EFDA–JET–CP(09)06/21

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** See annex of F. Romanelli et al, "Overview of JET Results",*
(Proc. 22nd IAEA Fusion Energy Conference, Geneva, Switzerland (2008)).

Preprint of Paper to be submitted for publication in Proceedings of the
36th EPS Conference on Plasma Physics, Sofia, Bulgaria.
(29th June 2009 - 3rd July 2009)

1. 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 2nd ELM occurs several 100ms later [1]. It is apparent from figure 1 that in all of these pulses the ne 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 1st 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.

2. MODELLING

To simulate a high pedestal temperature we used the Pulse No: 75417 as a template and we started the JETTO/SANCO simulations just after the L to H-mode transition at 13.5s and ended the simulation at 15.0s, 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 Z_{eff}. 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 $\Gamma_{inD,NBI} = 1.2\times10^{21}$ 1/s in the plasma core were not sufficient to fit the time evolution of the line average ne, 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]:

$$\chi_e = c_e\,(0.5\,\chi_{gB} + 0.5\,\chi_B + \chi_{neo\text{-}al});\ \chi_i = c_e\,(0.5\,\chi_{gB} + 0.5\,\chi_B) + \chi_i^{neo};$$

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

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

3. 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], $\alpha = \frac{-2\mu_0 R q^2}{B_\phi^2} \cdot \frac{\delta p}{\delta p}$ ’, reaches $\alpha_{crit} = 1.54$ 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 dELM. For this reason the enhancement of the ci, ce and c were determined by the Wth drop of the ELM with the perturbed region of 33cm (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 Zeff 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 ne 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.

ACKNOWLEDGMENTS

This work, which has been supported by the European Communities and the Instituto Superior Técnico (IST) under the Contract of Association between the European Atomic Energy Community and IST, was performed under the European Fusion Development Agreement. This work was also partly funded by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and UKAEA. The views and opinions expressed herein do not necessarily reflect those of the European Commission and IST.

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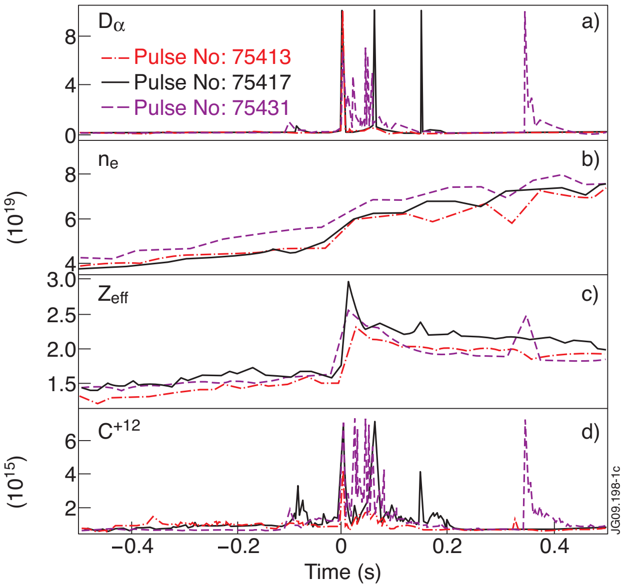

Figure 1: Time traces relative to the time of the first ELM for the high pedestal temperature plasmas of: a) D_α , b) line average n_e, c) Z_{eff} and d) C^{+2} spectral line intensity.

