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Electrostatic Turbulence in the TBR Tokamak

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A specially designed probe system was constructed and installed at the TBR tokamak to investigate the relation between plasma transport and plasma turbulence. The experimental data confirm the influence of temperature fluctuations in the amplitude and correlation of density and potential fluctuations, and consequently on transport parameters.

I. Introduction

Anomalous transport of energy and particles in tokamaks is usually attributed to turbulent fluctuations of the edge plasma. This paper presents measurements of turbulent fluctuations with the aim to relate fluctuation and transport phenomena.

In this study we focus on fluctuations observed with a specially designed complex probe [1,2] that provides simultaneous and local measurements of equilibrium and fluctuating values of density, potential and temperature, as well as turbulence induced particle and electron energy fluxes.

These measurements show that proper corrections for the electron temperature fluctuations are essential in these flux measurements [3].

A detailed study of the turbulent spectral behavior is also done. Correlations between measured fluctuations are determined. The spectrum of poloidal wave vector, its spectral width, dispersion relation, and phase velocity are computed for density and potential fluctuations.

Radial particle flux is calculated with and without temperature fluctuations correction and compared with a model in the SOL [4,5]. Energy fluxes are obtained and the relative convective and conductive parts are compared with the total energy flux. [6]

II. Experimental

The present experiment was carried out on the Ohmically TBR heated tokamak, filled with hydrogen. The plasma in the TBR has a circular cross section and a full poloidal limiter at one toroidal location.

The data were collected from a multipin Langmuir probe, this system permits the measurement of local electron density, electron temperature, plasma potential, and their fluctuations. Accurate tests were exhaustively done to assure the reliability of obtained data, especially in the case of the fluctuation temperature measurements with a modified triple probe. Further details of the experiment can be found in references [1,2].

The probe measurements were done during the flat top phase of the plasma current, in time intervals of approximately 4 ms and averaged throughout seven consecutive shots. All signals are digitized with 8 bit resolution and a sampling frequency of 1 MHz. The length of the used data consisted of 105 samples of 256 points.

From the measured temporal series we obtained relative level profiles and from spectral analysis the correlation between fluctuating parameters and the particle and energy fluxes. Taking into account the influence of temperature fluctuations corrections, the density and plasma potential power spectra and their correlations were reevaluated in order to correctly estimate the plasma turbulence.

III. Discussion and Conclusions

Fluctuating parameters are measured and correlated to determine the turbulence contribution to edge transport.

Fig. 1 shows the superposition of frequency power spectra of floating potential, ion saturation current, and temperature fluctuations measured at the radial position r/a=0.88. At plasma edge these power spectra are similar. This suggests a common driving force for these turbulent fluctuations. The broadband spectra show a turbulent behavior of the fluctuations.

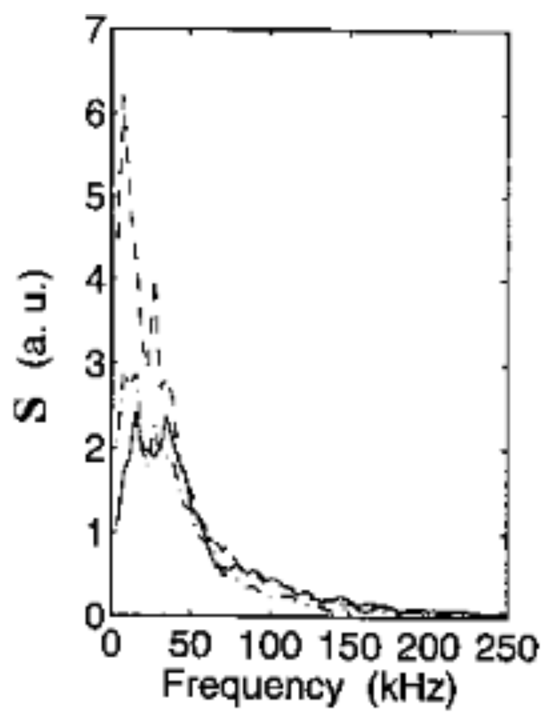

Figure 1. Spectra of floating potential (...) ion saturation current (-.-.-) and temperature fluctuations (-) at r/a=0.88.

