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Poloidal structure of the scrape off layer turbulence in the CASTOR tokamak

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Introduction: Understanding and control of the particle and heat transport at the tokamak edge is of primary importance for design of future large-scale experiments. It is recognized that the transport properties of the edge plasma can be controlled in some way by imposing electric fields. This contribution is devoted to the description of experiments with the biased electrode inserted into the scrape-off layer (SOL) of the CASTOR tokamak ($R=40$ *cm*, $a = 6$ *cm*, $B_t = 1.3$ *T*). Resulting electric fields and properties of the edge turbulence are measured with a high temporal and spatial resolution by means of Langmuir probe arrays. A significant modification of the edge turbulence and transport is reported.

Experimental arrangement: The electrode is immersed into the edge plasma from the top and biased positively with respect to the tokamak vessel. Properties of the edge plasma in the poloidal direction are measured by means of a ring of 124 Langmuir probes surrounding the whole poloidal cross section at the radius a = 60 mm, see Fig. 1.

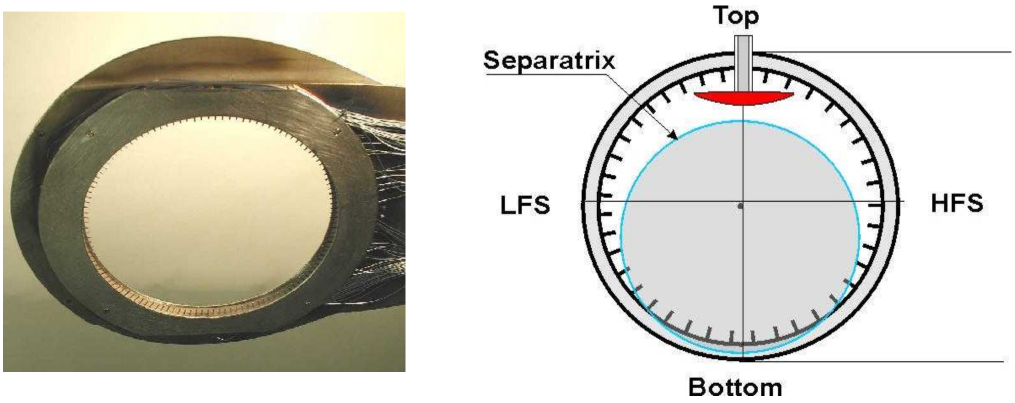

Fig1. *Left - Picture of the poloidal ring of the Langmuir probes. Right - Respective position of the plasma column and key elements of the experiment (biasing electrode, ring). The biasing electrode is inserted from the top into the additional SOL*

Individual probes measure either the ion saturation current or the floating potential with the spatial/temporal resolution up to 3 mm/1 μs, respectively. Particular feature of this experiment is a displacement of the plasma column. Consequently, the last closed flux surface (separatrix) is not defined by the ring, which represents the poloidal limiter. The electrode is inserted into the *additional* SOL, which is characterized by a long parallel connection length, $L_{//} \sim q2\pi R$ (see the right panel in Fig 1).

Poloidal distribution of mean floating potential and ion saturation current at biasing.

A complex picture is observed when the biased electrode is located in the SOL, as it is apparent from the poloidal distribution of the mean floating potential (see Fig. 2) in ohmic and biasing phase of a discharge.

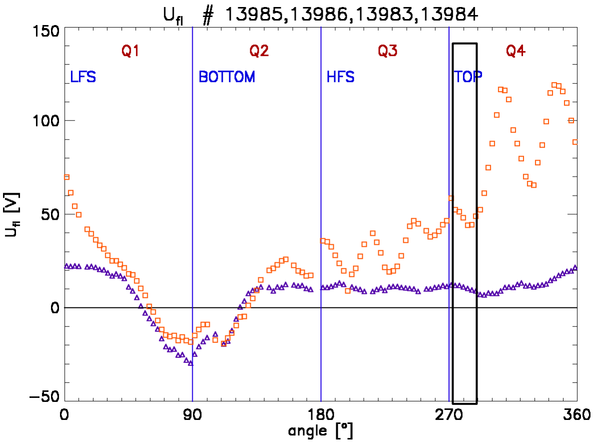

Fig2. *Poloidal distribution of the mean floating potential* U_{fl} *along the ring in ohmic (blue symbols) and biasing (red symbols) phase.*
Ohmic phase: Except the bottom part of the torus, the tips measure the positive floating potential, which indicate their location in the SOL. The bottom tips are effectively located inside the separatrix, since $U_{fl} < 0$.

