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Particle sources and SOL dynamics in JET strike point sweeping experiments

A. Salmi[1], Tala[1], A. Järvinen[2], D. Dunai[3], R. Gomes[4], P. Lomas[5], L. Meneses[4,6], S. Mordijck[7], V. Naulin[8], J. Juul Rasmussen[8], M. Romanelli[4], A.C.C. Sips[9,10], and JET contributors*

Eurofusion Consortium JET, Culham Science Centre, Abingdon, OX14 3DB, UK
[1]VTT, Espoo, Finland; [2]LLNL, Livermore, USA; [3]Wigner Research Centre for Physics, Budapest, Hungary; [4]IPFN, IST, Universidade de Lisboa, Portugal; [5]CCFE, Abingdon, UK; [6]ITER Organization, France; [7]College of William & Mary, Virginia, USA; [8]DTU Physics, Lyngby, Denmark; [9]JET Exploitation Unit, Culham, UK; [11]European Commission, Brussels, Belgium;

JET experiments to study plasma fuelling, edge transport and scrape-off-layer (SOL) behaviour have been performed for the first time using a technique based on strike point sweeping. Sweeping itself is routinely used in JET to, e.g., spread the heat flux or to measure high radial resolution SOL profiles with Langmuir probes. For this work the sweeping was commissioned for up to 18.5Hz to allow particle source and transport studies at faster time scales to complement gas puff modulations [1, 2].

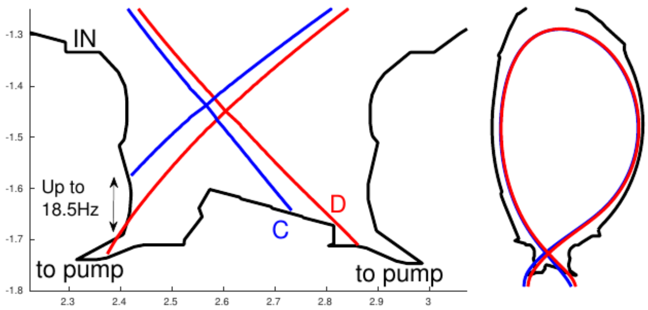

Figure 1 Strike point sweeping while keeping the main plasma nearly unchanged. The letters C and D show the minimum and maximum range of the sweeping cycle. The associated 2D grids used in modelling are later referred to as C or D.

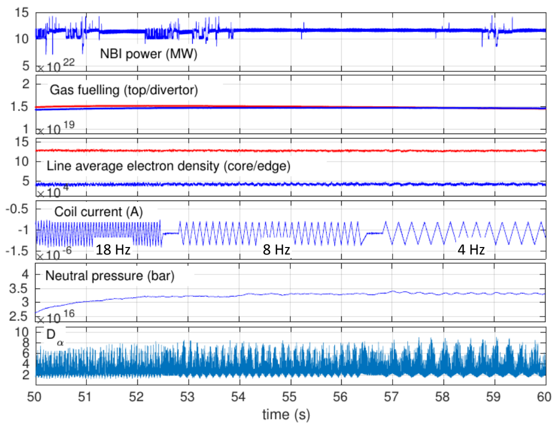

Figure 2 Experimental waveforms for #92347 (2.3T/1.7MA, ELMy H-mode) showing three distinct phases with varying strike point sweeping frequency.

Experiments and observations. The sweep modulations were tried in various strike point configurations, confinement modes and sweep frequencies whilst correlating the changes e.g. in SOL and confined plasma density, line radiation and probe measurements. While there are interesting observations also in other strike point configurations, such as periodic L-H transitions when the outer strike point moves from the horizontal tile to marginally touch the vertical tile and back (consistent with [3]), we focus here on the horizontal tile sweep as shown in the Figure 1. In this configuration the available modelling tools such as EDGE2D/EIRENE are better suited due to the grid limitations.

* See the author list of "X. Litaudon et al 2017 Nucl. Fusion 57 102001"

Figure 2 shows the discharge analysed with three different sweep frequencies while keeping all the other parameters constant. In this configuration, the discharge stayed in H-mode throughout the sweep cycles and the ELM frequency did not change significantly during the sweeps but remained stationary (~100 Hz). Figure 3 shows one sweep cycle coherently averaged over the full 4 Hz phase (57-60 sec). Here one can see that the midplane electron density in the SOL, the D_α at the outer midplane (OMP), and at the inner divertor ('IN', cf. Fig. 1) are synchronous. The SOL density is highest when the X-point (proxy for strike point) is at its innermost location potentially suggesting that pumping plays an important role. Consistent observations were also made for a repeat shot #92344.

