39th EPS Conference on Plasma Physics, Stockholm, Sweden P1.035

Characterisation of L-mode plasmas in the new ITER- like Wall in JET

D. Frigione[1], M. Clever[2], M. Beurskens[3], A. Boboc[3], S. Brezinsek[2], G. Calabro'[1], P. De Vries[4], L. Garzotti[3], E. Giovannozzi[1], M Groth[5], A. Huber[2], M. Lehnen[2], S. Marsen[7], E. Joffrin[8], K. McCormick[9], F. Rimini[3], B. Viola[1]
and JET-EFDA contributors*
JET-EFDA, Culham Science Centre, OX14 3DB, Abingdon, UK

1. *Associazione EURATOM-ENEA sulla Fusione, CP 65, Frascati, Rome, Italy*
2. *Association EURATOM-FZJ, Forschungszentrum Jülich ,Germany*
3. *EURATOM/CCFE Fusion Ass., Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK*
4. *DIFFER, Association EURATOM-FOM, Nieuwegein, The Netherlands*
5. *Aalto University, Association EURATOM-Tekes, Espoo, Finland*
6. *Consorzio RFX, EURATOM-ENEA Association, Corso Stati Uniti 4, 35127 Padova, Italy*
7. *Max-Planck Institute for Plasma Phys., EURATOM -Assoc., Greifswald, Germany*
8. *Association EURATOM-CEA, Cadarache 13108 Saint Paul Lez Durance, France*
9. *Max-Plank Institute fur Plasma Physik -Euratom Association, Boltzmannstr.2, 85748 Garching, Germany*

* *See the Appendix of F. Romanelli et al., Proceedings of the 23rdIAEA Fusion Energy Conference 2010, Daejeon, Korea.*

Introduction.

After the successful completion of the 2010-2011 shut down, JET resumed operation with completely new plasma facing components (PFCs) consisting of a tungsten (W) divertor and a beryllium (Be) inner wall complemented by some W tiles in small crucial areas [1]. These materials, as well as the shape of the plasmas they interact with, mimic very closely the scenarios foreseen for ITER especially when JET is run at high triangularity (δ~0.35). Operation was resumed with ohmic or slightly additionally heated L-mode discharges, in order to safely explore the effect of the new wall on fuelling efficiency, density limit, recycling, detachment, impurity behaviour and confinement.

One of the main reasons for turning to metals as PFCs, in spite of the remarkable capability of carbon to withstand large power fluxes and to yield intrinsic edge radiation, was to reduce the fuel retention, which in ITER would quickly saturate the maximum allowed tritium inventory. L-mode operation with the new wall at JET has immediately shown the beneficial effect of the new materials to this regard [2].

Data Base and Plasma Configurations

Pulses considered in this paper had a plasma current of I_p = 2.0 MA and were in the toroidal field range of B_T = 2.0-3.1 T corresponding to safety factors of q_{95} = 3.0-4.3. They were L-mode discharges additionally heated by low ICRH power (~1 MW) except for the core transport analysis which refers to an ohmic case. All of them were at relatively high triangularity (δ~0.35) with the inner strike point (ISP) on the vertical target (coated W) and the outer strike point (OSP) on the horizontal bulk W tile placed at the centre of the divertor. The OSP position could be more on the high filed side (HFS), in which case the configuration is called HT3L, or displaced towards the low field side (LFS) in the HT3R configuration. One of the main differences between the two configurations is the pumping capability: HT3R has got more SOL flux lines ending in the divertor corner where particles are pumped through the pumping slit by the divertor cryopump. Both, density ramps aiming at density limit disruptions, and density steps were performed, the latter being mainly intended for the characterisation of confinement and detachment [3, 4].

Density limit and response to gas injection

The examined data base showed a density limit (DL) dependence on the toroidal magnetic field (fig. 1) during a field scan at constant plasma current: i.e. the density limit was significantly higher (~40%) at lower safety factor $q_{95.}$ In the latter case, density profiles were more peaked performing a higher central density at the expenses of a lower central temperature, all of this resulting in an almost identical pressure profile (fig. 2). An influence of the magnetic field on the density limit, was also observed in FTU and was related to the different profile peaking and MARFE onset due to different connection length of the SOL magnetic lines [5]. Considering the two extremes at 2.1 and 3.1 T, figure 3 shows that the radiated power and the gas rate was the same when the same density was reached. During a fuelling position scan performed at 2.0 MA and 2.5 T it was seen that moving the gas source from the divertor private flux region to the LFS divertor SOL led to a reduced ion flux (I_{SAT}) to strike points together with a reduction of the D_α emission (fig. 4). When puffing from the outboard, more gas was needed to reach the same upstream density due to better pumping and, at this stage, the plasma was still in the low recycling regime while, pumping from the private region, it had reached, at same upstream density, the semi detachment (roll-over).

