Experimental analysis of ELM precursors with the Thermal Helium Beam diagnostic at TCV

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Introduction: The high confinement regime (H-mode) is a state of improved confinement in toroidal magnetic fusion devices [3]. It is often accompanied by the appearance of so-called edge localized modes (ELMs), which lead to a fast energy and particles loss from the plasma edge. These modes are often preceded by coherent oscillations in the magnetic field, known as ELM precursors, that, in a more general term, denote modes that systematically precede ELMs [4]. ELMs are generally classified according to the presence of magnetic precursors and the dependence of the ELM frequency on the energy flux through the separatrix [5]. Based on whether the repetition frequency increases or decreases with the energy flux, two main classes of ELMs can be identified: Type-I and Type-III. This work aims to draw an analysis of the ELM precursors in H-mode at TCV: the shots analyzed presented Type-I ELMs in peeling-limited pedestal regime. The shots selected were H-mode shots obtained using additional heating (ECRH and NBI). Specifically, the Thermal Helium Beam (THB) diagnostic, on loan from Consorzio RFX, now installed at TCV [6], is primarily used to detect them. The THB is a spectroscopic diagnostic that estimates the electron temperature (T_e) and density (n_e) in the edge and SOL region of fusion plasmas [7]. It is based on the line intensity ratio technique of four different neutral helium lines: 501.6 nm, 667.8 nm, 706.5 nm and 728.1 nm: the gas is puffed into the plasma edge, where n_e and T_e are estimated. The THB, that shares the GPI [8] collection optics and gas puff system, has 8 lines of sight (LoS) in the low field side of the equatorial midplane, radially aligned in the edge/SOL region, with spatial resolution of 5 mm. The acquisition rate of the diagnostic is 1 MHz.

H-mode shots: This work interest is to analyze the evolution of T_e and n_e profiles and the turbulence behavior between ELMs. The ELMs are identified by using the Halpha signal from photodiodes equipped with Halpha filters. The ELMs frequency appears almost constant in the analysed region. The portion of the signals between 1.2 ms before and 0.9 ms after each peak is considered as ELM, the remaining part is the inter-ELM phase selected for the analysis. The inter-ELM signal was then used to evaluate the average T_e and n_e profiles between ELMs. In Fig. 1 the profiles evaluated from the THB signal for the shot #76978 (about 2.7 MW of total ECRH power and 1.5 MW of NBI power) are shown in comparison with the Thomson Scattering (TS) evaluations. The values obtained from the two diagnostics are in good agreement and portray a good representation of the behavior of electron density and temperature across the separatrix (ρ=1). The slight discrepancies between TS and THB profiles can be ascribed to the different region measured: TS measures a vertical profile, THB a horizontal one in the outboard midplane. In Fig. 1 the 'TS top' measurements correspond to the LoS of the TS above the midplane, while the 'TS bot' measurements correspond to the region under the midplane.

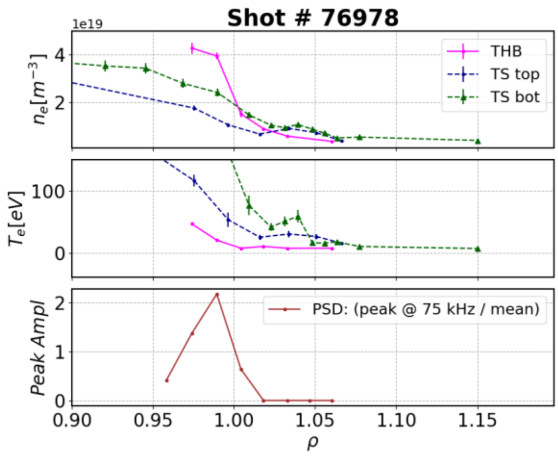

Fig. 1: Average inter-elm profiles of n_e (top) and T_e (middle). THB in purple, TS above and below the midplane in blue and green. Value of the peak amplitude observed in the power spectral density (PSD) over the mean value of the PSD itself (bottom).

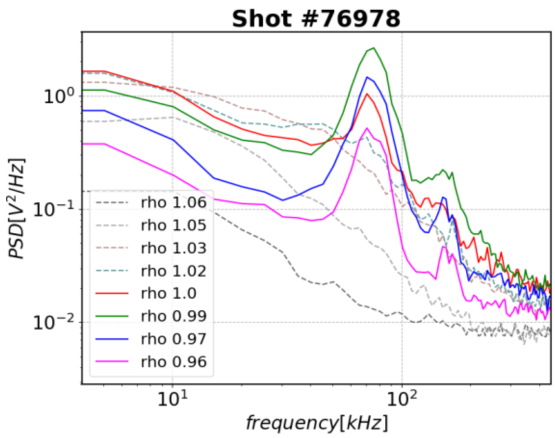

Fig. 2: Power spectral density (PSD) of the raw signal of line 667 nm from the THB data

ELM precursors analysis: In the brightest line (667 nm) raw signals for the LoSs inside the separatrix, a periodic fluctuation is detected. The evaluated power spectral density for the signals from the eight LoS of THB, reported in Fig. 2, show a dominant frequency of about 75 kHz for the LoSs internal to the separatrix, while the spectra collected outside the separatrix show a power law decay, typical of turbulent fluctuations. This is the evidence of a mode localized between ELMs in the edge region at around 1 cm inside the separatrix (bottom plot in Fig. 1). The smaller peak at about 150 kHz likely represents the second harmonic of this mode. From the spectrogram of the signal (Fig. 3 (a)) it is possible to see that the mode appears 0.8 ms after the ELM (A), with a frequency of around 80 kHz. In 3ms the frequency of the mode decreases to about 50 kHz (B), around 0.4 ms before the next ELM. From Fig. 3