Synergies between H-NBI fast-ions and ICRF heating in the non-activated operational phase of ITER

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To access the type-I ELMy H-mode scenarios in ITER during the Pre-fusion Power Operation 2 (PFPO-2) with hydrogen and helium plasmas, it is necessary to operate at reduced confining magnetic field to exceed the power threshold for the L-H transition [1]. During this operation phase it is planned the commissioning of the baseline auxiliary power heating, made up of 33 MW of NBI (hydrogen at a maximum injection energy of 870 keV), 20 MW of ECRH and 20 MW of ICRF (f=40-55 MHz) [2]. Depending on the ICRF frequency and the confining magnetic field, hydrogen can resonate at its harmonic cyclotron frequency (1st at half field and 2nd at one-third field) with the launched ICRF waves [2]. In particular, the NBI-ICRF synergies when the NBI species resonates at its 1st harmonic using three-ion scenarios have been recently observed in JET [3]. Therefore, synergies between fast-protons of NBI heating and ICRF waves can have an impact on ICRF-heating performances. To investigate these synergies, here, we use the 2-dimensional full-wave `TORIC` solver for the wave propagation and absorption of ICRF waves, and `SSFPQL` solver for the kinetic equation of the heated species in the simultaneous presence of NBI sources and ICRF heating. `TORIC` and `SSFPQL` are interfaced in such a way that the coefficients of `TORIC` wave equation are built directly from the numerical solutions of `SSFPQL` [4]. The kinetic equation is solved for all the ion species that can resonate with ICRF waves. The target plasma is generated with `ASTRA` transport code with appropriate pedestal [5], boundary conditions [6], and transport model [7]. As main scan parameters we consider ICRF frequency and H concentration. As common feature, we find that NBI heating increases the fraction of ICRF power directly absorbed by hydrogen and substantially broadens the profile of ICRF power absorbed by hydrogen.

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