ICRH and NBI Heated Dimensionless Identity Plasmas on JET

T. Tala[1], A. Salmi[1], E.R. Solano[2], R.B. Morales[3], I.S. Carvalho[4], J. Citrin[5], A. Chomiczewska Czarnecka[6], E. Delabie[3], F. Eriksson[7], J. Ferreira[4], E. Fransson[7], L. Horwath[3], P. Jacquet[3], D. King[3], E. Lerche[8], C. Maggi[3], P. Mantica[9], A. Mariani[9], M. Marin[5], M. Maslov[3], S. Menmuir[3], V. Naulin[10], F. Nave[4], H. Nordman[7], C. Perez Thun[6], P.A. Scheider[11], G. Sips[12], K. Tanaka[13] and JET contributors*

[1]VTT, P.O. Box 1000, FI-02044 VTT, Espoo, Finland
[2]CIEMAT, Av Complutense 40, Madrid 28040, Spain.
[3]CCFE, Culham Science Centre, Abingdon, OX14 3DB, UK
[4]Instituto de Plasmas e Fusão Nuclear, Universidade de Lisboa, Lisboa, Portugal
[5]DIFFER, Eindhoven, Netherlands
[6]IPPLM, Warsaw, Poland
[7]Chalmers University of Technology, Göteborg, Sweden
[8]LPP-ERM/KMS, TEC Partner, Brussels, Belgium
[9]Istituto di Fisica del Plasma, via Cozzi 53, Milano, Italy
[10]Danish Technical University Physics, Lyngby, Denmark
[11]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany
[12]European Commission, Brussels, Belgium
[13]National Institute for Fusion Science, Toki, Gifu, Japan
* See the author list of E. Joffrin et al 2019 Nucl. Fusion **59**, 112021.

Up to 15s H-mode plasmas with 8MW of ICRH power were executed on JET, with the JET record high injected ICRH energy of 108MJ. The ICRH discharges, using the H minority heating scheme at 3% minority concentration, were stationary without any major MHD activities or impurity accumulation. NBI heated discharges were executed consecutively to match the dimensionless plasma profiles of q, ρ^*, υ^*, β_n and T_i/T_e using the same shape. Both pulses had gas puff modulation at 3Hz for the whole duration of the discharges to extract perturbative particle transport coefficients. The ELM frequencies are 75Hz and 45Hz for the ICRH and NBI pulses, respectively, with mixed ELMs and affected by gas puff modulation.

The main dimensionless and dimensional profiles are compared in figure 1. The dimensionless profiles of q, ρ^*, υ^*, β_n and T_i/T_e were matched within 5% difference except in the central part of the plasma (ρ_{tor}<0.3). The most significant difference, in addition to rotation or Mach number (see table 1), is the density profile which is ~50% more peaked for the NBI discharge than for the ICRH peaked discharge.

The general conclusion is that 8MW of NBI and ICRH (roughly 4MW goes to ions and 4MW to electrons for each heating case) create very similar plasma profiles and performance in JET despite various differences, such as larger steady-state gas puff needed in the NBI pulse to get the same pedestal height in n_e. The main differences are the toroidal rotation (10km/s counter-I_p in ICRH pulse and 110km/s co-I_p for the NBI pulse), fast ion content (14% versus 8%), ELM characteristics, radiation and heavy impurity concentration. The effect of MHD activity is limited to the central region (ρ_{tor}<0.3), and does not affect the core (0.3<ρ_{tor}<0.8) transport analysis. The pedestal is similar between the shots and thus does not explain the higher n_e peaking. The possible candidates left are the rotation and fast ion content in NBI plasma modifying the particle transport or the NBI fueling.

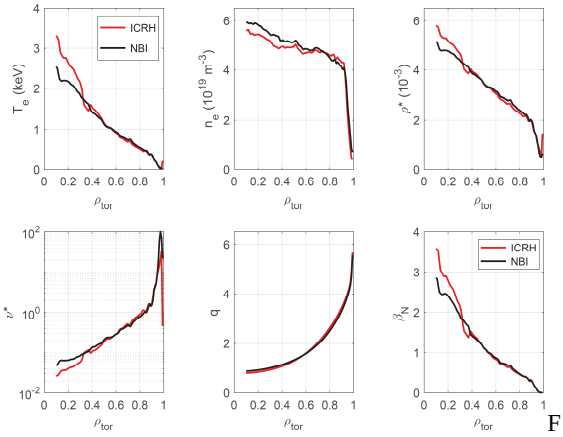

Figure 1. Comparison of the main dimensionless dimensional plasma profiles between the ICRH heated (#95097) and NBI heated (#95272) discharges.

The ICRH versus NBI identity plasmas in JET show that the NBI fuelled discharge has 50% higher density peaking. Otherwise the ICRH and NBI heated identity plasmas yield similar plasma parameters and performance despite the obvious differences in rotation and fast ion content. This result is valid at 8MW of heating power level, it remains to be seen how it will scale to larger power levels and to larger devices.