Detachment and core transport

The electron density was raised both in continuous ramps and in steps up to well beyond the roll over of the OSP ion saturation current (I_{SAT}) which was measured by Langmuir probes. The roll over took place at the same upstream density irrespective of the outer strike point position on the divertor central tile. Figure 5 shows divertor parameters versus the upstream density, taken during a density ramp in HT3L and HT3R configuration. The red trace of this graph, referring to HT3L configuration, has been cut during a transition to a higher density regime associated with the development of a little density pedestal while the electron temperature remained virtually unchanged [6]. The HT3R configuration was more resilient to the transition mentioned above and the full trajectory evolved smoothly towards the detachment.

A general reduction of about one order of magnitude of the Carbon and Oxygen content was observed with respect to former C-wall operation while no relevant W accumulation took place in these discharges [1, 6] As regarding the core confinement, preliminary JETTO [7] modelling shows that particle transport remains of standard Bohm-gyro-Bohm type and that, assuming ~5% fuelling efficiency, the recycling coefficient, needed to fit the data, is close to unity. In these simulations, both the fuelling efficiency and the recycling refer to the particle exchange between the SOL and the core plasma rather than to the divertor region. Figure 6 shows the capability of the code to reproduce the observed electron density and temperature profiles under these assumptions. The agreement looks reasonably good except for the central temperature possibly due to the effect of the sawtooth which was not taken into account in the simulation.

Conclusion

L-mode density scans at high tringularity showed a toroidal field dependence of the density limit: higher line average densities were achieved at lower field at same current. Gas injected into the divertor private region proved to be more efficient, with respect to direct injection into the SOL, in rasing the density and leading to high recycling. The transition to detachment (J_{sat} roll-over) taook place at similar average density i.e. at ~70% of the density limit irrespective of the OSP position. When moving the OSP closer to the pumping corner although staying on central tile (HT3R) somewhat higher DL and reduced recycling was observed. Code simulations indicate that the core transport remains of the standard Bohm-gyro-Bohm type and density profiles are compatible with a 5% fuelling efficiency and a recyclig coefficient close to one.

Acknowledgements

This work was supported by EURATOM and carried out within the framework of the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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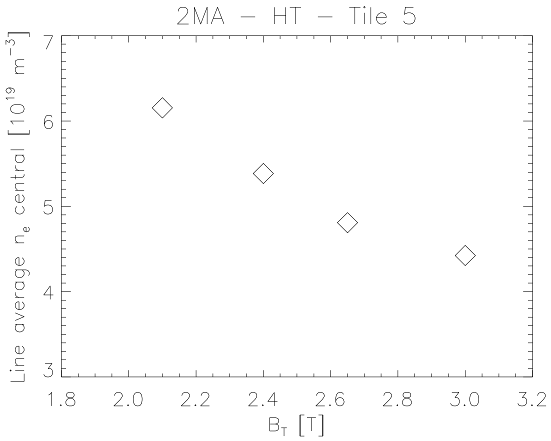

Fig 1 Density limit versus toroidal magnetic field at fixed plasma current (2.0 MA)

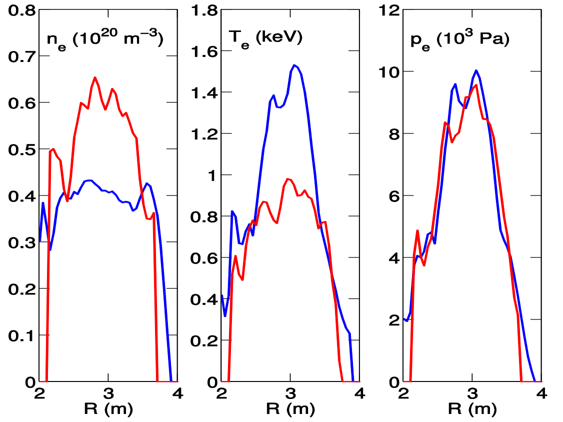

Fig. 2 N_e, T_e, P_e profiles (81197, 2T, 54.13s, blue; vs 81228, 3T, 62.63 red)