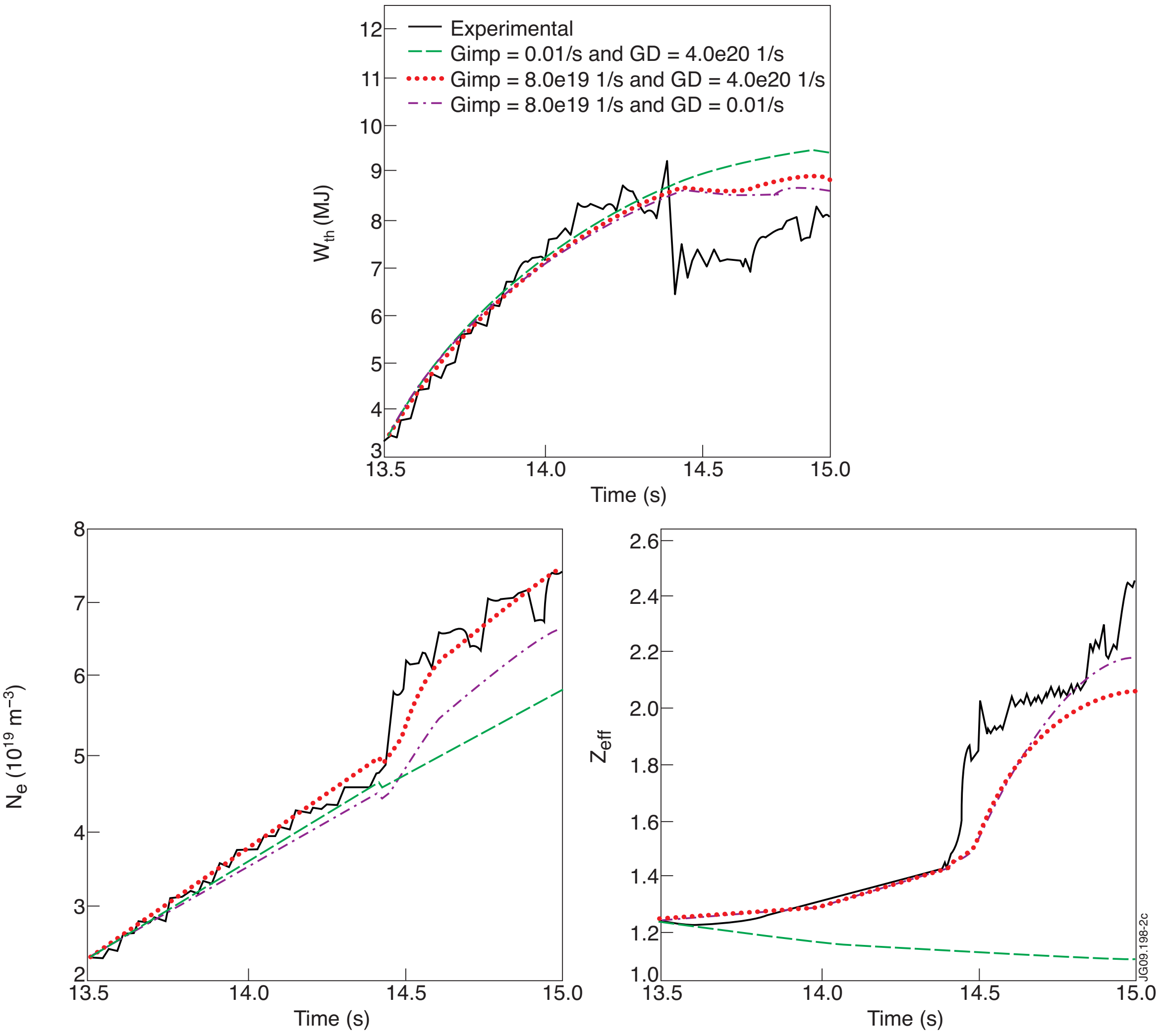

Figure 2: Time evolution of the: a) W_{th}*, b) line average ne and c)* Z_{eff} *from CX. The traces are experimental (black) and the simulated cases:* $\Gamma_{inC} = 0$ *1/s and with* $\Gamma^{inD} = 4.0e20$ *1/s (green);* $\Gamma_{inC} = 8.0e19$ *1/s and* $\Gamma_{inC} = 01/s$ *(purple) and with C and D sources (red)*

