

On the link between intermittent turbulent transport and non-exponential profiles in the plasma boundary of the TJ-II stellarator

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I. Introduction

The statistical properties of turbulent particle flux have been investigated in the plasma boundary region of tokamak and stellarator devices showing a striking similarity. In particular, a significant fraction of the total flux can be attributed to the presence of large and sporadic bursts [1]. Recently the importance of intermittent plasma turbulence has been investigated to explain non-exponential decays in the scrape-off layer (SOL) region of fusion devices [2]. Experimental evidence of intermittent events propagating radially with velocities in the range of 1000 m/s has been reported [2-4]. These radial velocities suggest the importance of the competition between both parallel and radial transport to explain particle losses onto the divertor plates in fusion devices. The present work shows a direct link between the statistical properties of turbulent transport and non-exponential density profiles in the SOL region in the plasma boundary region of the TJ-II stellarator.

II. Experimental set-up

Experiments were carried out in the TJ-II stellarator ($P_{\text{ECRH}} = 200 - 400$ kW, $P_{\text{NBI}} = 200$ kW, $B_T = 1$ T, $R = 1.5$ m, $\langle a \rangle \leq 0.22$ m, $\text{iota} (a) \approx 1.7 - 1.8$).

Edge radial profiles of different edge quantities have been simultaneously measured in the plasma edge region using a multi array of Langmuir / Mach probes. Probes are inserted into the plasma edge from the top of TJ-II. Edge electron temperatures are measured by swept Langmuir probes.

III. Edge turbulence and profiles in ECRH and NBI plasmas

The first experiments with Neutral Beam Injection (NBI) heated plasmas have been recently performed in TJ-II. Flattened core electron temperatures in the range 200 to 300 eV and bell-shaped density profiles with $n_0 \leq 5 \times 10^{19} \text{ m}^{-3}$ are achieved in NBI plasmas whereas ECRH plasmas show hollow density profiles with steep temperature profiles. Combined ECRH and NBI experiments reveal that, once ECRH heating power is switched-

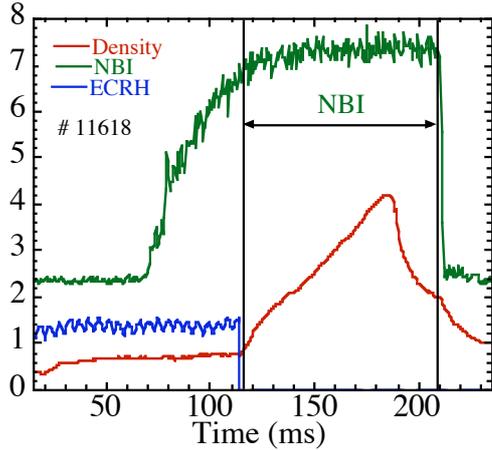


Fig. 1.- Time evolution of plasma density during the transition from ECRH to NBI plasmas.

off, a confinement regime characterized by a strong reduction in ExB turbulent transport and fluctuations and a significant increase in plasma density is achieved (Fig. 1).

Edge plasma turbulence and profiles have been compared in ECRH and NBI regimes. Fig. 2 (a) shows radial profiles of ion saturation current and level of fluctuations in ECRH and NBI plasmas. Tails in the ion saturation current profiles currently observed in ECRH plasmas in the far scrape-off-layer region disappear in the NBI heating regime.

Simultaneously, there is a drastic reduction in the ExB turbulent driven flux (given by $\Gamma_{ExB} = \langle \tilde{n}(t) \tilde{E}_\theta(t) \rangle / B$, \tilde{E}_θ being the fluctuating poloidal electric field and B the toroidal magnetic field) when the ECRH heating is turned off. This reduction in the level of turbulent driven transport is due to a decrease in electric field and density fluctuations. Typically edge electron temperatures are in the range 30 - 40 eV in ECRH plasmas, decreasing in the NBI phase to about 20 eV.

