Effect of wall temperature and divertor closure on the L-mode density limit at JET

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Introduction. It has been found that the L-mode density limit was decreased when going from the open MkI divertor to the closed MkII divertor. But simultaneously the wall temperature was increased from 40°C in the MkI divertor to 220°C in the MkII divertor. In order to disentangle the effects of the wall temperature and the divertor closure on the density limit new experiments in the JET gas box divertor, which is even more closed than MkII, have been carried out. The density limit is compared for 320°C and 200°C wall temperature, meaning 220°C and 140°C divertor target plate temperature. Additionally different configurations, which differ in the strike point heights on the vertical divertor targets and consequently leading to open and closed divertor configurations, were investigated.

Effect of wall temperature. In figure 1 two density limit pulses (52684 and 53077, V/SFE/LT) with low and high wall temperatures are compared. Both plasmas (2.0MA/2.4T) were heated with ≈ 2MW NBI. In line with previous observations [1] the onset of the X-point MARFE, which is a precursor to the ultimative density limit, occured at higher densities (+20%) when the wall temperature is reduced. The process of the density limit is thought to be a result of detachment of the inner divertor [2]. Tomographic reconstructions of the total radiated power show in the attached case strong radiation at inner vertical target, which vanishes with continous gas puffing, leading then to a more symmetric radiation distribution around the X-point before finally an X-point MARFE develops. The total radiated power just before the X-point MARFE

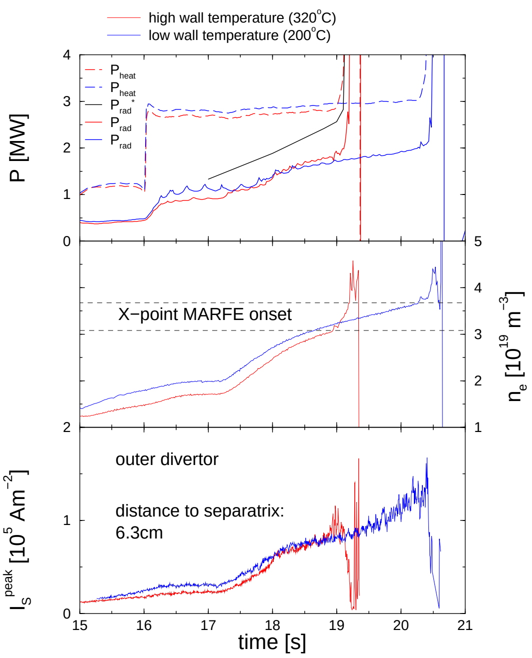

Figure 1: Comparison of two L-mode discharges (52684, 53077).

† see appendix of the paper by J. Pamela *Overview of recent JET results*, Proceedings IAEA Conference on Fusion Energy, Sorrento, 2000

formation is 70% (derived from an approximate integration) respectively 90% (derived after tomographic reconstruction, P^*_{rad}). An energy balance between input energy, radiated energy and energy deposited on the divertor tiles (measured by thermocouples) is consistent when taking P^*_{rad}. This consistency leads to the suggestion that the radiated power prior the X-point MARFE formation is larger than reported previously elsewhere [2]. The onset of the X-point

