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INTRODUCTION

Transport modelling of density profiles is usually described in terms of two coefficients in fusion plasmas: an effective Diffusivity (D) and an inward drift Velocity (V). Effective particle diffusivities are anomalous and it is usually accepted that anomalous transport is due to plasma turbulence. Evidence of inward drift velocities much larger than the value predicted by neoclassical theory has been recently reported [1]. Peaked density profiles have been also reported in stellarator plasmas showing evidence of convective inward particle transport [2]. Radially inward turbulent velocities have been observed in the plasma boundary region of fusion plasmas [3, 4]. From the theoretical point of view is has been argued that, in some cases, turbulence can give rise to a fully inward anomalous transport [5]. Radially peaked profiles might be also explained on the basis of a description of turbulent transport in tokamaks by invariants [6].

The importance of the statistical description of transport processes in fusion plasmas as an alternative approach to the traditional way to characterize transport based on the computation of effective transport coefficients (i.e. diffusion coefficients) and on average quantities (i.e., average correlation lengths) has been recently emphasized [7, 8]. Following this approach, we have investigated the Probability Density Function (PDF) of the effective radial velocity and radial scale of turbulent events as a strategy to identify the underlying physics of anomalous diffusivities and inward velocities in fusion plasmas.

2. EXPERIMENTAL SET-UP

Plasma profiles and turbulence have been investigated in the JET plasma boundary region using a fast reciprocating Langmuir probe system located on the top of the device. Plasmas studied in this paper were produced in X-point plasma configurations with toroidal magnetic fields B = 1−2.5T, Ip = 1−2MA (ohmic plasmas) in the JET tokamak. The local time resolved radial E×B turbulent induced fluxes, $\tilde{\Gamma}(t) \propto \langle \tilde{n}(t)\, \tilde{E}_\theta(t) \rangle / B$, (where ñ and $\tilde{E}_\theta$ are the fluctuating density and poloidal electric field, respectively) were calculated neglecting the influence of electron temperature from the correlation between poloidal electric fields and density fluctuations. An effective radial velocity has been defined as the normalized E×B turbulent particle transport to the local density, $v_{eff} = <\tilde{I}_s\, \tilde{E}_\theta> / I_s B_T$ where I_s is the ion saturation current. The statistical properties of the radial coherence of fluctuations and transport have been computed from the cross correlation of $\Gamma_{E\times B}$ signals and floating potential signals radially separated 0.5cm. The PDF of the veff and radial scale (L_r) of fluctuations of turbulent transport has been computed at different time scales.

3. EXPERIMENTAL RESULTS AND DISCUSSION

A velocity shear layer has been observed near the location of the Last Closed Flux Surface (LCFS) in the JET tokamak in agreement with previous experiments in fusion plasmas. As previously reported [8] the poloidal phase velocity of fluctuations (v_{phase}) increases in the electron drift direction up to 2000m/s, in the proximity of the separatrix and the radial gradient in vphase is in the range of

$10^5\ s^{-1}$, which turns out to be comparable to the inverse of the correlation time of fluctuations, in the range of t ≈10 ms [8]. Figure 1 shows the measured ion saturation and floating potential profiles in plasmas in which the reciprocating probe was radially shifted shot by shot from the Scrape-Off-Layer (SOL) up to the velocity shear layer location. The reproducibility in the measured radial profiles is very good.

Figures 2 and 3 show the PDF of the radial coherence of fluctuations and transport. The investigation of PDFs of the radial scale length of electrostatic turbulent transport has shown evidence of multiple radial scale lengths in the JET plasma boundary region, both in ohmic and L-mode plasmas. As shown in figure 3 the PDF of the radial coherence of E×B transport shows tails (i.e. sporadic events with high radial coherence). PDFs of the radial coherence of fluctuations are wider than those corresponding to the E×B turbulent in radial-PDFs are modified in the presence of sheared poloidal flows in the plasma boundary region. Far from the shear layer the radial correlation of the fluctuations exhibits a wide PDF that covers a large range of radial scales. When approaching the shear layer the PDF becomes narrowed. This results can be interpreted on the basis of the influence of sheared flows near marginal stability on the radial scale of fluctuations and transport.Figure 4 shows v_{eff}–PDFs. In the SOL region veff-PDFs show clear non-gaussian features with both positive (radially outwards transport) and negative (radially inwards transport) events. Although the most probable radial velocity is in the order of 10m/s, experimental evidence of intermittent events propagating radially with velocities in the range of 100 – 400m/s is clearly observed, in agreement with previous experiments [8]. This result illustrates the presence of large and sporadic transport (velocity) events. A clear modification in v_{eff}-PDFs takes place near the shear location: v_{eff}-PDFs become broader and more gaussian and about 20% of the particles move radially inwards with averaged radial velocities of about 50m/s.

