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** See annex of F. Romanelli et al, "Overview of JET Results",*
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ABSTRACT.
In JET plasmas there are several contributors to the Carbon distribution in the plasma besides the impurity transport: the pumping efficiency asymmetry, due to the fact that experimentally the pump is located at the outer subdivertor structure, the Carbon chemical and physical sputtering models.

INTRODUCTION

EDGE2D/NIMBUS is a 2D Scrape-of-Layer (SOL) transport code has been used to simulate many divertor and SOL JET experiments. Typically, the Haasz/Davis Carbon chemical sputtering model [1] with an ad-hoc factor of 0.5 has been used, because it allowed the EDGE2D/NIMBUS simulations to agree with the experimental CIII spectral line intensity [2]. The Haasz/ Davis model is not as accurate as more recent models for chemical sputtering [3]. However, two developments suggest that the optimum chemical sputtering model should be revised, which is the topic of this paper. Firstly a new divertor was implemented at JET (MKIIHD) which allowed more ITER relevant magnetic configurations. Secondly, the Monte Carlo code EIRENE was coupled to EDGE2D. EIRENE has a better neutral and molecular physics than the NINBUS. On the other hand, NIMBUS as a better characterization of the JET subdivertor structure and pump system while EIRENE uses neutral reflection factors from the pumping surfaces in the EIRENE triangular grid, called albedos, to mimic the effect of the pump, which could also contribute to the carbon distribution in the plasma. So, we had first to decide the albedo values. A single plasma was chosen from carbon migration experiments [4], Pulse No: 79448 to study the Carbon sputtering. Pulse No: 79448 is a L-mode plasma with a time evolution electron density (ne) scan. So the effect of the density on the carbon chemical sputtering could be evaluated. Also Pulse No: 79448 had a high magnetic triangularity configuration with the Outer Strike Point (OSP) on the JET divertor Load Bearing Septum Replacement Plate (LBSRP). This is important since the OSP is not in an obscured viewing visual spectroscopy diagnostic line of sight.

2. EXPERIMENTAL OBSERVATIONS

Figure 1 shows that in Pulse No: 79448 the $D\alpha$ line intensity is higher at the Inner Target (IT) than at the Outer Target (OT). The OT $D\alpha$ increases with n_e in contrast to the IT where $D\alpha$ does not change. At the highest line average n_e (3.5×10^{19} m^{-3}) the IT plasma is in high recycling regime.

The CIII line intensity increases with the n_e in the OT while in the IT it decreases. The Z_{eff} evolution with the ne is very similar to CIII line intensity. A possible explanation is the proximity of ISP to the main chamber (Fig.2). The distance from the OSP to the main chamber is 2 times longer than from the ISP. The lines of sight for the $D\alpha$ and CIII signals are shown in fig.2.

3. MODELLING

The parallel transport in EDGE2D/EIRENE is determined by Braginskii's formulas. The perpendicular transport coefficients defined at the Mid Plane (OMP) were determined to simulate

ne and electron temperature (T_e) profiles at the OMP and at the OT. The experimental values were measured by Thomson Scattering and Langmuir probes diagnostics. The perpendicular transport coefficients were constant in radius and were the same for carbon and deuterium with a diffusion coefficient of $D\alpha = 0.25\ m^2/s$. The thermal diffusivities of $\chi_{i,e} = 1.0\ m^2/s$ was derived, where the ion and the electron conductivities were assumed to be equal.

The n_e evolution was modelled on separate code runs using different deuterium inlet rates. The deuterium puff was localized at the IT, for both the experiments and the simulations.

EIRENE uses albedos to describe the pump system. Previously an albedo of 0.94 was used for both divertor legs. However (Fig.3a) for this albedo, $D\alpha$ emission is 2X higher at the OT than at the IT while experimentally (Fig.1) $D\alpha$ emission is 10X higher at the IT than at the OT. Since at JET the pump is in the subdivertor at the OT, there should be a higher pumping efficiency at the OT than at the IT. Simulations with asymmetric albedos were done with an albedo of 0.99 at the IT while at the OT the albedos were varied from 0.94 to 0.5. Figure 3a shows that the $D\alpha$ ratio between IT and OT decreases with the OT albedo. When the OT pump was 2X more efficient the $D\alpha$ emission was similar in both targets.

In all the simulations the carbon yield sputtering model was the Haasz/Davis with a factor of 1. Figure 3b shows that the model describes well the experimental asymmetry between the targets, but the simulated values only fit the experimental at the highest albedo, for the lowest albedos, the simulated CIII is 2X higher than the experimental one. The in/out asymmetry decreases as the OT albedo increases. Thus Fig.3.b suggests that the pump efficiency asymmetry also contributes to the carbon distribution in the plasma.