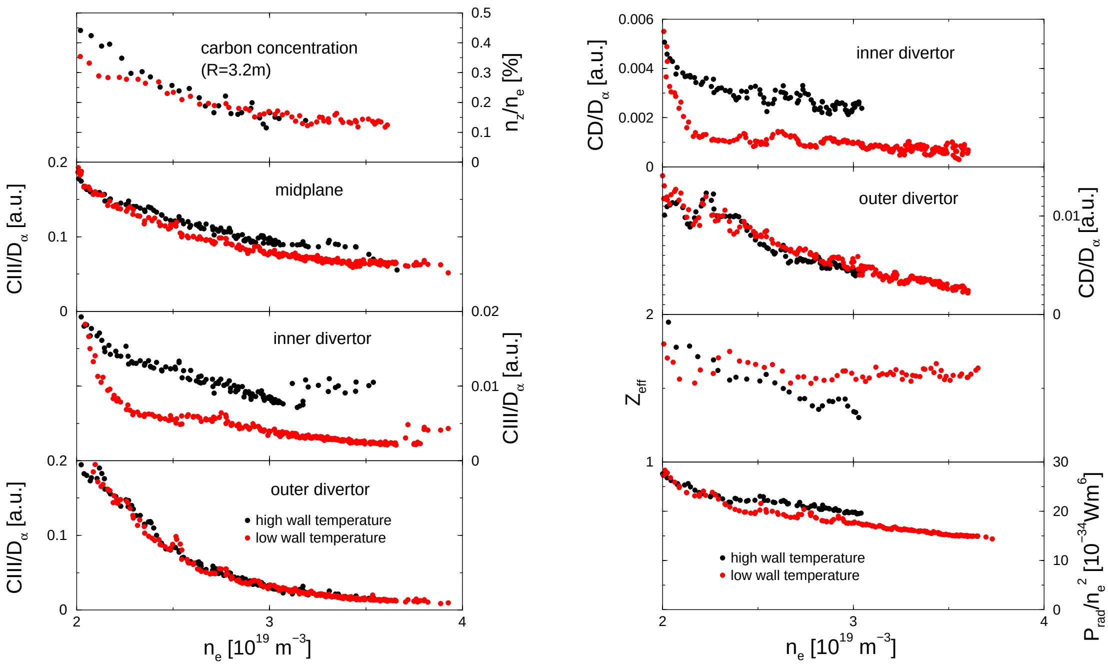

Figure 2: Carbon release: Normalized photon fluxes CIII/D$_\alpha$ and CD/D$_\alpha$, Z_{eff}, carbon concentration from CXRS.

MARFE at 20% higher densities for the lower wall temperature, respectively lower divertor target tile temperature, is most probably due a reduced carbon release in the inner divertor, as it is indicated by the strong reduction of CIII/D$_\alpha$ (fig. 2). As one can expect the chemical erosion is suppressed at lower wall temperatures in agreement with the reduction of the CD band emission (fig. 2). Though no change of carbon release was observed in the outer divertor. This is reflected by the CIII/D$_\alpha$ ratio in figure 2 and the CD/D$_\alpha$ ratio in figure 2. Similarly the carbon release in the main chamber is hardly influenced by the reduction in wall temperature. So it seems that the local release of carbon in the inner divertor determines the X-point MARFE formation.

Effect of divertor closure. In order to study the influence of the septum on the density limit a gas location scan in open (vertical target 22cm) and closed (vertical target 5cm) divertor configurations was performed. The plasma (1.7MA/2.4T, high clearance configuration) was heated by $\approx$ 2MW NBI. For further characterization the criterion DoD= $C \times \overline{n}_e^2/I_S$ (Degree of Detachment) [3] is used, with I_S being the ion saturation current. In figure 3 the DoD is plotted for individual divertor Langmuir probes. Puffing from the inner divertor leads to an early detachment of the inner divertor and late detachment of the outer divertor. The detachment at inner divertor develops gradually whereas the detachment at the outer divertor suddenly happens,

