Coupling between turbulence and flows during the L-H transition

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Abstract

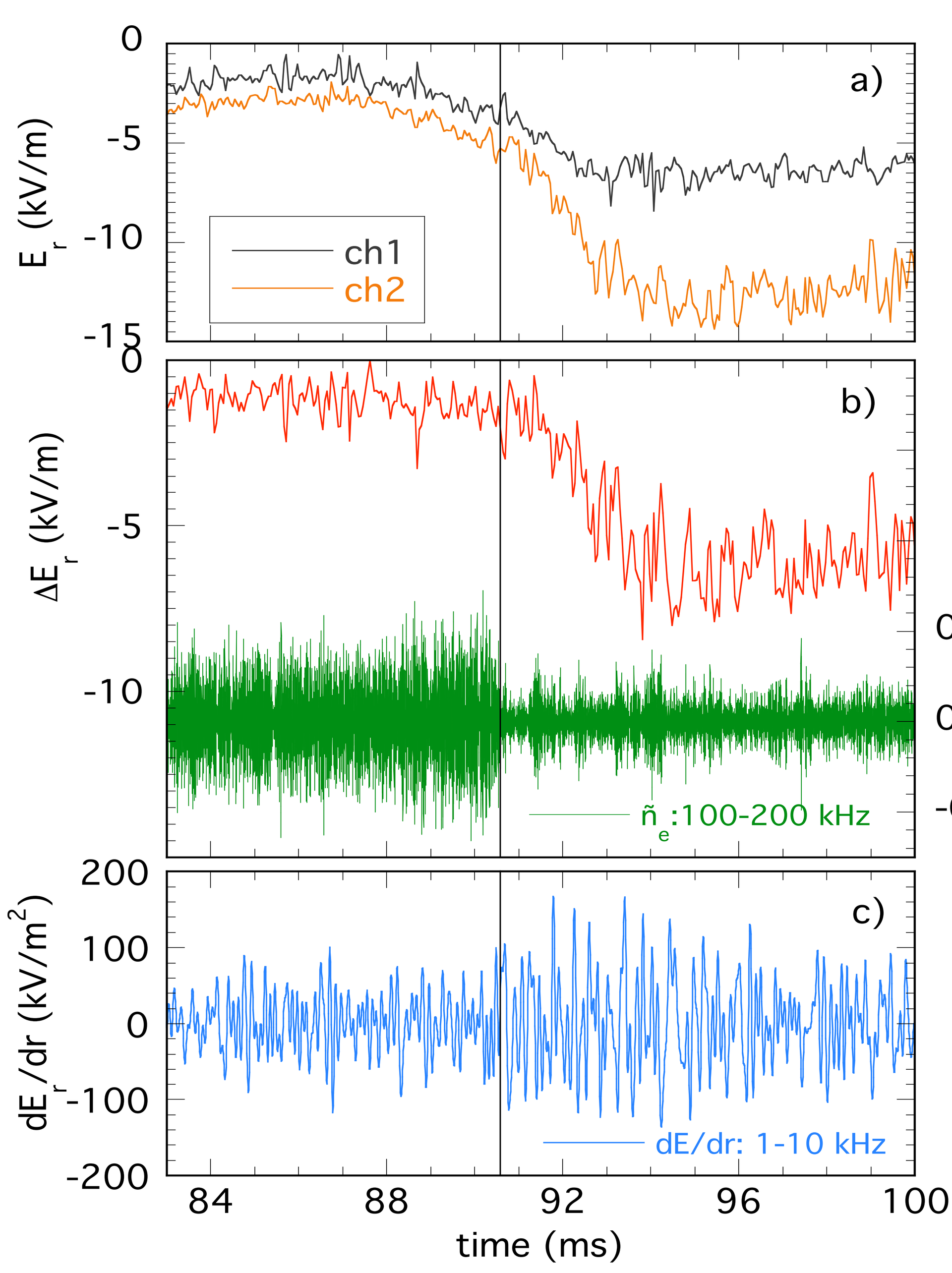
The dynamics of turbulence and plasma flows has been studied experimentally using Doppler reflectometry [1] during edge transport barrier formation and collapse in TJ-II plasmas

