

Turbulence behaviour in ion Bernstein wave heated discharges on FTU

M. De Benedetti, C. Castaldo, R. Cesario, M. Marinucci and the FTU Team

Associazione EURATOM-ENEA, Via E. Fermi 45, 00044, Frascati (RM), Italy

Experiments on FTU using Ion Bernstein Waves (IBW) heating have shown in the past^{1,2} a sharp reduction in the transport in a region inside the absorption layer of the radio-frequency wave. The standard explanation for such behavior is that the RF induces a shear flow that reduces the turbulence³. In order to test this hypothesis we have carried out a systematic campaign of fluctuation measurements using the two-channel poloidal correlation reflectometer of FTU. We report here the results of such campaign.

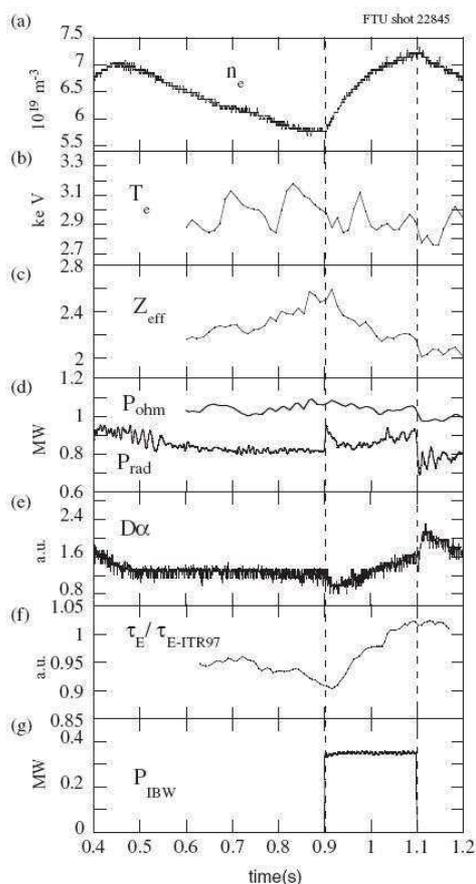


Figure 1 FTU pulse 22845. Confinement improvement in an IBW heated discharge. There is a sharp improvement inside the absorption layer.

Experiments of IBW heating have been carried out on FTU both with H and D plasmas in FTU. The IBW plant may inject up to 400 kW at a frequency of 433 Mhz. The target plasma had toroidal field $B_T=7.9$ T, plasma current $I_p=800$ kA, and central line averaged electron density $\langle n_e \rangle = 0.8 \times 10^{20} \text{m}^{-3}$. The IBW is absorbed on the 9th cyclotron harmonic of deuterium corresponding to a minor radius of $r/a \approx 6.4$. The density fluctuations are measured by a two-channel O-mode heterodyne poloidal correlation reflectometer⁶ launching frequencies in the range 50-80 Ghz, corresponding to a range of densities in the range 0.3×10^{20} to $0.8 \times 10^{20} \text{m}^{-3}$. This range of frequencies allowed us to probe both the region of the IBW absorption and a more internal region ($r/a \approx 0.3-0.4$). In figure 1 we show the behaviour of an FTU pulse from an old campaign (without turbulence measurements) with D plasma and IBW heating. During the heating phase there is a clear density peaking and an improved confinement is observed in a region inside the absorption layer. During the most recent experimental campaign, when the turbulence measurements were available, a similar density peaking was observed but not accompanied by the same transport

reduction. The reason why we could not reproduce the same results is probably due to an increased recycling. We could however, take some turbulence measurements which show some interesting properties.

The typical turbulence spectrum^{4,5} of the reflected **E** field is shown in figure 2. For reflection far from the plasma edge, the spectrum consists usually of three main components: a wide band component that extends from 0 up to 500 kHz, a low frequency (LF) peak in the range 0 – 20 kHz and two lobes at intermediate

frequencies that have been named quasi-coherent (QC) oscillations. In FTU (unlike on other machines) all three components rotate usually in the e-diamagnetic drift direction. We have compared three types of discharges: with high power IBW, with chopped IBW power, and with no IBW power but with gas puff to simulate the density increase associated with the IBW heating. Here are the discharges analyzed:

