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Role of the separatrix density in the pedestal performance in JET-ILW and JET-C

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Since the initial JET operations with the metal wall (JET-ILW), the experimental results have shown a pedestal pressure in baseline plasmas that tends to be 10-20% lower than in the corresponding earlier carbon wall operations (JET-C) [1]. While this degradation seems mainly correlated with the high fueling rates typical of JET-ILW [2,3] and/or the lack of carbon impurity [4,5], an exhaustive and comprehensive explanation for the lower pedestal performance has not been achieved yet. This work will address the role of fueling and its goals are:

- to prove that the lower pedestal performance in D fuelled JET-ILW plasmas are due to the higher separatrix density (n_e^{sep}) produced by the higher neutral pressure,
- to describe the corresponding physics mechanisms that lead to the pedestal degradation.

In the baseline scenario of JET-ILW, operations with no gas-fueling rate have been extremely challenging due to the problems related to tungsten influx and divertor heat loads. Since most of the JET-C plasmas have no gas fueling, a direct comparison of JET-ILW and JET-C pedestals obtained with identical engineering parameters is not possible. A further complication is related to the fact that the peeling-ballooning (PB) stability model (implemented with ideal MHD equations) does not describes correctly the experimental JET-ILW results (the experimental pedestal with high fueling rates does not seem to reach the stability boundary when the ELMs are triggered [1,2,3]). Therefore, the work is based on two levels. First, the work focuses on the empirical understanding of the pedestal behavior in JET. Then, based on these results, an investigation of the pedestal transport and an extension of the PB stability analysis is done with the GENE [6] and JOREK [7] codes.

Figure 1 shows the height of the electron pedestal pressure (p_e^{ped}) versus n_e^{sep} for a set of JET plasmas with the same engineering parameters apart from fueling rate and divertor configuration. The JET-C dataset has higher p_e^{ped} than the JET-ILW dataset. However, the two datasets align very well in the p_e^{ped}-n_e^{sep} diagram. Moreover, the JET-ILW pulses with lowest n_e^{sep} reach a pedestal pressure comparable to JET-C. This suggests that the separatrix density is one of the key parameters to understand the difference between carbon and metal wall. The higher n_e^{sep} in JET-ILW is likely due to the higher neutral pressure, as recently discussed for JET-ILW [8] and AUG [9], produced by the higher gas fueling and/or different recycling. In figure 1, note that the subsets with different divertor configurations show no systematic difference, strengthening the hypothesis that the neutral pressure plays the key role.

The standard PB stability analysis performed with ideal MHD can only partially explain the empirical trend. This is shown in figure 1 by the red line, which represents the pressure predictions obtained with the Europed code [10]. The increase in n_e^{sep} initially leads to a sharp reduction in the predicted p_e^{ped}. This is due to the fact that the increasing n_e^{sep} is intrinsically linked to the outward shift of the n_e position (n_e^{pos}), shifting the p_e profile and destabilizing the PB modes [3,11]. While this explains rather well the JET-C trend, the effect saturates at high n_e^{sep}. The prediction significantly overestimates the experimental p_e^{ped} for the JET-ILW pedestal with high n_e^{sep}.

Therefore, the next steps are to understand the mechanisms that (1) set the pedestal gradient and (2) trigger the ELMs at high n_e^{sep}. First of all, we note from figure 1 and figure 2(a) that the reduction of pedestal gradient is correlated with the increase in n_e^{sep} and in n_e^{pos}-T_e^{pos}. The increase in these parameters leads to the increase of η_e (ratio between n_e and T_e gradient length) [3], which in turn can destabilize microinstabilities, increase turbulent transport [12, 13] and hence reduce the pressure gradient. This hypothesis is under investigation with GENE and is supported by preliminary results shown in figure 2(b), where the growth rates (mainly of ETG modes) are higher in pedestals with higher n_e^{sep} and higher n_e^{pos}-T_e^{pos} [14,15].

Then, it is necessary to understand the ELM triggering mechanisms. The discrepancy between the experimental results and the ideal MHD results is quantified with the ratio $\alpha_{crit}/\alpha_{exp}$ (where α_{crit} is the normalized pressure gradient predicted by ELITE and α_{exp} is the experimental one). Figure 3 shows that $\alpha_{crit}/\alpha_{exp}$ increases with increasing resistivity. This suggests that resistivity might have a destabilizing effect on the PB modes, as theoretically discussed in [16]. This hypothesis is currently under investigation with the non-ideal MHD non-linear code JOREK.

