Fluctuations measurements in TEM and ITG dominated negative triangularity plasmas

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Introduction

The shaping flexibility of the Tokamak à Configuration Variable, or TCV (major radius R = 0.88 m, minor radius a = 0.25 m, B_0<1.45 T), has been used in past years to investigate the influence of plasma shape on transport. In particular, negative triangularity (δ) has been found to improve confinement in a variety of different scenarios, including ohmic and electron cyclotron (EC) heated [1] plasmas. Furthermore, density [2] and temperature [3] fluctuations are observed to be strongly suppressed in negative δ plasmas with respect to positive δ ones. Numerical simulations performed using the experimental equilibria and profiles managed to quantitatively reproduce the heat conductivity reduction in negative δ plasmas [4] and found trapped electron modes (TEM) to be the dominant source of instability in all these different discharges [4][5]. The investigation of the effects of negative triangularity also in plasmas where ion temperature gradient (ITG) driven fluctuations are dominant is considered to be necessary, since possible future reactors based on nuclear fusion will work in such a regime. To do so, positive and negative δ discharges, heated using the TCV neutral beam injection (NBI) system, have been studied. The main goal of these experiments is to determine whether negative triangularity discharges demonstrated strongly improved confinement also in cases where $T_e/T_i < 1$, since a lower T_e/T_i is considered to be key to trigger the transition from TEM to ITG dominated regimes.

Experimental setup

A model discharge (figure 1a) has been developed, with $\delta_{95} = -0.4$, elongation $\kappa = 1.4$, $I_p = 230$ kA, line averged density $n_{av} = 2.8 \cdot 10^{19}$ m^{-3}, in which a constant power of 300 kW of NBI (~205 kW absorbed in the plasma) has been injected for over a second of flat top. It has been compared with a positive triangularity discharge ($\delta = +0.4$, figure 1b) with comparable density profile where plasma current has been increased to 265 kA to obtain a similar q profile. This discharge has been heated with NBI in two different 0.4 s phases of 300 kW and 1 MW

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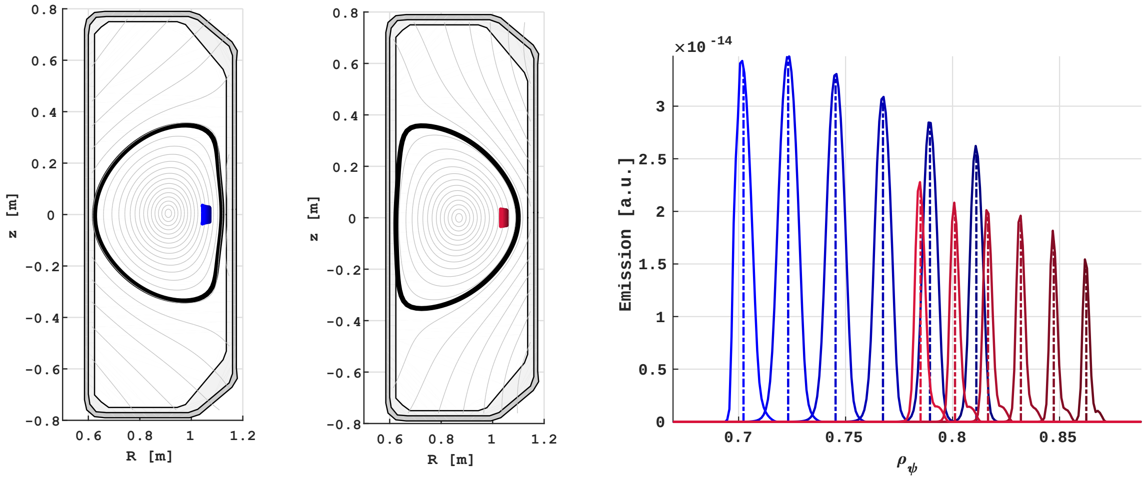


(a) (b) (c)

Figure 1: Plasma geometry and CECE emission volumes for the positive and negative δ discharges (a and b). Profile of the emissivity calculated for each of the ECE channels over the normalized radius.

respectively ($\sim$220 kW and $\sim$690 kW absorbed in the plasma in the two cases).

Comparing the phase where the same heating power has been applied (300 kW), the variation in the plasma current between the two shapes changes the ohmic power in the plasma from $\sim$180 kW to $\sim$280 kW in the negative and positive δ plasmas respectively. The total heating for the two differently shaped plasmas is then $\sim$385 kW ($\delta < 0$) and $\sim$500 kW ($\delta > 0$). Even though the latter case is then subjected to $\sim$100 kW more heating than the negative δ ones, the negative δ discharge shows higher electron and ion temperature across the whole profile, as it was observed for ohmic plasmas. The applied ion heating was successful in increasing the ion temperature to a point where $T_e/T_i \sim 1$ across a large part of the radial profile, in contrast to the previous ohmic and EC heated discharges, where $T_e/T_i > 2$ in the core and ~ 1 only for $\rho > 0.7$. When the NB power is increased to 1 MW in the positive δ discharge, P_{ohm} decreases to $\sim$ 180 kW, for a total of $\sim$870 kW. In this case, ion and electron temperature profiles in the positive δ case are almost matched with negative δ.

