*29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, O-2.05 (2002)*

Edge Localized Modes and fluctuations in the JET SOL region

C. Hidalgo, M.A. Pedrosa, B. Gonçalves[1], C. Silva[1], R. Balbín, M. Hron[2], K. Erents[3], G. Matthews[3], A. Loarte[4]

Laboratorio Nacional de Fusion, Euratom-Ciemat, 28040 Madrid, Spain
[1]Associação Euratom-IST, Av. Rovisco Pais, 1049-001 Lisbon, Portugal
[2]Institute of Plasma Physics, EURATOM-IPP, Prague, Czech Republic
[3]Euratom/UKAEA, Culham Science Centre, Abingdon, Oxon, OX14 3DB, UK
[4]EFDA – Garching, Max-Planck-Institut für Plasmaphysik Germany

Introduction

Understanding the impact of edge localized modes (ELMs) induced particle and energy fluxes in the divertor plates remains as one of the major concerns in the fusion community for future devices like ITER. ELMs affect both energy and particle confinement, thus providing particle control in improved confinement regimes. However, large amplitude ELM events might lead to unacceptable power loads in the divertor plates. The possible link between the amplitude and the radial propagation of ELMs might have an important consequence in the extrapolation of the impact of ELM in the divertor plates on future devices.

This paper presents the investigation of the radial propagation of ELMs in the JET scrape off layer (SOL) region.

Experimental results

The radial propagation of ELMs and the structure of fluctuations are under investigation in the JET SOL region using Langmuir probes located in the upper part of the device. The experimental set up consists of arrays of Langmuir probes radially separated 0.5 cm, allowing a unique investigation of the propagation of ELMs events and fluctuations with good spatial (0.3 cm) and temporal (2 μs) resolution. Plasma fluctuations are investigated using standard signal processing techniques and 500 kHz digitisers. Plasmas studied in this paper were produced in X-point plasma configurations with toroidal magnetic fields B = 1 - 2.5 T, Ip = 1 - 2 MA, P_{Total} = 2 - 13 MW (H-mode plasmas).

The frequency spectra of density and potential have been investigated during the ELMs occurrence. Modifications in the frequency spectra of fluctuations have been observed before and after the arrival of the ELM event propagation. In particular, bursts in frequency spectra

(50 – 100 kHz) have been detected after the ELM arrival in potential signals but not in density signals.

Figure 1 shows the time evolution of the ion saturation current as measured by two probes radially separated during the ELM propagation in the SOL region (B = 1 T, I = 1 MA). The response of ion saturation current and potential signals show an increase followed by decay during EMLs. However, it should be noted that the shape of ELMs, as measured by Langmuir probes with high frequency ADCs, shows high frequencies structures. We denote the initial sharp change in the time evolution of the ion saturation current traces by the time of arrival of the ELM event propagation. Typical time delays for the time of ELMs arrival are in the range of 2 - 10 µs for sensors radially separated 0.5 cm. This implies a radial velocity in the range of 1000 m/s. Perturbations in ion saturation current and potential signals induced by the appearance of ELMS are observed up to 7 cm beyond the LCFS in the SOL region (Fig. 2). This result implies that the ELMs convective SOL-width is much broader than the typical SOL-width measured during time intervals between ELMs (about 1 cm).

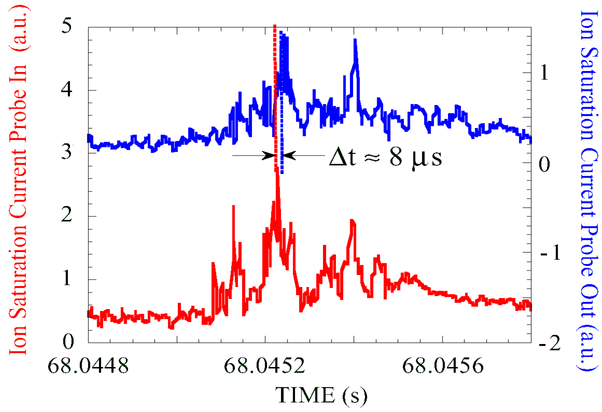

Fig. 1: Time evolution of the ion saturation current as measured by two probes radially separated during the ELM propagation in the SOL region (B = 1 T, I = 1 MA).