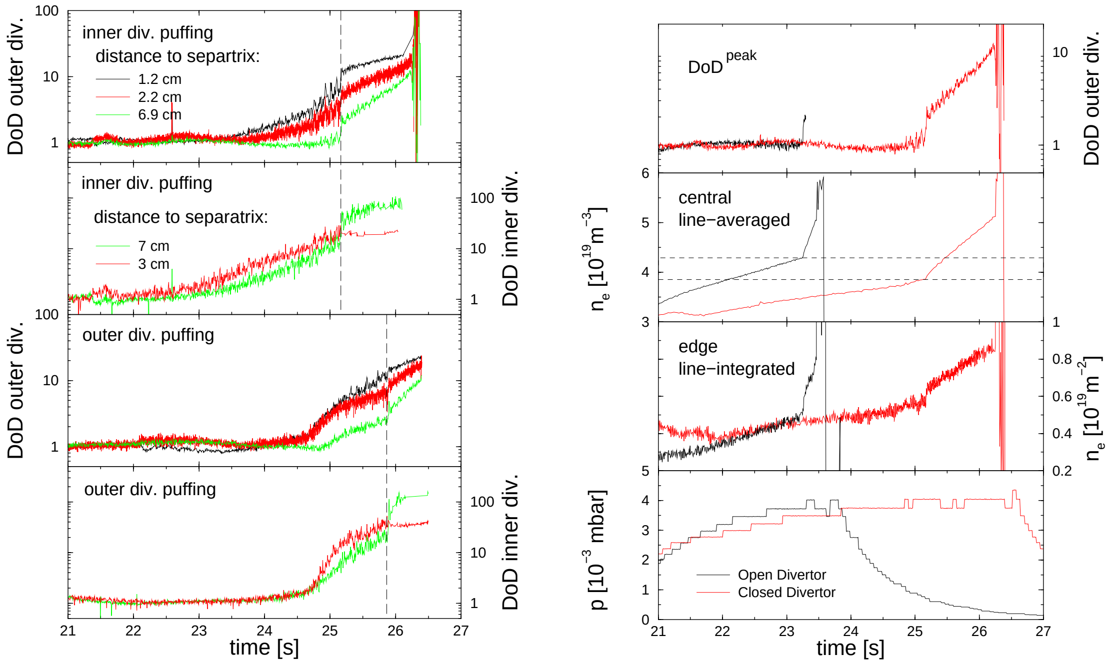

Figure 3: Left: Degree Of Detachment for inner divertor (53080) and outer divertor (53081) puffing in Closed divertor configuration; Right: Comparison of density limit in Open (53082) and Closed (53080) divertor configuration; X-point MARFE onset is indicated by dashed line.

when the X-point MARFE is formed. Puffing in the outer divertor leads to a later detachment of the inner divertor symmetric to the detachment of the outer divertor. The X-point MARFE forms at a 10% higher density. As can be seen in figure 3 the erosion of the ion saturation current profile starts at the separatrix in line with measurements in divertor JET-MK IIA [4]. The onset of the X-point MARFE is determined by a detachment of DoD^{peak} $\geq$ 2 (with DoD^{peak} being determined by the flux tube with highest ion current), which is in good agreement with measurements in JET-Mk I and JET-Mk II [3]. The sudden drop of I_S at the MARFE formation is an indication of loss of convective power to the target plates approaching 100% total radiated power fraction. When going to the open divertor configuration the difference in the X-point MARFE onset regarding the inner or outer divertor puffing is reduced to values of less than 5%. Systematically the X-point MARFE onset is at 15% higher densities in the open divertor configuration in comparison to the closed divertor configuration. Those systematic differences in the X-point MARFE onset are summarized in figure 5. A remarkable difference in the MARFE lifetime was observed in high clearance configurations (large clearance of the LCFS to the wall). Long lasting X-point MARFEs ($\geq$ 1s) were obtained (see also fig. 3). Tomographic reconstructions from bolometry and CIII line emission are compared in figure 4. Clearly the radiation from the MARFE is located inside the LCFS. During the long lifetime of the MARFE the density (central line-averaged and edge line-integrated) can be increased significantly until finally a MARFE at the inner main vessel wall forms. Shortly after the Wall MARFE formation the density limit is encountered. Figure 5 shows that although the X-point MARFE onset varies due to fueling, divertor closure or wall temperature, the onset of the Wall MARFE depends only on the wall clearance. That the onset of the Wall MARFE does not depend on the wall tem-

