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Recent Results of LHCD Coupling Experiments with Near Gas Injection in JET

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**See Annex of J. Pamela et al., "Overview of Recent JET Results and Future Perspectives", Fusion Energy 2000 (Proc. 18th Int. Conf. Sorrento, 2000), IAEA, Vienna (2001).*

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INTRODUCTION

Dedicated gas injection in the proximity of the Lower Hybrid Current Drive (LHCD) launcher is used routinely in JET for obtaining a good and stable coupling of the LH waves in severe conditions: H-modes, ITB (Internal Transport Barrier) plasmas and presence of strong Edge Localized Modes (ELMs). Moreover this technique is one of the candidates for allowing the coupling of LHCD power in ITER, where the distance between the Last Closed Flux Surface (LCFS) and the wall is expected to be more than 12cm.

The dedicated gas pipe (GIM6) was installed in JET in 1995, at a distance of 1.2 m from the LH launcher, in the equatorial plane. It has been used in the past to inject deuterium with different results [1,2], but has become an essential tool for LH coupling in high power phase of advanced scenario plasmas, injecting CD4 [3]. The CD4 was introduced for its larger ionization cross-section (σ) and lower ionization potential (12.5eV against the 13.9eV of D_2). This can lead to the proper densification of the SOL plasma with lower gas flow with less influence on the quality of confinement. Nevertheless the analysis of the results obtained with CD4 [4] evidenced that the simple local ionization of the gas alone cannot explain the amplitude of the effects (the increase of the SOL density) and some mechanism of modification of transport in the plasma edge has to be involved.

Aiming at demonstrating the possibility of using LHCD in ITER conditions (large clearance between LCMS and LH grill) and to assess the role of s in the control of the SOL density, an experiment with different gasses from the same injecting pipe was carried out on JET.

1. EXPERIMENTAL SETUP

The experiment was carried out in spring 2003 in two different experimental sessions. In the first we used CD_4 and D_2 while in the second one, on the same plasma configuration, propane (C_3H_8), ethane (C_2H_6) and D_2 were injected from GIM6. Standard propane and ethane were chosen both for the greater ionization cross section [5,6], with respect to CD_4 and D_2 (Fig.1), and for the easiness of procurement, with respect to the deuterated versions, that have no significant differences in cross section and ionization potential. Despite the fact that hydrocarbides will not be used in ITER, because of their tritium retention, the s related results will be relevant in general. The plasma target was chosen to be reactor relevant: H-mode with ITB, type I ELMs and large distance between the LCFS and the launcher (8 – 11cm), with the timing of the additional power as used in experiments aimed at achieving long pulses with steady state ITBs [7]. This scenario, with I_P = 1.5MA and B_T = 3_T, relies on a fast current ramp-up with 2-2.5MW LHCD, in order to produce a target q-profile with negative magnetic shear, before the application of Neutral Beam Injection (NBI) and Ion Cyclotron Resonance Frequency (ICRF) waves. High NBI power (14 – 15MW) was requested in these experiments in order to produce type I ELMs. The ICRF power was maintained at a moderate level, and the ICRF antenna located immediately next to the LH launcher was deselected for its detrimental effects on LH coupling. The launcher position was tipically at 1cm behind the poloidal limiter, but it was also varied between 2.0

and 0.5cm. In all the pulses the density profiles in the SOL was obtained by a Reciprocating Probe (RCP), magnetically connected with the LH grill and the injecting gas pipe (GIM6). The ICRF power was reduced during the RCP swept, in order to avoid the disturbance of the probe measurement.

