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Effect of the initial ELM on impurity transport in hot ion H mode plasma

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Introduction

The high pedestal temperature H-mode experiment at JET gave a good opportunity to study the effect of a single ELM on the particle transport, because these H-mode plasmas are characterized by a long ELM free period after the L to H transition and the 2^{nd} ELM occurs several 100 ms later [1]. It is apparent from figure 1 that in all of these pulses the n_e and the Z_{eff} increase slowly in time before the first ELM and significant increase of the n_e and Z_{eff} at the time of the 1^{st} ELM. At the first sight this contradicts the previous experimental observation that ELMs remove impurities from the plasma core [2]. Then what is the difference between these high pedestal H-mode plasmas and the typical H-mode plasmas at JET and other machines? We will try to answer this question using the 1.5D core transport code JETTO/SANCO.

Modelling

To simulate a high pedestal temperature we used the pulse 75417 as a template and we started the JETTO/SANCO simulations just after the L to H-mode transition at 53.5 s and ended the simulation at 55.0 s, half a second after the first ELM for this pulse. The high temperature plasmas do not reach the steady state before the first ELM, which leads to an extra unknown into the simulations, the neutral sources. To fit the time traces of the Z_{eff} and the line average n_e, (figure 2), C was introduced at the wall in all the JETTO/SANCO simulations (with and without ELMs) with $\Gamma_{inC} = 8.0\times10^{19}$ 1/s during the ELM free period to fit the experimental time evolution of the Zeff. To mimic an extra influx of C observed in figure 1d we increased Γ_{inC} to 3.0×10^{22} 1/s just before the ELM during 70 ms. SANCO has a rude description of the transport in the SOL and the fast parallel transport is not included. Γ_{inC} at the edge and the

[b] See the Appendix of F. Romanelli et al., Proceedings of the 22nd IAEA Fusion Energy Conference, Geneva, Switzerland, 2008

$\Gamma_{inD,NBI} = 1.2\times10^{21}$ 1/s in the plasma core were not sufficient to fit the time evolution of the line average n_e, it was necessary also to introduce an extra gas through the LCFS of $\Gamma_{inD} = 4.0\times10^{20}$ 1/s, while experimentally, was used $\Gamma_{inD} = 2.0\times10^{21}$ 1/s. In all these simulations R = 1 was used for impurities and main ions; therefore in these plasmas the through put is around 20% and the effect of the Γ_{inD} is not negligible.

The transport model we used in the plasma core was the Bohm/GyroBohm empirical model, defined as [3]: $\chi_e = c_e\left(0.5\chi_{gB} + 0.5\chi_B + \chi_{neo-al}\right)$; $\chi_i = c_i\left(0.5\chi_{gB} + 0.5\chi_B\right) + \chi_i^{neo}$;

$$D = c\frac{\chi_e\chi_i}{\chi_e + \chi_i}; V = 0.5D\frac{\nabla q}{q} + V_{neo}; \quad c_i, c_e, c \begin{cases} 1 & \rho < \rho_{top} \\ << 1 & \rho \geq \rho_{top} \end{cases}, \quad L_{ETB} = \left(1 - \rho_{Top}\right)a \approx 3cm$$

Within the ETB the transport factors were determined by the time evolution of the W_{th} before the first ELM, (figure 2).

ELMs

To simulate the ELM in JETTO/SANCO χ_i and D are increased within the ELM perturbed region (d_{ELM}). In this model the ELM is trigged when the parameter α defined by [5], $\alpha \equiv \frac{-2\mu_0 R q^2}{B_\phi^2}\cdot\frac{\partial p}{\partial r}$, reaches α_{crit}= 1.54 in these simulations. The W_{th} drop and the χ_i (figure 3a) due to the ELM are dependent not only on the enhancement of the transport factors but also on d_{ELM}. Figure 3d and figure 3c show that the jump of the line average n_e and the Z_{eff} increases are also dependent on the d_{ELM}. For this reason the enhancement of the c_i, c_e and c were determined by the W_{th} drop of the ELM with the perturbed region of 33 cm (figure 3b). Although d_{ELM} is much wider than it is observed in typical JET H-modes plasma (d_{ELM} = d_{ETB}). Figure 4 shows that the simulated change of the n_e and n_{imp} and T_e profiles due to an ELM describes well the change observed experimentally.

