32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-5.035 (2005)

Effect of poloidal flow on fluctuations

J.M. Delgado[1], L. García[1], D. López-Bruna[2]

[1] *Universidad Carlos III, 28911 Leganés, Madrid, Spain*

[2] *Asociación Euratom-CIEMAT, Madrid, Spain*

In an earlier work, a one-dimensional cylindrical transport model of edge transport barrier formation was developed [1] to study the dynamics of the L to H transition. It was a generalization of local transition models investigated earlier [2]. In brief, the model consisted of an equation for the evolution of the envelope fluctuation level ε,

$$\frac{\partial\varepsilon}{\partial t}=\left(\gamma-\alpha_1\varepsilon-\frac{\omega_s^2}{\gamma}\right)\varepsilon+\frac{1}{r}\frac{\partial}{\partial r}\left(rD_\varepsilon\frac{\partial\varepsilon}{\partial r}\right), \tag{1}$$

and transport equations for the ion density and temperature,

$$\frac{\partial N_i}{\partial t}=S_{NBi}+S_{gp}+\frac{1}{r}\frac{\partial}{\partial r}\left(rD_{N_i}\frac{\partial N_i}{\partial r}\right), \tag{2}$$

$$\frac{3}{2}\frac{\partial(N_iT_i)}{\partial t}=\frac{1}{r}\frac{\partial}{\partial r}\left(r\left(\chi_iN_i\frac{\partial T_i}{\partial r}+\frac{5}{2}D_{N_i}T_i\frac{\partial N_i}{\partial r}\right)\right)-D_{N_i}\frac{1}{N_i}\frac{\partial N_i}{\partial r}\frac{\partial N_iT_i}{\partial r}+Q_{NBI}{}^i. \tag{3}$$

In the fluctuation equation, the linear growth rate corresponded to a resistive ballooning mode [3] since these instabilities were considered as predominant at the plasma edge. The turbulence was stabilized by nonlinear couplings embedded in the α_1 coefficient and eventually reduced or suppressed via radial electric field shear, where

$$w_s\propto\frac{r}{q}\frac{\partial}{\partial r}\left(\frac{qE_r}{rB\phi}\right)\text{and}\,E_r=\frac{1}{Z|e|N_i}\frac{\partial(N_iT_i)}{\partial r}-V_\theta B_\phi \tag{4}$$

The transport equations were linked to ε through the transport coefficients. They were

$$D_\varepsilon=D_{neo}\,,D_{N_i}=D_{neo}+D_{\eta_i}+D_{RB}\,,\text{and}\,\chi_i=\chi_{io}+D_{\eta_i}+D_{RB} \tag{5}$$

where $D_{\eta_i}=w_{*e}\rho_s{}^2q(1+\eta_i)/(\hat{s}\,\tau)$, and the ε-dependent resistive ballooning diffusivity was calculated in the approximation of strong turbulence, $D_{RB}=\omega_0\Lambda^{7/6}k_\theta\rho_sc_s\varepsilon$.

We have added a new equation for the averaged poloidal flow. This equation contains a flow damping term due to magnetic pumping, an anomalous diffusion term, and the Reynolds stress drive. Reynolds stress term satisfies the condition of total momentum conservation.

$$\frac{\partial\langle V_\theta\rangle}{\partial t}=-\mu\langle V_\theta\rangle+\alpha_3\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\varepsilon\frac{\partial\varepsilon}{\partial r}\left(\frac{1}{r}\frac{\partial\langle V_E\rangle}{\partial r}-\frac{\langle V_E\rangle}{r^2}\right)\right)+\frac{D_0}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\langle V_\theta\rangle}{\partial r}\right)-D_0\frac{\langle V_\theta\rangle}{r^2} \tag{6}$$

<u>Stationary results.</u> For different values of the input power, we follow the evolution of fluctuations level and poloidal flow until a steady state is reached. Fig. 1 shows the radial averaged root mean squared (r.m.s.) values in the edge region, 0.8 < r/a < 1. For a fixed (low) value of the input power, 4-5 MW, the effect of the poloidal flow on fluctuations is very small or null and we have a L-mode where the turbulence is large at the edge. When the power reaches a threshold (5.5 MW), the poloidal flow increases although edge fluctuations are still large. Once above this threshold (5.75 MW) the system enters an oscillatory stage typical of the limit cycle regime of predator-prey models. In this regime, the radial average of the fluctuation level decreases, and the shear flow increases, which is consistent with a second-order transition and with experimental findings in the TJ-II stellarator [4]. Experimental results suggest that a minimum level of turbulence (plasma density gradient) is needed in the plasma edge to trigger the spontaneous formation of sheared flows. Then the level of fluctuations and turbulent transport slightly decreases as edge gradients and plasma density increase. When the power increases (8 – 10 MW) the system stays in the same oscillatory stage and we have very slightly varying values in the level of fluctuations and poloidal flow (saturation). Finally H-mode is reached when the diamagnetic term in the radial electric field suppresses the turbulence (12 MW).