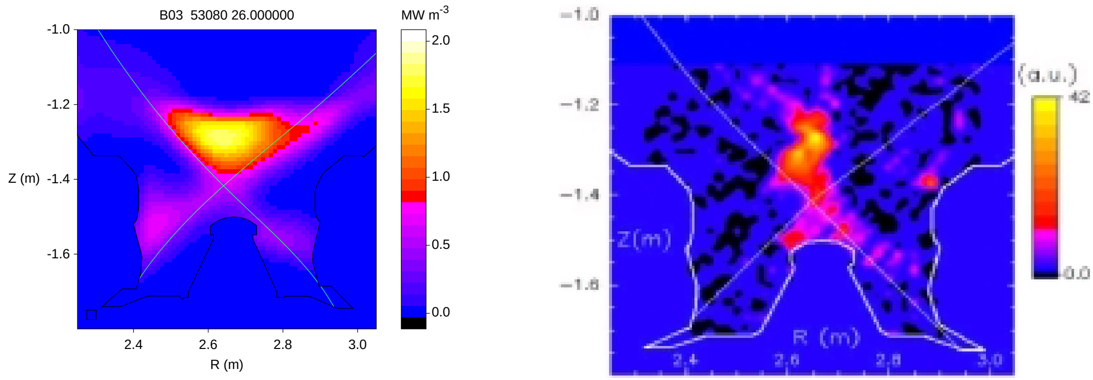

Figure 4: MARFE: comparison of bolometric tomographic reconstruction (left) with tomographic reconstruction of CIII line emission (right); 53080 at 26s.

perature is consistent with the observation that the carbon release in the main vessel and Z_{eff} do not change with lower wall temperature. Identical discharges with respect to $B_t = 2.4$T, $q_{95} = 4.2$, $q_\perp \approx 17$kW/m^2 but different wall clearance (standard fat configuration =: low wall clearance; high clearance configuration =: high wall clearance) experience the onset of the X-point MARFE at the same density of $\overline{n}_e = 3.8 \times 10^{19}$m^{-3}. Those results are in line with results obtained at TEXTOR, where the density limit in L-mode discharges was found to depend on the inner wall clearance [5].

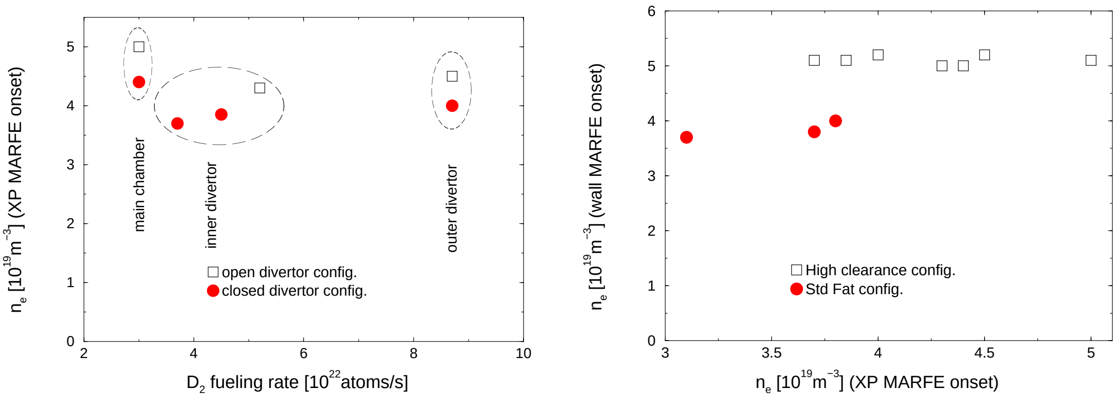

Figure 5: Summary of X-point MARFE onset and Wall MARFE onset for L-mode density limit discharges.

Summary and conclusion. The density at the X-point MARFE onset is increased by 20% when the wall temperature is reduced from 320°C to 200°C. This increased critical density is most probably due to less carbon erosion in the inner divertor. The divertor closure leads to an X-point MARFE onset at lower densities of 15%. The X-point MARFE onset does not determine the density limit. The final, disruptive density limit depends on the wall clearance.

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