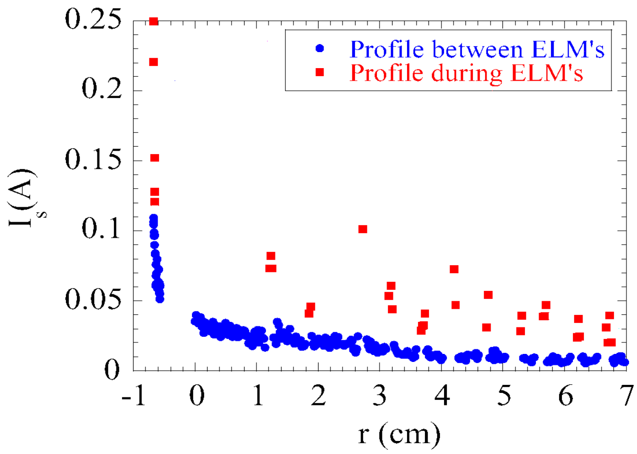

Fig. 2: Radial profiles of ion saturation current during and between ELMs.

Turbulent particle transport and fluctuations have been calculated, neglecting the influence of electron temperature fluctuations, from the correlation between poloidal electric fields and density fluctuations at the inner probe position. The poloidal electric field has been estimated from floating potential signals measured by poloidally separated probes, $E_\theta = \Delta\tilde{\Phi}_f / \Delta\theta$ with $\Delta\theta \approx 0.5$ cm. Fluctuations in the radial component of ion saturation current gradients have been computed as $\nabla \tilde{I}_s(t) = [\tilde{I}_s^{inner}(t) - \tilde{I}_s^{outer}(t)]$ with $< \Delta \tilde{I}_s > = 0$, where $\tilde{I}_s^{inner}$ and $\tilde{I}_s^{outer}$ are the ion saturation current fluctuations simultaneously measured at two different plasma locations radially separated 0.5 cm. An effective radial velocity has been defined as the normalized ExB turbulent particle transport to the local density: $v_r^{eff} = < \tilde{I}_s \tilde{E}_\theta > / I_s B_T$ where I_s is the ion saturation current of the inner probe. This effective velocity is not affected by uncertainties in the probe area.

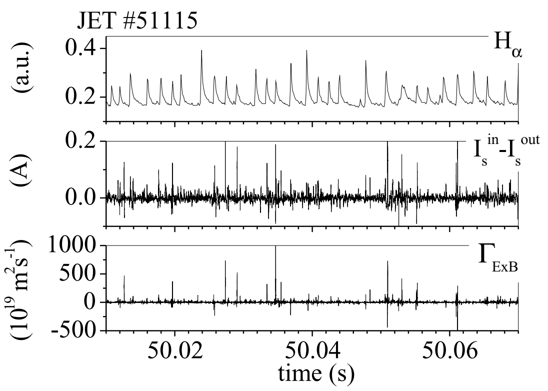

Fig. 3: Time evolution of H_α, radial gradients ($\nabla \tilde{I}_s$) and ExB transport signals on H-mode plasmas