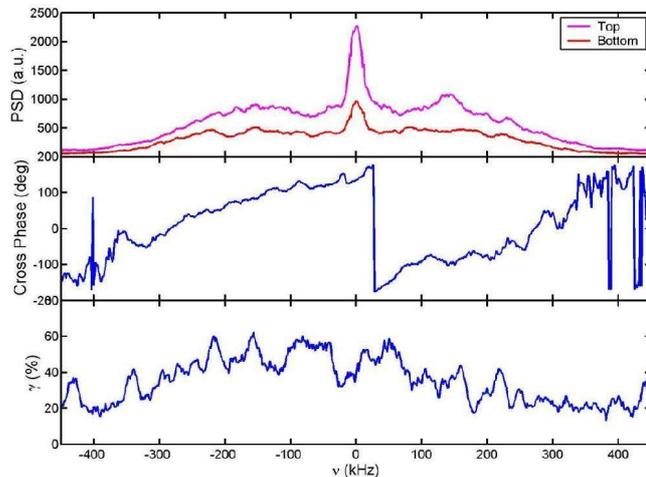


Figure 2 Spectra, cross phase and coherency for FTU discharge 24031 at $t=0.6$ s

behaviour both at the absorption layer and at the plasma center. We summarise here the main results obtained.

- At the absorption layer, the LF component is reduced (figure 3a). The reduction is not observed with just the extra gas puff. The QC component does not change.
- Inside the absorption layer the QC component is reduced (figure 3b).
- Inside the absorption layer the poloidal rotation frequency ω of the QC component is reduced. The rotation frequency related to the LF component does not change (figure 4a).
- Inside the absorption layer the self correlation half width Δt (see also figure 3) doubles (figure 4b). The lower power for the chopped case is below threshold for this effect. The correlation length (defined as $L_{\text{corr}} = \Delta t \times \omega \times r$) however does not change.
- The poloidal m number inside the absorption layer grows but this may be just an effect related to q.
- The value of $k_{\theta} \rho_i$ for the QC components remains of the order of 0.3 which is the value predicted for ITG turbulence⁵.

- 23961: With high IBW power and reflection at the absorption layer
- 23964: With just gas puff and reflection at the absorption layer
- 24031: With high IBW power and reflection inside the absorption layer
- 24055: With chopped IBW power and reflection inside the absorption layer