The in/out asymmetry is not adequately described in the albedo scan (Fig.3). Nevertheless the optimum values of 0.99 for the IT and 0.6 for the OT were used to study the chemical sputtering model. The experimental ne scan was simulated by four sets of EDGE2D/EIRENE simulations. The first used the factors 0.75 and the second the factor 0.5 for the Haasz/Davis carbon chemical sputtering model and the third and the forth we used the 1.5e9 and 1.0e9 factors for the Roth/Pacher models. The carbon chemical sputtering models do not influence significantly the $D\alpha$ emission at either divertor target or its dependency on the deuterium inlet rate (Fig.4). $D\alpha$ emission at the OT increases with the ne while at the IT $D\alpha$ saturates for inlet rates above $1.5\times10^{22}\ s^{-1}$, as was observed experimentally. However the asymmetry of the simulated the $D\alpha$ increases with the n_e while it decreases in the experiments.

Figure 4 shows that the Haasz/Davis model in EDGE2D/EIRENE with a factor of 0.5 describes better the experimental CIII emission confirming the previous results from EDGE2D/NINBUS. However this model is only better in attached plasmas. On the other hand the Roth/Pacher models, describes the experimental trend for all plasma regimes with a factor of 1.0[9].

Apparently the difference between the experiments and the simulations in $D\alpha$ at the IT, was not entirely caused neither by the pump asymmetry nor by the chemical sputtering model. Consequently, simulations which better describes the anomalous flow that exits experimentally in JET plasmas

[5] were studied. Simulations with EDGE2D/EIRENE using an external momentum force in the SOL can simulate the experimental flow. The force is in the direction from the OT to the IT and is positioned between the OMP. Even with an impose flow the D_α signal is similar for both targets (Fig.4).

CONCLUSION

This paper used the EDGE2D/EIRENE simulations in order to understand the mechanism for the distribution of Carbon sources in the plasma. The particle physics within the divertor was studied. However, effects of the geometry of the grid used in EDGE2D/EIRENE and the diagnostic uncertainty were not studied. This paper we studied the consequences of the pumping asymmetry caused by the structure of the JET subdivertor. The result was that the density dependence of the Carbon yield agreed with the Roth/Pacher models to within 20% in the cases studied.

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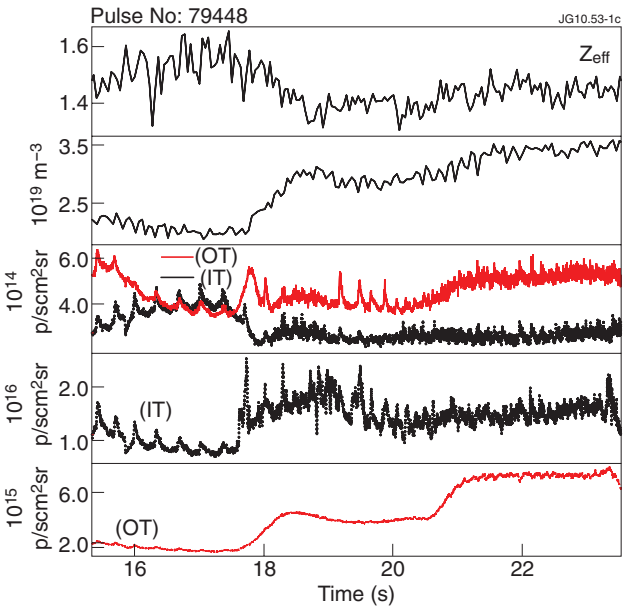

Figure 1: Experimental time traces of: a) Z_{eff} from the Bremsstrahlung radiation, b) the average ne from High Resolutions Thomson Scattering (HRTS), c) the line integrated spectrum intensities of CIII at the inner and outer divertor legs, d) Dα emission at the inner divertor leg and e) D_α emission at outer divertor leg.