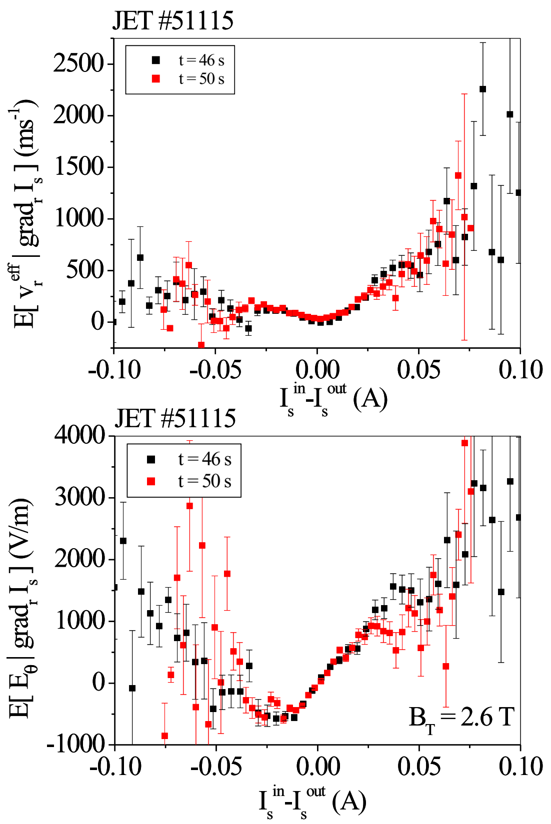

Fig. 4: (a) Effective radial velocity versus fluctuations in the radial gradient; (b) Poloidal electric fields versus radial gradient. Measurements were taken at r-$r_{LCFS} \approx 1$ cm.

Experimental results show a strong coupling between ExB transport, fluctuations in the radial gradient and ELMs (Fig. 3). Figure 4a shows the expected value of the radial effective velocity versus fluctuations in the radial gradient ($\nabla \tilde{I}_s / \sigma$). Radial effective velocities increase up to 2000 m/s during ELMs. Furthermore this radial velocity is consistent with the ExB velocity as shown in figure 4b. The present experimental results suggest that the radial velocity of ELMs increases with the ELM size.

The size of the radial perturbation ($\nabla \tilde{I}_s$) linked to ELMs decreases as increasing the distance to the LCFS. However, a preliminary investigation of the radial speed of ELMs at different radial location in the SOL region [r - r_{LCFS} = (1 – 6) cm] shows that the maximum radial speed of ELMs does not depends to the distance to the LCFS.

The effective radial velocity for large transport events (i.e. ELMs) is rather similar to the radial velocity of large transport events reported in L-mode plasmas [1]. Interestingly this value is rather close to the speed of 200 m/s reported during the evolution of transport through the L-H transition in JET [2]. However, ELMs radial speed in the SOL is much larger than the effective radial velocity of pure diffusive models for the SOL region. These results might suggest the existence of different transport mechanisms for small (diffusive) and large transport events (non-diffusive) in the JET plasma boundary region [1].

Mach probe measurements have shown that during the appearance of ELMs, perturbations in the ion saturation current are larger (about a factor of 3) in the probe facing the outer divertor (e.g. region of bad curvature) than in the probe facing the inner divertor (e.g. region of good curvature). This result implies that ELMs have strong ballooning character.

Conclusions

These results imply that ELMs arrival time to the plasma wall can be comparable to, or even smaller than, the characteristic time of transport to the divertor plates (in the range of 0.1 – 0.5 ms); in these circumstances we have to consider the competition between parallel and radial transport of ELMs to explain and predict particle and energy fluxes onto the divertor plates in ITER. The large radial speed of ELMs might explain experimental results showing that only about 60 % of the energy losses due to large type I ELMs arrives to the divertor plates [3].

The possible link between the amplitude and the radial propagation of ELMs might have an important consequence in the extrapolation of the impact of ELM in the divertor plates on future devices. A systematic investigation of the link between the radial propagation and the size of ELMs is in progress in plasma regimes with different ELMs properties (i.e. amplitudes, frequencies) in JET.

References

[1] C. Hidalgo et al., 15th International Conference on Plasma Surface Interactions in Controlled Fusion Devices (May 2002), Gifu, Japan

[2] J.G. Cordey et al., Nuclear Fusion 35 (1995) 101.

[3] T. Eich et al., 15th International Conference on Plasma Surface Interactions in Controlled Fusion Devices (May 2002), Gifu, Japan