On the momentum re-distribution via turbulence in fusion plasmas: experiments in tokamaks and stellarators

M.A. Pedrosa[1], C. Hidalgo[1], B. Gonçalves[2], C. Silva[2], K. Erents[3], G. Falchetto[4], X. Garbet[4], M. Hron[5], G. Matthews[3], R. O. Orozco[1], R. Pitts[6], E. Sánchez[1]

[1]Euratom-Ciemat, Spain; [2]Euratom-IST, Lisbon, Portugal; [3]Euratom-UKAEA, UK; [4]Euratom-CEA, Cadarache, France; [5]Euratom-IPP, Prague, Czech Republic, [6]CRPP-EPFL, , Switzerland

The mechanisms underlying the generation of plasma flows play a crucial role to understand transport in magnetically confined plasmas. The amplitude of parallel flow measured in the scrape-off layer (SOL) including the effects of diamagnetic, ExB and B x grad B drifts is significantly larger than those resulting from simulations [1]. Recent experiments have pointed out the possible influence of turbulence to explain flows in the plasma boundary region [2]. In the plasma core region evidence of anomalous toroidal momentum transport has been reported in different tokamaks devices [3-5]. Different mechanisms have been proposed to explain those results including neoclassical effects [6], turbulence driven models [7, 8] and, in the case of ICRF heating, fast particle effects. Spontaneous toroidal flow not driven by neutrals beams has also been observed in stellarator devices [9]. The flow reversal observed in CHS stellarator is explained by the spontaneous toroidal flow driven by large radial electric fields.

This paper reports the first experimental evidence of significant radial gradients in the cross-correlation between parallel and radial fluctuating velocities near the LCFS in JET tokamak and in the plasma boundary region of the TJ-II stellarator. These gradients can play a significant role in parallel momentum redistributions mechanisms.

Plasmas studied in this work were produced in X-point ohmic and L-mode regimes in JET tokamak and with ECR heating (P_{ECRH} = 200 – 400 kW) in the TJ-II stellarator. A fast reciprocating Langmuir probe has been used to investigate the structure of plasma profiles and their fluctuations. Plasma fluctuations are investigated using 500 kHz digitizers.

Both JET and TJ-II experimental results show that radial gradients in the degree of turbulence anisotropy $< \tilde{v}_r \tilde{M}_{parallel} >$, $\tilde{v}_r$ and $\tilde{M}_{parallel}$ being the fluctuating (ExB) radial velocity and the fluctuating parallel Mach number respectively, are in the order of 10^3 s^{-1} in the proximity of the LCFS (Fig. 1 and 2). These gradients are mainly due to the radial variations in the level of poloidal electric filed fluctuations and in the cross-phase coherence.

Experimental results show that the contribution of $\frac{d}{dr} < \tilde{v}_r \tilde{M}_{parallel} >$ is larger than charge-exchange loss mechanisms in the parallel momentum balance equation at the plasma boundary region.

Recent TJ-II experiments have been focussed on investigating the structure of $< \tilde{v}_r \tilde{M}_{parallel} >$ in the proximity of low-order rational surfaces, $n = 4/m = 2$ ($\iota(a)/2\pi \approx 2$) and during the transition to biasing induced confinement regimes [10, 11]. In both cases $< \tilde{v}_r \tilde{M}_{parallel} >$, perpendicular and parallel flows are significantly modified.

These findings might provide the underlying physics of spontaneous toroidal rotation and large parallel flows in plasma boundary reported in fusion plasmas.

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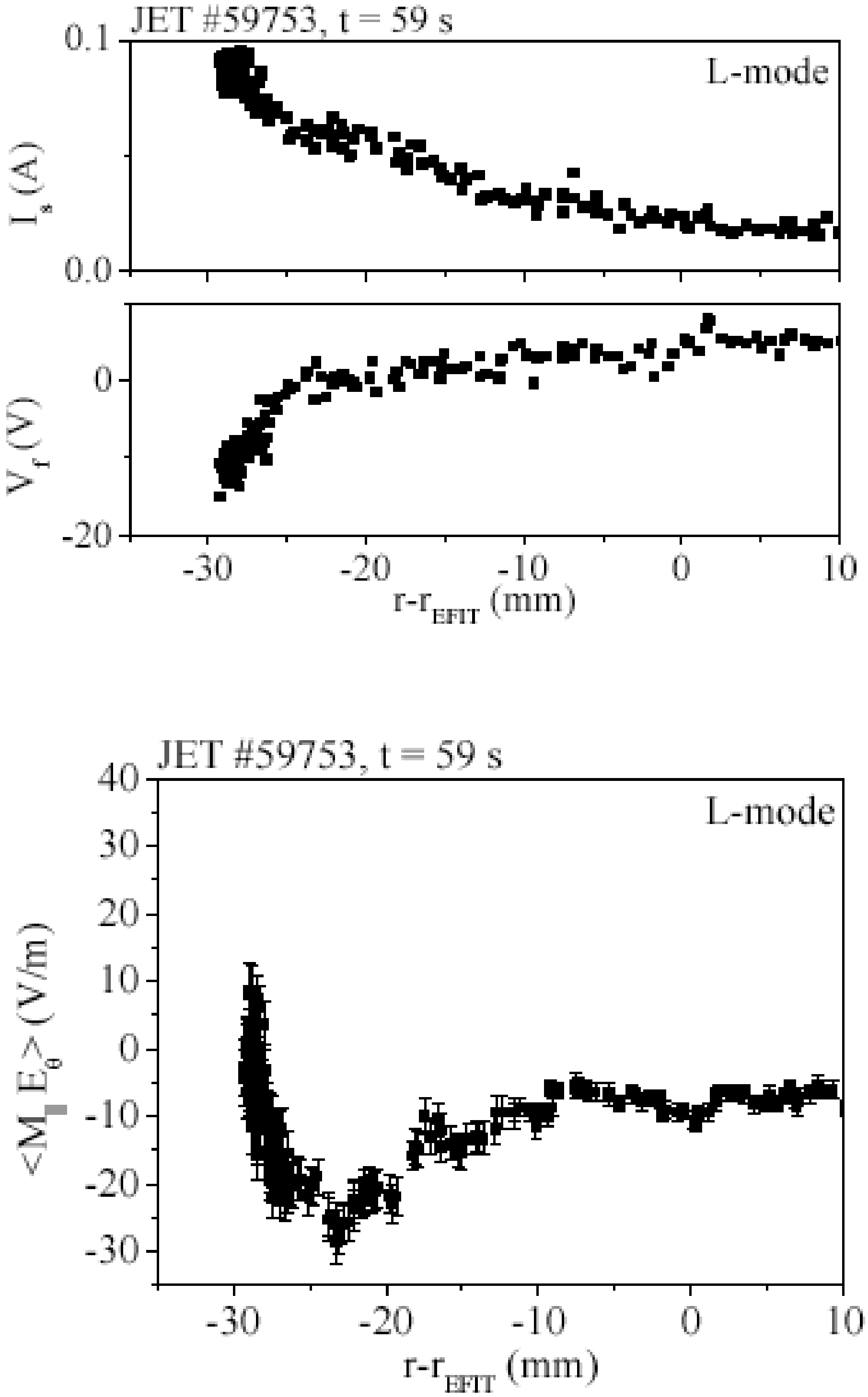

