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*\* See annex of F. Romanelli et al, "Overview of JET Results",  
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## 1. INTRODUCTION.

In view of possible realistic predictions for ITER-relevant scenarios with impurity seeding, JET discharges with nitrogen injection have been numerically simulated in recent years using the self-consistent transport code COREDIV [1, 2]. The coupled core-edge code COREDIV [1] (1-D radial transport in the core, 2-D poloidal and radial transport in the SOL, self-consistent with respect both to the interaction core-SOL and main plasma impurities) has been developed and benchmarked against JET discharges [2], proving its capability of reproducing - with the diagnostic and modeling uncertainties - the main features of JET seeded plasmas, as the electron temperature and density profiles, the total radiated power,  $P_{rad}$ , and the ionic effective charge,  $Z_{eff}$ . In the core, the electron and ion energy fluxes are defined by a local transport model which, for a given profile of the transport coefficients (usually parabolic), reproduces a prescribed energy confinement law (enhancement factor,  $H_{98P(y,2)}$ ). A simple slab geometry (poloidal and radial directions) with classical parallel and anomalous radial transport (order of  $0.5\text{m}^2\text{s}^{-1}$ ) is used for the SOL. Chemical and physical sputtering together with sputtering by seeded nitrogen account for the fluxes of the intrinsic carbon and recycling is a free parameter.  $Z_{eff}$ . It should be noted that COREDIV, although intrinsically time dependent, has been used so far to analyze only steady state plasmas (average values for ELMy discharges).

## 2. EXPERIMENTS AND SIMULATIONS.

We have considered a set of nitrogen seeded JET discharges in ELMy H-mode ( $I_p = 2.5\text{MA}$ ,  $B_T = 2.7\text{T}$ ,  $q_{95} = 3.5$ ,  $P_{in} \sim 15\text{MW}$ ) in which both the fuelling and seeding rates have been systematically changed, on a shot to shot basis [3, 4]. Keeping the N puffing at  $\Phi_N = 4.8 \times 10^{22}$  el/s, the D puffing changes in the range  $1.2 - 2.8 \times 10^{22}$  el/s and keeping  $FD = 2.8 \times 10^{22}$  el/s, FN changes in the range  $0 - 2.8 \times 10^{22}$  el/s. Increasing the D puffing, the volume average electron density  $\langle n_e \rangle$  is seen to increase from  $5.7$  to  $7.6 \times 10^{19}\text{m}^{-3}$  (with related decrease in  $Z_{eff}$ ) and the confinement enhancement factor  $H_{98P(y,2)}$  decreases from  $0.95$  to  $0.82$ . Increasing the N puffing,  $\langle n_e \rangle$  decreases from  $10$  to  $7.6 \times 10^{19}\text{m}^{-3}$  and  $H_{98P(y,2)}$  decreases from  $1$  to  $0.82$ .

### 2.1. $P_{RAD}$ AND $Z_{EFF}$

Considering the D puffing scan, we have first examined with COREDIV the effect on  $Z_{eff}$  of a change in recycling coefficient (higher the puffing, higher the recycling) in the range  $0.975 - 0.983$ . The effect both in  $Z_{eff}$  and in  $P_{rad}$  is negligible, although a significant effect is seen on the edge temperature and D flux leaving, however, their product nearly constant. A numerical test on the influence of a change in the position of the nitrogen inlet valve led to minor effects on  $Z_{eff}$  and  $P_{rad}$ , as well. Considering the value relatively high of  $H_{98P(y,2)}$  - and its spread - in these discharges, we have modeled impurity transport to account for a linear dependence of the inward impurity pinch on the confinement level. The simple analytical expression we have adopted reads:

$$\Gamma_z = D_{\perp} (dn_z/dr + S r/a^2 \times n_z)$$

where  $\Gamma_z$  is the flux of impurities of charge  $z$ ,  $D_{\perp}$  is the anomalous perpendicular main ion diffusivity and  $S \sim \tau_E^2$ . With this choice, the resulting inward impurity pinch is proportional to  $\tau_E$  ( $v_{\text{pinc}} \sim \tau_E r/a^2$ ) since in our transport model (see Introduction)  $D_{\perp} \sim 1/\tau_E$ . In Figures 1 and 2 the experimental and simulated  $P_{\text{rad}}$  and  $Z_{\text{eff}}$  are shown for the D puffing scan. While  $P_{\text{rad}}$  remains nearly constant with increasing D puffing,  $Z_{\text{eff}}$  decreases as a consequence of the increase in the electron density and of the decrease in confinement (in impurity inward pinch). For these pulses, the resulting simulated impurity peaking ( $-v_{\text{pinch}}/D$ ) is modest, in the range 0.3–0.6  $\text{m}^{-1}$ , consistently with previous analysis of impurity transport with radiofrequency heating in JET [5]. Please, note that for these discharges the highest discrepancy between the experimental and simulated  $P_{\text{rad}}$  is about .0.3–0.4MW. The discrepancy is much higher for the discharges of the N seeding scan, Figure 3. In fact, it reaches 0.8–0.9MW, which is above the modeling and experimental uncertainties. However, the assumption of a small amount of N in the discharge  $\Phi_N = 0$  (consistent with nitrogen legacy, observed to occur on JET during these experiments.[3]) would lead only to a marginal change in the calculated  $Z_{\text{eff}}$  (Fig.4), while it would increase the level of the calculated  $P_{\text{rad}}$ , mainly due to the high electron density of this discharge and to the rather good radiation properties of nitrogen in the considered range of temperatures. Numerical decomposition of  $Z_{\text{eff}}$  in the carbon and nitrogen concentration shows the linear increase of N and the decrease of C with increasing  $\Phi_N$ , thus confirming the replacement of C by the seeded N, previously observed on TEXTOR [6].

## 2.2. DEUTERIUM AND CARBON FLUXES.

Comparison simulation-experiment for the particle fluxes is a critical issue because, on top of the usual uncertainties related to the spectroscopic determination of the photon fluxes (absolute calibration, assumed symmetries), the evaluation of particle fluxes needs the ionization per photon ( $S/XB$ ) to be assigned. This number, which depends strongly on the local temperature and density, can be determined only with some approximation and, in principle, should be different for each pulse. Following [7] we have assigned, both for the  $D_{\alpha}$  and for CII line ( $\lambda = 515\text{nm}$ ),  $S/XB = 30$  for the outer divertor and  $S/XB = 15$  for the inner divertor. In Figures 5 and 6 the experimental and simulated D fluxes are shown for the D puffing and for the N seeding scans. For figure 5, either the experimental point at the lower D puff is too low or those at higher puffing are too high. This is consistent with the fact that for the lower D puffing (low density) the calculated  $T_e(\text{plate})$  is on the order of 30eV while for the remaining two points (higher density) the calculated  $T_e(\text{plate})$  is on the order of 10eV. Therefore the  $S/XB$  for the pulse at low puffing should be higher than that for the pulses at high puffing. Since for the N seeding scan the edge temperatures are rather similar to each other, the higher discrepancy simulation-experiment at the point  $\Phi_N = 0$  is most likely related to the underestimation of the recycling coefficient ( $R = 0.975$ ) we have assumed for that pulse. Very similar results are seen for the comparison simulatedexperimental carbon fluxes and very similar comments can be done.

