*29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, O-3.25 (2002)*

Intermittent events and electrostatic structures in the edge region of Reversed Field Pinch experiments

M. Spolaore[1], V. Antoni[1,2], H. Bergsåker[3], R. Cavazzana[1], J. Drake[3], E. Martines[1], G. Regnoli[1,2], G. Serianni[1], E. Spada[1], N. Vianello[1,2]

[1] *Consorzio RFX, Associazione EURATOM-ENEA sulla Fusione, corso Stati Uniti 4, 35127 Padova, Italy* - [2] *INFM, Unita' di Padova sez. A, Italy*
[3] *Alfvén Laboratory, Royal Institute of Technology, Association EURATOM/VR 10044 Stockholm, Sweden*

A main aim in fusion research is gaining insight in mechanisms related to particle and energy confinement. In particular it was confirmed by different kinds of magnetic confinement devices that most part of particle losses is due to the electrostatic turbulence in the edge region, so that an anomalous transport process is invoked [1]. Typically the electrostatic quantities, measured in the edge region of magnetic confinement devices, exhibit bursts and this feature is observed in tokamaks [2, 3] and stellarators [4] as well as in Reversed Field Pinch (RFP) experiments. The burst events have been investigated so as to obtain information about the associated electrostatic structures, a pioneering paper was presented by Zweben [5], and in some cases a primary role of the bursty behaviour on the electrostatic transport is deduced [6, 3].

Concerning RFPs, main subject of this paper, the burst feature is detected both in primary electrostatic quantities, such as floating potential and electron density, and in derived quantities, like the electrostatic particle flux.

Recently a study of the burst statistics observed in the electrostatic particle flux, measured in the RFX experiment [7], evidenced that these events, although representing a small fraction of the signal, carry a large fraction of the particle flux losses. A more detailed investigation of this feature has been carried out using a wavelet analysis, by which the bursts are studied distinguishing their different time scale occurrence. The comparison between the Probability Distribution Functions (PDF) of fluctuations at different time scales evidenced that they develop high tails at the smallest time scales exhibiting an intermittent character, i.e. the PDFs are not self-similar [8]: this characteristic of fluctuations was detected in RFX [9] and confirmed by T2R results [10]. By an iterative threshold method called Local Intermittency Measurement and described elsewhere [11], the time occurrence of the strongest events belonging to the non-gaussian tails, named intermittent events in the following, have been located. The aim of this paper is to provide a statistical analysis of electrostatic structures associated to intermittent events, comparing the fluctuation measurements of electrostatic parameters obtained in the edge region of two reversed field pinch experiments: RFX and T2R.

Both are toroidal devices with aspect ratio R/a of 2m/0.5m for RFX and higher, 1.2m/0.183m, for T2R. The first wall is covered by a full armour of graphite tiles in the RFX experiment, while the vacuum chamber is protected by a series of poloidal arrays of molybdenum limiters, which protrude by 11 mm, in T2R. The data presented here were measured in low current discharges, 300 kA and 80 kA respectively, to allow the insertion of arrays of Langmuir probes. The average electron density was about 1.5 $10^{19}m^{-3}$ in RFX and 1 $10^{19}m^{-3}$ in T2R. The statistical analysis was performed taking into account the most significant time scales for the electrostatic flux, which are peaked around 10 μs and 5 μs respectively for the two experiments. Measurements were performed with 1 MHz sampling rate for RFX data and 3 MHz for T2R data; the maximum bandwidth was 400 kHz in both cases due to the electronic conditioning of signals.

In order to obtain the typical features of the average electrostatic surroundings of an intermittent event the technique of conditional average was applied to floating potential time series. The condition is the presence of an intermittent event, furthermore positive and negative fluctuations are separately averaged. Typical results concerning RFX, are shown in fig. 1, where conditional averages are obtained on time windows of 40 μs. The average time behaviour of floating potential around intermittent events provides minima and maxima with a finite time width. Average radial electric field profiles, obtained on a shot by shot basis, confirm the presence of an inward directed (negative) radial electric field in the edge region of both devices. Since the average magnetic field in the edge region is mainly poloidal in RFPs, a toroidal E×B drift is deduced, with a double shear layer [12, 13]. Assuming the 'frozen turbulence' hypothesis [8], which is confirmed by cross correlation analysis of toroidally spaced V_f measurements, the time behaviour of V_f structures can be translated into a spatial information, so the two structure classes shown in fig. 1 represent minima and maxima in the average floating potential, along the toroidal direction. The toroidal extension is estimated around 10÷15 cm and depends on the $v_{E\times B}$ local velocity. An average radial extent of these structures has been estimated in RFX around 3 ÷ 4 cm, as deduced from V_f measurements by an array of probes radially extended over 50 mm. The average V_f structures associated to the intermittent events are deduced to be minima and maxima extended in the radial-toroidal plane and the ensuing local radial electric field, together with the mainly poloidal magnetic field at the edge, provides a local E×B motion. Therefore the electrostatic structures indicate that these events can be interpreted as single vortices with two opposite rotation directions.

