EFFECTS OF INDUCED RADIAL CURRENT ON TURBULENT TRANSPORT IN A LINEAR PLASMA MACHINE

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I. Introduction

Anomalous transport in plasmas has been the subject of many theoretical studies and experimental works. In order to improve our knowledge of dynamical mechanisms underlying the anomalous plasma transport processes, comparative studies of the plasma turbulence structure in different fusion devices have been carried out [1]. The overall similarity in the structure of the statistical properties of fluctuations[2,3], the empirical similarity in frequency spectra [4] and lately [5], the experimental evidence of an empirical similarity in the probability distribution functions of fluctuation-driven particle fluxes (PDFs), support the view that plasma turbulence in fusion devices displays universality. Besides, recent results emphasize the importance of comparitive studies between fusion and non fusion devices [1]. In this context linear plasma devices are well suited for experimental comparative studies of plasma turbulence.

In this paper preliminary studies of the statistical properties of plasma fluctuations have been carried out along the whole plasma radial column of a linear plasma machine (SLPM)[6]. Measurements were performed under different experimental plasma conditions. By biasing an axial electrode an induced radial current is generated. The experimental effects on statistical properties of fluctuations parameters have been investigated. PDFs of electron density, floating potential and radial fluctuation-induced flux have been determined.

II. Experimental Conditions
a. Setup

The plasma is generated in a cylindrical glass vessel with an internal diameter of 0.07 m and a lenght of 1 m. (see fig. 1). The vessel is located inside a circular waveguide of 0.08 m in diameter. A magnetized plasma is produced by launching longitudinally electromagnetic
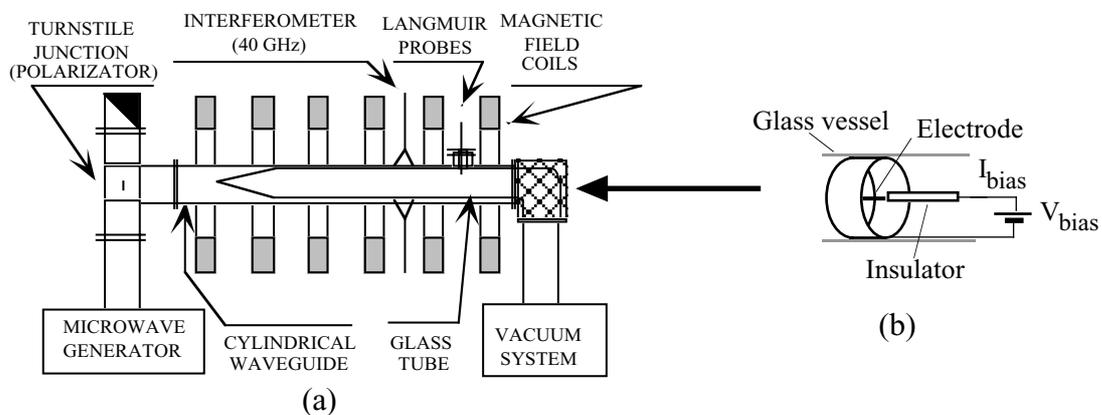

Fig 1.Scheme of the SLPM (a), scheme of the axial electrode (b)

waves with a frequency f=2.45 GHz. The incident power (P_{LMG}) is typically 1 kW and the system can operate in a continuous regime. The stationary longitudinal magnetic field (0.05 T < B_0 < 0.15 T) is generated by six water-cooled coils, wich are concentric with the waveguide. Measurements reported in this paper were performed for helium plasmas with a magnetic field B_0 = 0.12 T. The mean electron density is determined using an 8 mm interferometer, and ranges from 10^{15} m^{-3} to 10^{18} m^{-3}. Electron temperatures are in the range (5 - 40) eV. Finally, an induced radial current is generated by biasing an axial electrode (-120 V<V_{bias}<120 V) (fig 1).