## **CONCLUSION.**

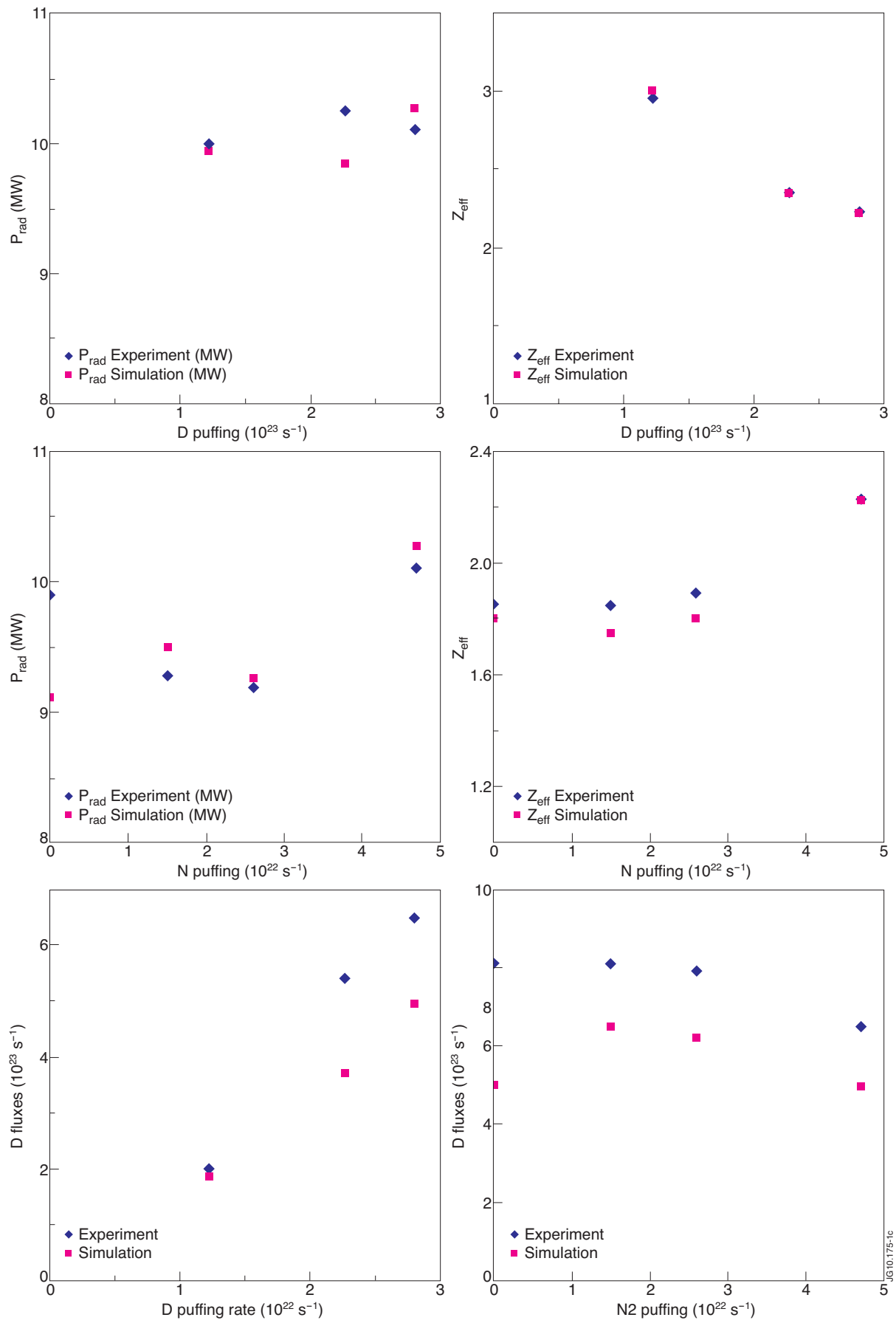
In spite of the limitations caused by the uncertainties in the measurements as well as in the model, including the oversimplified SOL model, the results presented in this paper show for the first time the capability of COREDIV of reproducing the main features of nitrogen seeded JET discharges at high confinement. To achieve this result, we had to modify the impurity transport model in COREDIV by introducing the anomalous pinch, linearly dependent on the level of confinement. Discrepancies between the experimental and simulated particle fluxes may partly be attributed to the oversimplification made in the evaluation of experimental data.

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