Properties of density, temperature and electric field structures in the turbulent regime of the simply magnetised toroidal plasma device THORELLO

R. Barni[1], E. Ghorbanpour[2], T. Abbaszadeh[3], C. Riccardi[1]

[1] *Dipartimento di Fisica G. Occhialini – Università degli Studi di Milano-Bicocca, Milano, Italy*

[2] *Department of Physics -Faculty of Science – University of Guilan, Rasht, Iran*

[3] *Department of Physics -Faculty of Basic Science – Sahand University of Technology, Tabriz, Iran*

Experimental investigation of magnetised plasma turbulence is actively pursued in fusion aimed as well as in basic plasma physics toroidal devices. In particular the understanding of turbulent transport mechanisms has a great interest for the improvement of the magnetic confinement [1,2]. At the edge of magnetic confinement devices, a large fraction of anomalous particles and energy transport is attributed to the propagation of density blobs [2,3]. These are isolated and intermittent structures, with density and temperature above the surrounding plasma, extending along field lines and propagating away from the bulk into the edge regions. In this contribution we discuss some properties of plasma structures that develop and propagate in the edge region of a low temperature toroidal plasma. In particular we aim to measure electron density and temperature inside the structure using electrostatic Langmuir probes. In order to identify coherent structures in the plasma state, we have employed the so called conditional sampling technique [4]. This is suitable to separate the coherent contribution against a background of, often larger, uncorrelated fluctuations. It also requires the use of only a couple of probes, without the need of a complete coverage of the full plasma region, which normally appears hard to achieve and to perturb plasma. By slowly varying the scanning probe potential, it is possible to reconstruct also a conditionally sampled Langmuir characteristics curve [6,7]. The curves could then be analysed in order to extract plasma parameters such as the electron temperature or the plasma potential, which usually cannot be estimated from ion saturation current or floating potential conditionally sampled measurements alone [2,6]. Here we report the results of an experimental investigation of plasma parameters fluctuations of a turbulent, low beta, low temperature plasma with a

simply magnetised torus configuration. Experiments have been performed in the Thorello device, operating at the University of Milano-Bicocca [8]. There a low temperature, high density plasma can be produced in a steady configuration for long times in a hydrogen low pressure discharge. Plasma parameters have been studied by means of multiple pin electrostatic probes and fairly long time series of fluctuations have been obtained and correlated [5,8]. For the conditional sampling, which requires a couple of probes, we have employed a standard probe and a plug probe [9]. The latter was used as a reference, at a fixed location, to record fluctuations in the plasma potential (more faithfully than using the standard probe floating potential, as normally it is done [8]), simply by connecting the probe to the high impedance input of a digital scope. The probe position, shown in Fig.1, was chosen carefully. It was located in the edge region and intersecting the mainly downwards flow imposed by the average ExB velocity field, also shown in Fig.1. As a trigger, we chose events corresponding to deep minima in the plasma potential (actually less than -2.5σ). This corresponds to the stronger than Gaussian tail in the negative fluctuations of the PDF, as shown in Fig.3. About 10^3 events were selected in each 2 Msamples, 2 MHz time series recorded by the scope. The so called autoconditional signal is shown in Fig.4, showing the passage of a negative plasma potential structure during about 80 μs and almost symmetric in time delay. In order to test the reconstruction method of conditionally sampled Langmuir characteristics curve, we chose to scan only a radial line intersecting the poloidal cross-section, as indicated in Fig. 1. A standard Langmuir probe, with a 4 mm cylindrical pin, was used. The probe potential was slowly varied with a sinusoidal signal at 1 kHz, applying a 40 V window, spanning across the local floating potential, while the actual voltage and current drawn from the probe were digitized and recorded simultaneously to the reference probe signal by the scope.

