EUROPEAN FUSION DEVELOPMENT AGREEMENT

EFDA–JET–CP(01)02-68

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**See appendix of the paper by J.Pamela "Overview of recent JET results", Proceedings of the IAEA conference on Fusion Energy, Sorrento 2000*

Preprint of Paper to be submitted for publication in Proceedings of the
EPS Conference,
(Madeira, Portugal 18-22 June 2001)

INTRODUCTION

Dimensionless scaling investigations have been used to reveal the physical dependencies of plasma transport in fusion plasmas. The dimensionless parameter ρ^* (gyro-radius normalized to the plasma minor radius) plays a mayor role in determining the transport processes (e. g. Bohm, gyro-Bohm or other non-Bohm type processes). In particular, if the radial scale is of the order of the gyro-radius, a gyro-Bohm type transport results, whereas the existence of radially elongated structures would imply Bohm type transport coefficients. However, the average radial correlation of broadband fluctuations is typically of the order of 1cm. These results emphasize the importance of studying the statistical properties of turbulent transport and fluctuations. In this paper we present experimental evidence of an empirical similarity in the statistical properties of turbulent transport and non-gaussian features in the radial coherence of ExB transport in the JET plasma boundary region, just inside the separatrix.

1. EXPERIMENTAL SET-UP AND PLASMA CONDITIONS

Plasmas studied in this paper were produced in X-point configurations with magnetic fields $B_T = (1 - 2.4)$ T and plasma current $I_p = (1 - 2.5)$ MA. Plasma profiles and turbulence have been investigated in the JET plasma boundary region using a fast reciprocating Langmuir probe system. The position of the last closed flux surface was determined by the equilibrium code EFIT. Nine Langmuir probes have been arranged in three groups of three. Two of them are at the same poloidal position, being separated 0.5cm in the radial direction. This set-up allows the investigation of the radial structure of fluctuations and turbulent transport, using the inner and outer probes. Plasma fluctuations are investigated using standard signal processing techniques and 500kHz digitizers. Figure 1 shows the radial profile of ion saturation current (I_s), floating potential (Φ_f), the root mean squared (rms) value of ion saturation fluctuations (I_{rms}) and the ExB turbulent transport (Γ_{ExB}) in plasmas with B = 1.8T, I_p = 2MA and plasma density in the range (2.9 – 6.7) x $19^{19}m^{-2}$. Turbulent transport and fluctuations are systematically modified as plasma density increases: I_s, Φ_f and Γ_{ExB} increase with plasma density. The effective plasma diffusivity, computed as $D_{eff} = -\Gamma_{ExB} / \nabla n$, is in the order of $1m^2/s$, in agreement with previous experiments [1].

2. EMPIRICAL SIMILARITY IN TURBULENT FLUXES

Figure 2 shows the probability density function (PDFs) of the ExB turbulent fluxes for measurements taken in the plasma edge region $r - r_{sep} \approx$ - (1-2) cm. In JET, as well as in other devices, the PDFs of fluctuating transport have significant non-gaussian features [2]. A significant fraction of the total ExB flux can be attributed to the presence of large and sporadic transport bursts, the magnitude of which are quite sensitive to the plasma conditions.

The PDF´s have an interesting property: they can be re-scaled assuming a functional form

$$PDF(\Gamma_{ExB}) = L^{-1} g(\Gamma_{ExB}/L)$$

where L is a scaling factor. As shown in Fig. 2 the re-scale PDF´s of Γ_{ExB} show the same behavior over the entire amplitude range of transport. The scaling factor L is directly related with the level of fluctuations computed as the rms value of the ion saturation current fluctuations (Fig.3) and with the mean turbulent flux.

The statistical properties of turbulent transport have also been investigated at different time scales. In order to do this, we have constructed time records with a time resolution ΔN, by averaging over blocks of ΔN elements from the original time series. The re-scaling properties of turbulent transport seem to be hold at different time scales (ΔN = 2 – 50μs).