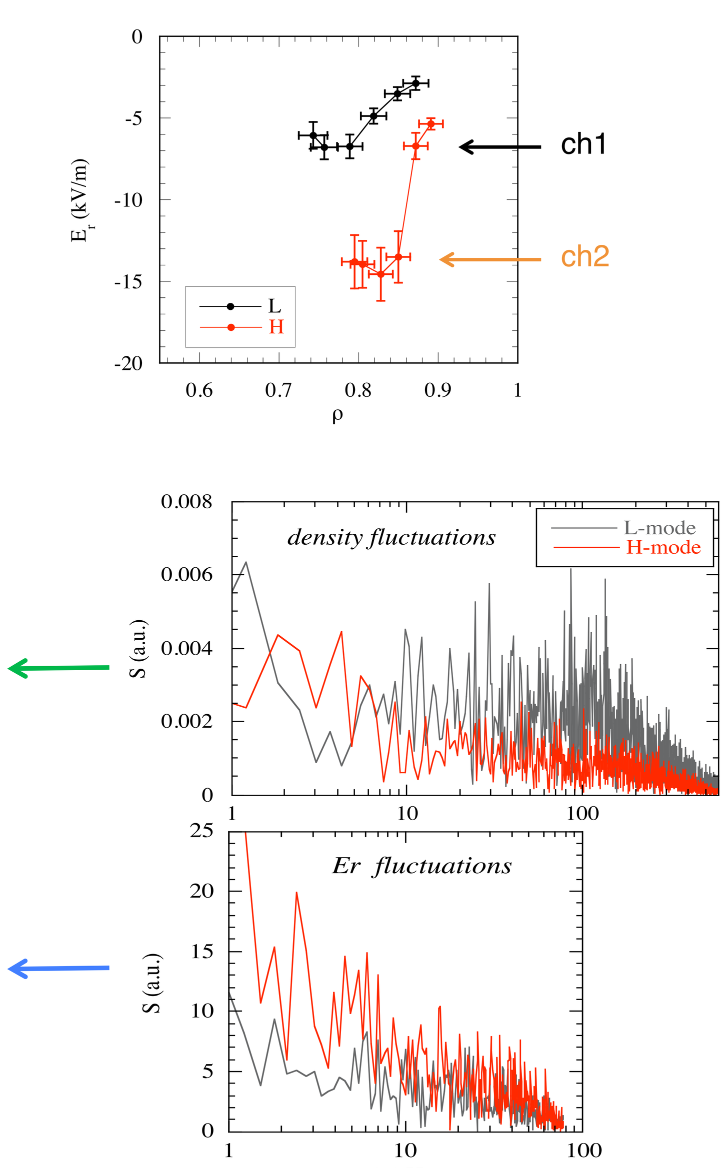
The coupling between turbulence and flows measured during the L-H transition is consistent with L-H transition models based on turbulence induced zonal flows

Signatures of the spatial spreading of the turbulence are found as the plasma approaches the H-L back-transition