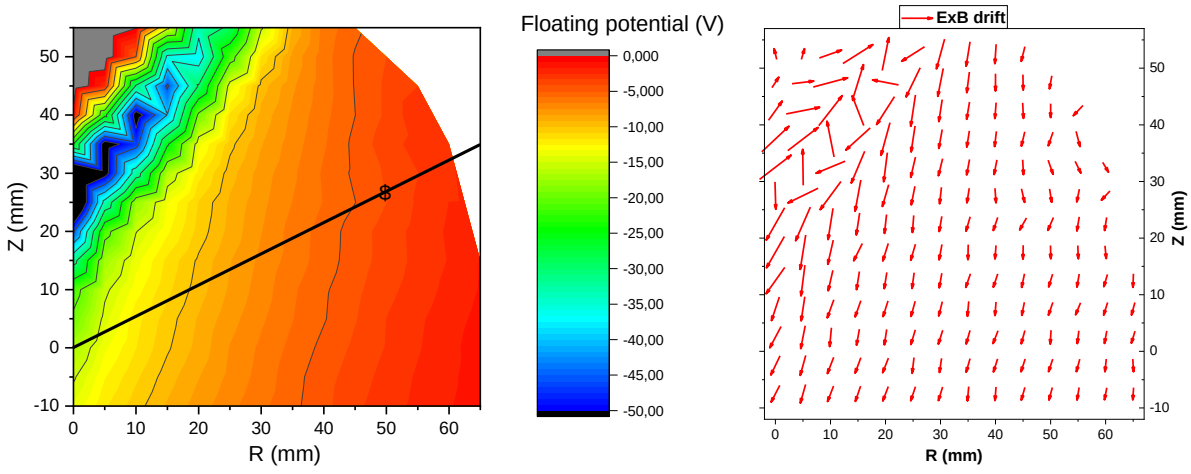

Fig. 1 – Average floating potential and ExB velocity field measured in the region of the experiments.