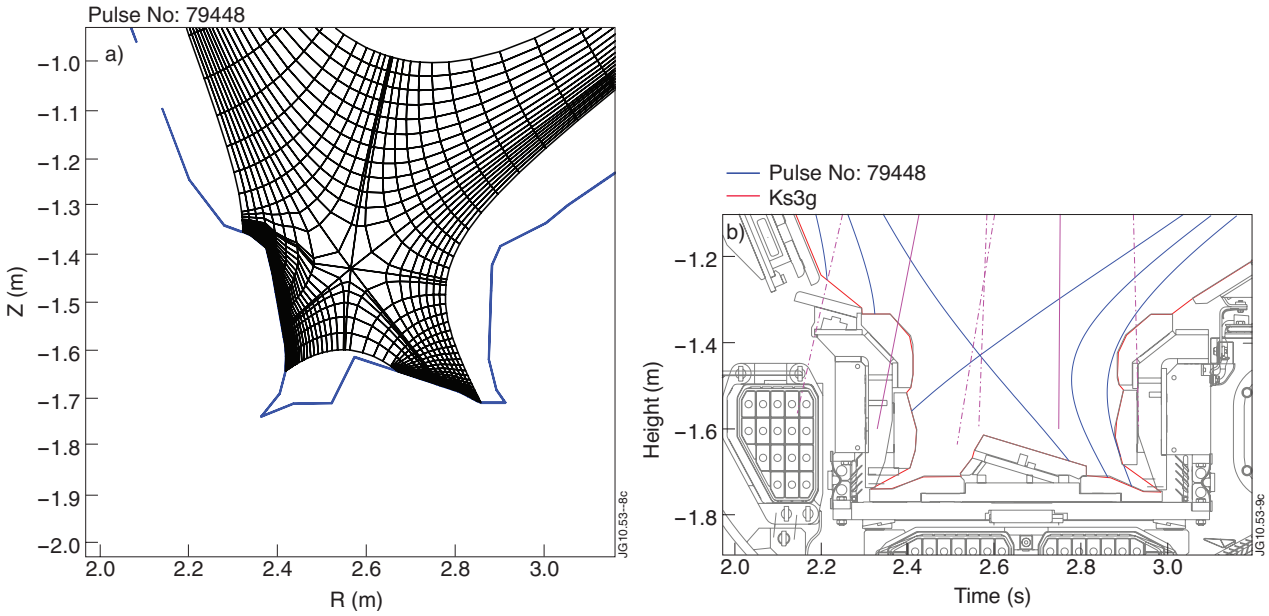

Figure 2: (a) EDGE2D/grid within the divertor region; (b) Visual Spectrum diagnostic geometry within the divertor region.

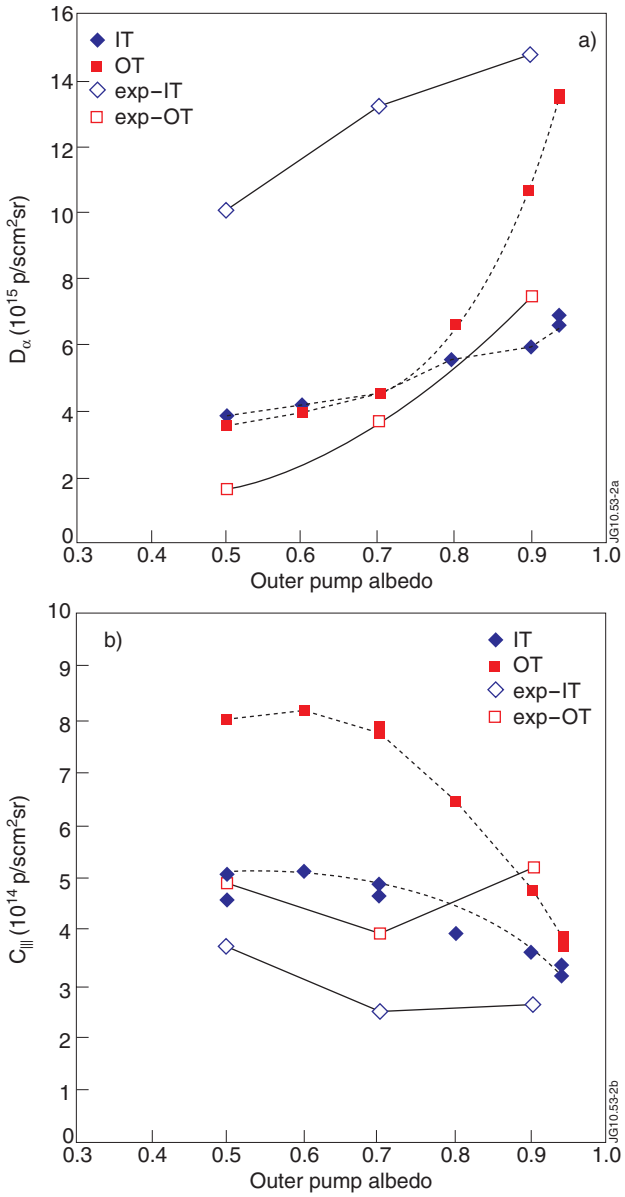

Figure 3: (a) Simulated (closed symbols) and experimental (open symbols) of D_α emission at the inner divertor leg (in squares) and outer divertor leg (in diamonds); b) simulated and experimental CIII line emission from the outer and inner divertor legs. The position of the experimental data was chosen based on the similarity between the experimental and the simulated outer mid plane ne and T_e profiles.