L-H transition

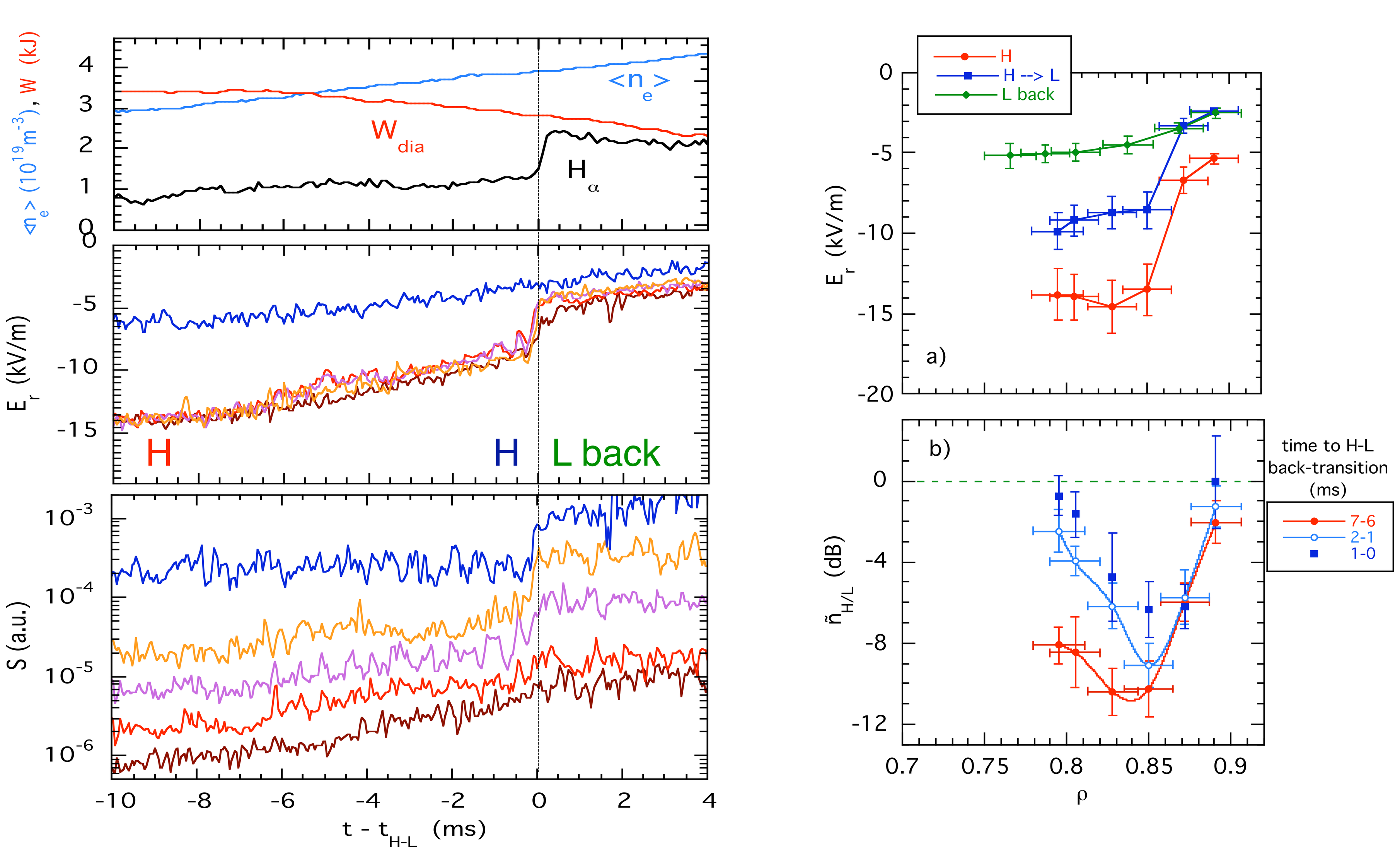
balanced-NBI: 900 kW port-through,
std configuration: : $\iota(a)=1.65$; H_{ISS04}: 1.3 – 1.4





At the L-H transition the turbulence reduction precedes the increase in the mean sheared flow, but it is simultaneous with the increase in the low frequency oscillating sheared flow [2]

