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Scrape-off-layer variations during Lower Hybrid ionization and ELMs

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It is known that lower hybrid (LH) wave increases the Scrape-off-Layer (SOL) density by direct ionization of the SOL due to parasitic LH wave energy absorption [1]. Similarly, also ELMs bring energy into the SOL, the SOL temperature is increased and the SOL ionization is enhanced. In this paper we present a modeling study of modifications in time of the JET SOL due to ELM events *and* direct SOL LH ionization. The modeling uses the fluid code EDGE2D, upgraded to include direct SOL ionization by the LH wave [1] and the effect of the limiters near the LH grill [2] simulating the LH grill private space. The ELM is modeled by a standard option available in EDGE2D, which consists in enhancing transiently the transport coefficients on the low field side in a region near the separatrix. In the computations presented, the diffusion coefficient D is five times enhanced for 5 ms in the interval $-0.02 < R-R_{sep} < 0.04$ m. The diffusion coefficient is assumed to grow linearly between 0 – 2.5 ms, and then it again returns to its previous value between 2.5 and 5 ms. The initial value of D is chosen [1] as 0.1 m^2/s for $R-R_{sep} < 0.03$ m, and 1 m^2/s for $R-R_{sep} >$ 0.03 m. It is assumed that the parasitic LH absorption takes place in the outer SOL, with the radial profile illustrated in Figures. The amount of the dissipated power was tuned to 50 kW [1] in front of the grill to fit the j_{sat} measurements without taking into account ELMs in the modeling. We concentrate on ITER like shots with wide SOL, shot number # 66972 and other shots from this series. As the computations show, plenty of the SOL

* See the Appendix of F. Romanelli *et al*., Fusion Energy Conference 2008 (Proc. 22nd Int. FEC Geneva, 2008) IAEA, (2008)

neutrals are ionized by the LH parasitic dissipation before the ELM arrives, so that any additional contribution to the ionization of the SOL due to ELMs can only be small, cf. Fig. 1 for the ionization source without and with LH heating, and Fig. 2 for the neutral molecules density without and with LH heating. The time interval of the first 6 ms is shown after the start of the ELM process.

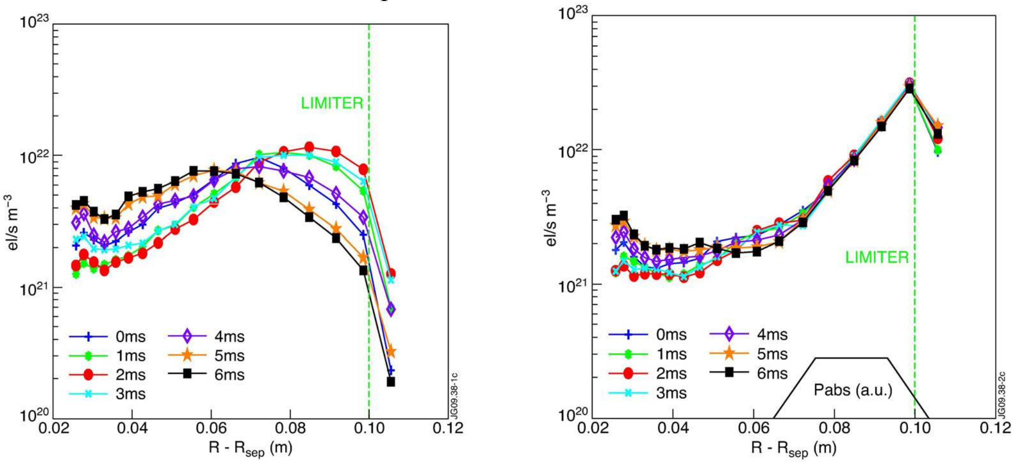

Fig 1. Ionization source during an ELM in 1 ms intervals, left: LH "off", right: LH "on".

