Inwards and outwards propagating plasma potential events and interplay between radial and toroidal correlation in the TJ-II stellarator

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I. INTRODUCTION

The mechanisms underlying the generation of plasma flows play a crucial role to control transport in magnetically confined plasmas. The dominant role of external momentum as a driving mechanism of plasma rotation is being questioned due to experimental evidence of significant toroidal rotation without momentum input [1].

Long-range correlations in potential fluctuations are present during the development of the edge sheared flows in TJ-II [2] and are amplified either by externally imposed radial electric fields or when approaching the L-H confinement edge transition [3]. Propagating inwards and outwards plasma potential events have been observed in the presence of the edge sheared flows developed at the plasma edge suggesting the emergence of a momentum source linked to the edge velocity shear layer in the TJ-II stellarator.

It is now widely recognized that fluctuating small scale $\boldsymbol{E}\times\boldsymbol{B}$ shear flows, such as zonal flows, ZFs, can be generated by turbulence and regulate transport [4]. Radial and toroidal correlations have been compared in the plasma edge (where the ZF amplitude is large) and scrape-off layer (SOL) (where no ZFs are observed) regions of the TJ-II.

II. EXPERIMENTAL SET_UP

Experiments were carried out in the TJ-II stellarator in Electron Cyclotron Resonance Heated (ECRH) plasmas ($P_{ECRH} \leq 400$ kW, $B_T = 1$ T, $\langle R \rangle = 1.5$ m, $\langle a \rangle \leq 0.22$ m, $\iota(a)/2\pi \approx 1.5 - 1.9$) and in pure Neutral Beam Injection (NBI) heated plasmas (P_{NBI} port through ≈ 450 kW). The reported results were made possible by the use of a rake probe (Fig. 1) made of twelve Langmuir probes radially separated 3 mm together with three poloidally separated tips at the rake probe front, and another 3 tips probe located approximately 160° toroidaly apart. This set-up has allowed studying and comparing the long-range (toroidal) and local (radial) correlations between potential and current signals in the edge plasma (large ZFs amplitude) and scrape-off layer (no ZFs observed) regions. The radial structure of

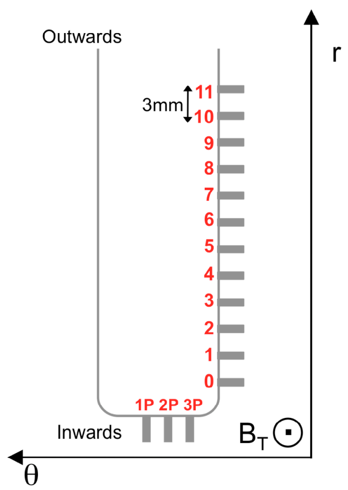

Fig. 1.- Rake probe arrangement.

fluctuations and correlations has been investigated at different plasma densities. Previous TJ-II experiments have shown that the emergence of the edge shear flow layer takes place [5, 6] at densities above a threshold value (typically in the order of $n_{th} \approx 0.6 \times 10^{19}$ m^{-3}) in ECRH plasmas. Recent experiments with Li-coating and NBI heating have shown spontaneous bifurcations (L-H transition) [7]. Then, using the plasma density as a control knob, sheared flows can be easily driven and damped at the plasma edge of the TJ-II stellarator.