A similar empirical similarity in the PDF´s of ExB turbulent transport has been recently observed in experiments carried out in the TJ-II stellarator [3]. Furthermore, these findings are in agreement with the empirical similarity in the frequency spectra of fluctuations reported in different fusion plasmas [4]. This striking similarity of the PDF´s of turbulent fluxes supports the idea that plasma turbulence displays universality and provides a critical test for plasma turbulence models.

3. RADIAL COHERENCE OF EXB TURBULENT TRANSPORT AND FLUCTUATIONS.

The statistical properties of the radial coherence of fluctuations and transport have been computed from the maximum cross correlation of Γ_{ExB} and Is signals radially separated 0.5cm, using a 50μs time window. As shown in Fig. 4 the probability density distribution of the radial coherence of ExB transport shows tails (i.e. sporadic events with high radial coherence). PDF´s of the radial coherence of fluctuations are more gaussian than those corresponding to the ExB turbulent flux. Although on average the radial coherence of turbulent transport is in the range of 0.5 – 1cm, in agreement with previous findings, there are sporadic transport events showing large radial coherence. These results show the importance of the spectral characterization of both the radial scales of transport and fluctuations to improve our understanding of the physics underlying transport processes in fusion plasmas.

CONCLUSIONS.

The statistical properties of turbulent transport show an empirical similarity in the plasma edge region, which support the view that plasma turbulence displays universality. The re-scale probability density function (PDF) of transport exhibits the same behavior over the entire amplitude range of transport events. PDFs of ExB turbulent transport show sporadic events with high radial coherence. These findings emphasize the importance of the statistical description of transport processes in fusion plasmas.

ACKNOWLEDGEMENT:

This work has been conducted under the European Fusion Development Agreement.

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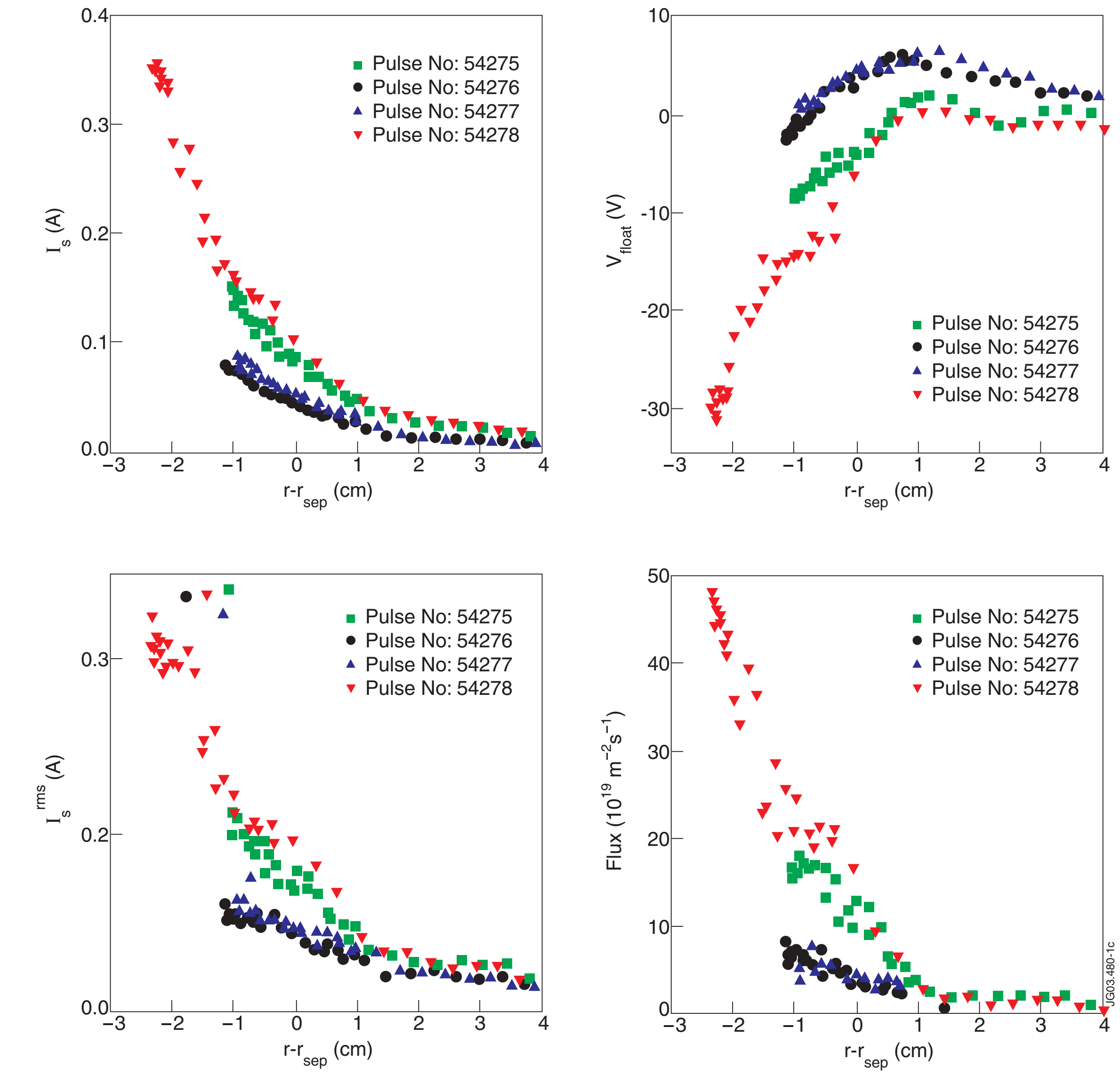