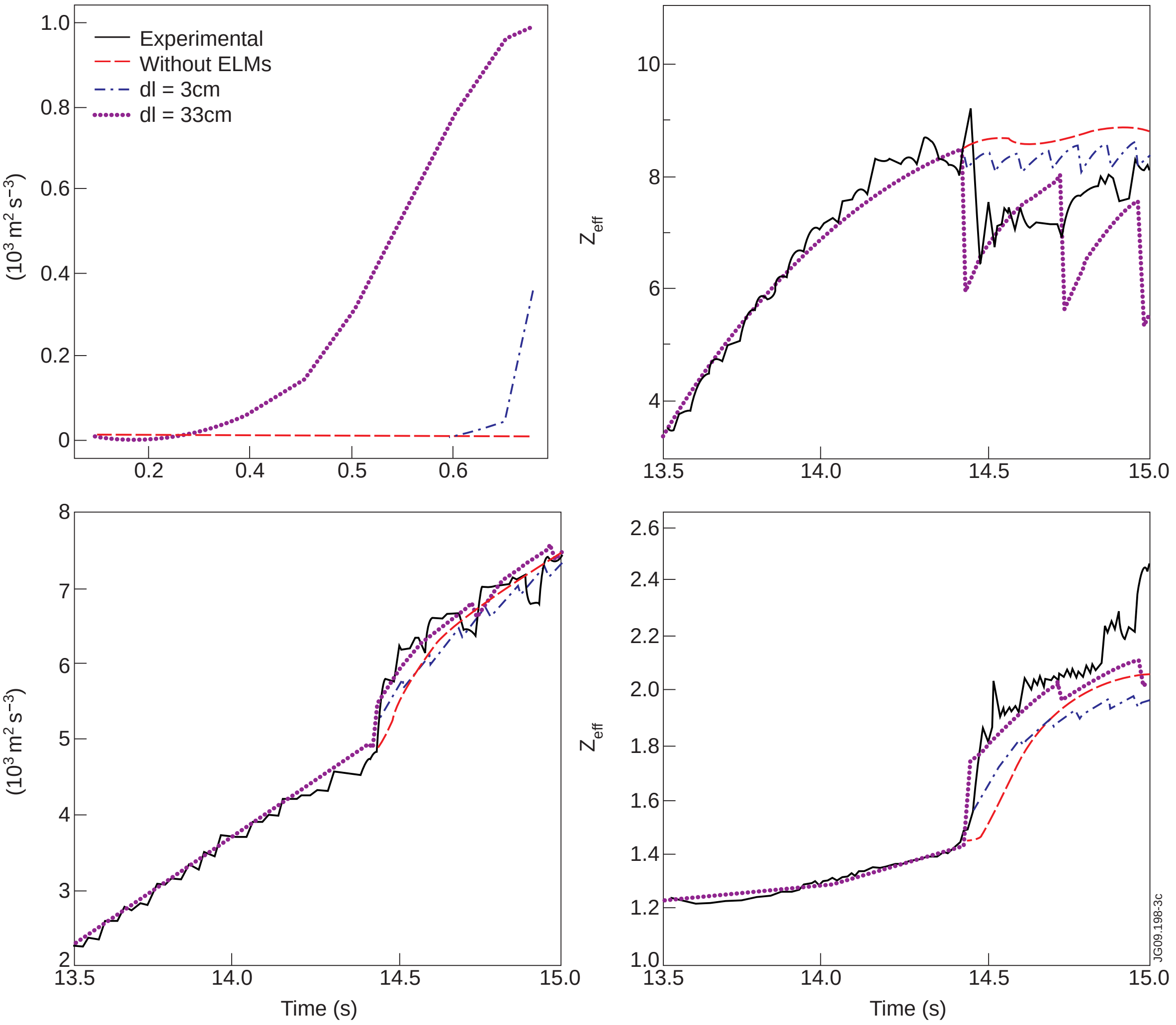

Figure 3: a) ELM perturbation width at the «i profile and time evolution of the: b) Wth; c) line average ne and d) Zeff from CX. The traces are experimental (black) and the simulated cases without ELMs (red) and with ELMs perturbed region of: 3 cm (blue); and 33 cm (pink).

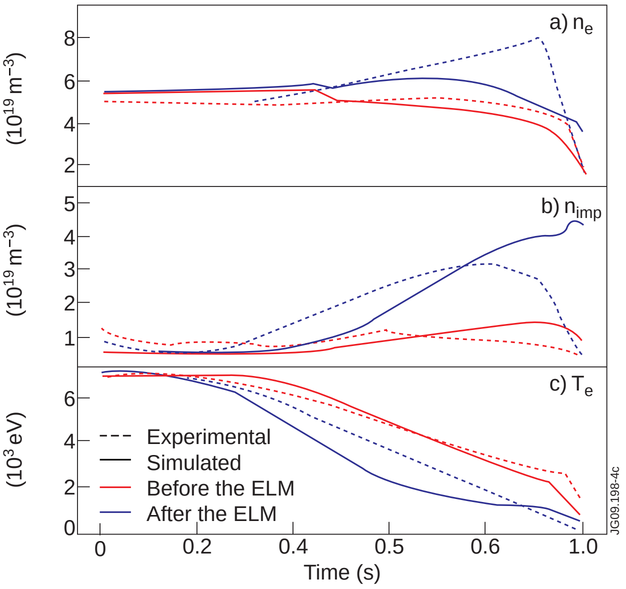

Figure 4: Simulated (continuous line) and experimental (dashed line) profiles of the: a) ne; b) nimp and c) Te, before the ELM (red) and after the ELM (blue).