Figure 3d shows a slower increase of the Z_{eff} for the simulation without the ELM than the simulations with the ELMs. Hence the ELM removes impurities from the edge to the plasma core. In addition the increase of the n_e at the time of the first ELM is also observed, (figure 3c), and is mainly due to the influx of C. The 2nd simulated ELM reduces the Z_{eff}, indicating removal of impurity from the plasma core. This leads us to the conclusion that the ELMs leads to a fast impurity penetration into the plasma core when the impurity density at the edge is higher than in the plasma core, and vice versa. Furthermore, after the first ELM the recovery of the W_{th} is slower for the experimental plasma than for the simulated one, thus the plasma confinement is reduced after the first ELM.

Conclusion

It is clear from these JETTO/SANCO simulations that the high pedestal temperature plasmas are more transparent to the D in the SOL than expected [6]. The increase of the Z_{eff} effect observed experimental is indeed due to the C released from the walls. The ELMs leads to a fast impurity penetration into the plasma core, observed in the Z_{eff} signal, when the impurity density at the edge is higher than in the plasma core, and vice versa.

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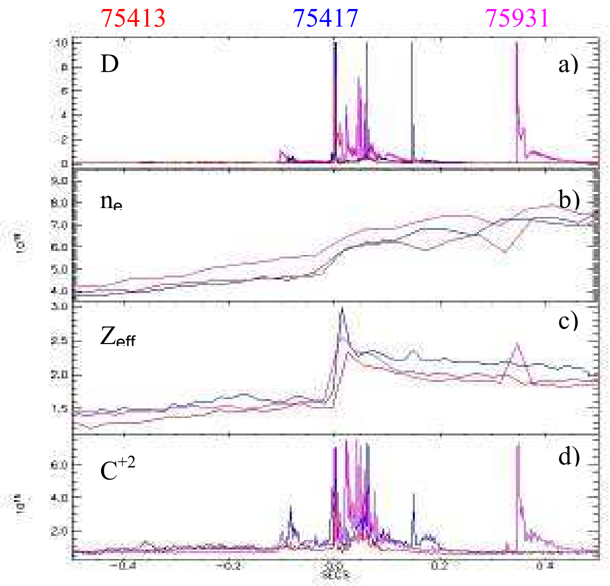

Figure 1: Time traces relative to the time of the first ELM for the high pedestal temperature plasmas of: a) D_α, b) line average n_e, c) Zeff and d) C^{+2} spectral line intensity.

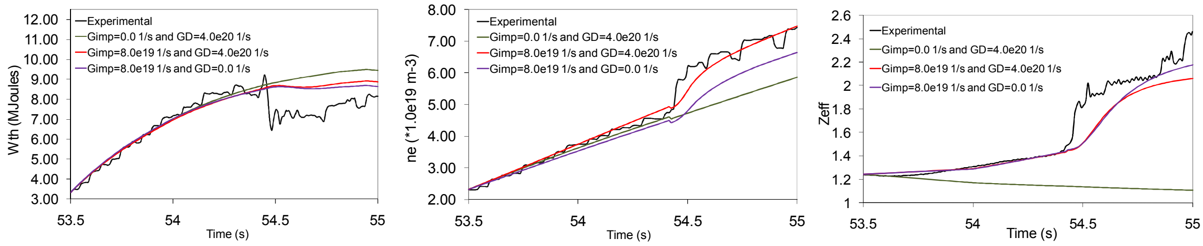

Figure 2: Time evolution of the: a) W_{th}, b) line average n_e and c) Zeff from CX. The traces are experimental (black) and the simulated cases: Γ_{inC} =0 1/s and with Γ_{inD} = 4.0e20 1/s (green); Γ_{inC} = 8.0e19 1/s and Γ_{inC} = 0 1/s (purple) and with C and D sources (red)