During the SOL biasing, the floating potential is amplified everywhere, except the bottom and a strong poloidal modulation of U_{fl} appears. This is interpreted as formation of a biased flux tube, associated with the electrode, which snakes around the torus along the helical magnetic field lines. The projection of the biased tube on a poloidal plane is schematically depicted in Fig. 3.

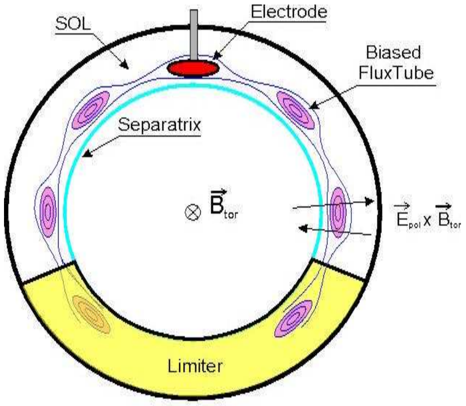

Fig.3
Distribution of floating potential in the poloidal cross section at the SOL biasing (schematically).
The biased flux tube emanates from the electrode upstream and downstream the magnetic field and terminates on the electron and ion side of the poloidal limiter at the bottom part of the torus.

The resulting perpendicular electric field $E_\perp$ is consequently two-dimensional and convects the plasma around the biased flux tube because of $E_\perp \mathrm{x} B_t$ drift. The plasma flow in the radial direction appears due to the poloidal component of the $E_\perp$, which drives the plasma either towards the plasma core or outward depending on its sign, as demonstrated in the left panel of Fig. 4.

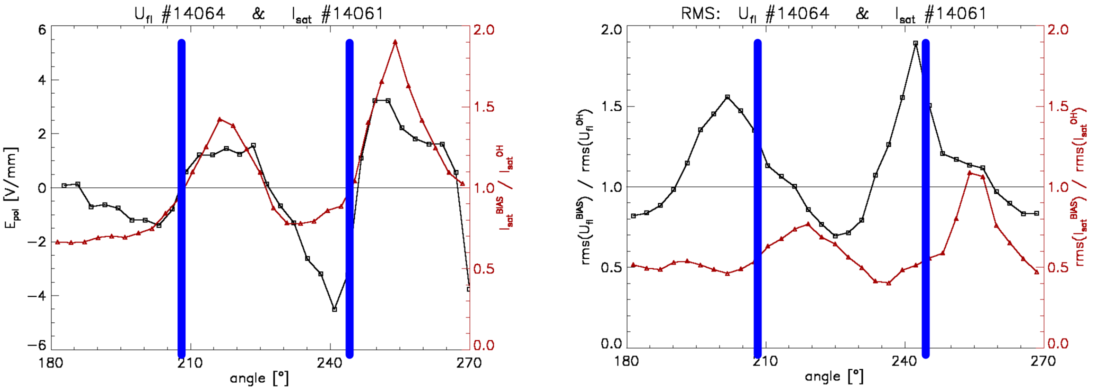

***Fig.4** Left - Poloidal distribution of mean poloidal electric field (black) and the ion saturation current normalized to its ohmic value (red) at the biasing phase of the discharge. Right - Corresponding levels of density and potential fluctuations at biasing normalized to their ohmic values. The projections of the biased flux tube are marked by blue lines.*

It is seen that during the SOL biasing the density fluctuations are reduced almost everywhere, but predominantly at the angular positions, where the DC poloidal electric field drives the plasma inward. On the other hand, the potential fluctuations are periodically either above or below the ohmic level, having maximum close to the centre of biased tube projections and minimum in between them.

Correlation analysis: Our configuration allows analyse the fluctuation - induced flux along a significant part of the poloidal circumference. For that reason, the tips operate sequentially in the I_{sat} and U_{fl} mode. Results of correlation analysis of density fluctuations from one quarter of the poloidal circumference are shown in Fig. 5.