III. PLASMA PROFILES AND RADIAL CORRELATION RESULTS

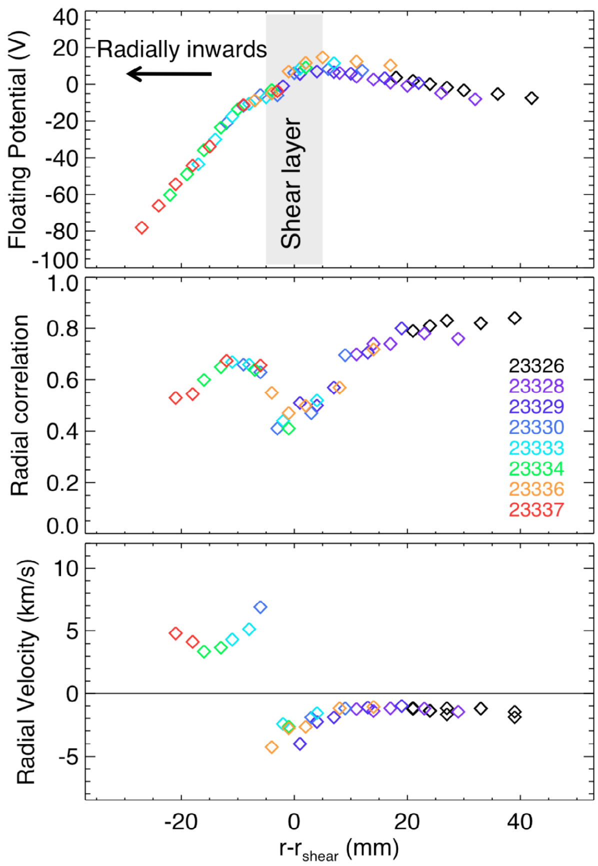

Fig. 2.- Radial profiles of floating potential, radial coherence and radial effective velocity of fluctuations obtained with the rake probe in NBI plasmas ($n \approx 2 \times 10^{19}$ m^{-3}).

Figure 2 shows the radial profiles of floating potential, maximum radial cross-correlation between two floating potential signals radially separated by 6 mm and the effective radial velocity deduced from the time delay for the maximum cross-correlation in NBI heated plasmas. Rake probe measurements allow identifying a reversal in the effective radial velocity of fluctuations and a decrease in the radial coherence of fluctuations in the shear layer region.

IV. PROPAGATING POTENTIAL EVENTS

Figure 3 shows the raw data of floating potential signals for a plasma discharges in which the rake probe is partially located in the edge and SOL regions. Floating potential events, propagating radially inwards (with effective radial velocity in the order of 1 – 10 km/s) in the plasma edge region and radially outwards in the SOL have been observed in TJ-II. These events have been

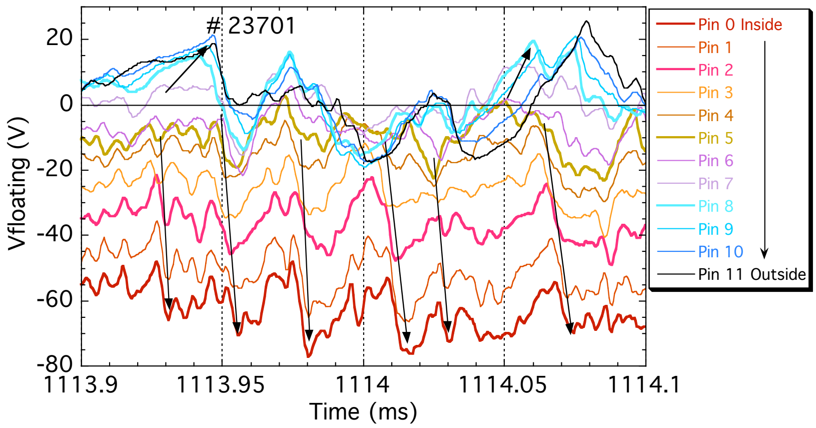

Fig. 3.- Raw data of floating potential fluctuations showing direct experimental evidence of floating potential events propagating inwards/outwards (see arrows) from the shear location (NBI plasmas).

observed developing in the presence of edge sheared flows close to plasma confinement transitions: shear flows development in ECRH low density plasmas, biasing induced transitions in ECRH plasmas and L-H transition in NBI plasmas.

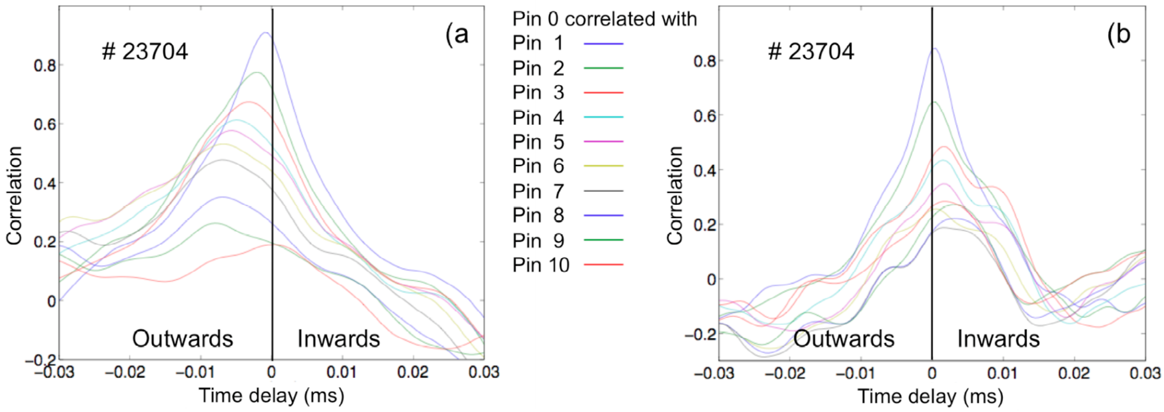

Fig. 4.- Cross correlation between the innermost pin (0) and the remaining rake probe pins for densities below (a) and above (b) the threshold value. Rake probe is located in the edge side of the shear layer location.