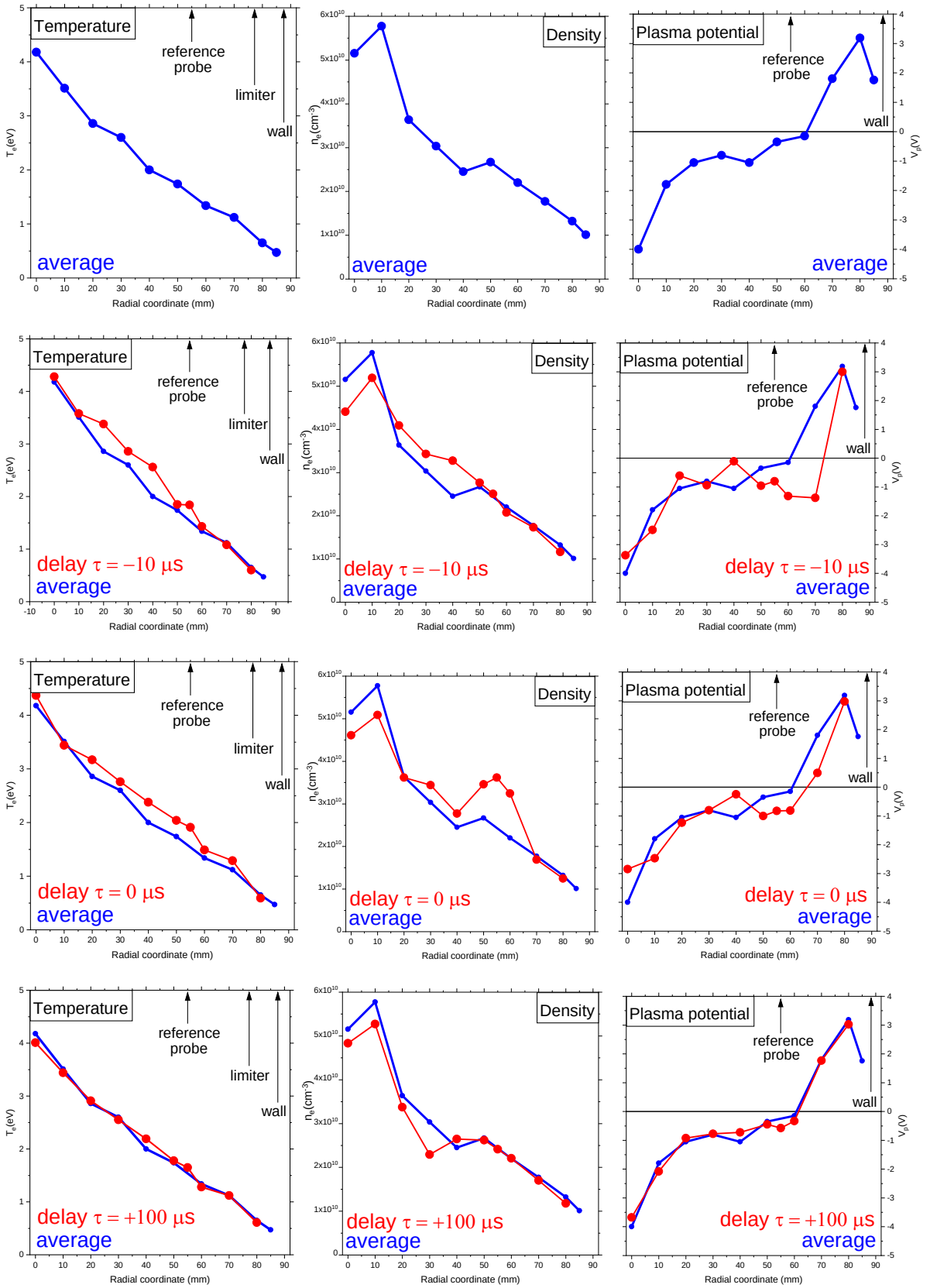

Fig. 2 – Conditionally sampled electron temperature, plasma density and plasma potential profiles.

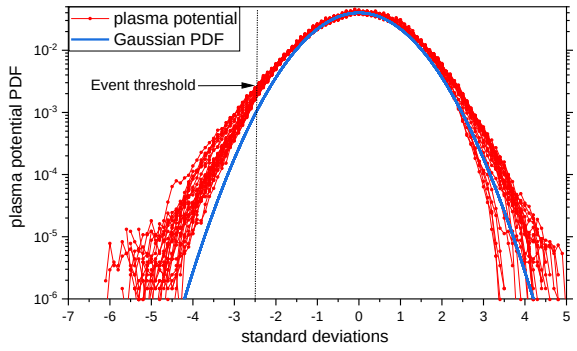

Fig. 3 - Event selection (peaks less than -2.5σ).

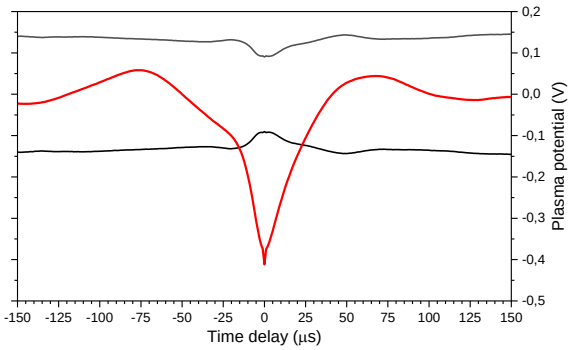

Fig. 4 – Autoconditional signal with error band.

We record therefore about $2x10^3$ full Langmuir characteristics for each time series, which could be used to measure the average electron density and temperature, as well as plasma potential. For each time delay from the reference event a conditionally sampled Langmuir characteristics curve, containing about 200 points, was recorded and automatedly fitted with a four parameters Langmuir curve. On the previous page, in Fig.2, the monodimensional profiles of plasma parameters are shown. It could be appreciated that a positive density fluctuation appears to arrive at the reference probe, associated with an electron temperature enhancement, a feature normally overlooked in conditionally sampling experiments. After about a hundred microseconds the signal associated with the coherent structure has disappeared both in the reference time series and in the shape of the plasma profiles, which is almost undistinguishable, apart their larger errors, from the average ones. This also suggests that our procedure of conditional averaging does not introduce any significant bias in the reconstructed Langmuir curves. We observe also a similar signature of plasma fluctuations somewhat in advance. It appears to cross the scan-line at a slightly inner location.

As a conclusion, we have demonstrated that conditional sampling technique could be stretched to measure independent plasma parameters inside of coherent structures, allowing to appreciate their interrelations and mutual influence between particle density and energy with the local velocity field, modified through correlations in the electric field and ExB drift.

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