Fig. 1 Radial profiles of ion saturation current, floating potential and cross-correlation between parallel and radial fluctuating velocities in JET L-Mode plasmas in the proximity of the LCFS.

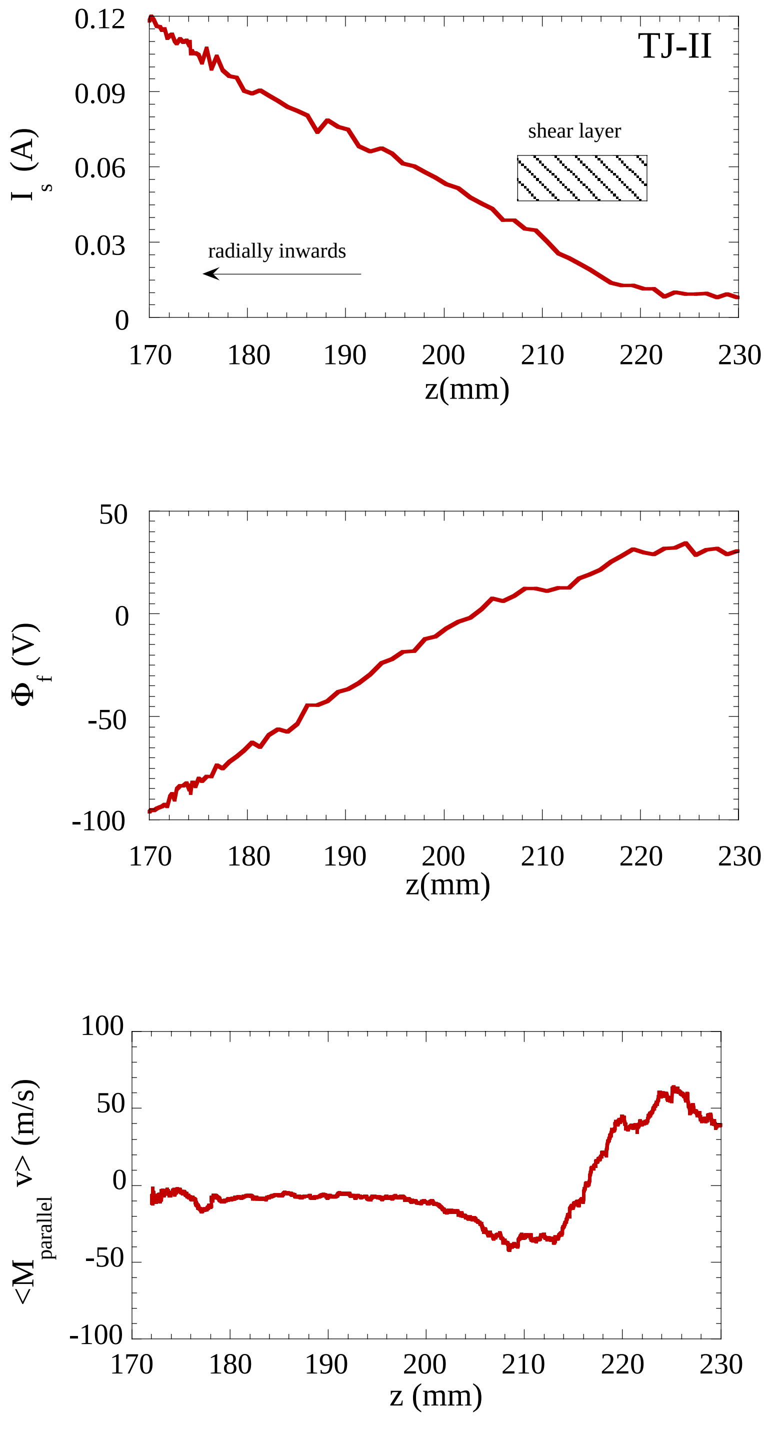

Fig. 2 Radial profiles of ion saturation current, floating potential and cross-correlation between parallel and radial fluctuating velocities in the proximity of the edge velocity shear layer in the TJ-II stellarator.