Present results suggest an interpretation of
radially peaked profiles based on the modification of PDFs in the radial velocity of turbulence in the presence of E×B sheared flows near marginal stability. The generation of internal and edge transport barriers is linked to plasma regions with a unique magnetic topology [9, 10]. Based on these results it can be argued that sheared flows (near marginal stability) are connected to the magnetic topology (e.g. rationals and LCFS). In the framework of this interpretation, peaked density profiles would be linked with gradient in q (e.g. density of low order rationals).

CONCLUSIONS.

The PDF of radial velocities of turbulence and the radial and poloidal correlation of the floating potential fluctuations and E×B transport has been investigated in the JET and the following conclusions have been reached:

1) Evidences of multiple radial scale lengths in the JET plasma boundary region were observed.
2) PDFs of radial effective velocities and radial correlation of turbulent transport are modified in the proximity to the velocity shear layer.

3) Present findings show the importance of the statistical characterization of the radial scales of transport and fluctuations to improve our understanding of the physics underlying transport processes in fusion plasmas.

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REFERENCES

[1]. G.T. Hoang, C. Bourdelle, B. Pegourié et al., Phys. Rev. Lett. **90** (2003) 155002.
[2]. U. Stroth, T. Geist, J.P.T. Koponen et al., Phys. Rev. Lett. **82** (1999) 928.
[3]. M. Shats, K. Toi, K. Ohkini et al., Phys. Rev. Lett. **84** (2000) 6042.
[4]. M.A. Pedrosa, C. Hidalgo et al., Plasma Phys. Cont. Fusion **43** (2001) 1. 2001
[5]. A.S. Ware et al., Phys. of Plasmas **4** (1992) 877.
[6]. V.V. Yankov and J. Nycander Physics of Plasmas **4** (1997) 2907.
[7]. B. Gonçalves, C. Hidalgo et al., Nuclear Fusion (2002)
[8]. C. Hidalgo, B. Gonçalves, M.A. Pedrosa et al., J. Nuclear Materials **313** (2003) 863.
[9]. E. Joffrin et al., 19th IAEA Fusion Energy Conference, Lyon-France Oct. 2002, paper EX/P1-13.
[10]. L. García et al., Phys. of Plasmas **9** (2001) 4111.

