel g). The analysis shows passing and trapped EP transport is ballistic during the burst phase, leading to a large enhancement of the passing and trapped EP fluxes (panel h). The simulations show a reasonable agreement with the enhanced magnetic perturbation observed in the experiment once the busting activity begins (panel i), the intensity of the radial electric field and shear flows location measured by the charge exchange spectroscopy diagnostic (CXS) as well as the instabilities frequency range and radial location. The analysis suggests the nonlinear interaction between passing and trapped EP may cause the destabilization of the bursting activity in the discharge. This conclusion has important consequences for the AE stability and EP transport in future fusion reactors with multiple EP populations including alpha particles, NBI EPs and ICRH EPs.

References

[1] Osakabe M.et al Nucl. Fusion 46 S911 (2006).
[2] Seki R., et al, Nucl. Fusion 59 096018 (2019).
[3] J. Varela et al Nucl. Fusion 62 126020 (2022).
[4] Du X.D. et al Nucl. Fusion 56 016002 (2016).
[5] J. Varela et al Nucl. Fusion 61 126016 (2021).
[6] J. Varela et al Front. Phys. 12:1422411 (2024).



Discharge 189008: (a) NBI heating pattern, (b) thermal plasma density, (c) plasma current, (d) magnetics spectrogram and (e)magnetic perturbation intensity. Simulation data: (g) transport of passing (black) and trapped (red) EP, (h) flux of passing (black) and trapped (red) EPs, (i) poloidal magnetic field perturbation.