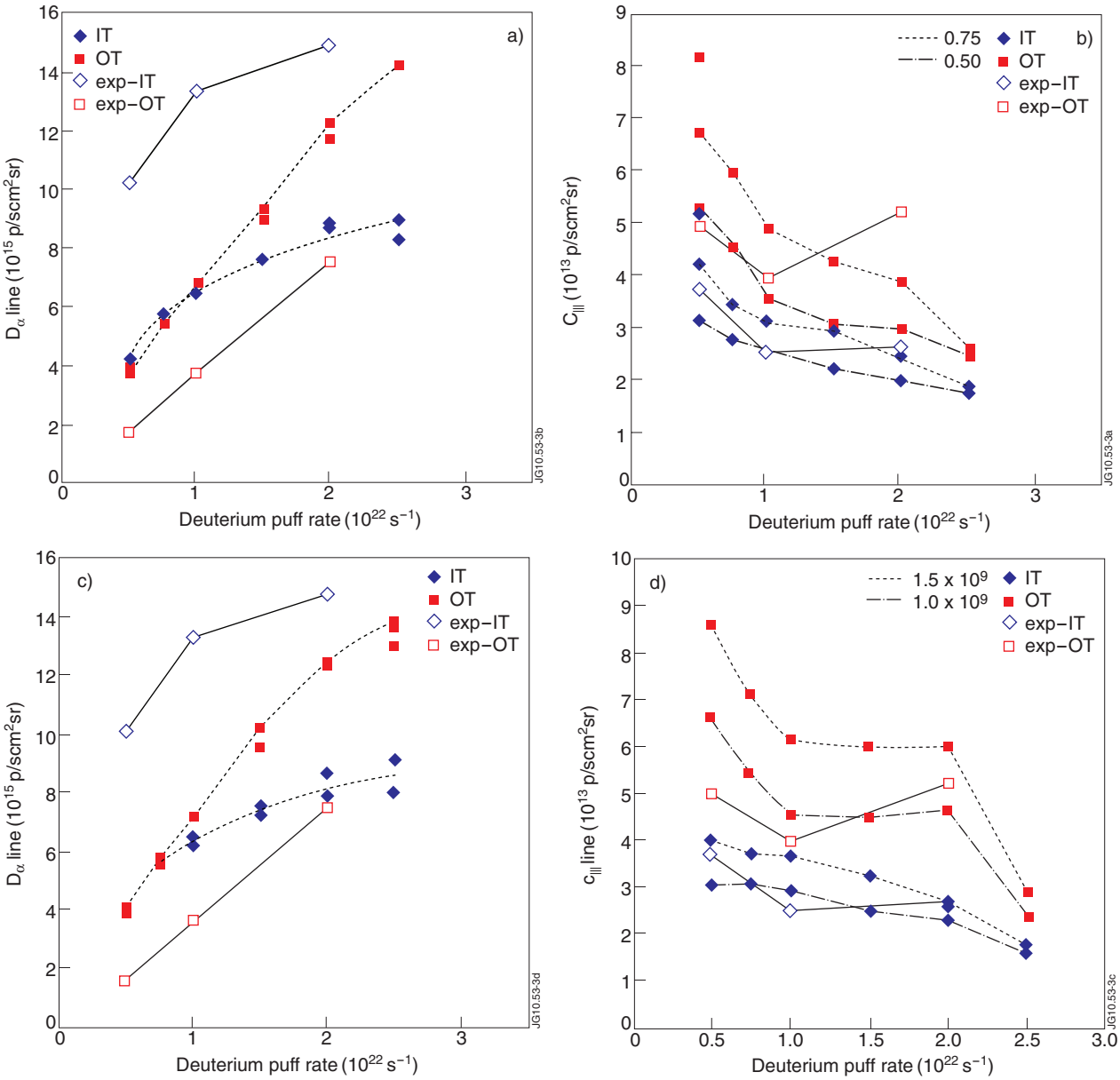

Figure 4: (a) Experimental (open symbols) and Simulated (closed symbols) of Dα emission at the inner divertor leg (in squares) and outer divertor leg (in diamonds) from EDGE2D/EIRENE simulations with the Haasz/Davis model [3] with factor of 0.75 and 0.5; (b) the correspondent simulated and experimental CIII line emission from the outer and inner divertor legs; c) experimental and simulated of D_α emission at the inner divertor leg and outer divertor leg from EDGE2D/EIRENE simulations with the Roth/Pacher models [2] with a factor of 1.5e9 and 1.0e9; d) the correspondent simulated and experimental CIII line emission from the outer and inner divertor legs.The position of the experimental data was chosen based on similarity between the experimental and the simulated outer mid plane electron density and temperature profiles.