The calculated relative magnitude of the temperature fluctuations is » 0.15%. The influence of the correction introduced by temperature fluctuations on the potential, and density fluctuation values are at least 30% higher than those obtained neglecting these fluctuations [2].

In order to determine a possible relationship between the measured fluctuations, their cross-spectra were computed. We observed that ion saturation current and floating potential fluctuations are in phase and present a linear coherence g » 0.5 at frequencies below 100 kHz. The linear coherence between floating potential and temperature fluctuations is lower than the coherence between ion saturation current and temperature fluctuations.

Fig. 2 shows the phase velocity profile with and without temperature fluctuation corrections at the plasma edge; the poloidal phase velocity is essentially in the same direction of the ion diamagnetic drift velocity. The effect of temperature fluctuation corrections is to enhance the phase velocity because of the reduction of the average wave vector. The absence of shear layer already reported [1,2] is confirmed in this new experiment.

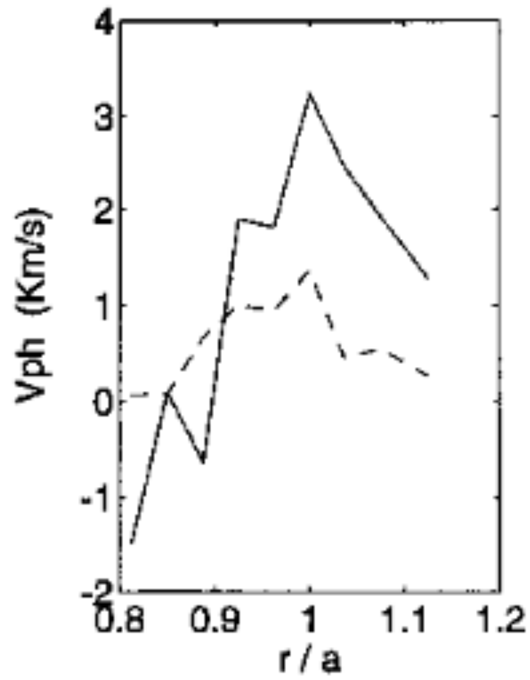

Figure 2. Radial profiles of phase velocity for floating potential fluctuations with (-) and without (- - - -) temperature fluctuations correction.

From a two points estimate we obtain, for floating potential and ion saturation current fluctuations the wave vector poloidal component, k_{q} , and its spectral width, $s_{k\text{q}}$; both are reduced if they are computed with temperature corrections. This effect is observed in Figs. 3 a, b, c, d. The figures show the spectra of the wave vector poloidal component and its width respectively for floating potential (a), ion saturation current (c), plasma potential (b) and plasma density (d) at r/a=0.88 ((b) and (d) corrected by temperature fluctuations). From this figures we note that the correction has the effect to lower the dispersion relation $s_{k\text{q}}/k_{\text{q}}$.