b. Measurements

Two radially movable arrays of Langmuir probes provide local value of electron density, floating potential, electron temperature and their fluctuations along the whole plasma radial column. One array consists of four tips, each of tungste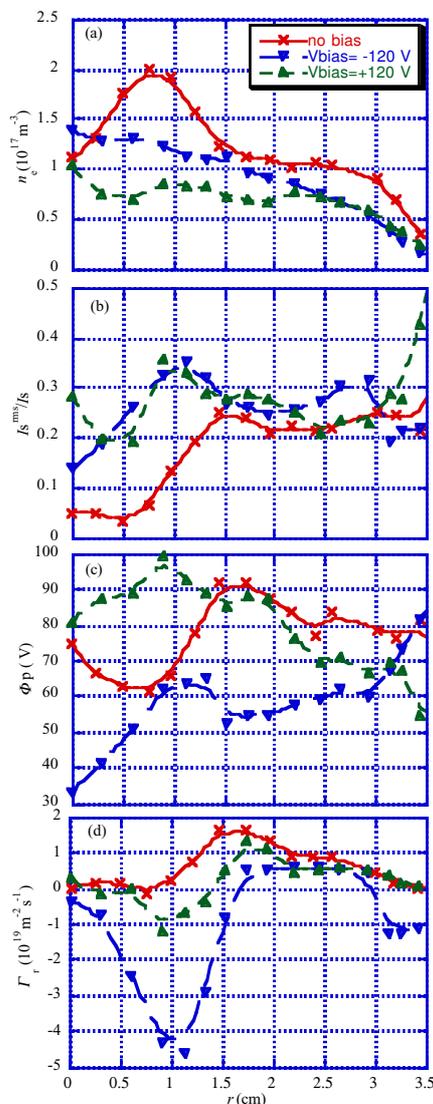n wire 0.5 mm in diameter and 2 mm long, arranged in a square array. Working on double probe configuration electron density and electron temperature profiles were obtained. Fluctuations of ion saturation current and floating potential were measured using the triple probe technique, i.e., one probe is in the ion saturation regime while two poloidally separated probes were unbiased to measure the floating potential. Radial profiles were measured on a shot to shot basis. Eigth fast data acquisition channels are arranged for fluctuations measurements: 200000 points per channel, sampling frequency 1 MHz with 12 bits ADCs resolution. Figure 2 shows radial profiles of electron density, normalized ion saturation current fluctuations, plasma potential, and fluctuation induced particle flux (Γ_{ExB}). Radial fluctuations profiles of electron density (20%-30%) and floating potential ($e\Phi^{rms}/kT_e \approx 5\%$) are very similar for V_{bias}>0 and V_{bias}<0. The fluctuation induced particle flux has been computed from the correlation between density and poloidal electric field fluctuations neglecting the influence of electron temperature. The resulting transport is in the order of 10^{19} m^{-2}s^{-1} and radially outward in the edge of the plasma. For V_{bias}<0 and r$\approx$ 1 cm a radially inward flux is found. This inward flux is correlated with the absolute fluctuation level of the flux.

Figure 2. Electron density (a), normalized ion saturation current fluctuations(b), plasma potential (b) and fluctuation induced particle flux (d)

III. Results

a. Statistical properties of fluctuations

The skewness (S) and kurtosis (K) of the ion saturation current, floating potential and fluctuation driven flux (fig. 3) have been computed. Ion saturation current has rather a PDF close to a Gaussian distribution (S=0, K=3) for no bias and $V_{bias}<0$ cases. When $V_{bias}>0$ PDFs of ion saturation current and floating potential deviate from a normal distribution. Fluctuation driven fluxes have a clear non-gaussian behaviour along the whole radial column. In particular, for V_{bias}=+120 V very high values of kurtosis have been obtained
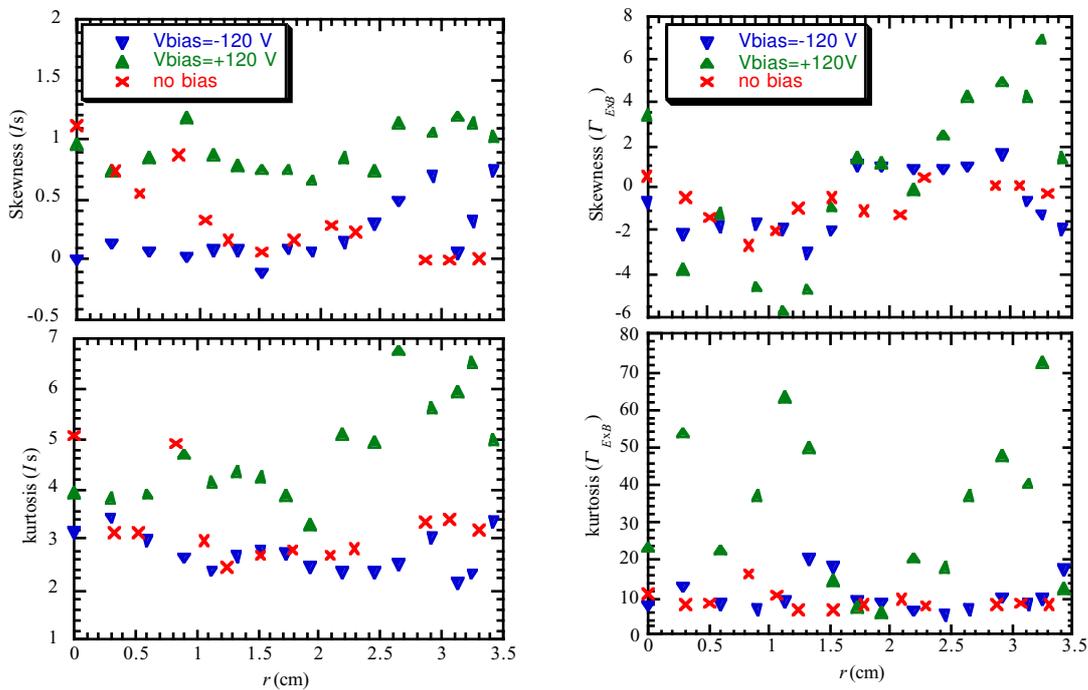
Figure 3. Skewness and kurtosis of Ion saturation current and fluctuation driven flux

