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The spatial structure of flows, Reynolds stress and turbulence in the CASTOR tokamak

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INTRODUCTION

Recently zonal flow like structures have been observed close to last closed flux surface of CASTOR tokamak by electrostatic probe measurement and their spatio-temporal characteristics have been described [1]. In order to obtain information about the underlying complex dynamical behavior of the flow fluctuations we have constructed a new array of electrostatic probes, which is able to measure the time evolution of the radial gradient of Reynolds-stress, what is supposed to be the driving force of zonal flows. In our recent measurements with this new Reynolds-stress probe, we found a strong radial gradient of Reynolds-stress in the same region, where zonal flow like structures appeared. The spatial structure of the basic plasma fluctuation (microsecond scale) was also studied using a poloidal ring of Langmuir probes together with a toroidally separated Reynolds probe. Additionally to radially and poloidally localized high correlation along a flux tube, structures with longer radial correlation and m=q poloidal mode number were observed. Measured characteristics of these features are presented in the paper.

MEASUREMENTS WITH THE DOUBLE RAKE PROBE

CASTOR is a small tokamak with a minor radius of 9*cm* and relatively low density and temperature, therefore it is possible to use Langmuir probes to diagnose fluctuations up to the 60% of the minor radius.

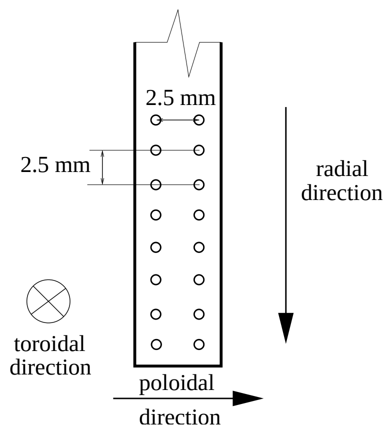

Figure 1: The scheme of the double rake probe.

Recently using autocorrelation width technique, random flow modulations have been observed [1] with relative fluctuation amplitude of about $10-20\%$, radial length of $1-2cm$ and high poloidal elongation. The importance of Reynolds-stress in generation of turbulence induced random flow was recognized by recent theories[2]. In order to investigate turbulent Reynolds-stress experimentally a new kind of rake probe was developed (see Fig. 1).

This new probe is a double-row array of individual Langmuir tips. These two rows are poloidally separated by 2.5mm and the radial resolution was also 2.5mm. During the measurements presented in this contribution all tips were used in floating potential mode. This allows us to determine the radial and poloidal electric field and its fluctuations at the same radial position. The turbulent Reynolds-stress can be defined as:

$$R_e = \left\langle \tilde{v}_r \tilde{v}_\phi \right\rangle \propto \left\langle \tilde{E}_r \tilde{E}_\phi \right\rangle .$$

From the definition above it is clear that using this probe the whole radial profile of the turbulent Reynolds-stress can be determined with high time resolution (see Fig. 2) which is the main advantage of such a probe.

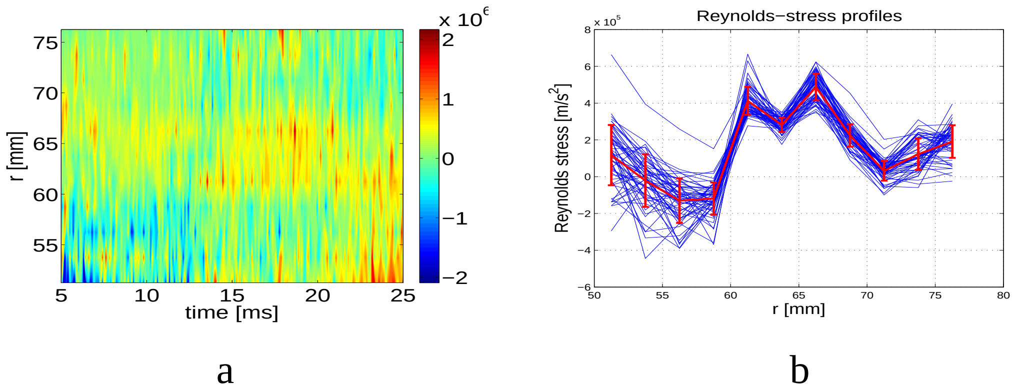

Figure 2: (a) Time history of the Reynolds-stress profile with 100μs time resolution. (b) Time averaged radial profiles of the Reynolds-stress (different shots).

The average profile of R_e shows large gradients near the LCFS, indicating the possibility of shear flow generation by Reynolds-stress or at least the contribution of Reynolds-stress gradient to generation mechanism. Further investigations are needed to quantify the shearing rate of fluctuating flows and to estimate the contribution of the observed R_e gradient to sheare flow generation.

