Experiments with second harmonic ICRF heating of T in JET third major campaign with D-T plasmas (DTE3)

M.J. Mantsinen[1,2], P. Jacquet[3], D. Gallart[1], K. Kirov[3], E. Lerche[3,4], D. Taylor[3], C.D. Challis[3], E. Delabie[5], A. Kappatou[6], D. Keeling[3], D. King[3], S. Silburn[3], E.R. Solano[7], Z. Stancar[3], E. Tsitrone[8]
JET Contributors* and the EUROfusion Tokamak Exploitation Team**

[1]Barcelona Supercomputing Center, Barcelona, Spain
[2]ICREA, Barcelona, Spain
[3]United Kingdom Atomic Energy Authority, Culham Science Centre, Abingdon, Oxon, OX14 3DB, United Kingdom of Great Britain and Northern Ireland
[4]Laboratory for Plasma Physics, ERM/KMS, B-1000 Brussels, Belgium
[5]Oak Ridge National Laboratory, TN 37830 Oak Ridge, USA
[6]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany
[7]Laboratorio Nacional de Fusión, CIEMAT, 28040 Madrid, Spain
[8]CEA, IRFM, F-13108 St-Paul-Lez-Durance, France
**, **See authorlists of C.F. Maggi et al and E. Joffrin et al, respectively, to be published in Nuclear Fusion Special Issue: Overview and Summary Papers from the 29th Fusion Energy Conference (London, UK, 16–21 October 2023)*

In the 2nd major D-T campaign (DTE2) at JET, experiments were carried out to integrate 2nd harmonic ion cyclotron resonance frequency (ICRF) heating of T and ^{3}He minority heating in JET 3.4 T/2.3 MA high-performance hybrid plasmas and to compare their performance with the more commonly used H minority heating [1]. These ICRF schemes are of a high relevance to ITER given the fact that they are reference schemes for ITER D-T plasmas at its full magnetic field of 5.3 T. While the JET DTE2 experiments were successful e.g. in confirming the bulk ion capabilities of these heating schemes [1], a few questions remained and put forward to the follow-up third major D-T campaign (DTE3). The results of these DTE3 experiments, both in high-performance hybrid plasmas and L-mode plasmas, are presented.

The DTE2 high-performance hybrid plasmas were carried out with half of NBI in T and half of NBI in D, while no T beams are planned for ITER. In DTE3, discharges like those in DTE2 were carried out with D beams only to provide a better match to ITER. High-performance hybrid plasmas with ~27 MW of NBI and ~4 MW of ICRF power were reproduced with D beams and compared to those with mixed D and T NBI. The resulting core ion and electron temperatures (T_i and T_e), fusion yield R_{NT} and plasma diamagnetic energy content W_{DIA} were up to 40% lower with D beams only. According to ICRF+NBI modelling with PION, ICRF power absorbed by T reduced from 55% to 30% of ICRF power due to weaker damping by T in the absence of T NBI, which resulted in a decrease of bulk ion heating by ICRF from 40% to 25% of ICRF power and an increase of bulk electron heating by ICRF from 60% to 75% of ICRF power when changing mixed beams to D beams only. According to NBI modelling with PENCIL, bulk electron and bulk ion heating by NBI increased and decreased, respectively, with D beams only. Our results suggest that bulk ion heating plays an important role for the performance of JET hybrid plasmas and that bulk ion heating by 2nd harmonic ICRF heating of T can be increased in JET by using T NBI which enhances T damping. While this option will not be available in ITER, modelling suggests that given the high plasma temperature and density in ITER, 2nd harmonic damping of T will be sufficiently strong to provide a significant fraction of bulk ion heating also in ITER.

In DTE3 L-mode plasmas, 2nd harmonic heating of T resulted in lower T_e and W_{DIA} than H minority heating while T_i, R_{NT}, and sawtooth-free periods were similar. ICRF fast ion and plasma heating characteristics are analysed and compared with experimental observations.

[1] M.J. Mantsinen et al 2023 Nucl. Fusion 63 112015.