2. LHCD COUPLING AND MAIN PLASMA BEHAVIOUR

For all the tested gasses a good LH wave coupling was obtained, but different gas flows were required. With CD_4 a good coupling was obtained with a rate of 1×10^{22}el/s at distance of 7cm between LCMS and the limiter. Increasing the clearance by 1 cm the ratehas to be increased up to 1.2×10^{22}el/s, indicating that this is the working limit for CD_4. Injecting D_2, a good coupling was obtained up to 10cm with a flux of 0.6×10^{22} el/s while we found poorer coupling at lower flux (0.35×10^{22} el/s). Propane and ethane were tested at smaller distance (7cm) with a rate of 0.4×10^{22} el/s and 0.3×10^{22} el/s respectively. Good coupling was obtained in both cases and, for the reduced number of pulses available, no limits in rate were found. The data shown refers only to the H-mode phase of the pulse, all of which had similar auxiliary heating power. A clear influence on ELMs (frequency increase and amplitude reduction) was observed for D_2, C_2H_6 and C_3H_8, while no change was observed with CD_4, at least at the used fluxes. The reduction in ELMs, in case of D_2 injection, leads also to an increase of ICRH coupling efficiency. The ELMs amplitude reduction coincides with gas injection and it is not related to the presence of LHCD power. Regarding the effects on the main plasma, the injection of different gasses does not affect the confinement (H factor = 1.4 for the selected pulses), or the ITB quality. The neutron yield reaches at least 5×10^{15} s $^{-1}$ for all the considered pulses.

3. SCRAPE-OFF LAYER MEASUREMENTS

In fig.2 the SOL density profile as measured by the RCP is shown. The presented data is collected from different pulses with different gas rate. Normalizing all the data at the same gas rate the spread is clearly reduced (fig.3). The density obtained with the injection of hydro-carbides scales with the ionization-cross section, whileÄD2 produces an unexplained greater density. A possible mechanism to explain such behaviour could be related to the recycling, which is more affected by D2 than by the other gasses.

The electron temperature profile is flat in the SOL, and temperature goes from 25 to 35eV for all the measured cases (D_2, C_2H_6 and C_3H_8). No clear variations are observed using different gas rates. Comparing the SOL electron density profile with or without LHCD power, we observe an increase during the injection of the LH wave, at least in the case of D_2 injection (fig.4). The increase is more pronounced in the outer region of the SOL, indicating a possible direct effect of the LH wave on the ionization rate accompanying the recycling effect mentioned above. At the moment no data for comparison with the other gasses is available.

REFERENCES

[1]. Ekedahl, A., et al., in Proc. of the 12th Top. Conf. on RF Power in Plasmas, Savannah, USA, 1997.

[2]. Söldner, F.X., et al., in Proc. of the 13th Top. Conf. on RF Power in Plasmas, Annapolis, USA, 1999.

[3]. Pericoli, V., et al., in Proc. of the 14th Top. Conf. on RF, Oxnard, USA, 2001.

[4]. G.F. Matthews et al. Proc. of the 28th EPS Conf. on Controlled Fusion and Plasma Physics. ECA vol 24A 1613-1616 (2001).

[5]. H. Chatham et all -J. Chem.Phys. **81** (4), 1774 (1984)

[6]. H. Tawara et all - Supp. to Nuclear Fusion vol.2 , **41**, (1992)

[7]. Litaudon, X., et al., in Proc. of the 19 th IAEA Fusion Energy Conf., Lyon, France, 2002

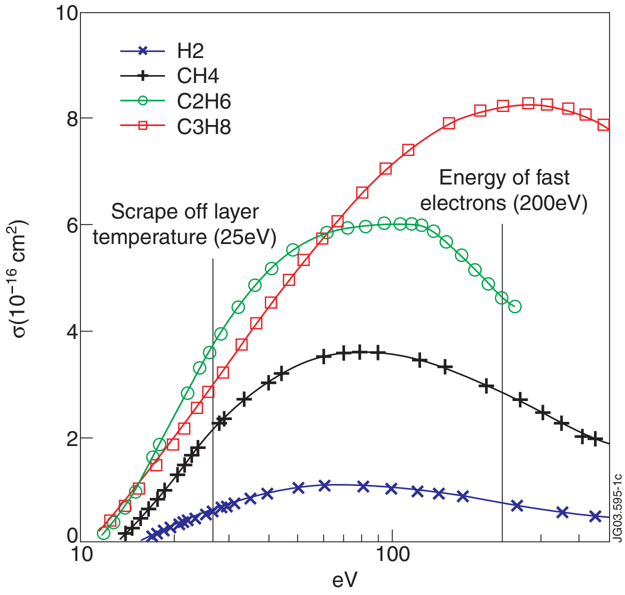

Figure 1: Total ionization cross-section versus impact electron energy. The data are taken from ref [5,6]. No modifications have to be considered in case of deuteration of the gasses.