The picture that is emerging is the following. Due to higher gas fueling rate / different re-cycling, JET-ILW has higher neutral pressure than JET-C. This leads to higher n_e^{sep} and higher n_e^{pos}, producing higher η_e, increasing the turbulent transport and reducing the pedestal gradient. In turn, the lower pedestal gradient leads to a lower temperature inside the separatrix, increasing the resistivity and making resistive effects on the MHD stability non-negligible.

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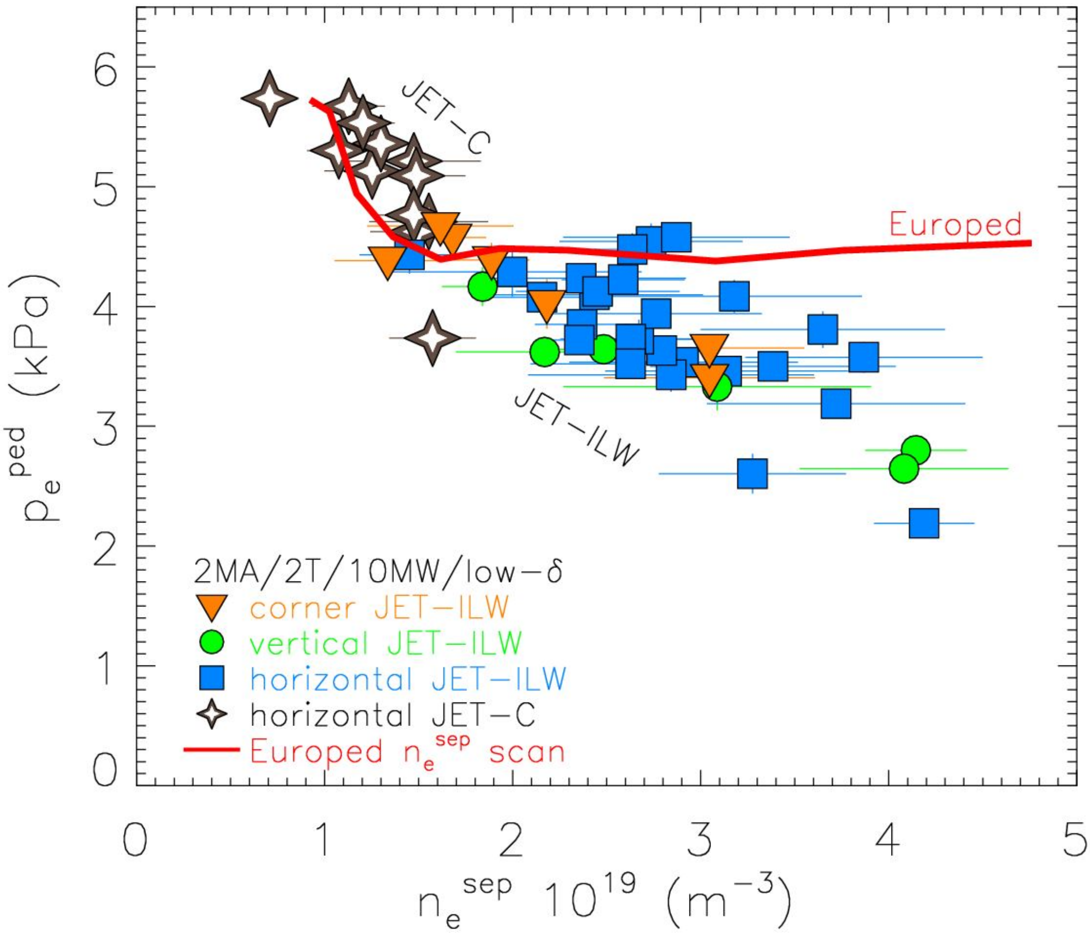

Figure 1: Correlation between p_e^{ped} and n_e^{sep} for a JET-C and a JET-ILW dataset with similar engineering parameters apart gas fueling rate and strike point position. The red line shows the predicted correlation between p_e^{ped} and n_e^{sep} obtained with Europed.