Figure 1: Radial profiles of ion saturation current , floating potential, RMS of ion saturation current and EB turbulent transport with different plasma densities.

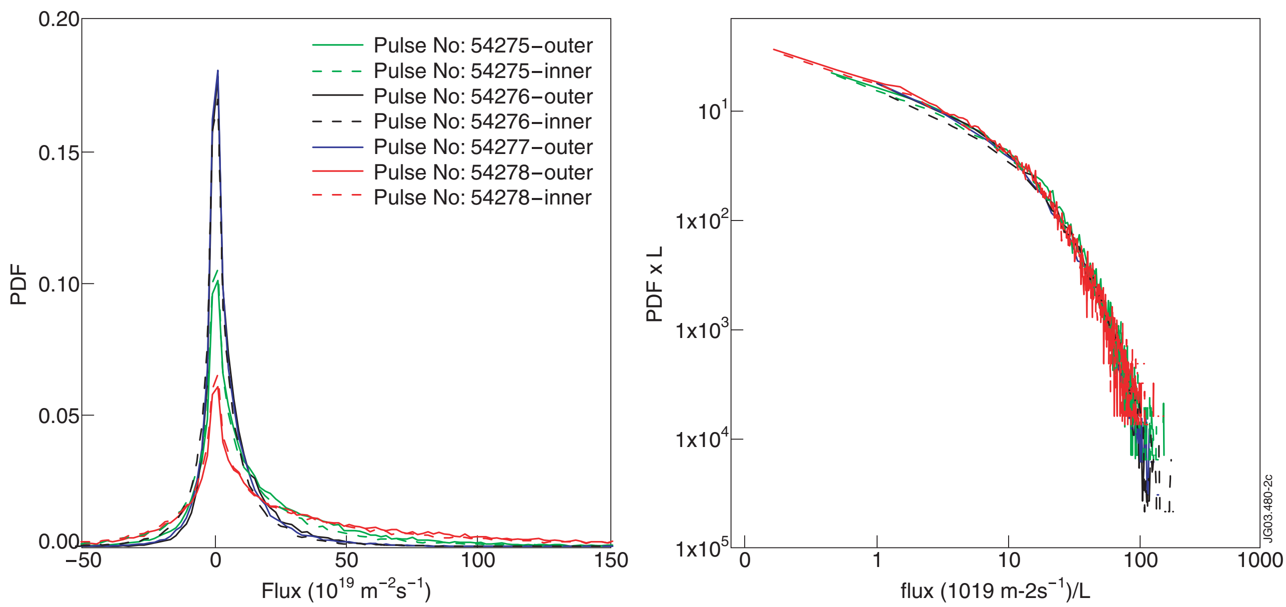

Figure 2: Probability distribution function of ExB turbulent fluxes for different plasma densities measured in the plasma edge region and re-scaled PDF's.