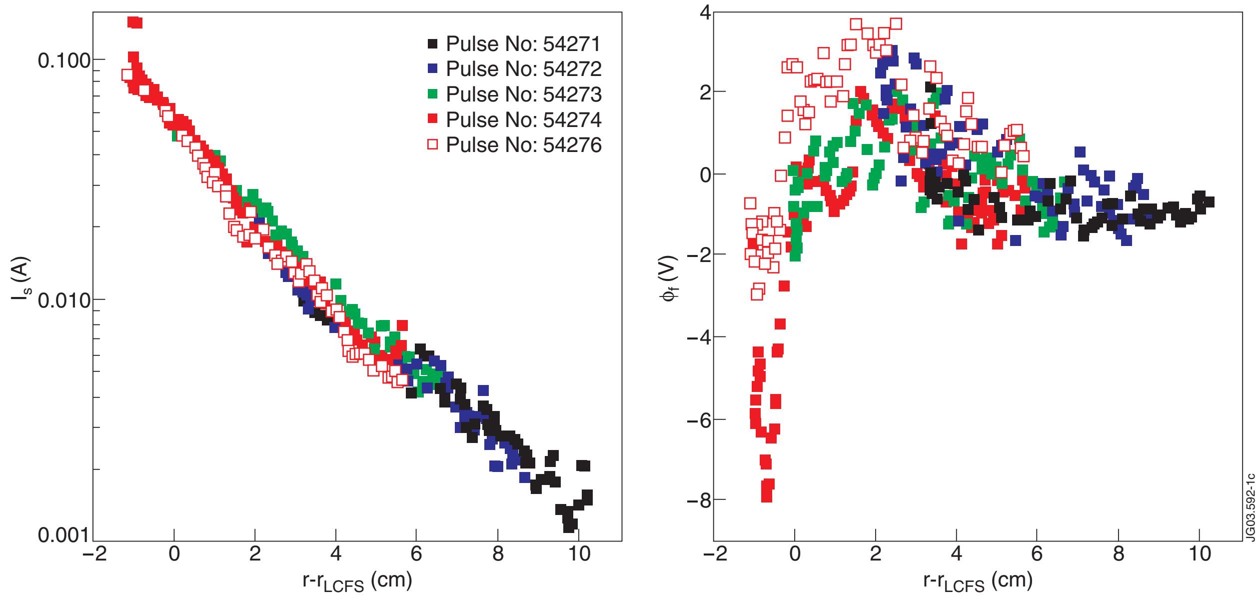

Figure 1: Radial profiles of ion saturation current and floating potential in the JET boundary region (ohmic plasmas) in reproducible discharges.

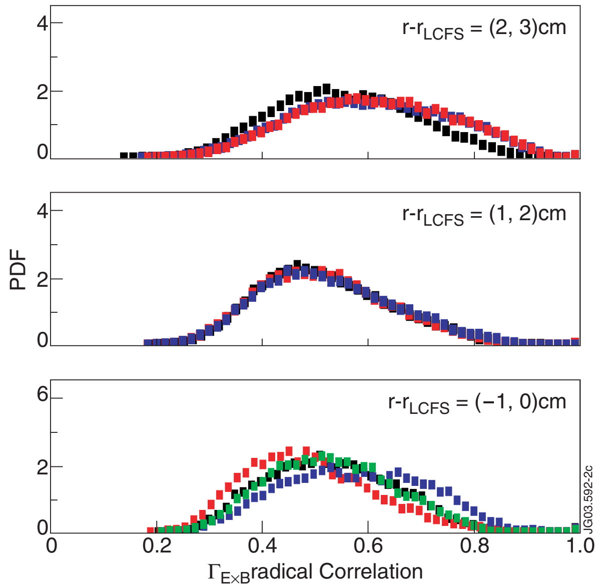

Figure 2: PDFs of the radial correlation of the floating potential fluctuations in the JET boundary region.

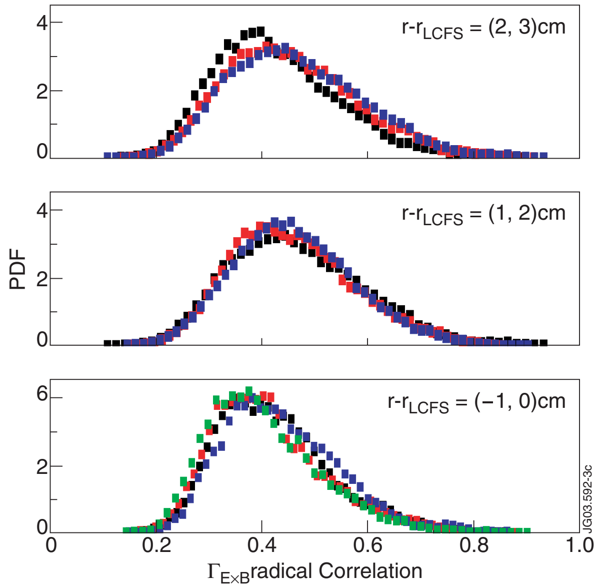

Figure 3: PDFs of the radial coherence of E×B transport in the JET boundary region.

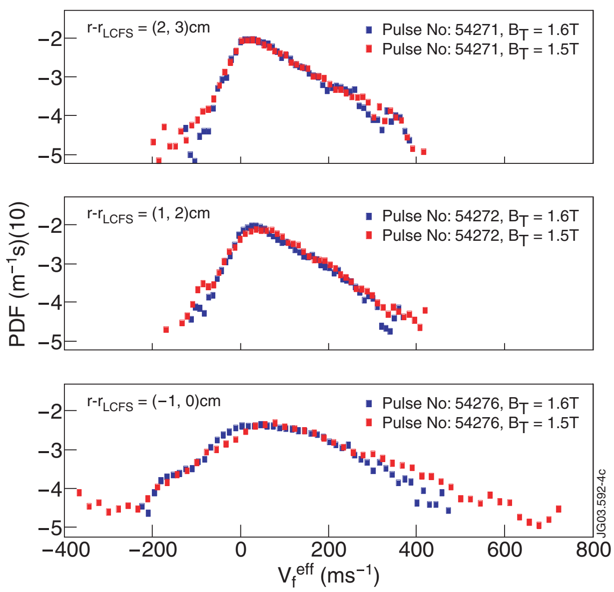

Figure 4: PDFs of radial effective velocity in the JET plasma boundary region.