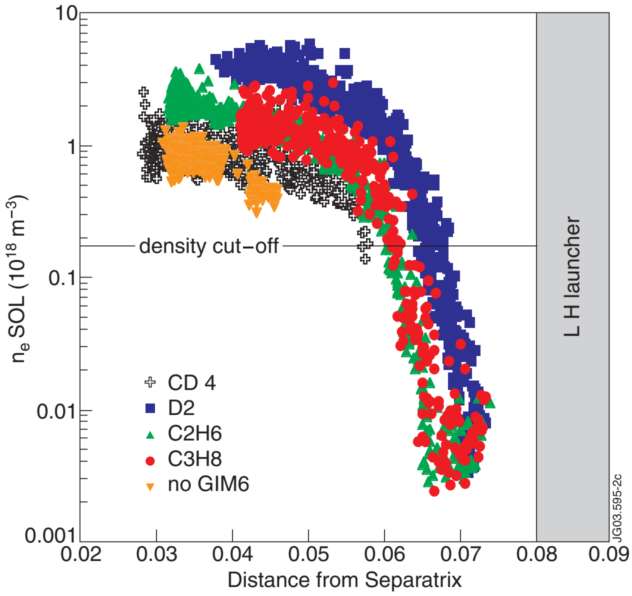

Figure 2: Density profile in the SOL as measured by RCP. The data are projected on the equatorial plane. The density cut-off for the LH wave in JET is reported.

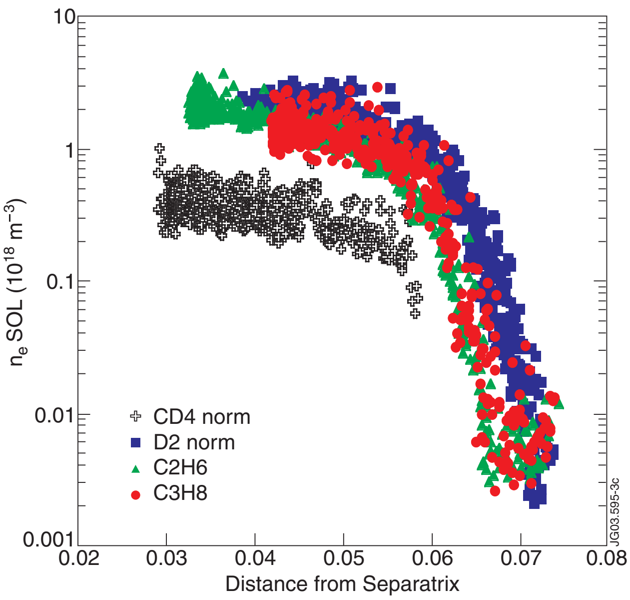

Figure 3: Density profile in the SOL as measured by RCP. The data, for CD_4 and D_2, are linearly normalized at the same electron rate of propane and ethane cases (4×10^{21} el/s).

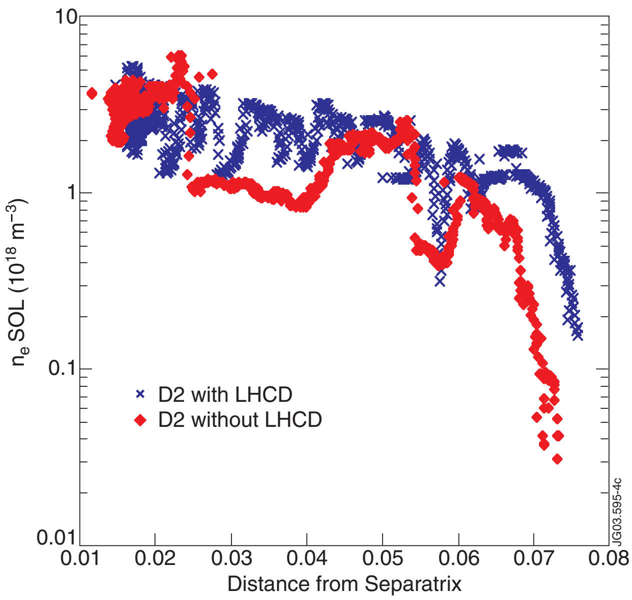

Figure 4: Electron density profile in Scrape Off Layer with or without the injection of LHCD wave. Deuterium is injected from GIM6 at the rate of 5×10^{21} el/s.