The modeled j_{sat} variations due to ELMs and LH ionization are shown in Fig. 3. It follows from the modeling that the SOL saturation current j_{sat} (and the plasma density) in the far SOL in front of the grill is higher during LH due to the direct LH SOL ionization, but the additional j_{sat} variations corresponding to ELMs are lower in front of the LH grill, where the LH power is dissipated. The reduction of j_{sat} variations with ELMs and corresponding reduction in the plasma density variations explains the reduction in variations of the LH wave reflection coefficient observed experimentally in ELMy plasmas, when the LH power is increased. The modeled j_{sat} with LH "on" is confined between the red curve with full circles and the black curve with full squares during ELMs. The blue dashed lines bound the region of the modeled j_{sat} during ELMs without LH.

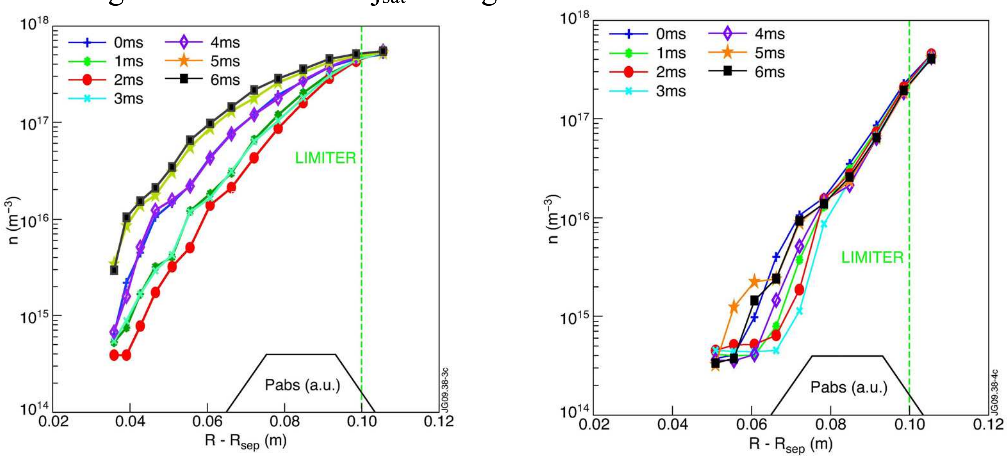

Fig 2 . Neutral molecule density during an ELM in 1 ms intervals, left -LH "off", right - LH "on".

The measurements of j_{sat} [1] are compared with modeling in Fig. 4. The RCP measurements are denoted by empty red squares. The modeled limiting curves during an ELM, the red curve with red full circles and the black curve with black full squares, can be fit better to experimental data by tuning the radial profile of the diffusion coefficient D [1]. Here we use a very simple step and ramp model of D, as described above.

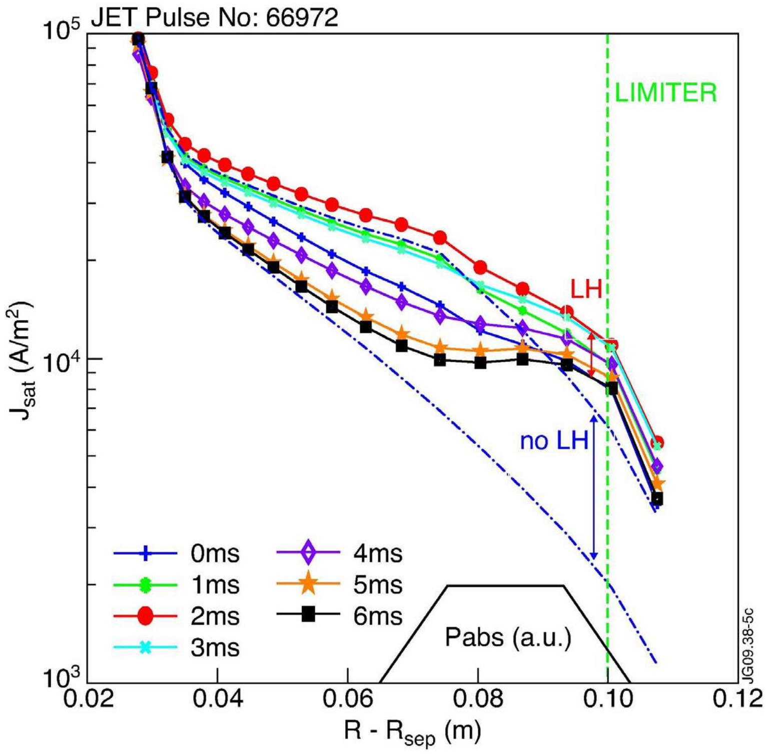

Fig 3 .Saturation current j_{sat} density during an ELM in 1 ms intervals, LH on, and modeled saturation current j_{sat} density limits during an ELM, LH "on"- red curve with full circles and the black curve with full squares, LH "off" - blue curves, dash and dot.