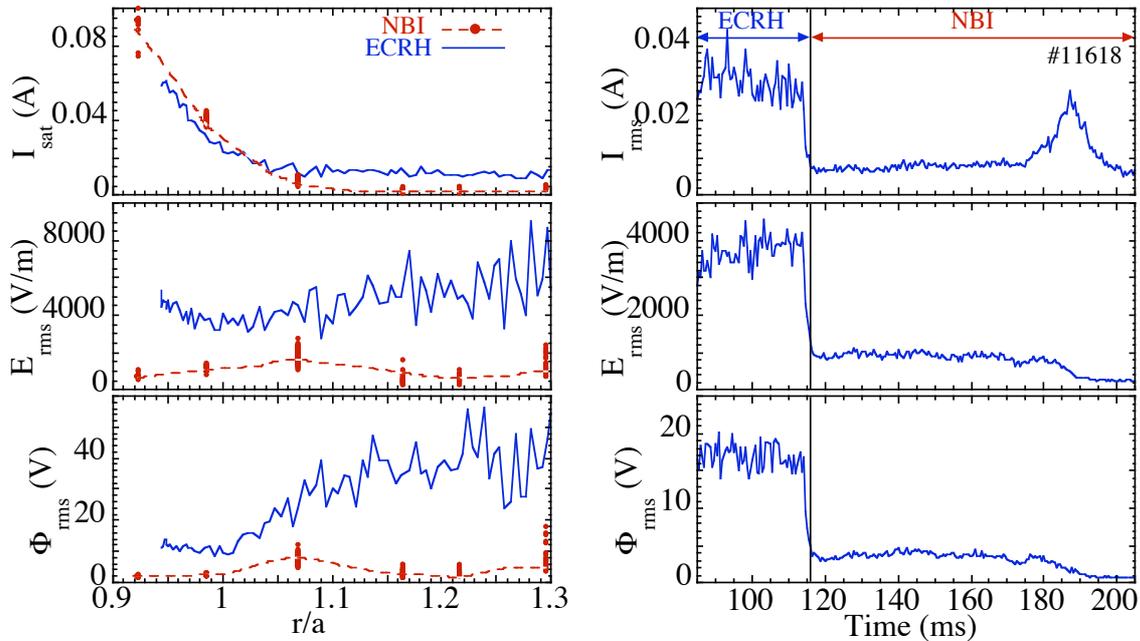


Fig.2.- (a) Radial profiles measured in ECRH and NBI plasmas. Measurements on NBI plasmas were taken shot to shot at a plasma density of about $3 \times 10^{19} \text{ m}^{-3}$. (b) Time evolution of edge level of fluctuation during the transition from ECRH to NBI plasmas.

The time evolution during the transition from ECRH to NBI plasmas of fluctuations in ion saturation current, poloidal electric fields and floating potential are shown in figure 2 (b).

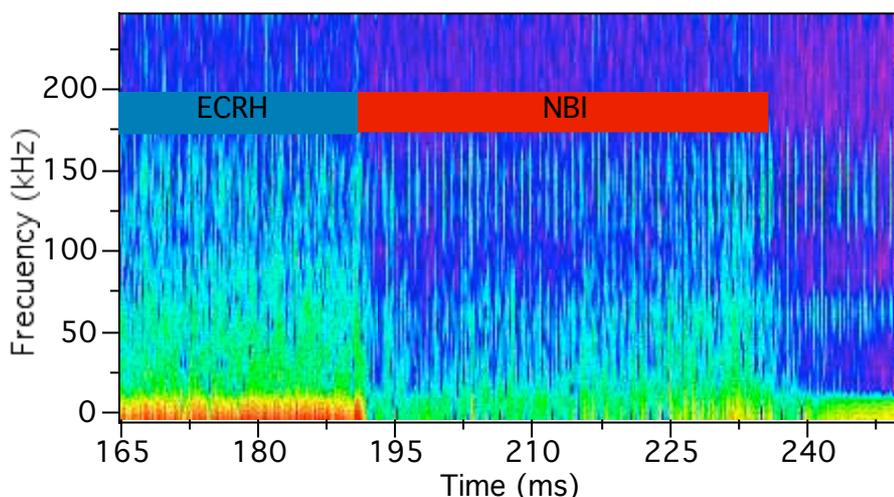


Fig. 3.- Power spectrum of ion saturation current fluctuations in the ECRH and NBI plasma phases in the SOL region, shot #10438.

The level of fluctuations rms for the ion saturation, the electric field E_{rms} and floating potential Φ_{rms} drastically decreases both in the edge and SOL in the neutral heating regime (once the ECRH system is turned off). The time evolution of frequency spectra reveals that the reduction of fluctuations is due to the decreasing of all frequency components (Fig. 3). The Probability Distribution Function (PDF) of the effective radial velocity, defined as $v_r = \langle \Gamma_{ExB} \rangle / \langle n \rangle$, has been compared in ECRH and NBI regimes (Fig. 4). The probability