MEASUREMENTS WITH THE RING PROBE

The ring probe is an array of 96 Langmuir tips which encircles the plasma column poloidally at a distance of 85mm from the center of the tokamak vessel. Operating this tips in floating potential mode and using correlation techniques poloidally periodic structures were found with $m \approx q(a)$ (see Fig. 3). These structures are not observable everywhere around the poloidal circumference, but where they are present they have large radial correlation length. The absence and the presence of such global wave-like structure may be explained by the concept of ’strange

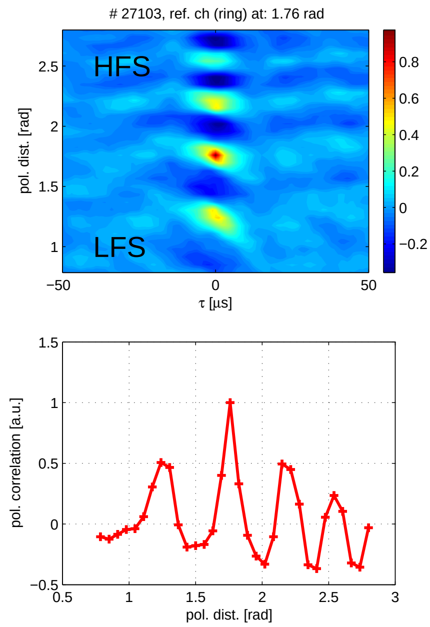

Figure 3: Spatial correlation pattern along the ring probe.

SOL' or long connection length region in CASTOR. As it is clear from Fig. 3, these wave-like structures 'live' on short (microsecond) timescale. Beside these wave-like events, of course the eddy-like structures are also present. The question we would like to address here is the following: Dealing with floating potential raw signals wether any significant differences in the statistical properties of a suitably defined quantity could be found or not? In order to separate wave-like structures from the poloidally and radially localized turbulent eddies it seems to be possible to apply poloidal correlation function for a spatial filtering of the fluctuating raw signal Fig. 4.

This procedure uses the poloidal correlation function (along the ring) at zero time lag as filter-function. Multiplying all raw signals at all time points by this filter-function and averaging over different reference points we can get a new time record which highten times where the wave-like structure dominates in the original signal. It has to be noted that the filtered signal has a clear bursty behavior in the tokamak regions where the wave-like correlations appear. It is also interesting to note (see Fig. 5) that this difference (see PDFs of different signals) is completely invisible when we look at the raw signals.

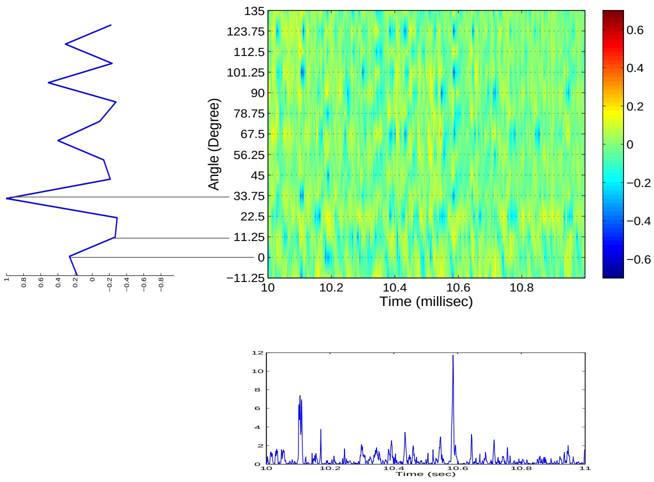

Figure 4: After multiplying the raw signal by the spatial correlation function as a filter, we can get the filtered signal which has a significant bursty behavior when wave-like events are dominant.

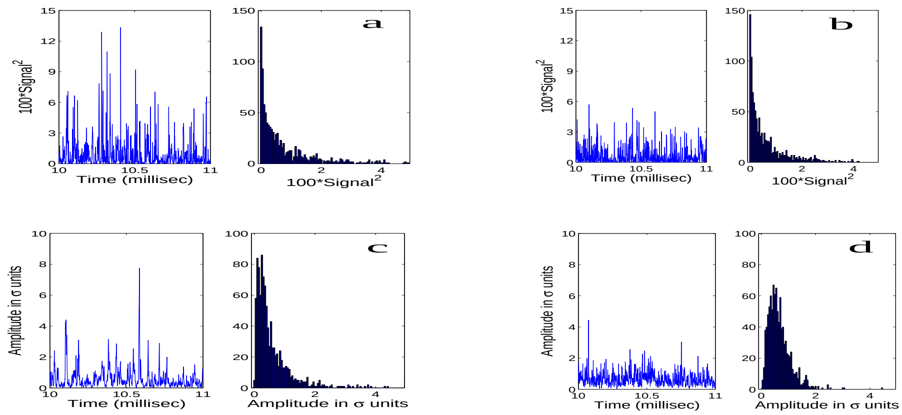

Figure 5: (a) Unfiltered signal and its PDF from the top of the plasma column. (b) Unfiltered signal and its PDF from the bottom of the plasma column. (c) Filtered signal and its PDF from the top of the plasma column. (d) Filtered signal and its PDF from the bottom of the plasma column.

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References

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