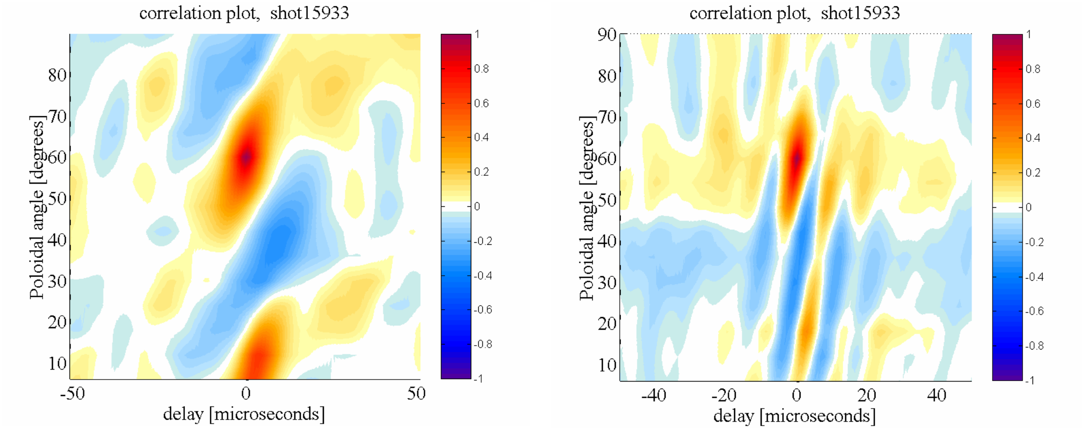

***Fig.5:** Temporal cross correlation function of density fluctuations in ohmic (left) and during biasing phase (right) of the discharge. Reference probe at the poloidal angle $\theta = 60°$.*

A poloidal periodicity is apparent from the cross-correlation function of density fluctuations. This observation is interpreted as a signature of existence of flute-like structure(s), elongated along the magnetic field lines and having the poloidal mode number equal the local safety factor [1]. They propagate poloidally due to the $E_r x B_t$ drift. The propagation velocity increases at biasing as expected, the life-time is reduced, but the poloidal periodicity seems to remain unchanged. Some regular oscillations (f ~ 100 kHz) are driven at biasing.

The amplitude of correlation between the density δn and radial velocity $\delta v r = \delta E_p/B_t$ fluctuations is plotted in Fig. 6.

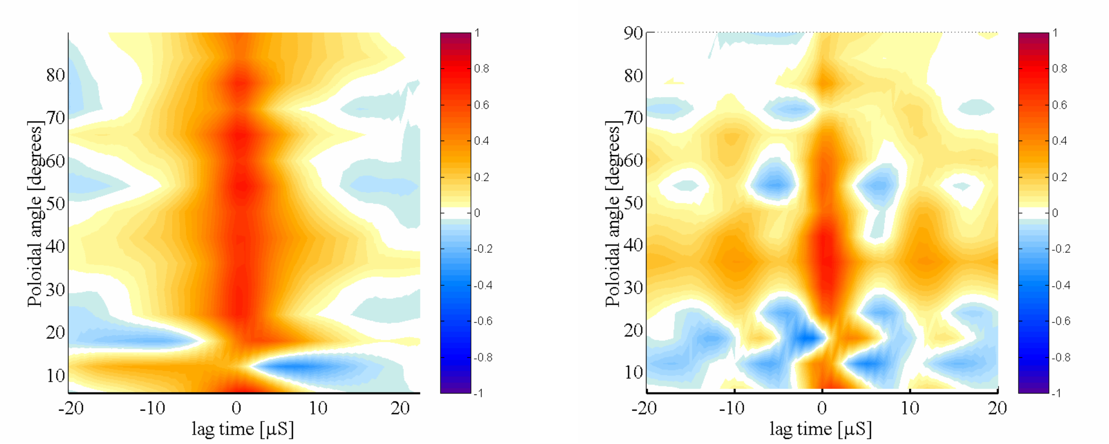

Fig.6: *Cross correlation function between δvr and δn at 15 poloidal positions along one quarter of the ring in ohmic (left) and biasing (right) phase.*

In the ohmic case (see the left panel) the correlation amplitude between δn and δv_r is quite high (almost 0.8 everywhere), reaching its maximum at zero time delay at all poloidal positions. This shows that the phase is adjusted to maximize the turbulent transport. During biasing (right panel), the maximum still occurs at zero time delay, but the correlation becomes periodic in time. However, the correlation amplitude at zero time delay is less than in the ohmic case so some de-correlation between δn and δv_r occurs. The mechanism responsible for reduction of the turbulent flux during biasing involves a decrease of density and radial velocity fluctuations coupled with a reduction of the correlation between δn and δv_r without any modification of phase between these two quantities. More results of the fluctuation measurements are presented in the accompanying contribution [2].

In conclusion, we demonstrated that the particle transport in the SOL can be significantly modified, when a material object is biased in this region. The underlying physics is quite complex because of two-dimensional character of the electric field and its understanding requires more experiments and data analysis.

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References:

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