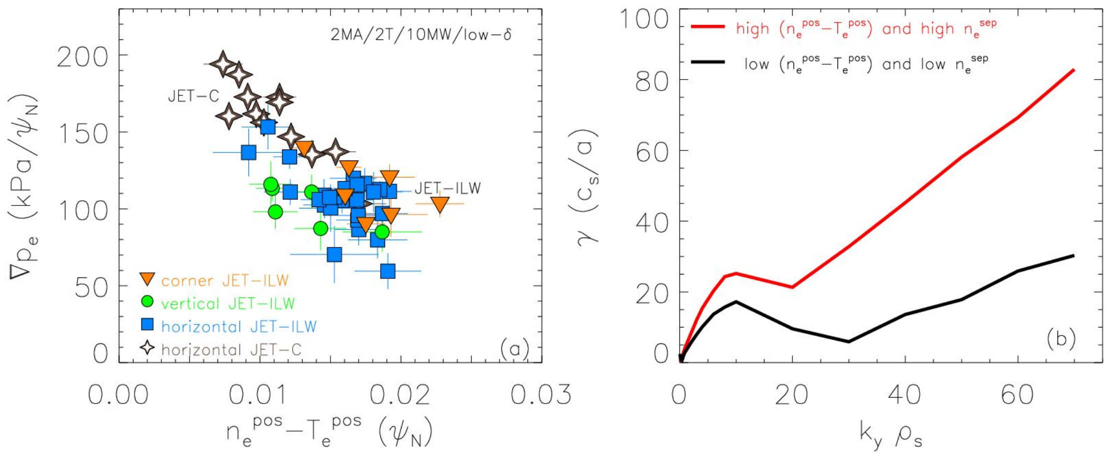

Figure 2: (a) Correlation between ∇p_e and n_e^{pos}-T_e^{pos}. (b) Growth rates of microinstabilities at ρ_t=0.99 obtained with GENE for a case with high n_e^{pos}-T_e^{pos} and high n_e^{sep} (red line) and a case with low n_e^{pos}-T_e^{pos} and low n_e^{sep} (black line).

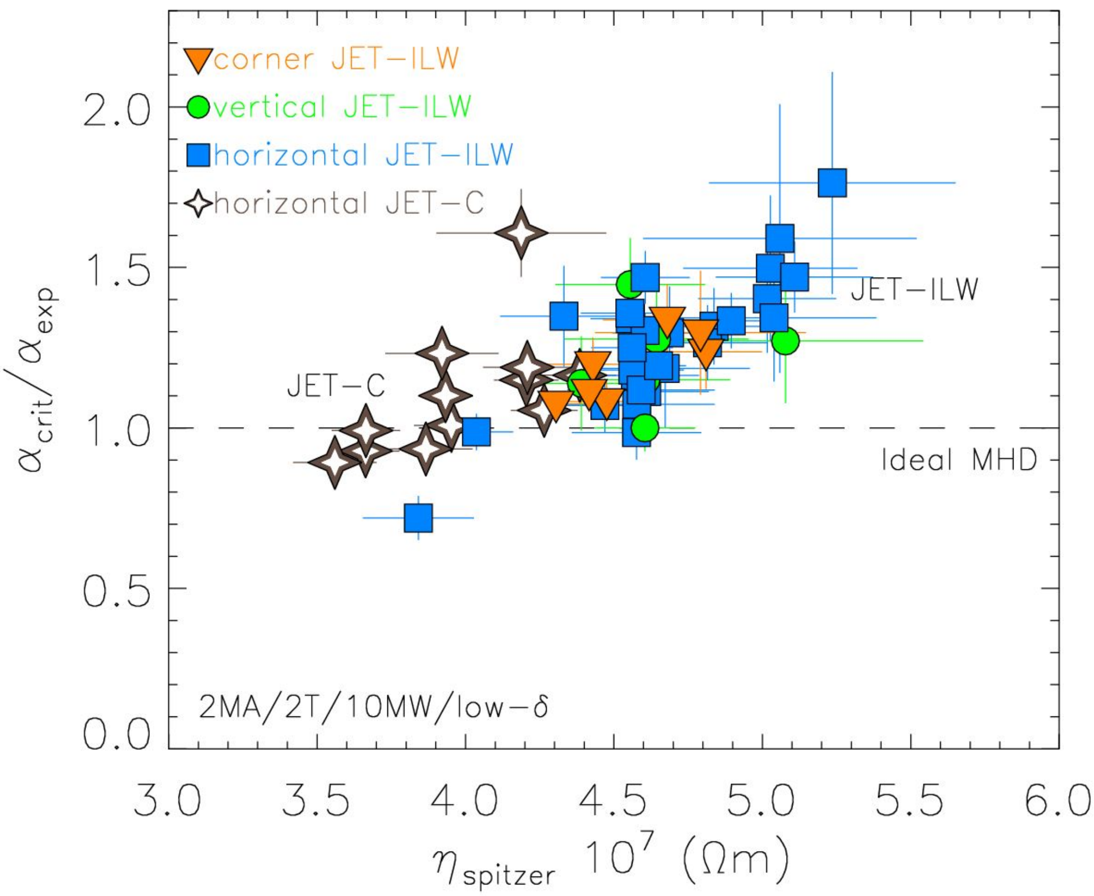

Figure 3: Correlation between $\alpha_{crit}/\alpha_{exp}$ and Sptizer resistivity at ρ_t=0.99

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