Characterization of Edge Turbulence in Neutral Beam Injection and Ion Cyclotron Resonance Heated Plasmas in ASDEX Upgrade

B. Kurzan, T. Kass, M. Maraschek, J. Schweinzer, A. Silva*, W. Suttrop, ASDEX Upgrade-, ICRH-, NBI-Teams

Max-Planck-Institut für Plasmaphysik, EURATOM-Association, D-85748 Garching, Germany

**Centro de Fusão Nuclear, EURATOM-Association, Instituto Superior Técnico, 1096 Lisboa Codex, Portugal*

1) Introduction

With increasing additional heating power first a regime of low confinement, or L mode is reached, and beyond a certain threshold power the regime of high confinement or H mode is obtained [1, 2]. In neutral beam injection (NBI) heated L mode plasmas a density and magnetic fluctuation level higher than during Ohmic heating is observed in the plasma edge [3, 4]. A low turbulence level is obtained again in the H mode [3, 5]. With Ion Cyclotron Resonance Heating (ICRH) the fluctuations observed in the L mode on ASDEX Upgrade are lower than in NBI heated plasmas and are not suppressed during the L-H transition.

2) Diagnostics

For measuring the turbulence of the electron density and the radial magnetic field a reflectometry system in O mode polarisation [6] and small coils sensitive to high frequency magnetic fluctuations placed within a distance of 10 cm near to the plasma surface were used. Electron temperature and density profiles near the outer plasma edge are measured by a multichannel Electron-Cyclotron-Emission- and a Li-beam diagnostic [7] respectively.

3) Observation

The turbulence of the density and the magnetic field is visualized in the following (figs 1, 3) by contourplots after application of a sliding FFT to the signals. With the onset of the first NBI source a broadening of the bandwidth of the fluctuations of the radial magnetic field and of the electron density is observed (fig. 1). After the second beam source has been turned on an additional broadening of the fluctuation spectrum is observed, followed by a L-H transition clearly visible in the decreasing D_α intensity, after which the fluctuations are totally suppressed. The gradients of the electron density and temperature profiles do not change from the Ohmic to the first L mode phase (1.35 s – 1.40 s) at the position of measurement, fig. 2. Thus the turbulence driven by these sources should stay constant which, however, is not observed. The increase of the bandwidth until 1.7 s might be ascribed to an increase of the turbulence because of the then steeper edge gradients, or to a source which has its maximum at the plasma edge and is switched off at the L-H transition. When applying ICRH heating alone it is found that the turbulence level in a L mode plasma is lower than in a NBI heated L mode plasma. This turbulence is not suppressed at the L-H transition (fig. 3).

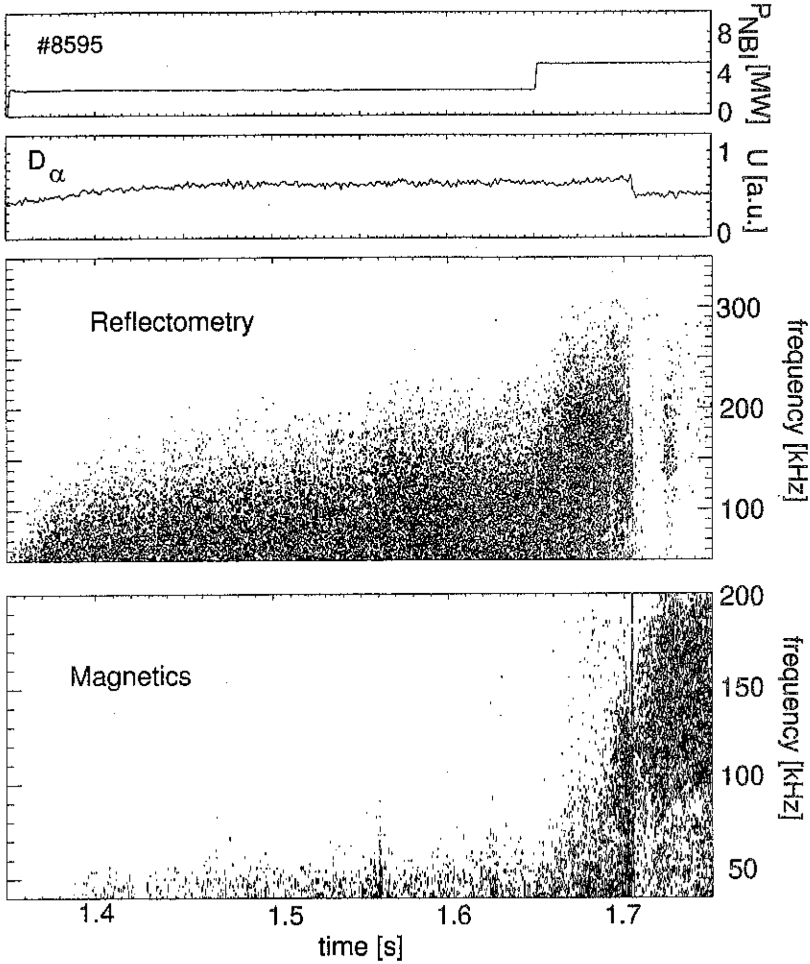

Fig. 1: The turbulence in a NBI heated L mode plasma is suppressed at $t = 1.704\,s$, *the time when also the* D_α *light at the divertor decreases, indicating the L-H transition. The turbulence quenching is observed both in the density, measured here by reflectometry (probed density* $2.6 \times 10^{19}\,m^{-3}$*) and in the radial magnetic field. In the H mode TAE modes with frequencies around 150 kHz are excited as clearly visible in the magnetic measurement.*

