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Efficient generation of energetic D ions with the 3-ion ICRH+NBI synergetic scheme in H-D plasmas on JET-ILW

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An extended version of the 3-ion scheme relies on using fast NBI ions as resonant species for heating mixed plasmas[1,2]. NBI ions can efficiently absorb RF power at the mode conversion (MC) layer, where the wave polarization is particularly favourable for ion cyclotron heating, through their Doppler-shifted resonance. This advanced ICRH+NBI scheme was earlier observed in D-3He plasmas on JET[3] and was recently demonstrated in JET-ILW H-D plasmas[1]. The neutron rate was increased by a factor of 10-15, when 2.5MW of RF power was coupled in addition to 3.5MW of D-NBI. In this contribution, we summarize fast-ion observations, confirming the high-efficiency of the 3-ion D-(DNBI)-H scheme to accelerate D-NBI ions to higher energies with ICRH. Good agreement between a range of fast-ion diagnostics (including the neutron rate, neutron spatial profile and energy spectrum, neutral particle analyzer, gamma-ray spectroscopy and MHD analysis) and time-dependent ICRH modeling (TRANSP/TORIC and PION) has been achieved[4,5].

The developed scheme is also relevant for fast-ion studies in stellarators. Since stellarators generally poorly confine energetic trapped ions, recently an idea of passing particle acceleration with ICRH was proposed for W7-X [6]. This idea relies on channeling RF power to resonant ions with a large Doppler shift, leading to more efficient increase in their parallel kinetic energies due to ICRH. In addition, as follows from the analysis of here reported JET experiments, plasma parameters for the 3-ion D-(DNBI)-H scheme can be tuned to provide strong core localization of RF power deposition, corresponding to the location of the MC layer in the plasma. This, in turn, brings forward effects associated with the non-standard particle orbits in the plasma core and sets up an additional spatial filter for resonant wave-particle interactions. For the conditions of the 3-ion JET experiments, theoretical analysis of the quasilinear evolution of ICRH-heated ions shows that originally passing NBI ions do not cross the trapped-passing boundary during their acceleration due to ICRH. These results are also backed up by TRANSP/TORIC modeling of JET pulse #91256[4]. Figure 1 illustrates ASCOT-computed orbits of passing NBI ions (ED=100keV, v||/v=0.62) and passing ICRH+NBI ions (ED=500keV, v||/v=0.45), together with the spatial distribution of the left-hand polarized RF electric field |E+|^2 (TORIC code).

We conclude the contribution with the discussion of the implications of the 3-ion schemes in D-3He and D-T plasmas on JET. In particular, these experiments could provide a deeper insight on the impact of highly energetic ions, mainly those in the alpha particle energy range, on the ITG turbulence. This can significantly clarify the role of alpha particles on ITER plasmas, for which recent theoretical studies have shown that they could significantly reduce heat transport [7].

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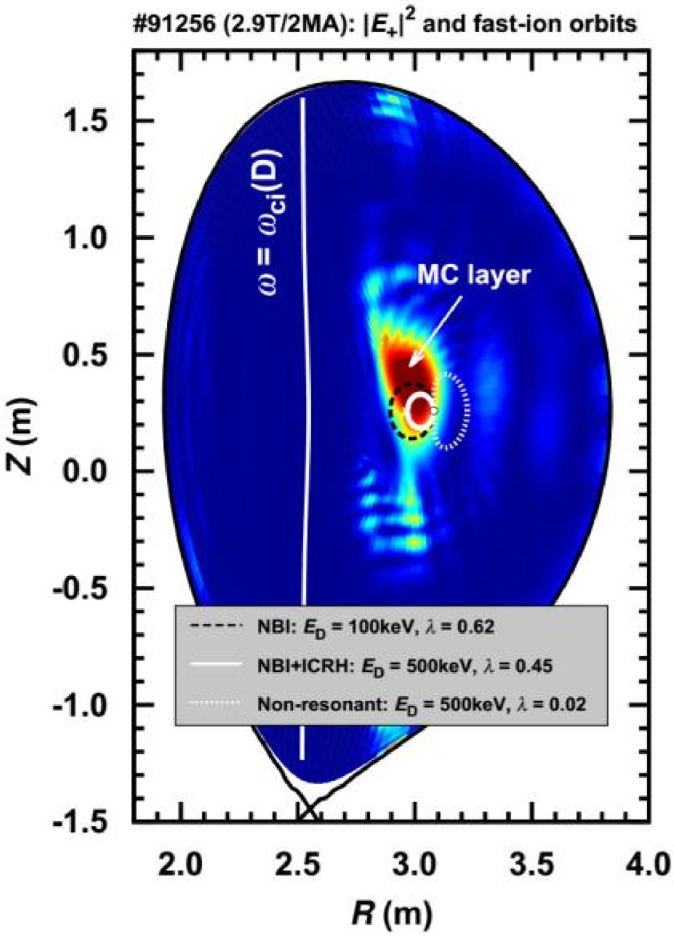

Figure 1: Computed left-hand polarized RF electric field, $|E_+|^2$ and orbits of energetic D ions for JET pulse #91256 (2MA/2.9T, X[H] ≈ 85-90%, X[D] ≈ 10-15%), in which the 3-ion D-(D_{NBI})-H scheme was applied.

Figure 1: Fig1

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