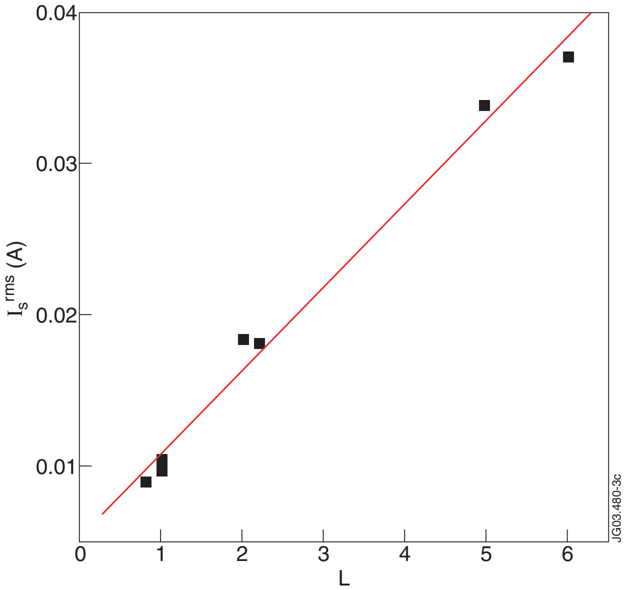

Figure 3: The scaling factor versus the RMS of ion saturation current.

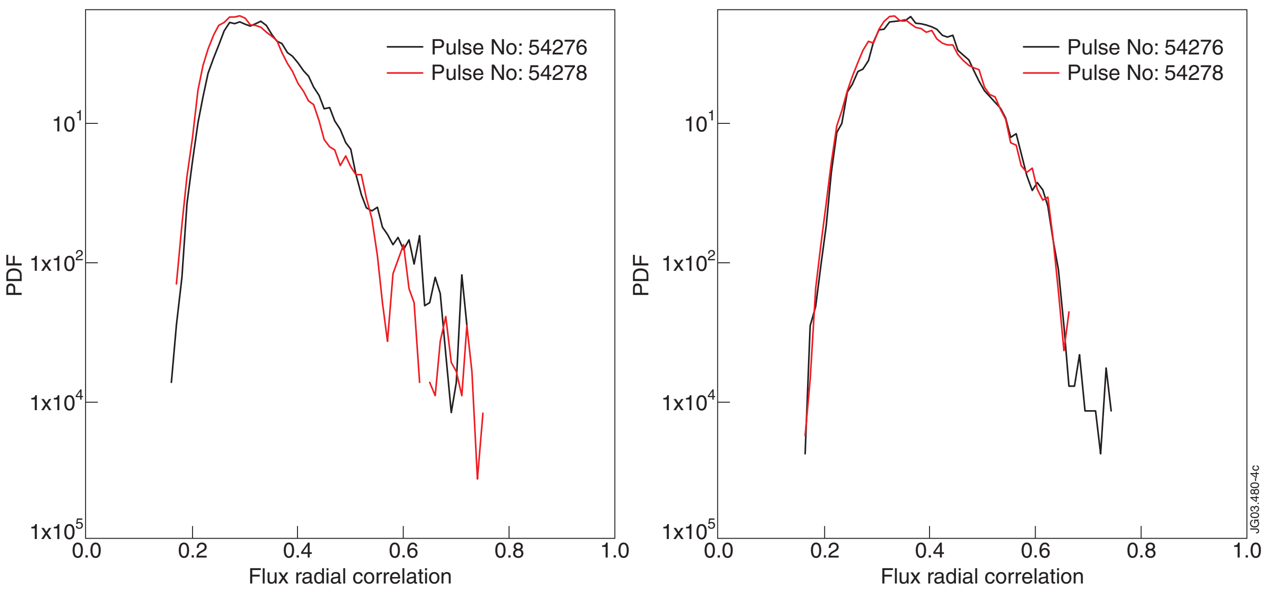

Figure 4: PDF's of the radial coherence of ExB transport and ion saturation current fluctuations.