H-L back-transition

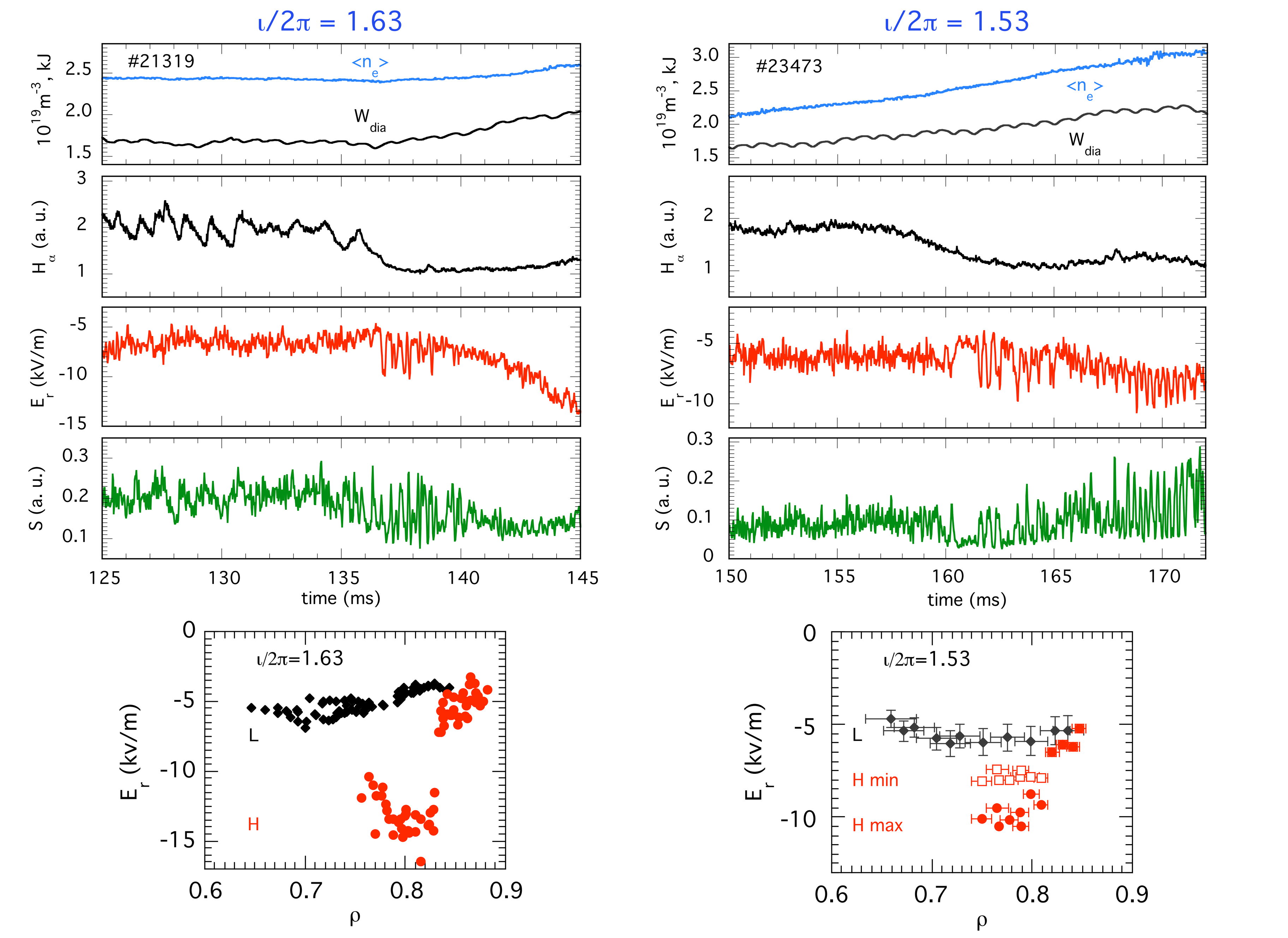


These results suggest the following scenario: radial spreading of turbulence, braked during the H-mode due to the strong E_r-shear, becomes visible as E_r-shear declines and produces a gradual increase in the turbulence at the innermost radial positions reaching the E_r-shear position right before the H-L back-transition [3]

TJ-II results resemble the global gyrokinetic simulation studies where the key quantity to the control of turbulence spreading is the *Er*-shearing rate [4]: depending on the shearing rate level, turbulence can penetrate transport barriers with the subsequent impact on transport barrier width