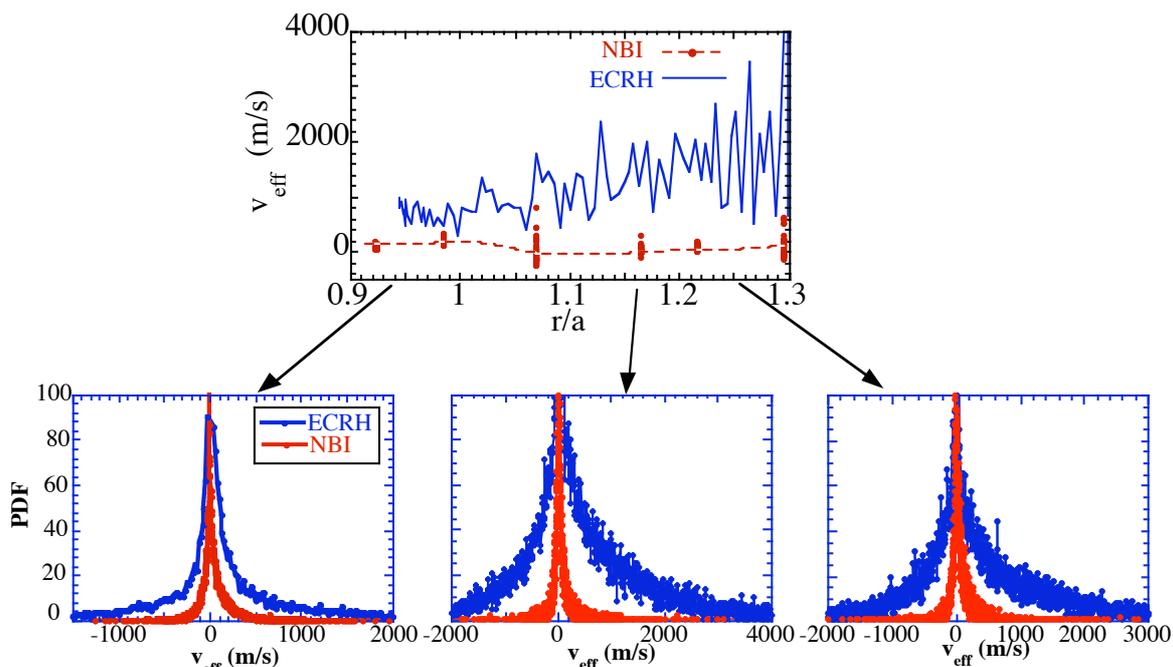


Fig. 4 Radial effective velocities and probability distribution functions in NBI and ECRH plasmas.

distribution function of v_r has been measured at different radial locations. This radial velocity is clearly reduced from values in the range of 500 m/s in the ECRH phase to about 50 m/s in the NBI phase. Interestingly non-exponential profiles currently observed in the scrape off layer region in ECRH plasmas (i.e. with radial velocities up to 500 m/s), disappear in NBI plasmas (i.e. with radial velocities of about 50 m/s).

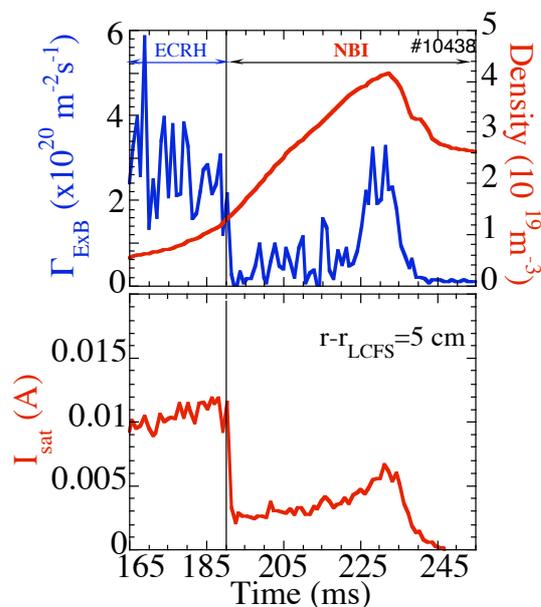


Fig. 5.- Increase in the ExB transport and edge density as plasma approaches the highest NBI density. Measurements were taken in the far SOL ($r-r_{LCFS}=5\text{cm}$)

Finally, it should be noted that as plasma approaches the highest NBI density ($4 \times 10^{19} \text{ m}^{-3}$) an increase in the level of fluctuations and ExB transport has been systematically observed (Fig. 5). Considering that these densities fall within the stellarator density limit scaling law, this finding can be interpreted in terms of the increasing of edge transport mechanisms near the density limit of TJ-II. Experimental results suggest the importance of both radiative and edge transport mechanisms in the physics of the density limit of TJ-II. This topic is under investigation and a detailed characterization of transport and electric fields near the density operational limit will be present elsewhere.

IV. Conclusions

First comparative studies of the structure of turbulence in ECRH and NBI plasmas in the TJ-II stellarator have shown a drastic decrease in the level of turbulence in the transition from ECRH (200 - 400 kW) to NBI (200 kW) plasmas. As a consequence the radial effective velocity of transport decreases by about a factor of ten and non-exponential tails usually observed in ECRH plasmas disappear in the NBI regime. These findings provide the first direct coupling between radial velocity of turbulent transport events and the structure of edge profiles.

Acknowledgments

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- [1] C. Hidalgo et al., New Journal of Physics **4** (2002)51.1
- [2] J.A. Boedo et al., Phys. of Plasmas **10** (2003) 1670
- [3] G.J. Antar et al., Phys. Rev. Lett **87** (2001) 065001.
- [4] M.V.A. Heller et al., Phys. Plasmas **6** (1999) 846.