Linear gyrokinetic simulations, performed using the GENE code [6] on the experimental equilibria and profiles of the positive and negative δ discharges, heated with 300 kW NBI, show that ITG are expected to be the dominant source of instability in this case, as shown in figure 2. From these measurements it appears that negative triangularity does still cause an improvement in confinement also in plasmas where, for each k_y, the linearly dominant mode is ITG. Similar analysis on ohmic or EC heated discharges always revealed TEM as the linearly

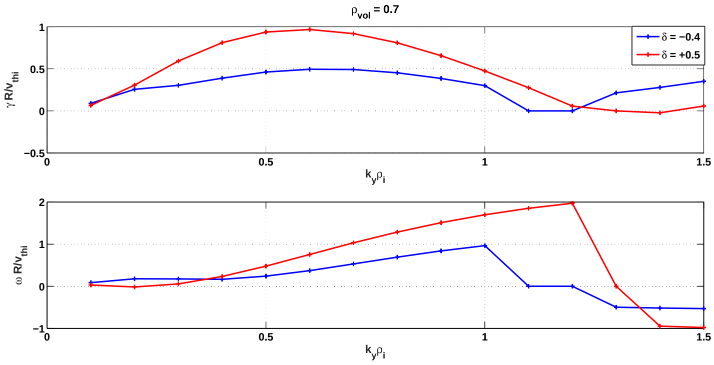


Figure 2: Growth rate γ and frequency ω of the most unstable linear mode found by linear GENE runs using the reconstructed equilibria and profiles from positive and negative triangularity plasmas. Positive and negative frequencies correspond to ITG and TEM respectively.

dominant source of instability.

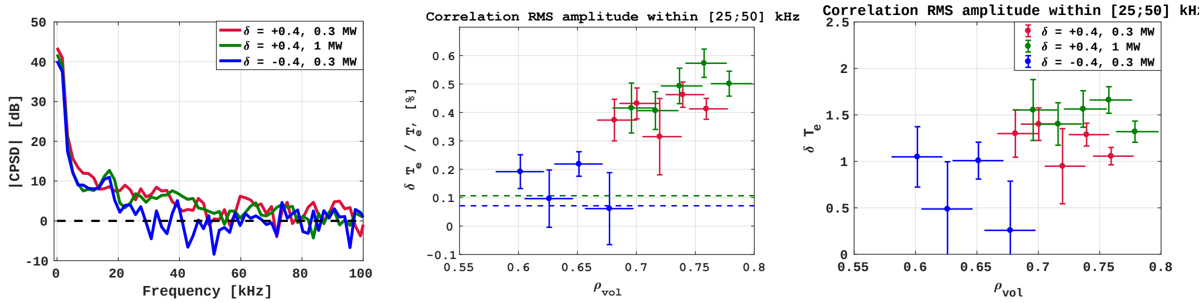
Temperature fluctuations measurements

Temperature fluctuations have been studied in these discharges using the CECE diagnostc of TCV [7]. The diagnostic has been connected to the midplane, low field side, horizontal line of sight, perpendicular to the magnetic field. The six channels' YIG filters have been set 300 MHz apart one from each other, covering the region between $0.57 < \rho_{vol} < 0.78$. The emission volumes for the two shapes are shown in figure 1a and 1b, and the corresponding emissivity profiles over the plasma normalized radius in figure 1c.

The spectra obtained from correlation of neighbouring channels, shown in figure 3a, show higher fluctuations across the 20-50 kHz regions in the positive triangularity plasma, in both heating phases. The corresponding fluctuations amplitude, in figure 3b and 3c, are obtained by integrating the spectra over that frequency range. Fluctuations in the positive δ plasma are about twice those in the negative δ one in both NB phases, similar as to what has been observed in ohmic discharges [2][3].

Conclusions

The confinement improvement due to negative δ has been investigated in NB heated discharges in TCV. In negative and positive δ plasmas where the same 300 kW NB heating power has been used, the former showed higher electron pressure across the whole profile. To obtain comparable temperature profiles in positive δ, it has been necessary to increase the NB power to 1 MW. Linear GENE simulations suggest that, in these plasmas, fluctuations are ITG dominated. Temperature fluctuations have been found to be consistently higher in the positive δ case, similarly to what was observed in TEM dominated discharges. Negative δ seems to provide



(a) (b) (c)

Figure 3: Cross power spectral density of fluctuations for two neighbouring channels at $\rho_{vol} \sim 0.75$ (a) Relative (b) and absolute (c) amplitude of the fluctuations obtained by integrating the CPSD of neighbouring channels between 25 and 50 kHz.

confinement improvement also in ITG dominated plasmas.

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