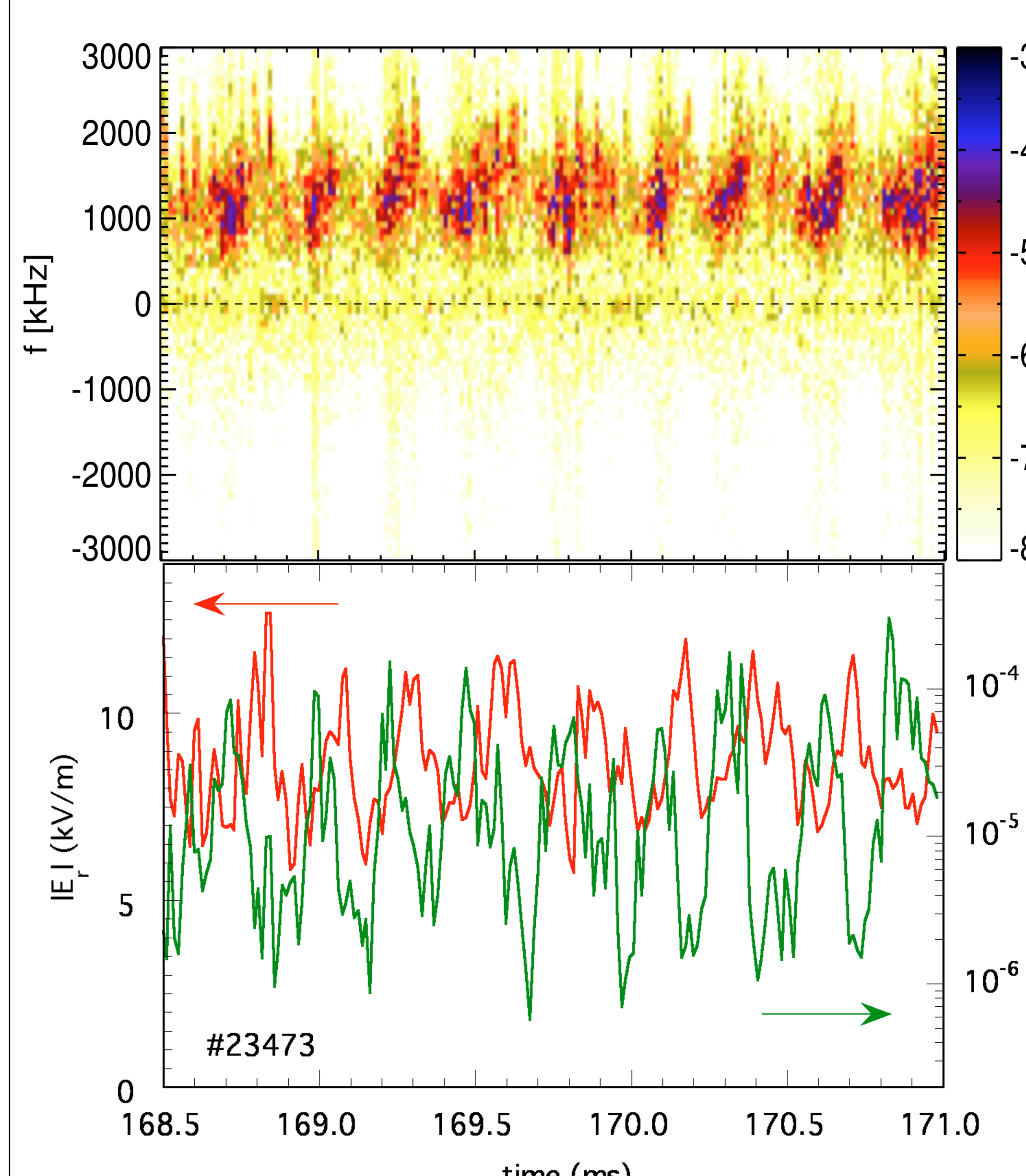
[1] T. Happel *et al.*, Rev. Sci Intrum. **80**, 073502 (2009)
[2] T. Estrada *et al.,* Plasma Phys. Control. Fusion **51,** 124015 (2009)
[3] T. Estrada *et al.*, Nuclear Fusion **51**, 032001 (2011)
[4] W. X. Wang *et al.*, Phys. Plasmas **14**, 072306 (2007)
[5] T. Estrada *et al.*, EPL (Europhysics Letters) **92**, 35001 (2010)
[6] P.H. Diamond *et al.*, Phys. Rev. Lett. **72**, 2565 (1994)
[7] E. Kim and P.H. Diamond. Phys. Plasmas **10**,1698 (2003)