Huge j_{sat} spikes found in some other shots [1] was not possible to model by the fluid EDGE2D model used, as further transport enhancement during ELMs resulted in numerical problems. For comparison with experiments, the modeled D_{alpha} line intensity was also integrated along the standard diagnostic vertical line of sight from the top of the machine to the outer divertor apron. However, here the modeling does not reproduce well the measured D_{alpha} amplitude even for a very low LH power. The measured maxima are significantly larger than the modeled ones, and the measured minima are lower than the modeled ones. Similar discrepancy is present also for LH off for the wide SOL shots. One can speculate that the ELM model used in EDGE2D is not sufficient for taking into account important kinetic ELM features necessary for a good description of D_{alpha}. Problems with comparison of modeled D_{alpha} with experiments in JET diagnostic optimized configuration shots were reported also in [3]. It is obvious that further amended modeling is needed for D_{alpha} signal during LH.

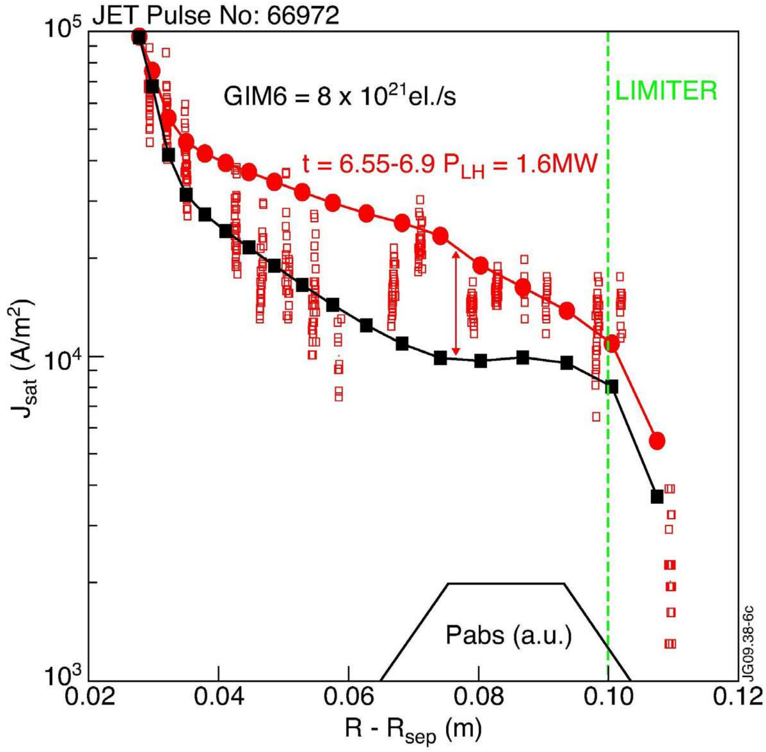

Fig 4. Modeled saturation current j_{sat} density limits during an ELM and LH "on" - red curve with red full circles and black curve with black full squares, measured data are represented by empty red squares [1].

In conclusion, the modeled j_{sat} is in a good agreement with the RCP measurements during LH on and ELMs. The modeled j_{sat} features explain the reduction of the LH wave reflection coefficient oscillations at enhanced LH power. In addition, some insight into the SOL ionization by common action of ELMs and parasitic SOL LH wave dissipation was obtained: The LH ionizes the SOL even before the ELM arrives, and there remains less neutrals for ionization by the ELM. However, it is obvious that further amended modeling is needed for the D_{alpha} signal during LH.

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[1] M. Goniche et al., Plasma Phys. Control. Fusion **51** (2009) 044002.

[2] V. Petrzilka et al., 34th EPS Warsaw 2007 Conference, paper P-4.100.

[3] A. Kallenbach et al., Plasma Phys. Control. Fusion **46** (2004) 431.