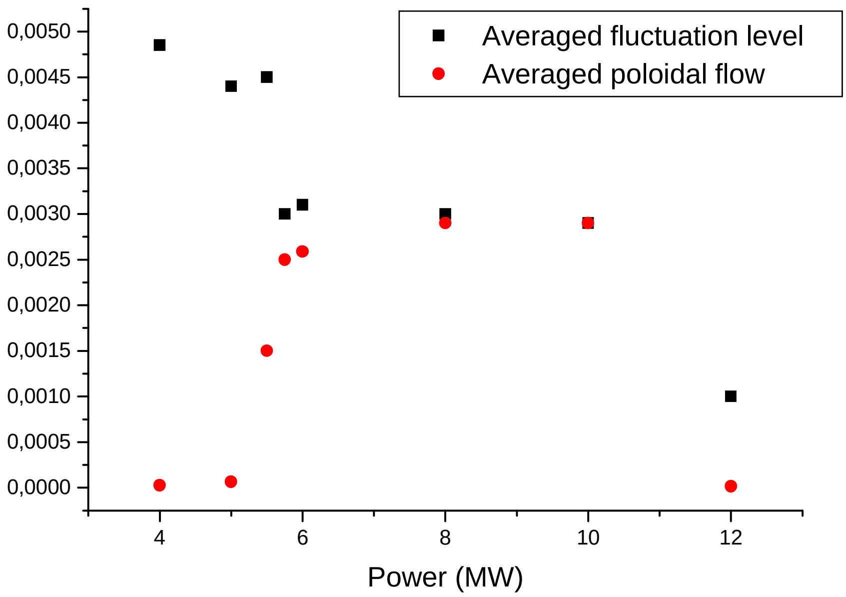

Figure 1. Averaged poloidal velocity and averaged fluctuation level calculated in the range $0.8 < r/a < 1.0$.

Dynamical results. Here we increase separately several parameters in a continuos and gentle way to obtain a first scan in parameter space. In Fig. 2 we show the time evolution of the fluctuation level and the poloidal flow at $r/a = 0.95$ when NBI power is slowly ramped up from 4 to 7 MW and simultaneously gas puffing is increased from 0.1 to 0.25. The results are in accordance with stationary results. Initially, the fluctuation level increases because the growth rate is the dominant term in Eq. (1). Further increasing the power causes the poloidal velocity to reverse sign in the plasma edge from negative to positive values (5.25 MW). The radial electric field shear increases (Eq.4) and the system enters the oscillatory regime (5.75 MW), which drives the fluctuation level to a lower average value. In this regime the ∇p and V_θ terms of Eq. 4 are comparable among them and to the growth rate. Recalling that $\omega_s \sim \gamma$ is our condition of transition to improved confinement regimes, these results indicate that spontaneous sheared flows and fluctuations keep themselves near marginal stability. In the H-mode, the diamagnetic term in E_r takes over the V_θ term and a regime of almost suppressed turbulence is sustained in the region (0.8 < r/a < 1.0). In the predator-prey behavior shear oscillates and we have local reduction of fluctuations in the points where the poloidal flow is large.