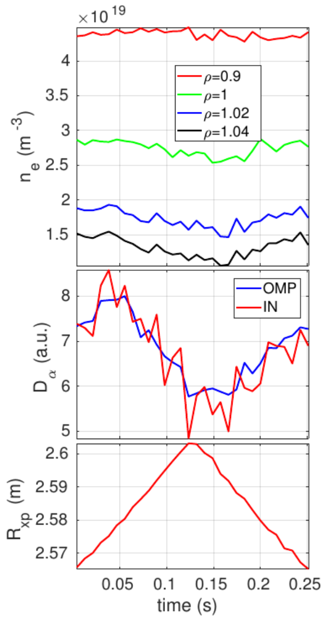

Figure 4 Coherently averaged signals for one full sweep (4 Hz) show midplane electron density from reflectometer (top), D_α line of sight measurement at the midplane and at the inner divertor apron (middle) and the X-point major radius location (bottom). See Fig. 1 for 'IN' location.

Figure 4 shows the electron density profile response during the three sweep phases. One can observe that the maximum amplitude is nearly the same for all frequencies and that they have the same phase around $0.98<\rho<1.05$. This together with synchronous D_α at midplane and at inner divertor indicates that SOL adjusts to the new strike point configuration quickly (<5ms). The estimated time resolution obtained with the 18 Hz sweep frequency is about (5ms). For comparison, the distance travelled by a 3eV Deuteron in 5ms is about 100m (≈roughly the parallel connection length between the divertor plates). Another observation that still lacks an explanation is seen in the phase (at $\rho\approx0.95$) in Figure 4. For edge localised source or SOL density oscillation one would expect a monotonically increasing phase when going into the plasma showing the inward propagating density perturbation. Instead the phase minimum around $0.85<\rho<0.9$ could indicate the presence of a subdominant particle source. It would have a maximum at a particular sweep phase and the source would penetrate up to the pedestal top but is weak enough so that it is masked by the SOL effects outside $\rho>0.95$.

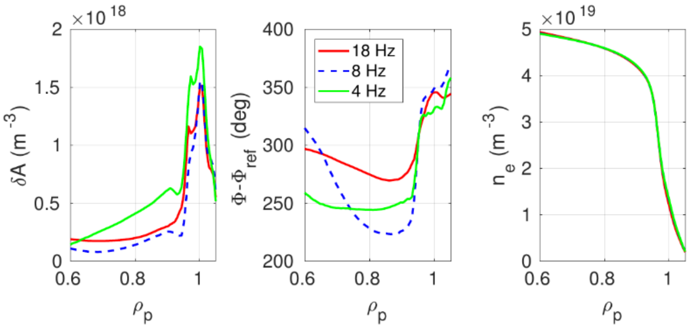

Figure 3 Midplane electron density measurements from profile reflectometer comparing the three different phases of the discharge #92347 (cf. Fig. 2). From left to right: modulation amplitude, phase and time averaged electron density.

Edge modelling. To gain insight into the mechanisms that are responsible for these experimental observations EDGE2D/EIRENE [4, 5] modelling was undertaken. It is not possible to simulate a time-dependent strike point sweeping cycle and therefore two extreme equilibria were selected (see **C** and **D** in Fig. 1) for which steady state calculations were performed. The analysis approach was the following: (1) Grids were prepared so that the SOL width for **D** would be as wide as possible while still retaining a realistic divertor geometry (EDGE2D grid limitations). This resulted in about 2cm SOL at the outer midplane. For **C** a wider SOL could be obtained, however, relatively similar width (~3cm) was chosen for its stability and comparability with **D**. (2) Upstream density and temperature profiles for **C** were fitted to match the outer midplane experimental T_e and ne profiles (from Thomson scattering diagnostics) by adjusting the radial diffusion coefficients (see Fig. 5) and pumping efficiency (albedo=0.8). Experimental level of gas puffing from the inner divertor and the plasma top ($1.5 \times 10^{22} s^{-1}$ from each) were used together with PENCIL [6] calculated NBI heat and particle sources (12MW / $1.3 \times 10^{21} s^{-1}$). (3) The parameters found in the previous step for **C** were used in **D** so that the only difference between the two cases was the magnetic equilibrium (grid).

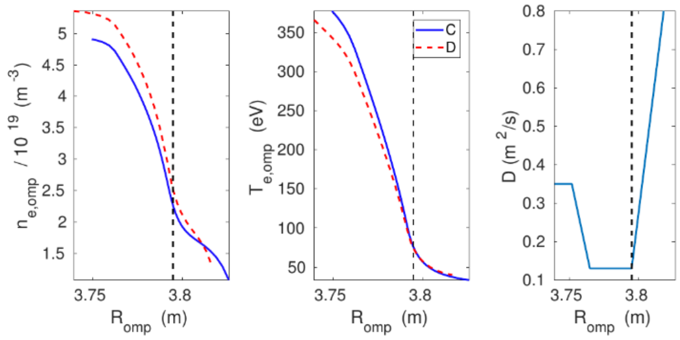

Figure 5 EDGE2D/EIRENE modelled density and temperature profiles and the perpendicular particle diffusion coefficient used to obtain a match with the experiment in C. Approximate separatrix location is shown with the dashed vertical lines.