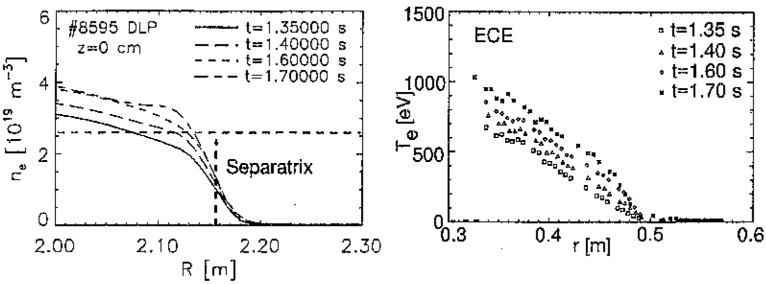

Fig. 2: Evolution of the profiles of the electron density and temperature at the plasma edge. The probed density layer in fig. 1 of $2.6 \times 10^{19}\,\mathrm{m}^{-3}$ *is indicated by a horizontal line.*

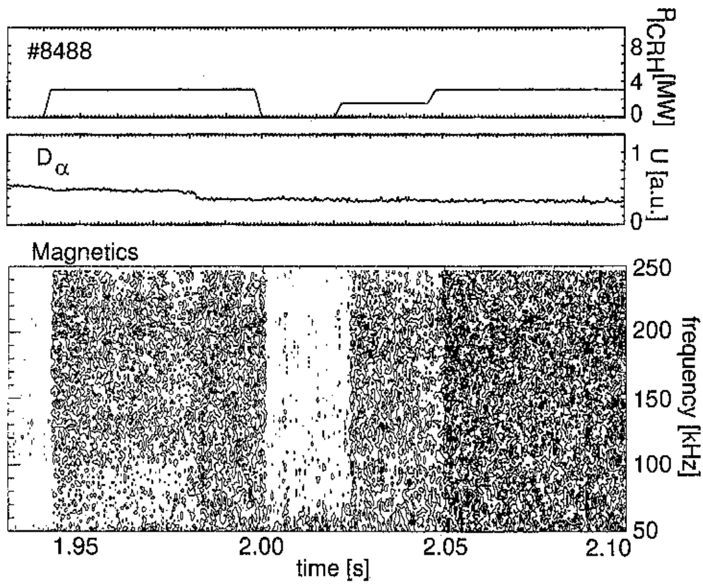

Fig. 3: The turbulence generated by ICRH is not reduced at the L-H transition at the time $t = 1.982\,\mathrm{s}$ *as indicated by the decrease of the* D_α *light. In the Ohmic phase during the H mode where ICRH was switched off (2.000 — 2.020 s) the turbulence is reduced, confirming that the observed level is generated by ICRH.*

4) Characterization of the turbulence regimes with NBI heating

The neutral beam entering the fusion plasma is being partially ionized immediatally there. This zone of first ionization of the beam is one fast ion's gyroradius within the plasma because only there their space charge can be neutralized which is necessary for stable gyro orbits (degree of ionization there: 1%). The speeds of the slow, intermediate, fast Alfvén waves, c_{SL}, c_I, c_F were calculated at this position and compared with the beam speed v_b

resulting in $c_{SL} < v_b < c_I$ for the L mode (fig. 4). At the L-H transition the density profile

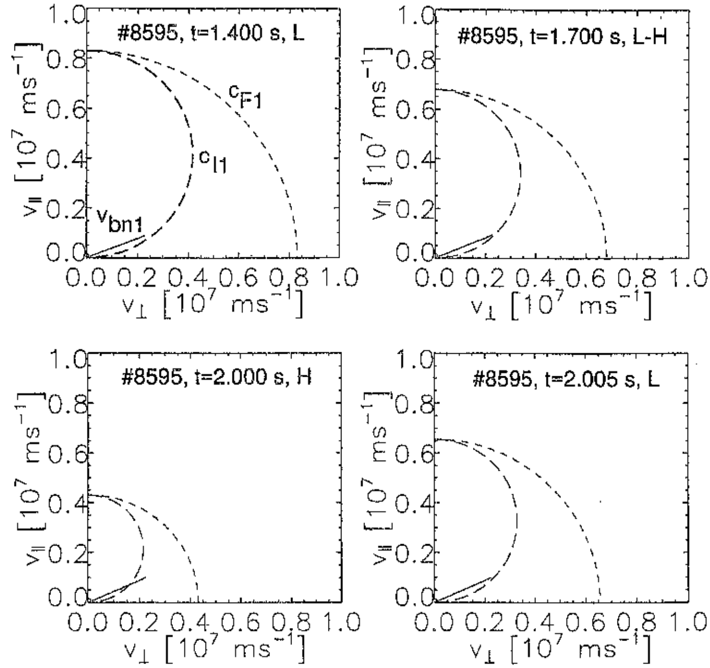

Fig. 4: Comparison of the beam speed (arrow) with the three Alfvén speeds at the plasma edge for the 3 phases L, L-H, H as indicated in the upper right corner of each plot (magnetic field 1.94 T, injection angle of the beam with respect to the magnetic field 72.8°, energy of the deuterium beam 60.5 keV, for the density and temperature of the deuterium plasma measured values were used).

steepens so that in the H mode $c_I < v_b < c_F$ is valid (fig. 4).

5) Conclusion

The different turbulence levels of the L and H mode observed only in NBI heated plasmas can be correlated with the relation of the beam speed with respect to the intermediate Alfvén speed at the plasma edge.

References

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