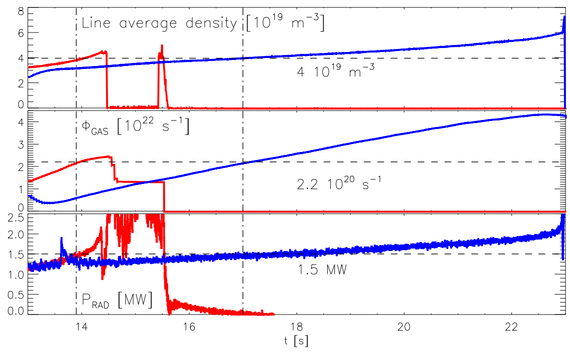

Fig. 3 Line average lectron density, D_2 fuelling rate and total radiated power for the two discvharges of fig. 2.

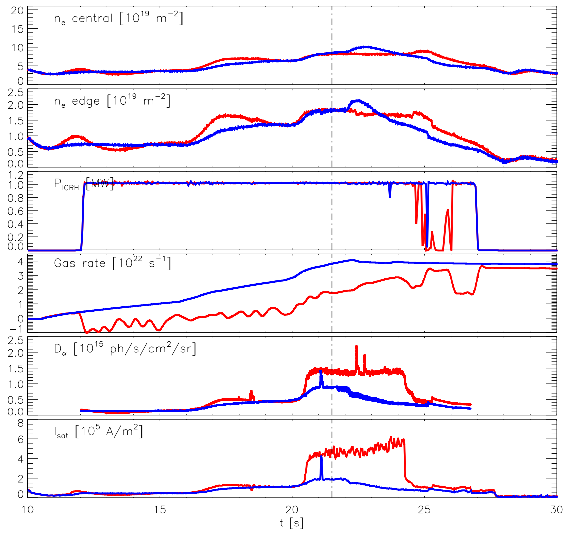

Fig 4 Gas injection position scan from divertor private region (80967, red) to SOL (80968, blue). Vertical line: same density t=61.8 s.

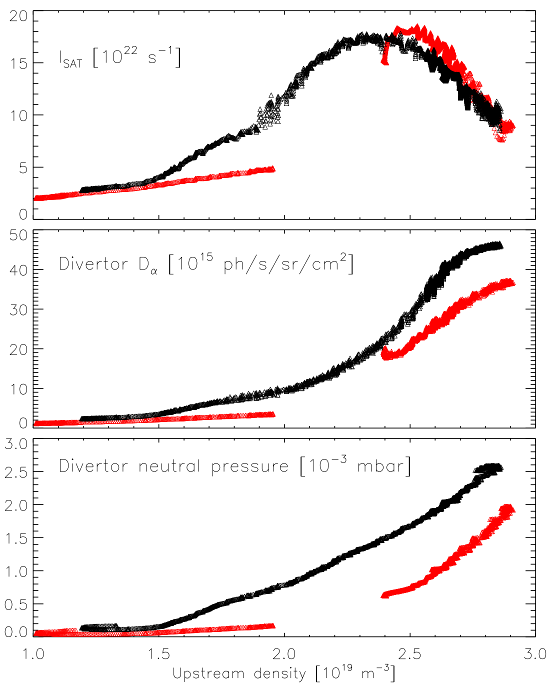

Fig 5. HT3L(red) vs HT3R(black) density scan. From top: I_{SAT}, divertor D_α and neutral pressure. Red line interrupted during a transient H-mode phase.

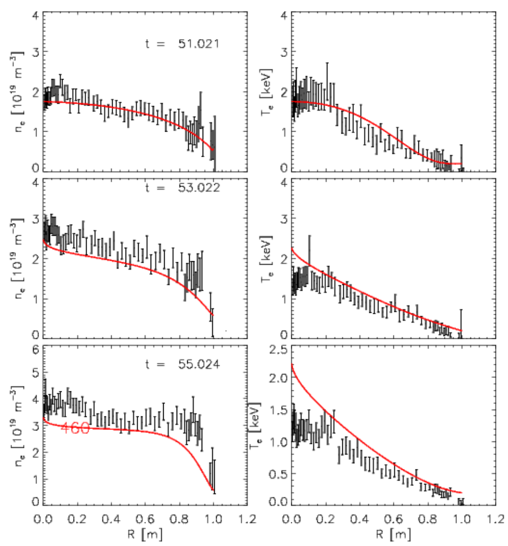

Fig 6. JETTO simulations (red) performed using Bohm-gyro-Bohm coefficients vs experimental profiles