The IBW is responsible for a change in the turbulence

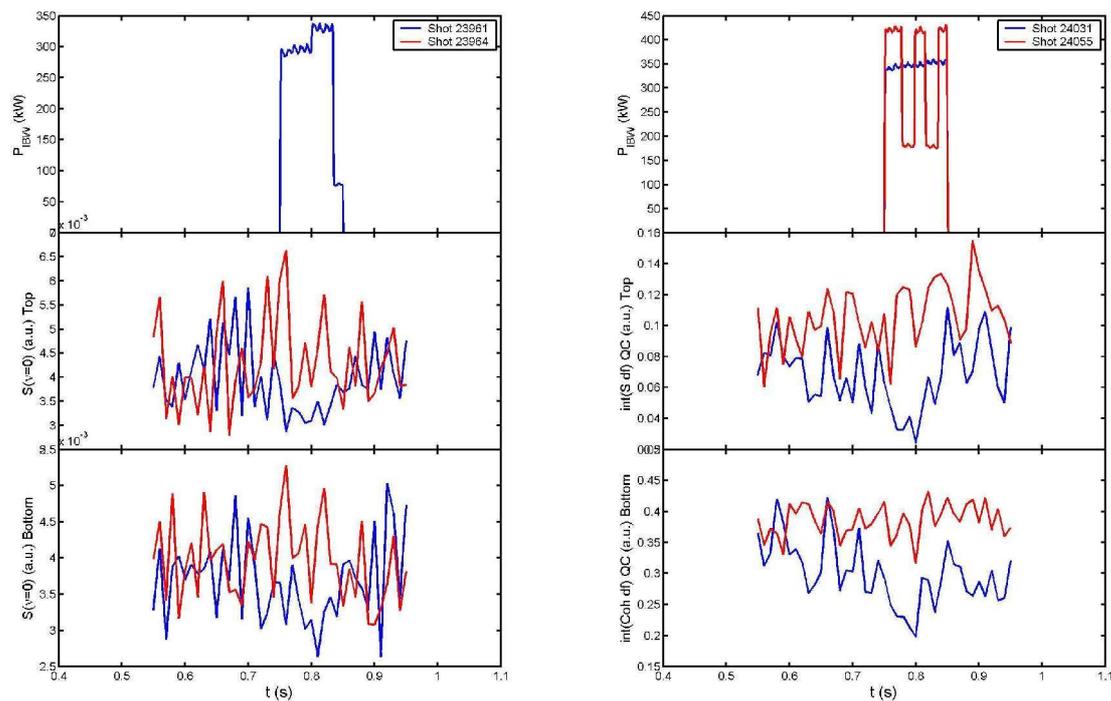


Figure 3 **a)** Reduction of the LF component at the absorption layer: comparison between with and without IBW heating **b)** Reduction of the QC component in the central region: comparison between full and reduced IBW heating

Conclusions

- We have made turbulence measurements in discharges with IBW heating.
- Even though there was not a macroscopic confinement improvement as was observed in the past on FTU, there were nonetheless some interesting results.
- There are clearly two regions where different things occur: a region inside the absorption layer and one around the absorption layer.
- In the first region we observe a reduction of QC turbulence, a reduction of the rotation frequency and a growth of the self correlation function.
- In the second one we observe a reduction of the LF turbulence.
- It is not clear yet why we do not observe any reduction in the transport but it seems that either the turbulence reduction is not sufficient to produce any macroscopic effects or the modes that are suppressed play a little role in the first place for the transport mechanisms.
- It seems that a reduction in transport may occur only if the recycling is sufficiently low. Further experiments should keep this fact into account.

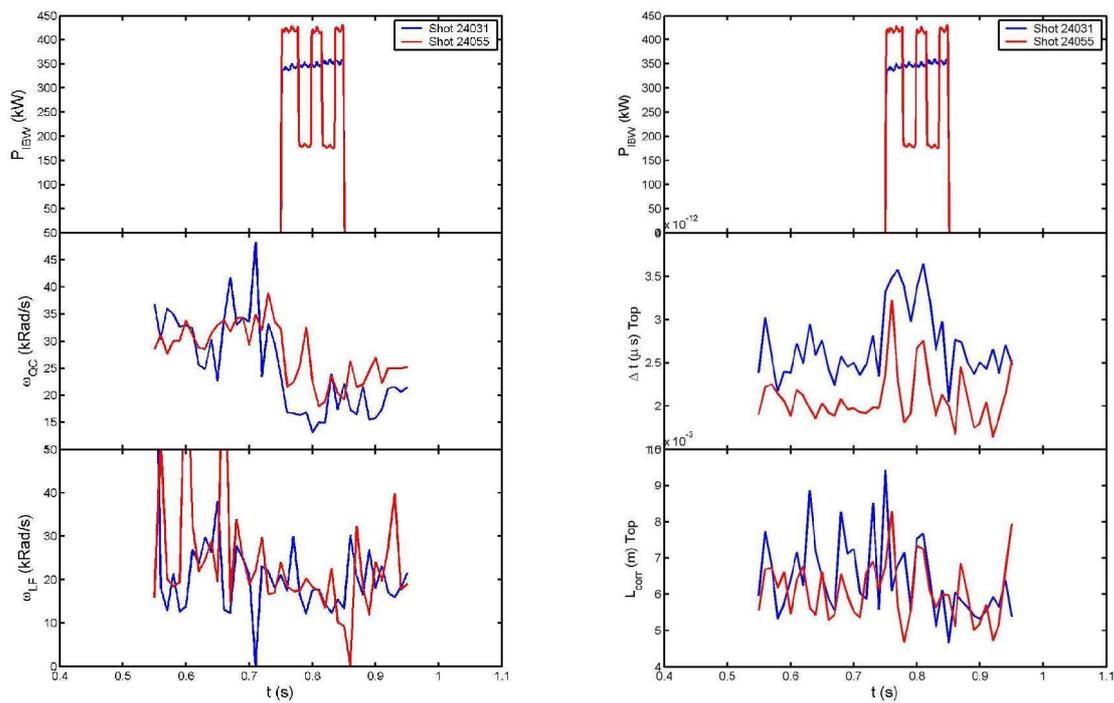


Figure 4 a) Reduction of the poloidal rotation frequency for the QC component for central reflection. b) Growth of the self correlation half width for central reflection. The radial correlation length does not change.

Acknowledgements

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