The effective radial propagation of potential events has been investigated with and without the emergence of the edge velocity shear layer (i.e. above and below the density threshold, n_{thr}) with the rake probe located in the edge side of the shear layer location (figure 4). At low densities ($n<n_{thr}$) potential fluctuations are predominantly propagating radially outwards across the whole edge sampled region, whereas above the density threshold evidence of both outwards/inwards propagation has been observed depending on the probe position relative to the shear layer.

V. RADIAL AND TOROIDAL CORRELATION INTERPLAY

The radial and toroidal correlations have been compared in the edge plasma (where the ZFs amplitude is large) and in the SOL (where no ZFs are observed) regions. Results shown in figure 5 indicate that in the SOL side of the shear layer location the radial coherence at

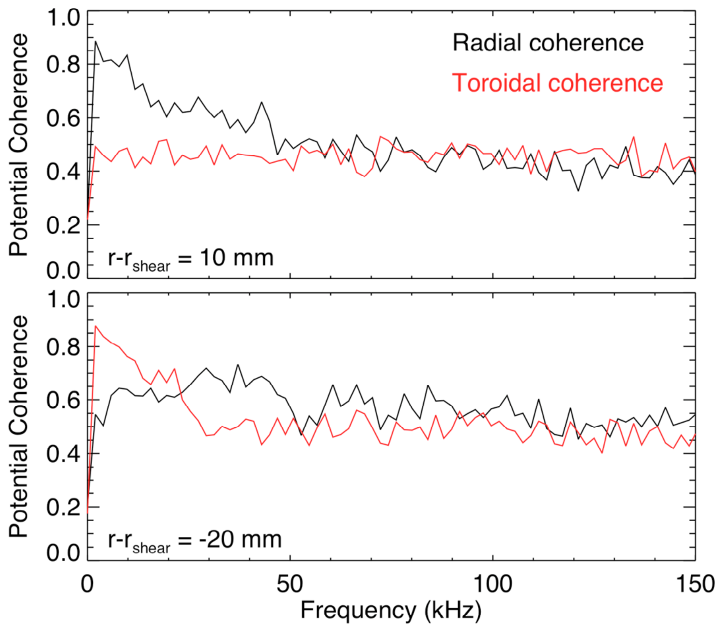

Fig. 5.- Coherence between floating potential signals radial (6 mm) and toroidaly apart, measured in the SOL side and in the edge side of the shear layer location.

low frequencies is higher than the toroidal one, whereas in the edge plasma region the opposite behaviour is observed. Furthermore, it is observed that the radial turbulent transport driven by low frequencies (those showing long-range correlations) is strongly reduced in the plasma edge side of the shear layer radial location. These results show that the radial transport and the radial correlations are reduced in the region dominated by ZFs, providing direct evidence that the long-range correlations play an important role in the control of the radial transport mechanisms.

VI. CONCLUSIONS

A direct experimental evidence of the edge sheared flows as a source of propagating plasma potential events has been shown. Considering that potential events propagating radially outwards will be lost in the SOL region or/and interacting with the plasma-wall whereas those propagating radially inwards will remain confined, these findings suggest the development of a momentum source linked to the edge velocity shear layer. In addition, the radial correlation of fluctuations decreases in plasma regimes where long-range correlations (ZFs) are enhanced, suggesting the role of ZFs on edge transport control.

[1] J. E. Rice et al., Nucl. Fusion, **45** (2005) 251.
[2] M. A. Pedrosa et al., Phys. Rev. Lett. **100** (2008) 215003.
[3] C. Hidalgo et al., EPL **87** (2009) 55002.
[4] P. Diamond et al., Plasma Phys. Control. Fusion **47** (2005) R35
[5] C. Hidalgo et al., Phys. Rev. E **70** (2004) 067402
[6] M. A. Pedrosa et al., Plasma Phys. Control. Fusion **47** (2005) 777
[7] T. Estrada et al., Plasma Physics and Control Fusion **51** (2009) 124015

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