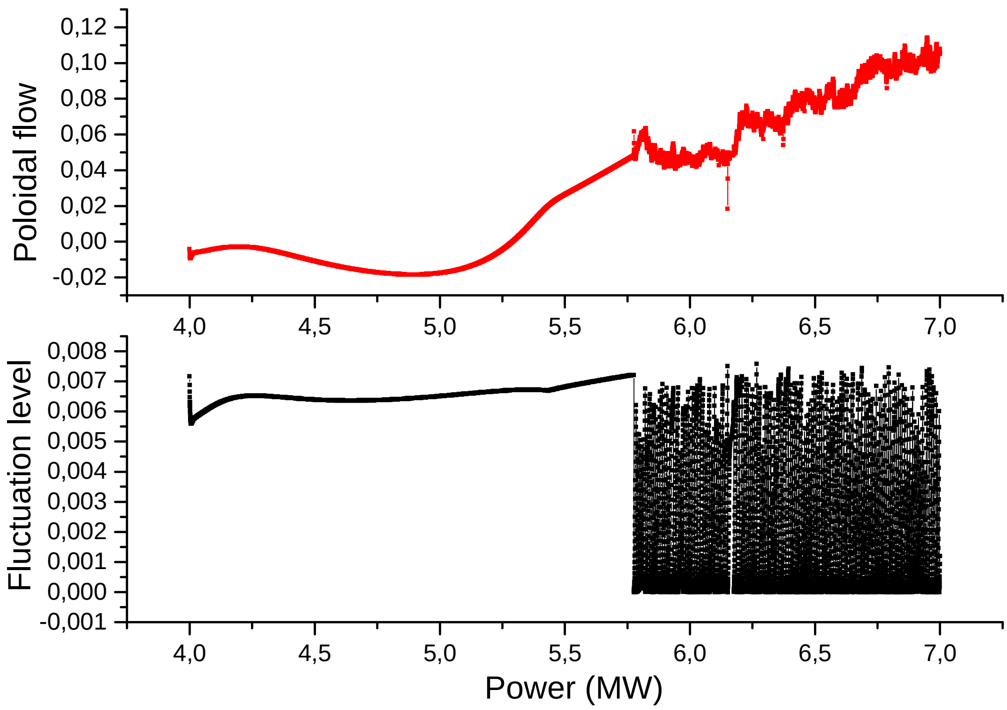

Figure 2. Evolution of the poloidal velocity and fluctuation level at the edge when NBI power is ramped up.

In Fig. 3 we show the time evolution of the fluctuation level and the poloidal flow at $r/a = 0.95$ when gas puffing is ramped up from 0.1 to 0.325 and NBI power is fixed to 4 MW. In this ramp temperature decreases and density increases. When the gas puffing is low we have a L-mode where the turbulence is large at the edge. When the gas reaches a threshold (0.19) the system enters in the predator-prey behavior. Poloidal flow saturation is not reached. Poloidal flow decreases when the gas puffing is very large (0.275) although the fluctuation level is similar.

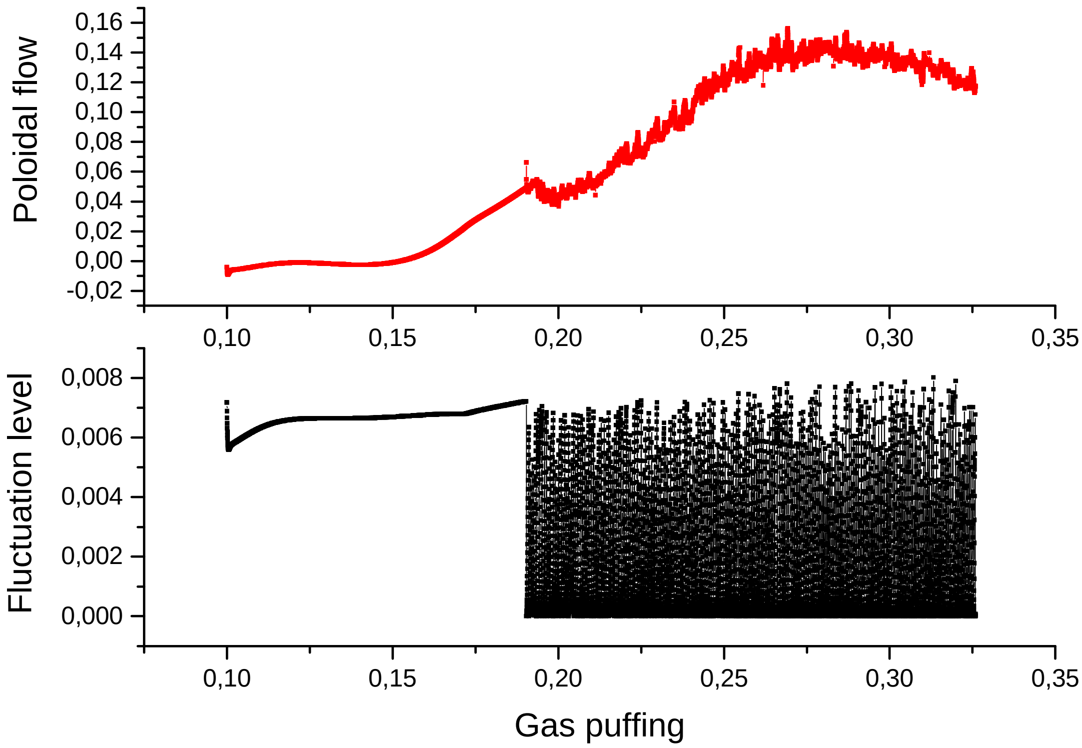

Figure 3. Evolution of the poloidal velocity and fluctuation level at the edge when gas puffing is ramped up. The NBI power is fixed.

[1] J. M. Delgado, et al., 30th EPS. St. Petersburg, Russia (2003)

[2] P.H. Diamond, et al., Phys. Rev. Lett. 72, 2565 (1994)

[3] L. García, et al., Phys.Plasmas 6, 107 (1999)

[4] C. Hidalgo, et al., Phys. Rev. E 70, 067402 (2004)