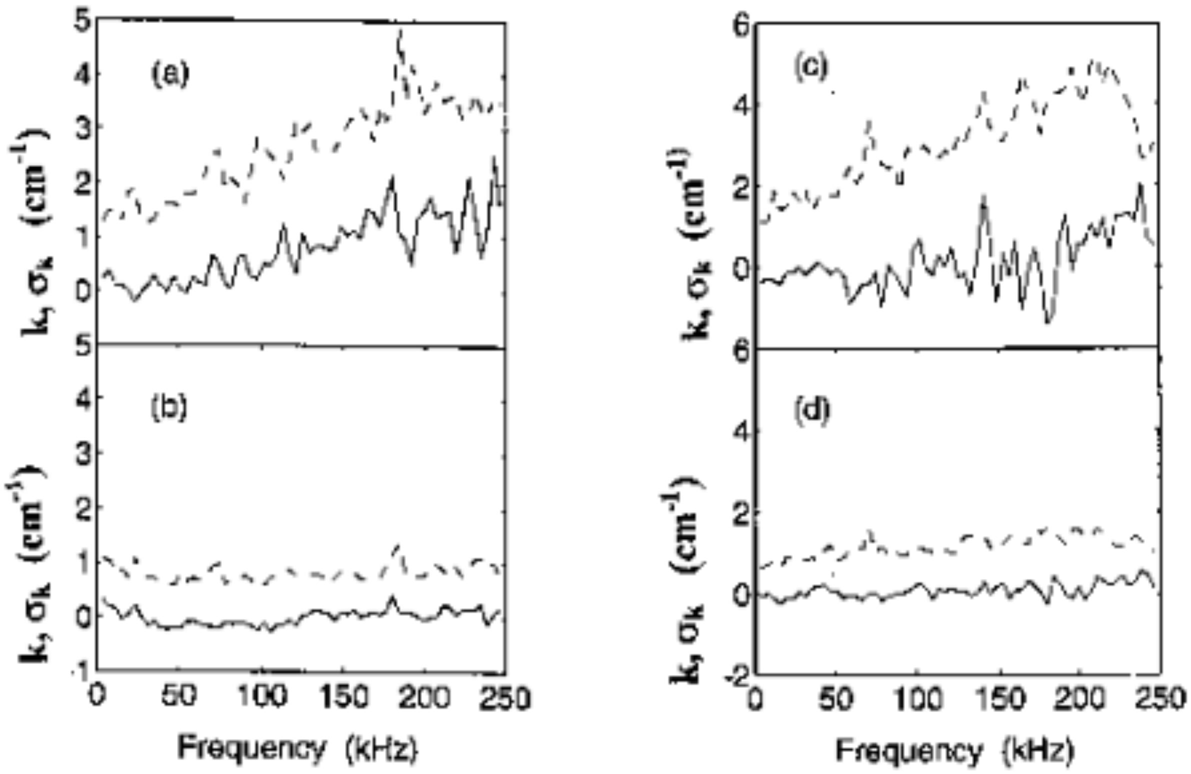

Figure 3. Spectra of k (-) and s_k (- - -) for floating potential fluctuations (a), ion saturation current (c). The same for plasma potential (b) and density fluctuations (d) at r/a=0.88 (corrected for temperature fluctuations).

The fluctuation driven particle flux $G_{nE\text{q}}$ is derived from the cross correlation betweenthe density fluctuations ($\tilde{n}$) and the poloidal electric field fluctuations (E_{q}) [6] Fig. 4 shows the radial particle fluxes with and without temperature fluctuations correction. The corrections introduce a substantial increase in the particle flux at the internal positions of plasma edge. The role of the fluctuations in edge transport can be determined by comparing the fluctuation driven fluxes with those estimated from equilibrium measurements using a simple model [4]. However, significant asymmetries exist in the scrape-off-layer, so this comparison is not exact. The flux calculated with this model gives G_{SOL} » 1 x 10^{19} $N.m^{-2}.s^{-1}$,, and our experimental results give approximately the half of this value, however the statistical uncertainties are considerables.

The electron energy flux can be divided into a convective and a conductive component [4,6]. The convective part is related to particle flux by $q_{conv.} = 5T_e < \tilde{n}\tilde{E}_\theta > /(2B)$, and the conductive part $q_{cond.} = 5n < \tilde{T}_e\tilde{E}_\theta > /(2B)$ can be determined from correlation between temperature fluctuations and electric field fluctuations.