In Figure 5 one can also see that the modelling result is the *opposite* compared to the previously presented experimental observations. The modelling predicts higher electron density in the SOL in **D** suggesting that some important physical processes are not included in the modelling or that something in the simulation setup is not suited for this type of comparison. Despite this failure we investigate what the modelling shows about the ionisation sources around the plasma cross section. Figure 6 illustrates the grids used and compares the ionisation sources (S_e) in the divertor area. We see that qualitatively the sources are

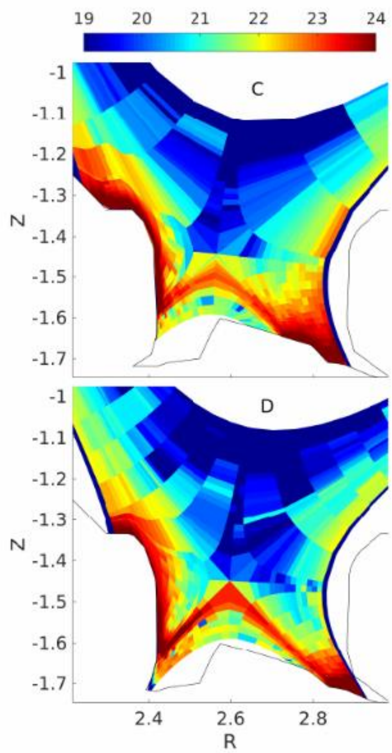

Figure 6 EDGE2D/EIRENE neutral ionisation source density (log S_e) in the divertor region. In both cases the HFS electron density (not shown) is high suggesting that the inner strike point is detached.

similar and that most of the ionisation happens close to the plasma facing components and very little neutrals are able to cross the separatrix. We also see that although in **D** the ionisation is smaller near the outer strike point (stronger pumping) it is not reflected in the SOL density. Looking more closely at the ionisation source in the confined plasma region we plot the ionisation source density in ψ/Θ coordinates (normalised poloidal flux and geometrical poloidal angle) in

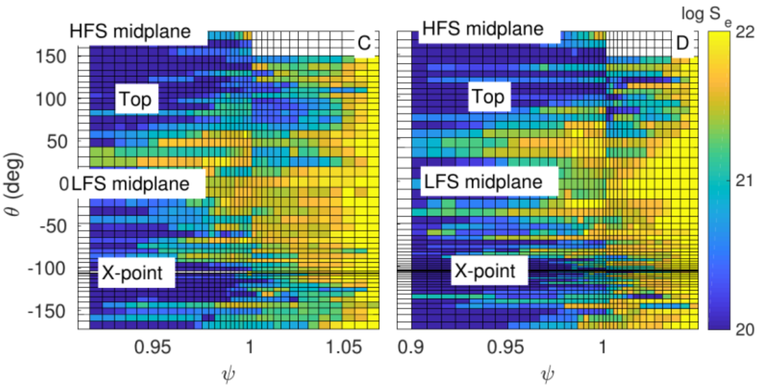

Figure 7 EDGE2D/EIRENE ionisation source density in the main chamber unwrapped in radial and poloidal coordinates. The geometrical poloidal angle is w.r.t. the magnetic axis.

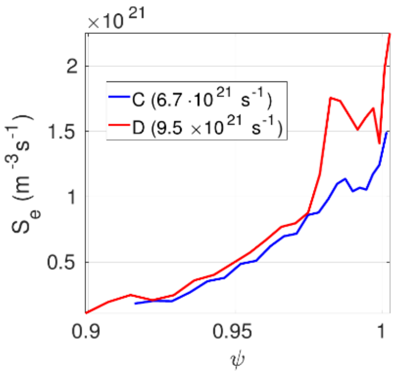

Figure 8 Flux surface averaged neutral ionisation source density and totals in the legend.

Figure 7 and the flux surface averaged ionisation source density in Figure 8 for a more quantitative comparison. One can observe that in **D** the modelling yields higher ionisation source especially in the LFS midplane region both inside the separatrix and in the SOL which may explain the resulting higher SOL density in the modelling.

Conclusions. It is clear that further effort is needed to discover the reasons causing the first modelling attempts to fail in reproducing the experiments. With good agreement in the future the modelling can help to explain the phase profiles seen in the electron density profile response and to shed new light on the details of the fuelling process. Experimentally, we have observed SOL density variations of the order of 30% due to the strike point movement (~6cm) and that the SOL adjusts to the new strike point geometry faster than we can measure (~5ms). Strike point sweeping yields plenty of interesting data much of which we haven't covered here and which would have a good potential for highly accurate model validation. Full use of this data would, however, require more realistic geometry models and better coverage of synthetic diagnostics to include cameras and probes.

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