b. Non similarity in turbulent fluxes

Recent experiments on fusion plasmas [5] show an interesting property of the PDFs of the *ExB* turbulent fluxes in the edge of the fusion plasmas. They can be re-scaled assuming a finite size scaling functional form PDF(Γ_{ExB})=L^{-1}g(Γ_{ExB}/L), where L is a scaling factor related linearly with the root mean squared (rms) value of the turbulent flux. Figure 4 shows the PDFs of fluctuation-driven fluxes for measurements taken in the plasma along the whole plasma radial column. The statistical properties of turbulent transport have also been analyzed at different time scales. We have constructed time records with a time resolution ΔN, by averaging over blocks of ΔN elements from the original series (ΔN=80 µs - 4 ms). The

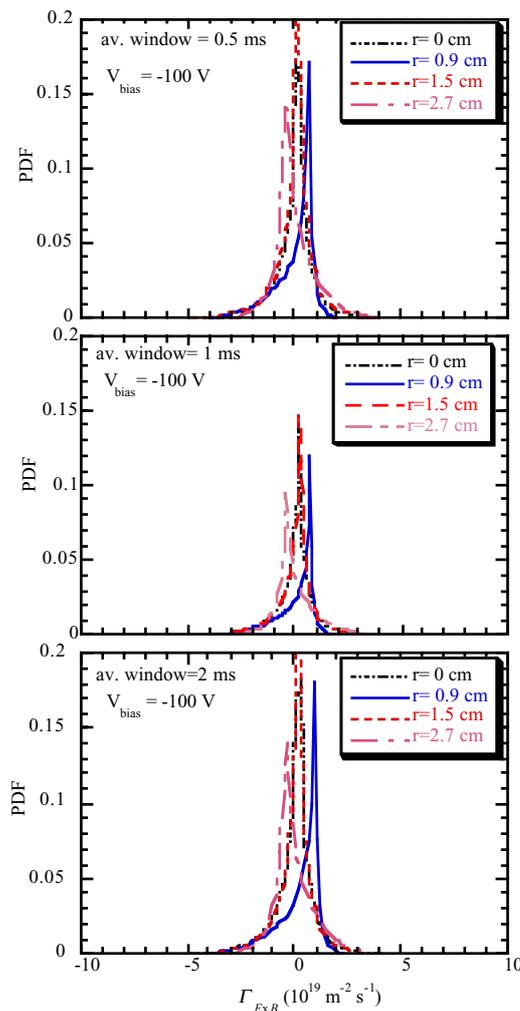original time series are 200 ms (i.e. 200000 points). The figure shows changes in the shape of PDFs as the averaging parameter ΔN increases from 0.5 ms to 2 ms. Like in fusion plasma

devices the PDFs of fluctuating transport have non-gaussian features. Fluctuation induced fluxes have a bursty character. However, unlike it happens on fusion plasmas, it is not possible to re-scale the PDFs. This non similarity condition occurs for different time scales and for all studied values of V_{bias} . This result could be an indication that the functional form for the PDF found in [5] cannot be explained considering that the flux is a quadratic function of two fluctuating and correlated density and radial velocity fields.

Summary

The radial profile of electron density and floating potential fluctuations are similar for all studied values of V_{bias}. The radial dependence of turbulent flux has been determined. A maximum radially inward flux at around r=1 cm for V_{bias}<0 is found. This maximum is correlated with the absolute fluctuation level of the flux. Fluctuation of ion saturation current and floating potential have a non-gaussian character for V_{bias}>0. Finally, similarity properties on frequency spectra and PDFs of fluctuation driven fluxes have not been found

Figure 3. PDFs of fluctuation driven flux computed at different time scales (0.5 ms, 1 ms and 2 ms) for V_{bias}=-100 V

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