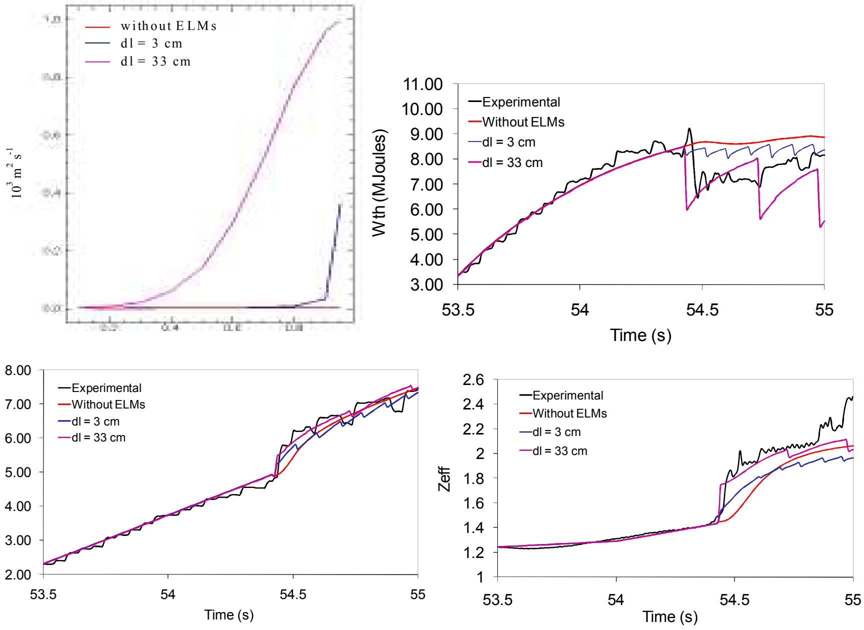

Figure 3: a) ELM perturbation width at the χ_i profile and time evolution of the: b) W_{th}; c) line average n_e and d) Zeff from CX. The traces are experimental (black) and the simulated cases without ELMs (red) and with ELMs perturbed region of: 3 cm (blue); and 33 cm (pink).

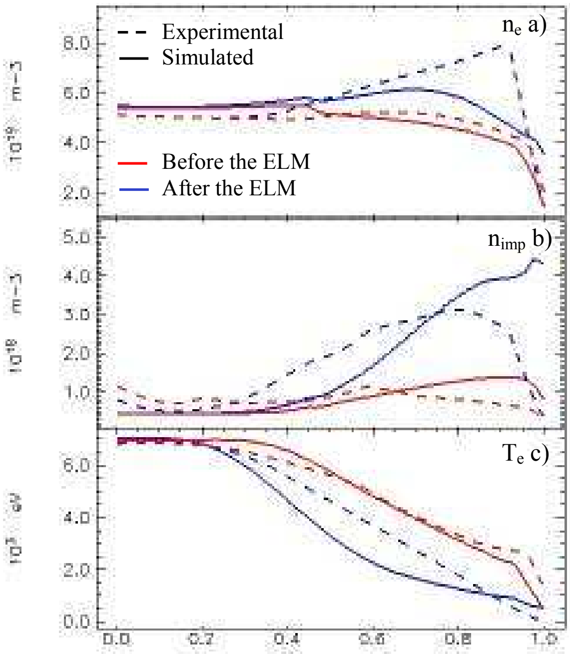

Figure 4: Simulated (continuous line) and experimental (dashed line) profiles of the: a) n_e; b) n_{imp} and c) Te, before the ELM (red) and after the ELM (blue).