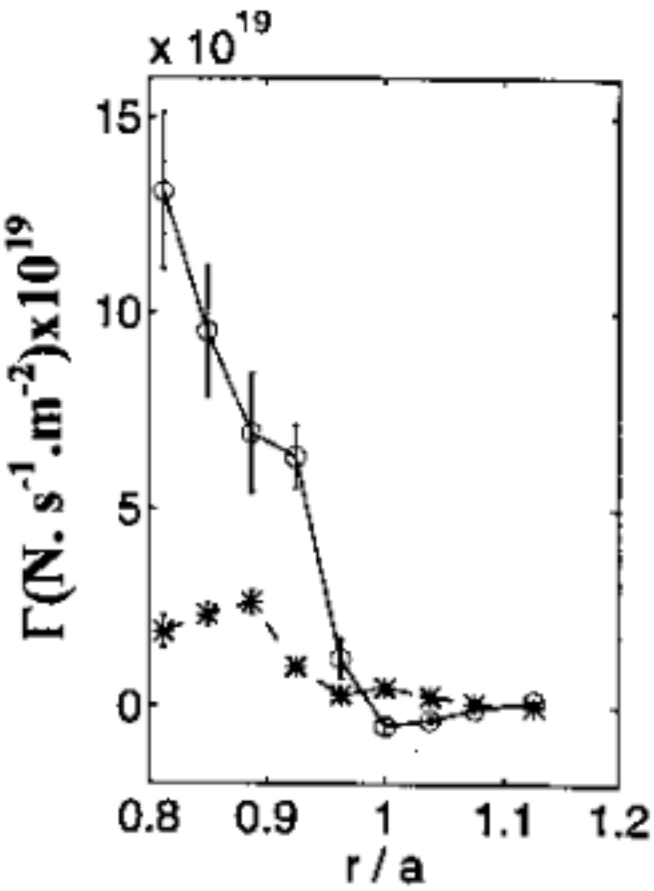

Figure 4. Radial profiles of particle fluxes with (o) and without (*) temperature fluctuations corrections.

Fig. 5 shows the radial profiles of conducted, convected and total energy fluxes. At the plasma edge conducted energy fluxes are in general lower than convected energy fluxes as observed in other tokamaks [4,6]. Because of the large uncertainties in the evaluated energy fluxes the total energy flux can be essentially explained as a convection flux. For a total input power of 18 kW/m ^{2} the energy fluxes have some significance only in more internal positions; at the limiter we observe very low values for them. Possibly the power flux is dominated by other losses, such as radiation.

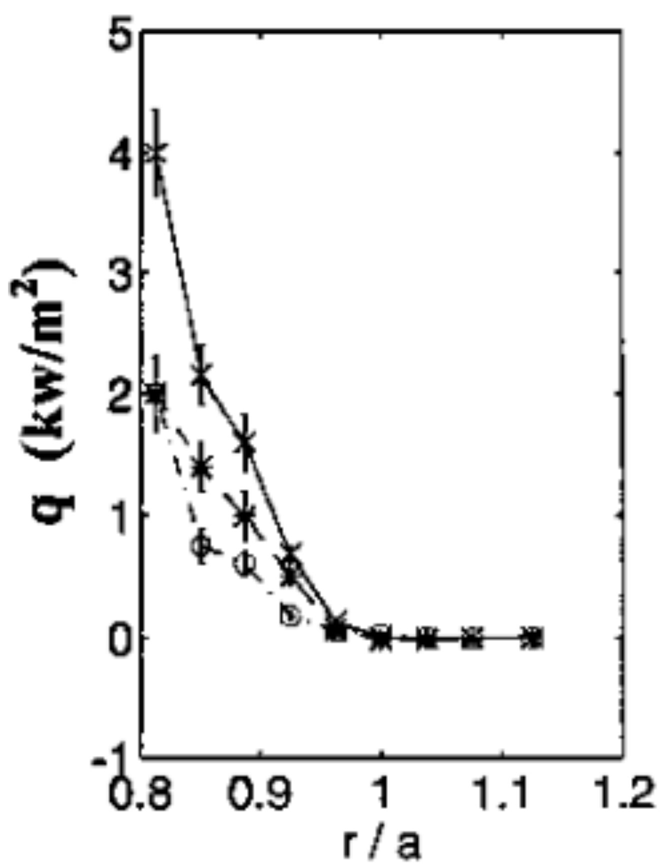

Figure 5. Radial profiles of conducted (-.-.), convected (- -) and total energy fluxes (-).

Experimental results confirmed a strong turbulence at the plasma edge. The data on the electron temperature fluctuations enable a better evaluation of the turbulent particle and heat flows and a more reliable description of turbulence at TBR plasma edge.

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