L-H transition close to the threshold

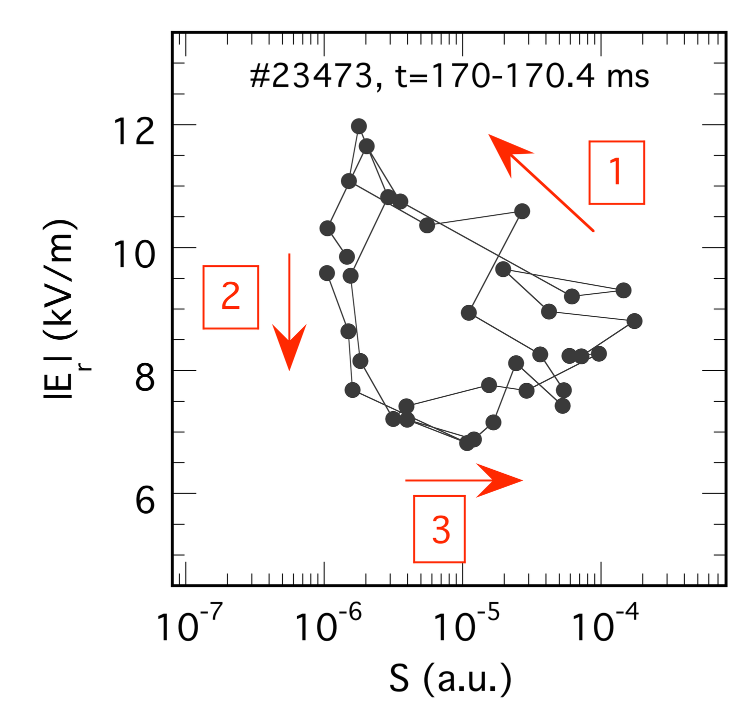


Pronounced oscillations in both E_r and $\tilde{n}_e$ are measured right inside the E_r-shear layer position but not outside: E_r-shear oscillation amplitude ≈ 200 kV/m^2 (≈ 2 10^5 s^{-1})

The oscillations appearance and duration depend on the magnetic configuration



Spectrogram of Doppler reflectometer signals:
$\tilde{n}$ (colour code)
E_r (frequency)



Periodic behaviour of E_r and $\tilde{n}_e$ reveals a characteristic predator-prey behaviour, with E_r (predator) following $\tilde{n}_e$ (prey) with 90º phase delay [5]

E_r and $\tilde{n}_e$ evolve following closed trajectories in a limit-cycle: **1** the turbulence induced sheared flow is generated causing a reduction in $\tilde{n}_e$, **2** the subsequent drop in the sheared flow and **3** the posterior increase in $\tilde{n}_e$

The coupling between fluctuations and flows, described as a predator-prey evolution, is the basis for some L-H transition models [6,7]

Conclusions

L-H transition: the turbulence reduction precedes the increase in the mean sheared flow, but it is simultaneous with the increase in the low frequency oscillating sheared flow. No indications of radial spreading of turbulence have been found

Close to the transition threshold conditions: the dynamics of the radial electric field and density fluctuations reveals a characteristic predator-prey behaviour consistent with models based on turbulence induced zonal flows

H-L back-transition: the spatio-temporal evolution of the turbulence as the plasma approaches the H-L back-transition shows signatures of radial spreading of turbulence; these results point to the possible role of turbulence spreading determining the width of transport barriers

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