A statistical analysis has been performed on the two classes of events, focusing on their relative radial distribution. Figure 2b shows the relative fraction of minima and maxima vs normalized radial position r/a obtained in the edge of T2R. It can be observed that in the region $r/a<1$ the major population consists of minima and an inversion point is detected in outer positions, where the maxima prevail. A comparison with the average radial profile of $v_{E\times B}$ is proposed in fig. 2a. A fairly clear correlation can be deduced between the two mentioned regions and the shear $dv_{E\times B}/dr$ sign. A similar correlation has been observed in the RFX V_f data, although characterized by a lower $v_{E\times B}$ shear, and confirmed in both cases considering different time scales of intermittent event occurrence, ranging from 2.5 to 50 μs. Vortex-like structures associated to the events result then as governed by the following selection rule, according to the local $v_{E\times B}$ shear: the vortex survives better when the condition $\omega\cdot\nabla\times V>0$ is fulfilled, but is inhibited for $\omega\cdot\nabla\times V<0$, where $V=v_{E\times B}+\delta v$ is the total flow velocity and δv its fluctuating part, $\omega=\nabla\times\delta v$ represents the structure vorticity[14]. A clear analogy with numerical simulations, concerning vortex dynamics in ordinary fluids, characterized by sheared flows [15], could be inferred.

Further information on the structures associated to intermittent events can be obtained by applying the conditional average, based on events detected on V_f, to the electron density signal measured in the same position and to the electrostatic particle flux as well. Figure 3 shows an example of this kind of analysis performed on T2R data: the V_f structures are associated with density structures and to positive, i. e. outward directed, flux events. Similar results are provided by analysis based on density events and on flux events.

In conclusion intermittent events are associated with electrostatic structures. In particular the floating potential provides vortex-like structures that result highly correlated to the average $v_{E\times B}$ radial profile, exhibiting a dynamics quite similar to that found in ordinary fluids. Furthermore V_f and density structures are tightly correlated and in most cases are associated to outward-directed flux events.

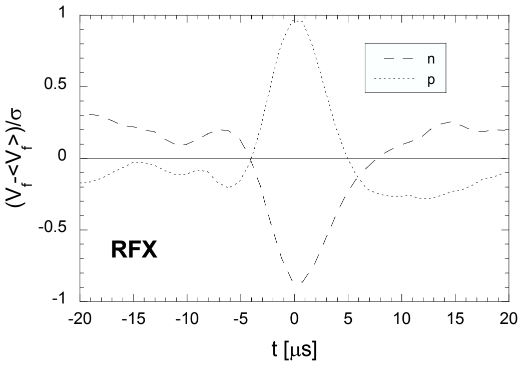

Fig 1 Conditional average based on events located at 10 μs time scale on V_f signals; data from RFX

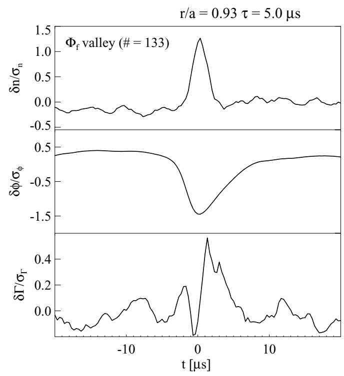

Fig 3 Conditional average on electron density, floating potential and electrostatic particle flux based on events located at 5 μs time scale on V_f signals; data from T2R

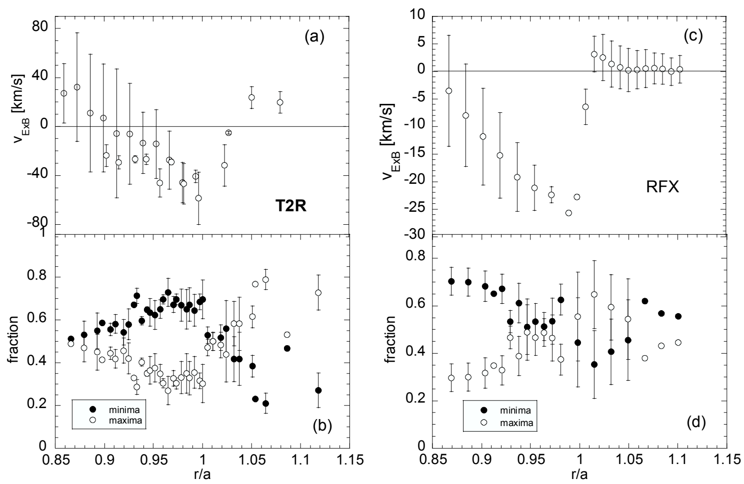

Fig 2 Average $v_{E\times B}$ radial profile (a), relative fraction of minima/maxima (black/open symbols) events vs radial position (b), data from T2R; analogous data respectively in (c) and (d) from RFX

[1] B. A. Carreras, IEEE Trans. Plasma Science **25** (1995) 1281
[2] R. Jha *et al.*, Phys. Rev. Lett, **69** (1992) 1375
[3] J. A Boedo *et al.*, Phys. Plasmas, 8 (2001) 4826
[4] O. Grulke *et al.*, Phys. Plasmas, **8** (2001) 5171
[5]S. J. Zweben, Phys Fluids, 28 (1985) 974
[6] S. Benkadda *et al.*, Phys. Rev. Lett, **73** (1994) 3403
[7] V. Antoni *et al.*, Phys. Rev. Lett., **87** (2001) 045001 1-4
[8] U. Frisch, *Turbulence: The legacy of A. N. Kolmogorov*, Cambridge University Press, Cambridge 1995
[9] V. Carbone *et al.*, Phys. Plasmas **7** (2000) 445
[10] N. Vianello *et al.*, *Turbulence in the edge region of T2R Reversed Field Pinch experiment*, submitted to Plasma Physics and Controlled Fusion
[11] M. Farge, Annu. Rev. Fluid Mech., **24** (1992) 395
[12] V. Antoni et *al.*, Phys. Rev. Lett. **79** (1997) 4814
[13] G. Serianni et al., Czech. J. Phys. **51** (2001) 1119
[14] M. Spolaore *et al.*, *Effect of ExB velocity shear on electrostatic structures*, to be published on Phys. Plasmas
[15] P. S. Marcus et *al.*, Phys. Plasmas, **7** (2000) 163